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Evaluating asset pricing models in the Korean stock market ☆

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ABSTRACT

This paper evaluates and compares asset pricing models in the Korean stock market. The asset pricing models considered are the CAPM, APT-motivated models, the Consumption-based CAPM, Intertemporal CAPM-motivated models, and the Jagannathan and Wang conditional CAPM model. By using various test portfolios as well as individual stocks, we conduct time-series tests and cross-sectional regression tests based on individual *t*-tests, the joint *F*-tests, the Hansen and Jagannathan (1997) distance, and R-squares. Overall, the Fama and French (1993) five-factor model performs most satisfactorily among the asset pricing models considered in explaining the intertemporal and cross-sectional behavior of stock returns in Korea. The Fama and French (1993) three-factor model, the Chen et al. (2010) three-factor model, and the Campbell (1996) model are the next. The results indicate that the two bond portfolios, term spread and default spread, play an important role in explaining stock returns in Korea.

1. Introduction

Since the introduction of the Capital Asset Pricing Model (CAPM) of Sharpe (1964), Lintner (1965), and Black (1972), it has long been a major paradigm in financial economics. The CAPM is still widely used in estimating cost of capital for firms, measuring abnormal returns, and evaluating the performance of managed portfolios, etc. The prediction by the CAPM is that the expected return on a risky asset is linearly proportional to its beta only. In other words, the cross-sectional differences in average returns are determined solely by the beta, not by other variables. However, the validity of the CAPM has been seriously challenged. Empirical research has uncovered a number of anomalies that the CAPM could not explain. A systematic pattern in beta-adjusted returns across some firm characteristic variables is observed, which is dubbed anomaly. Many anomalies have been reported in the literature. Such anomalies are firm size (Banz, 1981; Reinganum,

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1981), book-to-market (Fama and French, 1992), short-term price continuation (or momentum) (Jegadeesh and Titman, 1993), long-term price reversal (DeBondt and Thaler, 1985), earnings information uncertainty (Kim, 2006, 2010), liquidity (Amihud and Mendelson, 1986; Pastor and Stambaugh, 2003), post-earnings-announcement-drift (PEAD) (Ball and Brown, 1968; Foster et al., 1984; Bernard and Thomas, 1989), and asset growth (Cochrane, 1996; Cooper et al., 2008; Chen et al., 2010; Yao et al., 2011).[1]

The inability of the CAPM to explain the cross-sectional spread in average returns has led to the development of alternative asset pricing models. As an alternative model, Ross (1976) suggests the arbitrage pricing theory (APT). However, the theory contains no clue about the number of factors and the identification of the factors. Researchers have therefore suggested empirical factors which are based on the pricing errors by the CAPM or the anomalies. Among the APT-motivated models containing those empirical factors, the most prominent are Fama and French (1993). They suggest a three-factor model containing the market factor, SMB, and HML, and a five-factor model containing the above-mentioned three factors plus two bond factor portfolios; term spread (TERM) and default spread (DEF). Kim (2006) suggests a two-factor model containing the market factor and the earnings information uncertainty risk factor and shows that his two-factor model performs well in explaining the firm size effect and the January effect.[2] Chen et al. (2010) suggest a three-factor model containing the market factor, an investment factor (INVEST), and a return on asset factor (ROA) and argue that their model outperforms traditional asset pricing models in explaining anomalies associated with short-term price continuation, PEAD, accruals, and stock valuation ratios.

Since the failure of the CAPM in explaining the cross-section of average returns could be attributed to its static single-period nature, multi-period or continuous time models are also emerged as alternative models. Such models are the Consumption-based CAPM (CCAPM) of Rubinstein (1976), Lucas (1978), and Breeden (1979) and the Intertemporal CAPM (ICAPM) of Merton (1973). In particular, the ICAPM requires risk factors additional to the market factor. Merton argues that when there is stochastic variation in investment opportunities, there will be risk associated with innovations in the state variables that describe the investment opportunities. Since there is no theory to specify the exact form of the state variables, several ICAPM-motivated models, like APT-motivated models, are suggested according to the choice of the state variables. Among several such models, Campbell (1996) uses the relative Treasury-bill rate, the dividend yield, the growth rate in real labor income, and the term spread, Vassalou (2003) suggests future GDP growth, and Kim et al. (2011) suggest future labor income growth as the state variables.

As mentioned above, many asset pricing models are suggested in the literature. The purpose of this paper is to comprehensively evaluate and compare these asset pricing models in the Korean stock market. Basically, we consider unconditional asset pricing models only with one exception. Conditional models depending on instrumental variables are not considered, since the choice of instrumental variables for conditioning information is somewhat arbitrary and there can be many conditional models according to a combination of instrumental variables. The (unconditional) asset pricing models we consider are (i) CAPM, (ii) APT-motivated models, (iii) CCAPM, and (iv) ICAPM-motivated models. The exception is the Jagannathan and Wang (1996) conditional CAPM, since it does not depend on instrumental variables and, thus, is different from typical conditional models. APT-motivated models considered are Fama and French's (1993) three-factor model (FF3) and five-factor model (FF5), Chen et al.'s (2010) three-factor model (CNZ3), and Kim's (2006) two-factor model. In addition to these models, we also consider two-factor APT-motivated models; the market factor plus the liquidity factor, and the market factor plus the long-term reversal factor.[3] ICAPM-motivated models considered are Campbell's (1996) five-factor model, a two-factor model containing the market factor and the GDP factor, and another two-factor model containing the market factor and the labor factor.

To evaluate and compare the asset pricing models, we perform time-series tests and cross-sectional tests based on individual *t*-tests, the Gibbons et al. (1989) (GRS) *F*-tests, the Hansen and Jagannathan (1997) (HJ distance), and R-squares. Since test results could be sensitive to the test portfolio formation, we use various

[1] Chui and Wei (1998) examines book-to-market, firm size, and the turn-of-the-year effect for Pacific-Basin emerging markets.

[2] Chen and Chien (2011) explain the January effect in Taiwan with the Chinese culture bonus hypothesis within behavioral finance framework.

[3] Since the momentum effect is not observed in Korea, we do not consider any factor models containing the momentum factor in the comparison.

test portfolios as well as individual stocks. Overall, time-series tests and cross-sectional regression tests for the period from 1990 through 2009 show that FF5 performs best among the asset pricing models considered in explaining the intertemporal and cross-sectional behavior of stock returns in Korea. FF3, CNZ3, and the Campbell model are the next. The results that FF5 outperforms FF3 in many aspects indicate that the bond portfolios, TERM and DEF, play an important role in explaining stock returns in Korea.[4]

The rest of the paper is organized as follows. Section 2 describes asset pricing models under consideration, Section 3 explains how to construct risk factors to be used in the models, Section 4 describes data, Section 5 presents empirical results, and Section 6 concludes.

2. Asset pricing models

To determine which asset pricing model explains well intertemporal and cross-sectional behavior of stock returns in Korea, we consider the following asset pricing models.

2.1. The CAPM

The Sharpe–Lintner version of the CAPM is considered. The value-weighted return with dividends of all stocks traded on the Korea Stock Exchange (KSE) in excess of the risk-free rate of return is used as the market factor, MKT.

2.2. APT-motivated models

We consider various models constructed within the APT framework for the evaluation and comparison. Fama and French (1993) suggest a five-factor model, since it does a good job in explaining common variation in bond and stock returns and cross-section of average returns across firm size and book-to-market. Fama and French (1996) shows that the anomalies such as size, book-to-market, long-term price reversal, earnings-price, and past sales growth, except for short-term price continuation, largely disappear in their three-factor model. We thus include their two models; five-factor model and three-factor model. More specifically, the two models are

(i) The Fama and French (1993) three-factor model, FF3, containing the market factor, SMB (risk factor associated with firm size), and HML risk factor associated with book-to-market.
(ii) The Fama and French (1993) five-factor model, FF5, containing the market factor, SMB, HML, default spread (DEF), and term spread (TERM).

Chen et al. (2010) motivate a new three-factor model, CNZ3, from investment-based asset pricing. Intuitively, investment and ROA affect discount rates and then future stock returns. Although their new factors are constructed on economic fundamentals, not on mispricing by the CAPM, they argue that CNZ3 explains many patterns in the cross-sectional returns (or anomalies) that traditional asset pricing models including the Fama and French models cannot. CNZ3 is described below:

(iii) The Chen et al. (2010) three-factor model containing the market factor, an investment factor (INVEST), and a return on asset factor (ROA).

Kim (2006) provides a risk-based explanation for the seasonal regularity of January in stock returns by suggesting a two-factor model containing a common risk factor related to earnings information uncertainty. Kim argues that there is a remarkable improvement in explaining the January effect as well as the size effect when his two-factor model is used. The Kim two-factor model is described as

(iv) The Kim (2006) two-factor model containing the market factor and the earnings information uncertainty risk factor (EIU).

Besides the above models, we also consider the following two-factor APT-motivated models, since the recent literature shows that liquidity plays a significant role of explaining stock returns, and the long-term

[4] Hong et al. (2009) examine if the betas on DEF and TERM affect the bond returns in the Korean bond markets and find that these betas do not provide significant explanations.

price reversal phenomenon is prominent in the Korean stock market while the short-term price continuation is not[5,6];

(v) A two-factor model containing the market factor and the liquidity factor (LIQ);
(vi) A two-factor containing the market factor and a long-term price reversal factor (REVSL).

2.3. The CCAPM

Breeden (1979) demonstrates that the expected return of an asset is proportional to its covariance with the aggregate consumption in a continuous time model of an intertemporal portfolio decision. The CCAPM seems to have theoretical preference to the CAPM. This model contains the market factor and the consumption factor (CONSU).[7]

2.4. ICAPM-motivated models

Campbell (1996) develops a five-factor dynamic asset pricing model that allows for both changing investment opportunities and human capital. In his model, an expected return of an asset depends on the covariance of its return with the market portfolio and with innovations in state variables that help to forecast future market returns and future labor income. For such state variables, Campbell suggests the relative Treasury-bill rate, the dividend yield, the growth rate in real labor income, and the term spread.[8] Vassalou (2003) argues that changes in the investment opportunity set are summarized by changes in future GDP growth and suggests a two-factor model containing the market factor and the GDP factor. Kim et al. (2011) suggest future labor income growth as the state variable and construct a risk factor which is associated with its innovations. Among many ICAPM-motivated models, therefore, we consider the following three unconditional models.

(i) A two-factor model containing the market factor and the GDP factor (GDP).
(ii) A two-factor model containing the market factor and the labor factor (LABOR).
(iii) The Campbell (1996) five-factor model;

This model contains the market factor and the innovations (or residuals) generated from the first-order vector autoregressive (VAR(1)) of the above-mentioned four state variables: the relative bill rate (RTB; the difference between the one-month Treasury bill rate and the 1-year backward moving average), the dividend yield (DIV; a 1-year backward moving average of dividends divided by the most recent stock index), the growth rate in per capita real labor income (LBR), and the term spread (TERM). Note that LBR is not a factor portfolio, while LABOR is a factor mimicking portfolio based on the factor loading on LBR.

2.5. The Jagannathan and Wang (1996) conditional CAPM

Jagannathan and Wang (1996) formulate a two-factor model by assuming that the CAPM holds in a conditional sense where market betas and the market risk premium vary over time. Their two-factor model for unconditional expected returns is driven from the one-factor conditional CAPM. The two factors are the return on the portfolio of the aggregate wealth and a variable that forecasts future business conditions. Since the portfolio of the aggregate wealth includes tradable and non-tradable assets, the first factor is decomposed into the return on the stock index portfolio (as tradable assets) and the return on human capital (as non-tradable assets). In empirical setting, this model contains three factors; MKT (as a proxy for

[5] Ramiah et al. (2011) investigate the profitability of contrarian investment strategies for stocks listed on the Hong Kong Stock Exchange and report significantly higher contrarian profits.

[6] Narayan and Zheng (2010) report that financial market anomalies such as firm size, book-to-market, the turnover rate, and momentum both with and without the inclusion of the market liquidity risk factor can explain cross-sectional stock returns of the Chinese stock market. Chang et al. (2010) report a negative relation of liquidity with stock returns in the Tokyo Stock Exchange.

[7] Kim (2009) reports that the CCAPM performs no better than the standard CAPM in Korea and adding the return on human capital as an additional risk factor does not help explain the cross-section of average stock returns.

[8] Hahn and Lee (2006) shows that shocks to conditioning variables such as dividend yield, term spread, default spread, and one-month Treasury bill yield fully replace the explanatory power of HML and SMB in the cross-section of average returns.

the return on the stock index), LBR (as a proxy for the return on human capital), and DEF (a proxy for the variable which is most helpful in predicting future business condition and for time-varying market risk premium).

3. Construction of the factors

This section explains how to construct the factors used in the asset pricing models. The factors constructed here are all factor mimicking portfolios based on some firm characteristics or factor loadings on macroeconomic variables.

3.1. MKT

The market factor, MKT, is the value-weighted return with dividends of all KSE stocks in excess of the risk-free return.

3.2. SMB and HML

SMB and HML are constructed from a two-by-three sort on size and book-to-market as in Fama and French (1993). At the end of March of each year *y* from 1989 to 2009, all stocks are ranked on market capitalization (or size).[9] The median value of the size is used as a size break point to split all stocks into two groups, small (S) and big (B). We also rank all stocks on book-to-market (BM) ratio and then break all stocks into three book-to-market groups based on the break points for the bottom 30% (L), middle 40% (M), and top 30% (H). We form six portfolios from the intersections of the two size and the three BM groups. Monthly equally-weighted returns on the six portfolios are calculated from April of year *y* to March of year $y+1$. SMB is the difference, each month, between the simple average of the returns on the three small portfolios (S/L, S/M, and S/H) and the simple average of the returns on the three big stocks (B/L, B/M, and B/H). HML is the difference, each month, between the simple average of the returns on the two high BM portfolios (S/H and B/H) and the simple average of the returns on the two low BM portfolios (S/L and B/L).

3.3. INVEST

The investment factor, INVEST, is constructed from a two-by-three sort on size and investment-to-asset (IA) ratio as in Chen et al. (2010). At the end of March of each year *y* from 1989 to 2009, we sort all stocks into one of three IA groups based on the break points for the bottom 30% (low), middle 40%, and top 30% (high) of the IA ranked values. We also sort all stocks one of two size groups based on the median size value. We form six portfolios from the intersections of the two size and the three IA groups. Monthly equally-weighted returns on the six portfolios are calculated from April of year *y* to March of year $y+1$. INVEST is the difference, each month, between the simple average of the returns on the two low IA portfolios and the simple average of the returns on the two high IA portfolios.

3.4. ROA

The return-on-asset factor, ROA, is also constructed from a two-by-three sort on size and ROA. ROA is constructed in the same way as INVEST except that stocks are sorted twice a year (at the end of March and September) based on the ranked values of semiannual ROA. Quarterly or semiannual earnings are used in portfolio sorts in the months immediately after the most recent public earnings announcement month.

[9] More than 80% of Korean firms have the fiscal-year end month of December. Since relevant accounting information is nowadays transmitted much faster than before, we choose the April–March cycle for portfolio rebalancing, assuming that investors are informed of relevant accounting information within 3 months after the fiscal year end month. We have also used the July–June cycle for portfolio rebalancing. However, the results are qualitatively unchanged.

3.5. LIQ

At the end of March of each year from 1989 to 2009, we sort all stocks according to Amihud's (2002) liquidity measure [=−monthly average($|r_t|$/dVol$_t$), where r_t is daily return in day t and dVol$_t$ means daily volume in dollars]. The liquidity risk factor, LIQ, is constructed as the return on a zero-investment portfolio by buying long the top 20% (poor liquidity) firms and selling short the bottom 20% (good liquidity) firms in terms of the magnitude of the illiquidity measure.

3.6. EIU

This is a risk factor associated with earnings information uncertainty. At the end of March and September of each year from 1989 to 2009 (rebalanced twice a year), we sort all stocks according to their standard deviations of forecasting errors. The earnings information uncertainty risk factor, EIU, is constructed similarly to Kim (2006) as the return on a zero-investment portfolio by buying long the top 20% firms and selling short the bottom 20% firms in terms of the magnitude of the standard deviation of forecasting errors.

The standard deviation of forecasting errors (STDFE) is computed as follows. The earnings forecast error is defined as the difference between the actual semi-annual earnings per share (EPS) and the forecasted EPS. Since Korean firms announced earnings semiannually over the most sample period, the number of semiannual earnings observations is not enough to forecast earnings by applying a statistical model as in Foster et al. (1984) and Kim (2006). As a compromise to maintain the sufficient test period, we use the earnings of the same period in the previous year as the forecasted earnings of this period. We compute the standard deviation of the period by using past 7 (at least 5) forecast errors available up to the period.

3.7. REVSL

At the end of each month from December 1989 to December 2009 (monthly rebalanced), we sort all stocks according to their past returns compounded over $t-60$ months through $t-13$ months, where t is the sorting month. A long-term price reversal factor, REVSL, is constructed as the return on a zero-investment portfolio by buying long the top 20% past loser firms and selling short the bottom 20% past winner firms.

3.8. LABOR

At the end of March of each year y from 1989 to 2009, we sort all stocks according to their factor loading on the growth rate in (seasonally-adjusted) real labor income, β_{LABOR}. The labor factor, LABOR, is constructed as the return on a zero-investment portfolio by buying long the 20% of high-β_{LABOR} firms and selling short the 20% of low-β_{LABOR} firms.[10] The factor loading is estimated by regressing monthly returns of past 36 months on monthly growth rates in real labor income available up to December of year $y-1$.

3.9. GDP

At the end of March of each year y from 1989 to 2009, we sort all stocks according to their factor loadings on the growth rate in (seasonally-adjusted) GDP, β_{GDP}. The GDP factor, GDP, is constructed as the return on a zero-investment portfolio by buying long the 20% of high-β_{GDP} firms and selling short the 20% of low-β_{GDP} firms in terms of the magnitude of β_{GDP}. The factor loading is estimated by regressing monthly returns of past 36 months on transformed monthly growth rates in GDP available up to December of year $y-1$. Since GDP data is of quarterly frequency, monthly growth rates are obtained by transforming quarterly growth rates. The transformed monthly growth rate is assigned into the corresponding three calendar months.

[10] Labor income data is of monthly frequency over the period 1990–2007. Over the period 2008–2009, however, the date is of quarterly frequency. For this period, the quarterly growth rate is transformed into monthly growth rate, and the same transformed monthly growth rate is assigned into the corresponding three calendar months.

3.10. CONSU

The consumption factor is constructed in the same way as GDP. We use the item 'Composition of final consumption expenditure of households by type' issued by Bank of Korea as the amount of consumption.

3.11. TERM

TERM is the term spread which is the difference between the yield on 5-year National Housing Bond Type I and the yield on one-year Monetary Stabilization Bonds issued by the Bank of Korea.

3.12. DEF

DEF is the default spread which is the difference between the 3-year AA-rated corporate bond yield and the 3-year financial debentures yield issued by the Korea Development Bank (which is equivalent in terms of credit rating to Korea government bonds).

4. Data

Stock return and trading volume data are obtained from the databases of Korea Capital Market Institute and Kis-Value, and account data is obtained from the database of Kis-Value. GDP, consumption, and bond yield data are obtained from Bank of Korea.[11] Labor income data is obtained from FnGuide.

5. Empirical results

5.1. Constructing test portfolios

Test results of asset pricing models are sensitive to how to form test portfolios. We thus consider various test portfolios. In order to be good test portfolios, the characteristics of the portfolios should well represent those of whole individual stocks with respect to average return and risk. Thus, the cross-sectional spread in average returns of test portfolios should be monotonic and sufficiently wide. The literature shows that there are several firm characteristic variables that generate such cross-sectional spread in average returns when individual stocks are sorted by these variables. Such firm characteristic variables are firm size, book-to-market, past returns (from t-60 through t-13 months), standard deviation of earnings forecast errors (STDFE), liquidity, standardized unexpected earnings (SUE), and asset growth rate. Cross-sectional spreads in average return of the portfolios formed by these variables are not explained by the CAPM, which are dubbed anomalies. Note that the momentum effect, which is significantly observed in most countries of North America and Europe, is not observed in the Korean stock market.[12] To examine how well the asset pricing models explain these anomalies, we use portfolios sorted by these variables as test assets.

At the end of March of each year y from 1989 to 2009, we sort all stocks into one of ten decile portfolios according to the value of each firm characteristic variable available up to the rebalancing time. Monthly equally-weighted returns on the ten decile portfolios are calculated from April of year y to March of year $y+1$. Portfolios sorted by STDFE and SUE are rebalanced twice a year at the end of March and September. We use Amihud's (2002) liquidity measure for the liquidity variable.

Table 1 shows average monthly returns of ten decile portfolios sorted by each of the firm characteristic variables over the period from January 1990 through December 2009. Average returns across the firm characteristic variables show the similar pattern observed in international stock markets. Average returns have a negative relation with firm size, past returns, liquidity, and asset growth and a positive relation

[11] The link is http://ecos.bok.or.kr/EIndex_en.jsp.

[12] The momentum effect is not observed in the Korean stock market. When ten decile portfolios are formed based on past three-month compounded returns, we observe even a moderate price reversal. Specifically, the monthly average returns of the ten decile portfolios are 1.94, 1.47, 1.43, 1.48, 1.56, 1.47, 1.43, 1.49, 1.66, and 1.00%, respectively. The difference between portfolio 10 (pas winner) and portfolio 1 (past loser) is −0.94% (t-statistic of −1.35).

Table 1
Average returns of ten decile portfolios sorted by a sorting variable. This table presents the average returns (in%) of ten decile equally-weighted portfolios constructed by each sorting variable over the whole period from January 1990 through December 2009. Firms listed on the KSE are ranked according to the magnitude of the sorting variable and are allocated into one of ten decile portfolios. Financial firms and firms with negative book-to-market value are excluded. Portfolios are rebalanced at the end of March every year except for portfolios sorted by STDFE and SUE. STDFE portfolios and SUE portfolios are rebalanced semi-annually at the end of March and September every year. Portfolios 1 (10) contains firms with the smallest (largest) value of the sorting variable. 'P10 − P1' is the difference in average returns between Portfolio 10 and Portfolio 1. 'Firm size' is the market capitalization of common stocks, 'Book-to-market' is the ratio of book value to market value of common stocks, 'Past returns' is the compounded return over past 4 years from t-13 to t-60 (t is the portfolio formation month and, thus, the portfolios are formed one year after the computation of the past returns), 'STDFE' is the standard deviation of semi-annual earnings forecast errors (see Kim; 2006), 'Liquidity' is Amihud's (2002) liquidity measure (=−monthly average($|r_t|/dVol_t$), where r_t is daily return and $dVol_t$ means daily volume in dollars), and 'SUE' is the standardized unexpected earnings [=the change in the most recently announced semi-annual earnings per share (EPS) from last year's EPS over the same period divided by the standard deviation of the changes in semi-annual EPS's over the prior 7 semi-annual periods (at least 5 semi-annual periods)], 'Asset growth' is the annual growth rate of total assets.

Portfolio	Sorting variable						
	Firm size	Book-to-market	Past returns	STDFE	Liquidity	SUE	Asset growth
1 (small)	3.21	0.03	1.51	0.63	3.53	0.86	1.76
2	1.97	0.65	1.54	1.11	1.95	1.01	1.57
3	1.49	1.03	1.59	1.04	1.81	1.07	1.61
4	1.01	1.22	1.61	1.14	1.69	0.73	1.39
5	1.05	1.04	1.30	1.07	1.47	0.92	1.22
6	0.91	1.30	1.39	1.35	1.04	1.15	1.49
7	0.68	1.33	1.09	1.25	0.97	1.64	1.26
8	0.55	1.44	1.18	1.46	0.56	1.51	0.91
9	0.69	1.99	1.08	1.43	0.67	1.61	0.65
10 (large)	0.79	2.32	0.62	1.95	0.63	1.75	0.32
P10 − P1	−2.42	2.29	−0.89	1.33	−2.90	0.90	−1.44
(t-Statistic)	(−2.99)	(4.94)	(−1.24)	(2.45)	(−1.79)	(2.47)	(−4.13)

with book-to-market, STDFE, and SUE. The similar cross-sectional pattern in average returns is also found for the two subperiods before and after the Asian foreign currency crisis; 1990–1998 and 1999–2009.[13] The cross-sectional spreads of average returns are monotonic across such firm characteristic variables and are sufficiently wide. In particular, the differences in average returns between the bottom decile portfolio and the top decile portfolio (P10 − P1) are statistically significant. Thus, each set of portfolios is adequate to use as test assets in time-series and cross-sectional tests.

5.2. Computing risk-free returns

Since expost realized returns are used in asset pricing tests, expost realized risk-free return should also be used in computing excess returns for consistency. To compute realized bond yields, bond trade prices are needed. However, monthly trade prices of short-term government bonds are unavailable in Korea over the sample period. Instead, annual yields on Monetary Stabilization Bonds (MSB) with one year maturity are available in monthly frequency.[14] This data is promised yield, not realized yield. Based on these annual promised yields, we estimate bond trade prices and compute monthly realized yield.

Suppose an investor purchased an MSB with face value of $1 and one year to maturity at price P_{t-1} at month $t-1$. Let y_{t-1} be the yield on the MSB based on P_{t-1}. Then, $P_{t-1} = \$1/(1+y_{t-1})$. After holding this bond for one month, the investor sells it at P_t in month t. Let y_t be the yield at month t based on P_t. Then,

[13] The results for the subperiods are available upon request.
[14] Monetary Stabilization Bonds (MSB's) are regularly issued by Bank of Korea. These bonds are regarded as equivalent to Korean government bonds with the same maturity in terms of credit rating. These bonds are pure discount bonds and have a variety of maturity from 14 days to 546 days. Among these, MSB's with one year maturity are most popular and actively traded. MSB's with one year maturity are usually used as the risk-free asset in the Korean literature.

$P_t = \$1/(1+y_t)^{\frac{11}{12}}$, since this bond has 11 months to maturity. Therefore, the holding period return (or realized yield) on this bond is

$$R_{ft} = \frac{P_t - P_{t-1}}{P_{t-1}} = \frac{\left[1/(1+y_t)^{\frac{11}{12}}\right] - [1/(1+y_{t-1})]}{1/(1+y_{t-1})}. \tag{1}$$

Based on Eq. (1), we compute the (realized) risk-free return each month over the whole sample period from January 1990 through December 2009.

5.3. Basic statistics of the factors

Table 2 shows monthly average returns, standard deviations, and first-order autocorrelation of the factors to be used in the asset pricing models over the period 1990–2009. The average returns of the factors associated with the firm characteristics, which are the factor risk premiums, are all statistically significant at the 5% significance level; SMB (0.85% with t-statistic of 2.45), HML (1.26% with t-statistic of 3.91), LIQ (2.09% with t-statistic of 2.02), EIU (0.82% with t-statistic of 1.99), and INVEST (0.95% with t-statistic of 4.77). ROA (0.57% with t-statistic of 1.68) is also statistically significant at the 10% significance level. The market factor, MKT (0.91% with t-statistic of 1.51), and the long-term reversal factor, REVSL (0.67% with t-statistic of 1.34), are barely significant. The bond market factors, DEF and TERM, are also significant. The average returns of DEF and TERM are 0.03% (with t-statistic of 9.29) and 0.02% (with t-statistic of 2.76), respectively. However, the factors constructed by factor loadings on the macroeconomic variables have insignificant or even negative average returns; LABOR (0.16% with t-statistic of 0.50), GDP (−1.31% with t-statistic of −1.64), and CONSU (0.32% with t-statistic of 0.96).

5.4. Time-series tests

5.4.1. Test statistics

We estimate the asset pricing models with test portfolios formed on various anomaly variables by using time-series regressions of the following form:

$$R_{pt} - R_{ft} = \alpha_p + \beta_{p1}F_{1t} + \cdots + \beta_{pK}F_{Kt} + \varepsilon_{pt},$$

or (2)

$$R_{pt} - R_{ft} = \alpha_p + \beta_p' F_t + \varepsilon_{pt}$$

where R_{pt} is the return on the test portfolio p ($p = 1, \cdots, N$) at time t ($t = 1, \cdots, T$), R_{ft} is the risk-free return, F_{kt} is the return on the k-th factor portfolio at time t, β_{pk} is the factor loading on the k-th factor portfolio, and ε_{pt} is the residual or idiosyncratic return with mean zero and covariance matrix Σ_ε. β_p is a $(K\times 1)$ vector of the factor loadings, and F_t is a $(K\times 1)$ vector of the factor portfolio returns. If the asset pricing model is well-specified, the intercept estimates should not be different from zero.

To evaluate the performance of the asset pricing models, we first use individual t-tests for the intercept (or Jensen alpha) estimates of the test portfolios when a particular asset pricing model is applied. In particular, we are interested in the significance of the difference in the intercept estimates between the bottom decile portfolio and the top decile portfolio, denoted P10−P1. This difference implies an arbitrage return obtained from buying long the bottom portfolio and selling short the top portfolio, even after adjusting for all factor risks of the applied model.

In addition to the individual t-tests, we also use the GRS F-statistic for a joint test for the null hypothesis $H_0: \alpha = (\alpha_1, \alpha_2, \cdots, \alpha_N)' = 0$. Assuming the error terms are jointly normally distributed with mean zero and nonsingular error covariance matrix Σ_ε, GRS suggest the following test statistic for the null hypothesis:

$$W = \left[\frac{T(T-N-K)}{N(T-K-1)}\right]\left[\frac{\hat{\alpha}'\widehat{\sum}_\varepsilon^{-1}\hat{\alpha}}{\left(1+\hat{\vartheta}^2\right)}\right] \sim F(N, T-N-K), \tag{3}$$

Table 2

Summary statistics of the factors. 'MKT' is the value-weighted market factor with dividends of all KSE stocks; SMB and HML are the risk factors associated with firm size and book-to-market, respectively; LIQ is the liquidity risk factor which is the difference in returns between low-liquid stocks and high-liquid stocks; EIU is the risk factor associated with earnings information uncertainty which is the difference in returns between high earnings uncertainty stocks and low earnings uncertainty stocks; REVSL is the long-term price reversal factor which is the difference in returns between past loser stocks and past winner stocks; INVEST is the investment risk factor which is the difference in returns between low-investment stocks and high-investment stocks; ROA is the return-on-asset factor which is the difference in returns between high ROA stocks and low ROA stocks; and LABOR, GDP, and CONSU are the labor, GDP, and consumption growth factors, respectively. LABOR is the difference in returns between high-β_{LABOR} stocks and low-β_{LABOR} stocks. GDP and CONSU are also similarly constructed according to the corresponding factor loadings. DIV is the dividend yield; DEF is the default spread which is the difference between the 3-year AA-rated corporate bond yield and the 3-year financial debentures yield issued by Korea Development Bank (which is equivalent in credit to Korea government bonds); TERM is the term spread which is the difference between the yield on 5-year National Housing Bonds Type I and the yield on one-year Monetary Stabilization Bonds (MSB); R_f is the risk-free return computed by using the yields on 1-year MSB issued by Bank of Korea. All returns are monthly.

	MKT	SMB	HML	LIQ	EIU	REVSL	ROA	INVEST	LABOR	GDP	CONSU	DIV	DEF	TERM	R_f
Panel A: average returns and standard deviation (%)															
Average (%)	0.91	0.85	1.26	2.09	0.82	0.67	0.57	0.95	0.16	−1.13	0.32	0.21	0.03	0.02	0.76
Std dev (%)	9.32	5.38	4.99	16.07	6.42	7.82	5.29	3.09	5.05	10.64	5.17	0.09	0.05	0.08	0.55
(*t*-stat)	1.51	2.45	3.91	2.02	1.99	1.34	1.68	4.77	0.50	−1.64	0.96	35.8	9.29	2.76	21.39
ρ(1)	0.09	0.04	0.08	−0.11	−0.05	0.07	0.06	−0.17	0.09	0.02	0.15	0.93	0.44	0.93	0.63
Panel B: correlation coefficients															
MKT	1	−0.21	0.13	−0.17	0.04	0.02	−0.19	−0.03	0.04	0.05	0.24	0.02	0.03	0.19	0.08
SMB	−0.21	1	−0.06	0.52	0.79	0.46	−0.36	0.34	0.09	0.13	0.19	0.01	−0.13	−0.03	0.09
HML	0.13	−0.06	1	0.27	0.05	0.39	−0.12	0.12	0.14	0.19	0.38	−0.05	0.11	0.09	0.02
LIQ	−0.17	0.52	0.27	1	0.47	0.58	−0.18	0.42	0.15	0.10	0.31	−0.02	0.02	−0.01	0.00
EIU	0.04	0.79	0.05	0.47	1	0.60	−0.54	0.37	0.08	0.11	0.31	−0.02	−0.03	0.08	0.04
REVSL	0.02	0.46	0.39	0.58	0.60	1	−0.55	0.36	0.20	0.04	0.43	−0.02	0.12	0.08	0.04
ROA	−0.19	−0.36	−0.12	−0.18	−0.54	−0.55	1	−0.10	−0.13	−0.08	−0.34	−0.03	−0.04	−0.06	−0.06
INVEST	−0.03	0.34	0.12	0.42	0.37	0.36	−0.1	1	0.08	0.04	0.31	−0.02	0.00	0.06	−0.02
LABOR	0.04	0.09	0.14	0.15	0.08	0.20	−0.13	0.08	1	0.26	0.07	−0.10	0.03	0.06	0.04
GDP	0.05	0.13	0.19	0.10	0.11	0.04	−0.08	0.04	0.26	1	0.18	−0.04	−0.13	−0.02	0.02
CONSU	0.24	0.19	0.38	0.31	0.31	0.43	−0.34	0.31	0.07	0.18	1	0.09	0.15	0.01	0.10
DIV	0.02	0.01	−0.05	−0.02	−0.02	−0.02	−0.03	−0.02	−0.10	−0.04	0.09	1	−0.11	−0.51	0.44
DEF	0.03	−0.13	0.11	0.02	−0.03	0.12	−0.04	0.00	0.03	−0.13	0.15	−0.11	1	0.41	−0.08
TERM	0.19	−0.03	0.09	−0.01	0.08	0.08	−0.06	0.06	0.06	−0.02	0.01	−0.51	0.41	1	−0.43
R_f	0.08	0.09	0.02	0.00	0.04	0.04	−0.06	−0.02	0.04	0.02	0.10	0.44	−0.08	−0.43	1

where $\widehat{\sum}_{\varepsilon}$ is the unbiased residual covariance matrix, $\hat{\vartheta}^2 = \overline{F}' \widehat{\sum}_F^{-1} \overline{F}$ ($\hat{\vartheta}$ is the Sharpe ratio), $\overline{F}$ is a $(K \times 1)$ vector of average returns of the factor portfolios $(= (1/T)\sum_{t=1}^{T} F_t)$, $\widehat{\sum}_F$ is the covariance matrix of the factor portfolio returns, N is the number of test assets, and T is the number of time-series return observations.

The individual t-tests and the GRS F-test are valid under the assumption that the residual returns are serially uncorrelated, homoskedastistic, and normally distributed. If the residual returns violate the assumption, the above tests may be biased, and thus a robust test is needed. For this circumstance, a test based on the HJ distance with the generalized method of moments (GMM) is performed. The HJ distance is defined as

$$\delta = \left[\underset{\theta}{Min}\, g(\theta)' W g(\theta)\right]^{1/2}, \tag{4}$$

where

$$g(\theta) = E(m_t R_t) - 1_N, \tag{5}$$

$$m_t = b_0 + b_1' F_t, \tag{6}$$

$\theta = (b_0, b_1')$ is a vector of parameters to be estimated, R_t is a $(N \times 1)$ vector of gross returns of test portfolios, and W is a weighting matrix. $E[R_t R_t']^{-1}$ is used for the weighting matrix to compute the HJ distance. The HJ distance can be interpreted as the maximum pricing error for the set of assets mis-priced by the model (Campbell and Cochrane, 2000). The p-value for the null hypothesis $H_0: \delta = 0$ is computed based on Jagannathan and Wang (1996). We also perform a test for equality of the HJ distances based on Kan and Robotti (2009), when two models are compared with respect to the HJ distance.

5.4.2. Regression results

Table 3 presents the intercept (or Jensen alpha) estimates of each of the ten decile test portfolios and their t-statistics and the average adjusted R-squares when a particular asset pricing model is applied. This table also reports the GRS F-statistic and the HJ distance for each asset pricing model. Test portfolios (all ten decile portfolios) are size portfolios (in Panel A), book-to-market portfolios (in Panel B), liquidity portfolios (in Panel C), STDFE portfolios (in Panel D), asset growth portfolios (in Panel E), long-term reversal portfolios (in Panel F), and SUE portfolios (in Panel G). Note that since some factors of the Campbell model and the Jagannathan and Wang model are not the returns of factor mimicking portfolios, their intercept estimates do not have the same economic implications as and are not comparable to those of the other asset pricing models. Thus, the intercept estimates of the two models and GRS F-statistics are not reported. Only the HJ distances and R-squares of these models are reported.

With respect to t-tests of the intercept estimates, FF5 and CNZ3 perform better than the other models in explaining intertemporal behavior of the test portfolios' returns. When FF5 is applied, the differences in the intercept estimate between P10 (largest portfolio) and P1 (smallest portfolio), P10−P1, are insignificant, and more importantly, the cross-sectional pattern observed in raw returns almost disappears in the intercept estimates for the most test portfolios except for asset growth, long-term reversal, and SUE portfolios. When CNZ3 is applied, we also observe the similar results, and P10−P1 is insignificant in the most test portfolios except for size, BM, and STDFE test portfolios. Meanwhile, CAPM, CCAPM, and ICAPM-motivated models (MKT + GDP, MKT + LABOR) fail to explain the cross-sectional spread observed in raw returns for all test portfolios except for long-term reversal portfolios. The differences in the intercept estimates between P10 and P1 from these models are almost the same in magnitude as those in average raw returns observed in Table 1. In other words, the cross-sectional spread in the factor loadings of these models does not explain almost at all the cross-sectional spread in raw returns.

The GRS F-statistic and the HJ distance are for simultaneous tests of pricing errors from an asset pricing model. The GRS test results indicate that when test assets are size, BM, asset growth, and SUE portfolios, all pricing models considered show pricing errors significantly different from zero except for only two cases.[15] The GRS test rejects the joint null hypothesis $H_0: \alpha = (\alpha_1, \alpha_2, \cdots, \alpha_{10})' = 0$ for all asset pricing

[15] For example, FF5 shows pricing errors insignificantly different from zero in size portfolios, and CNZ3 shows pricing errors insignificantly different from zero in SUE portfolios.

models considered. These results indicate that the anomalies by size, BM, asset growth, and SUE could be difficult to be explained by the asset pricing models considered or the GRS test is so conservative that the type I error may be too high. The investigation of the test power and test size of the GRS *F*-test is beyond the scope of this paper. Nonetheless, the GRS test does not reject the null hypotheses for FF5 and CNZ3 when test assets are liquidity and STDFE portfolios.

With respect to the HJ distance, FF5, CNZ3, and the Campbell model perform better than the other models. Among these three models, FF5 performs better than the other two models.[16] Table 4 presents the differences in the HJ distance between FF5 and the competing models ($= \mathrm{HJ}_k - \mathrm{HJ}_{\mathrm{FF5}}$, where k is each competing model) (in Panel A) and between CNZ3 and the competing models ($= \mathrm{HJ}_k - \mathrm{HJ}_{\mathrm{CNZ3}}$, where k is each competing model) (in Panel B). This table also reports *p*-values for the equality test of the HJ distance by Kan and Robotti (2009). Positive values of the difference indicate that FF3 or CNZ3 outperforms the competing model in terms of the HJ distance. We add 16 (4×4) size-BM portfolios as test assets to the previous test portfolios. Panel A of Table 4 shows that the differences in the HJ distance between FF5 and the competing models are all positive and are mostly statistically significant, except when the competing model is CNZ3. This implies that FF5 outperforms the other competing models in terms of the HJ distance except for CNZ3 for any test portfolios considered. To compare the performance of FF5 and CNZ3 with respect to the HJ distance, we examine the difference in the HJ distance between CNZ3 and FF5, $\mathrm{HJ}_{\mathrm{CNZ3}} - \mathrm{HJ}_{\mathrm{FF5}}$, for each set of the test portfolios. This difference is positive for five test portfolios; it is statistically significant for size-BM and size portfolios, but statistically insignificant for BM, STDFE, and long-term reversal test portfolios. The difference is negative for three test portfolios (liquidity, asset growth, and SUE portfolios); it is all statistically insignificant. Furthermore, the magnitude of the negative differences is smaller than that of the positive differences. These results indicate that FF5 somewhat outperforms CNZ3. Panel B of Table 4 shows that CNZ3 outperforms the other competing model in terms of the HJ distance except for FF5, FF3, and the Campbell model. While $\mathrm{HJ}_{\mathrm{FF3}} - \mathrm{HJ}_{\mathrm{FF5}}$ is all positive and $\mathrm{HJ}_{\mathrm{Campbell}} - \mathrm{HJ}_{\mathrm{FF5}}$ is negative only for one test portfolio (asset growth), $\mathrm{HJ}_{\mathrm{FF3}} - \mathrm{HJ}_{\mathrm{CNZ3}}$ or $\mathrm{HJ}_{\mathrm{Campbell}} - \mathrm{HJ}_{\mathrm{CNZ3}}$ is negative for five test portfolios. In summary, FF5 performs best with respect to the HJ distance, and FF3, the Campbell model, and CNZ3 are the next in order.

Overall, the time-series tests show that FF5 performs better than any considered model in explaining intertemporal behavior of the portfolio returns in Korea. FF5 also has the greatest average adjusted R-square for all test portfolios.[17] FF5 has two additional factors over FF3; TERM and DEF. Therefore, the above results that FF5 outperforms FF3 indicate that the bond portfolios, TERM and DEF, play an important role in explaining stock returns in Korea.

5.4.3. Explanatory power of term spreads and default spreads after controlling for SMB and HML factors

Fama and French (1993) report that the explanatory power of TERM and DEF for U.S. stock returns disappears when SMB and HML are added in the model. Different from the case of the U.S., however, the previous results show that TERM and DEF play an important role in explaining stock returns in the Korean stock market even after SMB and HML are still in the model. To further confirm this, we construct the orthogonalized TERM and DEF with respect to SMB and HML and examine whether these orthogonalized factors still have a significant explanatory power for stock returns in Korea. To construct the orthogonalized TERM and DEF, we estimate the following time-series regression models separately:

$$\mathrm{TERM}_t = c_0 + c_1 \mathrm{SMB}_t + c_2 \mathrm{HML}_t + \xi_t, \tag{7}$$

and (8)

$$\mathrm{DEF}_t = d_0 + d_1 \mathrm{SMB}_t + d_2 \mathrm{HML}_t + \eta_t.$$

[16] The HJ-distances of the Jagannathan and Wang model are 0.31[0.02], 0.35[0.00], 0.23[0.14], 0.13[0.82], 0.36[0.08], 0.14[0.76], and 0.27[0.01], respectively, when test assets are size, book-to-market, liquidity, STDFE, asset growth, long-term reversal, and SUE portfolios. Numbers in bracket are *p*-values.

[17] The $\overline{\mathrm{Adj}}\ R^2$ the Jagannathan and Wang model are 0.57, 0.58, 0.50, 0.60, 0.59, 0.55, and 0.60, respectively, when test assets are size, book-to-market, liquidity, STDFE, asset growth, long-term reversal, and SUE portfolios.

Table 3

Intercept (or Jensen's alpha) estimates of the factor models and tests for pricing errors. This table presents the intercept estimates (or Jensen's alphas) of each of ten decile test portfolios from the factor models for the whole period 1990–2009. 'FF3' indicates the Fama and French (1993) three-factor model containing the market factor, SMB, and HML; 'FF5' indicates a five-factor model containing Fama and French's three factors plus the default spread (DEF) and the term spread (TERM); 'CNZ3' indicates Chen et al.'s (2010) three-factor model containing the market factor, an investment factor (INVEST), and a return on asset factor (ROA); 'MKT + LIQ' is a two-factor model containing the market factor and a liquidity factor (LIQ); 'MKT + EIU' is the Kim (2006) two-factor model containing the market factor and an earnings information uncertainty risk factor (EIU); 'MKT + REVSL' is a two-factor model containing the market factor and a long-term price reversal factor (REVSL); 'MKT + GDP' is a two-factor model containing the market factor and a GDP factor; 'MKT + LABOR' is a two-factor model containing the market factor and a labor factor; CCAPM is the Consumption-based CAPM; and 'Campbell' indicates the Campbell (1996) five-factor model containing the market factor and the innovations from the first-order VAR of the following four state variables : the relative bill rate (the difference between the 1-month Treasury bill rate and the 1-year backward moving average), dividend yield, real labor income growth rate, and term spread. 'P10 − P1' is the intercept estimates in the difference between Portfolio 10 and Portfolio 1, GRS is the Gibbons et al. (1989) *F*-statistic for a joint test whether all intercept estimates are significantly different from zero, and 'HJ-distance' is the Hansen and Jagannathan (1997) distance. Numbers in parentheses indicate *t*-values, and numbers in square brackets indicate *p*-values. $\overline{\text{Adj}}\ R^2$ is the time-series average of month-by-month CSR's. For the Campbell model, the intercept estimates and the GRS statistic are not shown since the factors of the model are not portfolios. The Jagannathan and Wang (1996) model is also considered. When test assets are size, book-to-market, liquidity, STDFE, asset growth, long-term reversal, and SUE portfolios, its HJ-distances are 0.31[0.02], 0.35[0.00], 0.23[0.14], 0.13[0.82], 0.36[0.08], 0.14[0.76], and 0.27[0.01], respectively, and its $\overline{\text{Adj}}\ R^2$ are 0.57, 0.58, 0.50, 0.60, 0.59, 0.55, and 0.60, respectively.

Panel A: tests asset = size portfolios

	CAPM	APT-motivated models						CCAPM	ICAPM-motivated models		
		FF3	FF5	CNZ3	MKT + LIQ	MKT + EIU	MKT + REVSL		MKT + GDP	MKT + LABOR	Campbell
Size portfolio											
1	2.33 (2.91)	−0.14 (−0.33)	−0.27 (−0.54)	1.29 (1.98)	1.18 (2.00)	1.03 (2.22)	1.64 (2.67)	2.08 (2.45)	2.52 (3.15)	2.26 (2.86)	
2	1.09 (1.75)	−0.61 (−1.64)	−0.43 (−1.00)	0.56 (0.99)	0.41 (0.77)	0.12 (0.31)	0.70 (1.27)	0.98 (1.32)	1.19 (1.89)	1.08 (1.73)	
3	0.62 (1.17)	−0.85 (−2.55)	−0.47 (−1.23)	0.04 (0.09)	0.11 (0.23)	−0.14 (−0.37)	0.31 (0.64)	0.52 (0.78)	0.73 (1.38)	0.61 (1.15)	
4	0.13 (0.27)	−1.29 (−4.12)	−0.99 (−2.73)	−0.36 (−0.78)	−0.35 (−0.80)	−0.54 (−1.51)	−0.16 (−0.35)	0.06 (0.10)	0.25 (0.51)	0.11 (0.23)	
5	0.17 (0.37)	−1.00 (−2.93)	−0.70 (−1.77)	−0.31 (−0.69)	−0.17 (−0.39)	−0.41 (−1.14)	−0.04 (−0.10)	0.13 (0.20)	0.26 (0.58)	0.17 (0.38)	
6	0.03 (0.06)	−1.13 (−3.11)	−0.87 (−2.07)	−0.46 (−1.04)	−0.38 (−0.94)	−0.49 (−1.32)	−0.19 (−0.46)	−0.03 (−0.05)	0.14 (0.32)	0.02 (0.04)	
7	−0.21 (−0.54)	−0.92 (−2.50)	−0.53 (−1.25)	−0.47 (−1.15)	−0.42 (−1.10)	−0.60 (−1.74)	−0.34 (−0.87)	−0.18 (−0.27)	−0.15 (−0.38)	−0.22 (−0.54)	
8	−0.34 (−0.99)	−1.03 (−3.14)	−0.82 (−2.18)	−0.67 (−1.96)	−0.55 (−1.64)	−0.65 (−2.09)	−0.48 (−1.44)	−0.35 (−0.56)	−0.30 (−0.87)	−0.34 (−0.99)	
9	−0.22 (−0.74)	−0.60 (−2.05)	−0.44 (−1.30)	−0.42 (−1.38)	−0.33 (−1.14)	−0.38 (−1.34)	−0.29 (−1.00)	−0.21 (−0.33)	−0.23 (−0.78)	−0.21 (−0.71)	
10	−0.13 (−0.68)	−0.04 (−0.22)	−0.08 (−0.36)	−0.11 (−0.53)	−0.14 (−0.71)	−0.11 (−0.58)	−0.14 (−0.72)	−0.10 (−0.17)	−0.19 (−1.04)	−0.12 (−0.64)	
P10 − P1	−2.46 (−3.07)	0.10 (0.27)	0.18 (0.44)	−1.39 (−2.19)	−1.32 (−2.23)	−1.14 (−2.54)	−1.78 (−2.87)	−2.19 (−2.82)	−2.71 (−3.43)	−2.38 (−3.02)	

GRS	2.87 [0.00]	2.76 [0.00]	1.51 [0.14]	2.76 [0.00]	2.44 [0.01]	2.76 [0.00]	2.89 [0.00]	3.91 [0.00]	2.86 [0.00]	2.83 [0.00]	
HJ-distance	0.34 [0.00]	0.19 [0.67]	0.13 [0.65]	0.22 [0.23]	0.23 [0.23]	0.18 [0.76]	0.21 [0.44]	0.26 [0.11]	0.34 [0.00]	0.33 [0.00]	0.15 [0.88]
$\overline{\text{Adj}}\ R^2$	0.57	0.79	0.79	0.65	0.66	0.76	0.65	0.07	0.57	0.57	0.59

Panel B: tests asset = book-to-market portfolios

BM portfolio											
1	−0.86 (−2.13)	−1.29 (−4.33)	−1.14 (−3.29)	−1.00 (−2.61)	−1.15 (−2.99)	−1.41 (−4.86)	−1.02 (−2.65)	−0.87 (−1.37)	−0.81 (−2.00)	−0.86 (−2.13)	
2	−0.23 (−0.57)	−0.77 (−2.32)	−0.48 (−1.25)	−0.65 (−1.66)	−0.54 (−1.44)	−0.69 (−2.16)	−0.36 (−0.94)	−0.23 (−0.38)	−0.17 (−0.43)	−0.22 (−0.56)	
3	0.14 (0.34)	−0.29 (−0.85)	0.07 (0.18)	−0.26 (−0.66)	−0.07 (−0.18)	−0.29 (−0.86)	0.02 (0.05)	0.16 (0.25)	0.12 (0.29)	0.15 (0.37)	
4	0.33 (0.75)	−0.62 (−1.88)	−0.46 (−1.19)	−0.16 (−0.39)	−0.03 (−0.08)	−0.25 (−0.75)	0.13 (0.33)	0.28 (0.44)	0.43 (0.99)	0.32 (0.74)	
5	0.15 (0.37)	−0.59 (−1.69)	−0.43 (−1.06)	−0.26 (−0.66)	−0.16 (−0.42)	−0.31 (−0.93)	−0.03 (−0.08)	0.14 (0.22)	0.19 (0.46)	0.15 (0.38)	
6	0.42 (0.98)	−0.68 (−2.08)	−0.35 (−0.93)	0.09 (0.22)	0.06 (0.15)	−0.14 (−0.45)	0.19 (0.48)	0.38 (0.59)	0.48 (1.11)	0.41 (0.95)	
7	0.44 (1.06)	−0.80 (−2.61)	−0.54 (−1.52)	0.08 (0.19)	0.06 (0.16)	−0.08 (−0.26)	0.20 (0.54)	0.39 (0.63)	0.52 (1.24)	0.44 (1.04)	
8	0.55 (1.25)	−0.86 (−2.88)	−0.63 (−1.82)	0.16 (0.38)	0.15 (0.38)	−0.02 (−0.06)	0.30 (0.76)	0.48 (0.76)	0.65 (1.49)	0.54 (1.23)	
9	1.10 (2.27)	−0.65 (−2.14)	−0.51 (−1.44)	0.48 (1.07)	0.60 (1.41)	0.51 (1.32)	0.77 (1.84)	0.99 (1.50)	1.20 (2.47)	1.08 (2.23)	
10	1.43 (2.39)	−0.79 (−2.20)	−0.81 (−1.92)	0.77 (1.39)	0.63 (1.35)	0.65 (1.43)	0.93 (1.98)	1.24 (1.69)	1.58 (2.66)	1.39 (2.34)	
P10 − P1	2.28 (4.92)	0.50 (2.02)	0.33 (1.16)	1.77 (3.74)	1.77 (4.45)	2.07 (4.54)	1.95 (4.98)	2.11 (4.96)	2.39 (5.17)	2.25 (4.90)	
GRS	3.40 [0.00]	2.88 [0.00]	2.54 [0.01]	2.20 [0.02]	2.95 [0.00]	3.94 [0.00]	3.24 [0.00]	4.19 [0.00]	3.47 [0.00]	3.36 [0.00]	
HJ-distance	0.36 [0.00]	0.22 [0.18]	0.19 [0.63]	0.26 [0.20]	0.32 [0.00]	0.36 [0.00]	0.31 [0.00]	0.31 [0.01]	0.36 [0.00]	0.34 [0.01]	0.25 [0.60]
$\overline{\text{Adj}}\ R^2$	0.57	0.79	0.79	0.65	0.65	0.74	0.65	0.07	0.58	0.57	0.60

Panel C: tests asset = liquidity portfolios

Liquidity portfolios											
1	2.66 (1.60)	−1.04 (−0.70)	−2.26 (−1.31)	0.33 (0.21)	−0.69 (−1.56)	1.07 (0.72)	1.41 (1.02)	2.17 (1.35)	2.91 (1.74)	2.59 (1.55)	
2	1.08 (1.60)	−1.07 (−2.40)	−1.02 (−1.97)	−0.04 (−0.07)	−0.03 (−0.07)	0.16 (0.32)	0.53 (0.99)	0.84 (1.17)	1.21 (1.80)	1.02 (1.53)	
3	0.93 (1.55)	−1.01 (−2.62)	−0.89 (−2.01)	0.12 (0.22)	0.18 (0.38)	0.09 (0.20)	0.50 (0.98)	0.75 (1.05)	1.13 (1.90)	0.89 (1.49)	

(continued on next page)

Table 3 (*continued*)

Panel C: tests asset = liquidity portfolios

	CAPM	APT-motivated models						CCAPM	ICAPM-motivated models		
		FF3	FF5	CNZ3	MKT + LIQ	MKT + EIU	MKT + REVSL		MKT + GDP	MKT + LABOR	Campbell
Liquidity portfolios											
4	0.81 (1.61)	−0.57 (−1.59)	−0.33 (−0.80)	0.13 (0.28)	0.23 (0.54)	0.14 (0.37)	0.52 (1.14)	0.73 (1.08)	0.85 (1.68)	0.78 (1.56)	
5	0.58 (1.14)	−0.80 (−2.18)	−0.56 (−1.32)	−0.11 (−0.24)	0.04 (0.09)	−0.12 (−0.33)	0.29 (0.62)	0.51 (0.75)	0.70 (1.37)	0.55 (1.08)	
6	0.16 (0.34)	−0.88 (−2.47)	−0.58 (−1.40)	−0.24 (−0.53)	−0.19 (−0.44)	−0.43 (−1.18)	−0.05 (−0.11)	0.16 (0.23)	0.23 (0.50)	0.15 (0.33)	
7	0.08 (0.18)	−1.00 (−2.68)	−0.57 (−1.34)	−0.19 (−0.43)	−0.24 (−0.54)	−0.49 (−1.35)	−0.15 (−0.35)	0.05 (0.08)	0.17 (0.37)	0.08 (0.17)	
8	−0.33 (−0.80)	−1.04 (−2.88)	−1.01 (−2.42)	−0.37 (−0.93)	−0.55 (−1.36)	−0.83 (−2.49)	−0.51 (−1.29)	−0.34 (−0.51)	−0.29 (−0.69)	−0.32 (−0.77)	
9	−0.24 (−0.65)	−0.76 (−2.12)	−0.59 (−1.43)	−0.37 (−0.99)	−0.37 (−0.98)	−0.62 (−1.88)	−0.37 (−1.00)	−0.26 (−0.38)	−0.22 (−0.58)	−0.23 (−0.60)	
10	−0.28 (−1.27)	−0.43 (−1.86)	−0.58 (−2.20)	−0.27 (−1.23)	−0.36 (−1.59)	−0.46 (−2.19)	−0.36 (−1.64)	−0.29 (−0.46)	−0.31 (−1.37)	−0.28 (−1.25)	
P10 − P1	−2.95 (−1.83)	0.61 (0.42)	1.67 (1.00)	−0.60 (−0.39)	0.34 (1.02)	−1.52 (−1.05)	−1.76 (−1.31)	−2.46 (−1.58)	−3.22 (−1.99)	−2.87 (−1.79)	
GRS	1.57 [0.12]	1.49 [0.15]	1.58 [0.11]	0.53 [0.87]	1.13 [0.34]	1.46 [0.16]	1.40 [0.18]	2.07 [0.03]	1.85 [0.05]	1.57 [0.12]	
HJ-distance	0.24 [0.10]	0.16 [0.43]	0.16 [0.26]	0.11 [0.82]	0.20 [0.22]	0.20 [0.19]	0.21 [0.15]	0.20 [0.24]	0.23 [0.10]	0.17 [0.72]	0.16 [0.69]
$\overline{\text{Adj}}\ R^2$	0.50	0.72	0.72	0.61	0.70	0.69	0.61	0.09	0.51	0.51	0.52

Panel D: tests asset = STDFE portfolios

	CAPM	FF3	FF5	CNZ3	MKT + LIQ	MKT + EIU	MKT + REVSL	CCAPM	MKT + GDP	MKT + LABOR	Campbell
STDFE portfolios											
1	−0.26 (−0.89)	−0.60 (−2.09)	−0.08 (−0.26)	−0.55 (−1.83)	−0.38 (−1.35)	−0.38 (−1.34)	−0.26 (−0.91)	−0.21 (−0.37)	−0.23 (−0.78)	−0.25 (−0.85)	
2	0.22 (0.68)	−0.42 (−1.38)	−0.02 (−0.05)	−0.11 (−0.32)	0.04 (0.12)	0.01 (0.04)	0.14 (0.43)	0.26 (0.44)	0.24 (0.73)	0.20 (0.63)	
3	0.15 (0.42)	−0.60 (−1.92)	−0.03 (−0.09)	0.02 (0.06)	−0.03 (−0.09)	−0.17 (−0.52)	0.06 (0.17)	0.19 (0.31)	0.21 (0.59)	0.13 (0.38)	
4	0.25 (0.64)	−0.63 (−1.84)	−0.32 (−0.82)	−0.13 (−0.32)	0.02 (0.05)	−0.12 (−0.36)	0.13 (0.33)	0.25 (0.38)	0.29 (0.74)	0.25 (0.65)	
5	0.18 (0.45)	−0.62 (−1.73)	−0.31 (−0.76)	−0.02 (−0.04)	−0.03 (−0.06)	−0.25 (−0.72)	0.02 (0.05)	0.22 (0.33)	0.23 (0.56)	0.17 (0.43)	
6	0.46 (1.11)	−0.57 (−1.67)	−0.52 (−1.33)	0.14 (0.35)	0.16 (0.40)	−0.04 (−0.11)	0.26 (0.67)	0.42 (0.66)	0.52 (1.25)	0.45 (1.08)	

7	0.36 (0.88)	−0.69 (−2.07)	−0.69 (−1.78)	−0.08 (−0.19)	0.07 (0.19)	−0.12 (−0.35)	0.16 (0.41)	0.34 (0.53)	0.40 (0.98)	0.35 (0.86)	
8	0.58 (1.22)	−0.56 (−1.53)	−0.47 (−1.11)	0.08 (0.16)	0.16 (0.36)	−0.02 (−0.06)	0.36 (0.80)	0.53 (0.81)	0.65 (1.37)	0.57 (1.20)	
9	0.55 (1.00)	−0.72 (−1.87)	−0.42 (−0.95)	0.09 (0.17)	0.08 (0.17)	−0.32 (−0.96)	0.25 (0.50)	0.51 (0.71)	0.63 (1.15)	0.55 (1.00)	
10	1.06 (1.64)	−0.60 (−1.39)	−0.51 (−1.01)	0.37 (0.64)	0.37 (0.66)	−0.05 (−0.17)	0.61 (1.10)	0.94 (1.19)	1.17 (1.80)	1.02 (1.58)	
P10 − P1	1.32 (2.43)	−0.01 (−0.02)	−0.42 (−0.96)	0.92 (2.04)	0.75 (1.59)	0.33 (1.57)	0.87 (2.04)	1.15 (2.25)	1.40 (2.57)	1.27 (2.37)	
GRS	1.02 [0.43]	0.70 [0.73]	0.96 [0.48]	1.38 [0.19]	0.69 [0.74]	0.63 [0.79]	0.85 [0.58]	1.48 [0.15]	1.03 [0.42]	0.99 [0.45]	
HJ-distance	0.20 [0.31]	0.07 [0.99]	0.05 [0.99]	0.12 [0.75]	0.12 [0.88]	0.15 [0.55]	0.12 [0.81]	0.15 [0.77]	0.19 [0.31]	0.15 [0.68]	0.10 [0.82]
$\overline{\text{Adj}}\ R^2$	0.60	0.75	0.76	0.65	0.65	0.75	0.65	0.04	0.60	0.60	0.61

Panel E: tests asset = asset growth portfolios

Asset growth portfolios											
1	0.87 (1.54)	−0.48 (−1.29)	−0.47 (−1.08)	−0.16 (−0.34)	0.22 (0.47)	0.02 (0.04)	0.49 (1.00)	0.75 (1.03)	0.94 (1.67)	0.86 (1.52)	
2	0.68 (1.50)	−0.60 (−1.88)	−0.27 (−0.73)	0.11 (0.27)	0.23 (0.57)	0.05 (0.17)	0.39 (0.97)	0.61 (0.97)	0.78 (1.71)	0.66 (1.46)	
3	0.73 (1.69)	−0.40 (−1.24)	−0.17 (−0.46)	0.22 (0.55)	0.29 (0.76)	0.15 (0.47)	0.47 (1.22)	0.68 (1.08)	0.77 (1.79)	0.72 (1.66)	
4	0.50 (1.23)	−0.62 (−1.96)	−0.30 (−0.84)	−0.04 (−0.10)	0.09 (0.23)	0.00 (0.01)	0.27 (0.73)	0.47 (0.75)	0.55 (1.34)	0.51 (1.23)	
5	0.34 (0.84)	−0.62 (−1.92)	−0.20 (−0.53)	−0.20 (−0.50)	0.02 (0.04)	−0.11 (−0.33)	0.17 (0.45)	0.33 (0.52)	0.38 (0.95)	0.34 (0.85)	
6	0.60 (1.58)	−0.39 (−1.33)	−0.07 (−0.21)	0.29 (0.78)	0.23 (0.68)	0.12 (0.40)	0.39 (1.12)	0.56 (0.91)	0.72 (1.90)	0.59 (1.56)	
7	0.38 (0.98)	−0.60 (−1.98)	−0.39 (−1.11)	0.10 (0.25)	0.06 (0.18)	−0.09 (−0.28)	0.19 (0.54)	0.36 (0.58)	0.43 (1.11)	0.37 (0.96)	
8	0.01 (0.03)	−0.94 (−2.88)	−0.72 (−1.92)	−0.18 (−0.44)	−0.30 (−0.79)	−0.49 (−1.54)	−0.17 (−0.45)	−0.02 (−0.03)	0.09 (0.22)	0.02 (0.04)	
9	−0.24 (−0.62)	−1.17 (−3.77)	−0.97 (−2.70)	−0.37 (−0.96)	−0.52 (−1.43)	−0.71 (−2.30)	−0.41 (−1.11)	−0.25 (−0.4)	−0.15 (−0.40)	−0.24 (−0.62)	
10	−0.57 (−1.33)	−1.55 (−4.53)	−1.54 (−3.86)	−0.53 (−1.24)	−0.91 (−2.25)	−1.12 (−3.37)	−0.77 (−1.92)	−0.62 (−0.96)	−0.49 (−1.14)	−0.59 (−1.37)	
P10 − P1	−1.44 (−4.12)	−1.07 (−3.29)	−1.07 (−2.82)	−0.36 (−1.35)	−1.13 (−3.53)	−1.13 (−3.58)	−1.26 (−3.88)	−1.37 (−4.00)	−1.43 (−4.07)	−1.44 (−4.12)	
GRS	4.84 [0.00]	4.10 [0.00]	4.06 [0.00]	2.56 [0.01]	4.33 [0.00]	4.62 [0.00]	4.72 [0.00]	5.11 [0.00]	4.77 [0.00]	4.79 [0.00]	
HJ-distance	0.39 [0.01]	0.37 [0.00]	0.32 [0.08]	0.30 [0.04]	0.32 [0.06]	0.37 [0.01]	0.34 [0.02]	0.44 [0.00]	0.38 [0.02]	0.39 [0.00]	0.17 [0.97]
$\overline{\text{Adj}}\ R^2$	0.59	0.78	0.78	0.67	0.67	0.76	0.66	0.07	0.59	0.59	0.61

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Table 3 (*continued*)

Panel F: tests asset = asset growth portfolios

	CAPM	APT-motivated models						CCAPM	ICAPM-motivated models		
		FF3	FF5	CNZ3	MKT + LIQ	MKT + EIU	MKT + REVSL		MKT + GDP	MKT + LABOR	Campbell
Reversal portfolios											
1	0.62 (0.80)	−1.69 (−3.04)	−2.43 (−3.78)	−0.24 (−0.38)	−0.52 (−0.93)	−0.56 (−1.12)	−0.22 (−0.47)	0.33 (0.41)	0.76 (0.97)	0.55 (0.72)	
2	0.64 (1.22)	−1.00 (−2.82)	−1.09 (−2.65)	0.21 (0.45)	0.06 (0.14)	−0.09 (−0.24)	0.16 (0.42)	0.52 (0.73)	0.74 (1.43)	0.61 (1.17)	
3	0.70 (1.42)	−0.83 (−2.44)	−0.52 (−1.33)	0.24 (0.55)	0.19 (0.44)	0.03 (0.08)	0.30 (0.77)	0.60 (0.88)	0.82 (1.69)	0.67 (1.37)	
4	0.72 (1.49)	−0.68 (−1.92)	−0.52 (−1.27)	0.13 (0.28)	0.24 (0.56)	0.10 (0.26)	0.41 (0.96)	0.63 (0.95)	0.79 (1.63)	0.70 (1.45)	
5	0.41 (0.96)	−0.87 (−2.83)	−0.52 (−1.48)	−0.02 (−0.06)	0.01 (0.02)	−0.12 (−0.37)	0.17 (0.44)	0.37 (0.57)	0.49 (1.14)	0.39 (0.92)	
6	0.51 (1.18)	−0.62 (−1.84)	−0.24 (−0.61)	−0.04 (−0.08)	0.09 (0.25)	0.00 (0.00)	0.30 (0.75)	0.48 (0.75)	0.60 (1.41)	0.50 (1.16)	
7	0.20 (0.50)	−0.58 (−1.70)	−0.13 (−0.33)	−0.24 (−0.59)	−0.05 (−0.13)	−0.21 (−0.62)	0.10 (0.25)	0.21 (0.33)	0.26 (0.65)	0.20 (0.49)	
8	0.29 (0.67)	−0.64 (−1.75)	−0.20 (−0.47)	−0.11 (−0.26)	−0.05 (−0.12)	−0.20 (−0.56)	0.13 (0.32)	0.27 (0.41)	0.38 (0.89)	0.27 (0.63)	
9	0.19 (0.49)	−0.55 (−1.60)	−0.31 (−0.78)	−0.39 (−0.99)	−0.12 (−0.32)	−0.20 (−0.57)	0.14 (0.36)	0.16 (0.26)	0.29 (0.75)	0.18 (0.46)	
10	−0.27 (−0.68)	−0.63 (−1.67)	−0.33 (−0.75)	−0.45 (−1.09)	−0.44 (−1.11)	−0.61 (−1.66)	−0.20 (−0.50)	−0.24 (−0.38)	−0.21 (−0.52)	−0.27 (−0.66)	
P10 − P1	−0.90 (−1.24)	1.06 (1.76)	2.10 (3.04)	−0.22 (−0.36)	0.08 (0.15)	−0.04 (−0.07)	0.02 (0.08)	−0.58 (−0.90)	−0.96 (−1.32)	−0.82 (−1.16)	
GRS	0.75 [0.67]	1.53 [0.13]	2.12 [0.02]	0.64 [0.78]	0.73 [0.70]	0.86 [0.57]	0.58 [0.83]	1.13 [0.34]	0.83 [0.60]	0.73 [0.69]	
HJ-distance	0.18 [0.45]	0.12 [0.84]	0.10 [0.83]	0.14 [0.59]	0.17 [0.42]	0.17 [0.38]	0.16 [0.53]	0.16 [0.60]	0.17 [0.57]	0.17 [0.49]	0.12 [0.85]
$\overline{\text{Adj } R^2}$	0.55	0.75	0.75	0.64	0.65	0.73	0.66	0.08	0.55	0.55	0.57

Panel G: tests asset = SUE portfolios

SUE portfolios											
1	−0.04 (−0.09)	−1.39 (−4.05)	−1.16 (−2.91)	−0.29 (−0.66)	−0.49 (−1.13)	−0.74 (−2.25)	−0.35 (−0.83)	−0.14 (−0.20)	0.09 (0.19)	−0.05 (−0.11)	
2	0.12 (0.29)	−1.10 (−3.45)	−1.10 (−2.95)	−0.23 (−0.58)	−0.30 (−0.78)	−0.41 (−1.23)	−0.14 (−0.36)	0.04 (0.07)	0.24 (0.57)	0.10 (0.24)	
3	0.18 (0.44)	−0.81 (−2.52)	−0.65 (−1.74)	−0.04 (−0.10)	−0.16 (−0.43)	−0.34 (−1.10)	−0.04 (−0.11)	0.15 (0.23)	0.24 (0.60)	0.16 (0.40)	
4	−0.16 (−0.37)	−1.10 (−3.38)	−0.65 (−1.73)	−0.45 (−1.12)	−0.53 (−1.32)	−0.74 (−2.29)	−0.39 (−0.97)	−0.19 (−0.30)	−0.10 (−0.23)	−0.17 (−0.39)	
5	0.03 (0.07)	−0.85 (−2.44)	−0.80 (−1.98)	−0.18 (−0.44)	−0.23 (−0.55)	−0.54 (−1.65)	−0.18 (−0.44)	0.01 (0.01)	0.09 (0.21)	0.03 (0.08)	
6	0.26 (0.61)	−0.78 (−2.32)	−0.54 (−1.39)	−0.09 (−0.20)	−0.06 (−0.16)	−0.27 (−0.80)	0.05 (0.13)	0.23 (0.36)	0.32 (0.75)	0.27 (0.63)	
7	0.75 (1.83)	−0.05 (−0.15)	0.29 (0.73)	0.39 (0.95)	0.47 (1.19)	0.26 (0.79)	0.59 (1.50)	0.76 (1.16)	0.77 (1.87)	0.76 (1.86)	
8	0.62 (1.57)	−0.26 (−0.77)	0.11 (0.27)	0.17 (0.43)	0.33 (0.87)	0.20 (0.59)	0.47 (1.23)	0.64 (1.00)	0.64 (1.60)	0.62 (1.56)	
9	0.73 (1.78)	−0.20 (−0.59)	0.21 (0.53)	0.15 (0.36)	0.42 (1.09)	0.29 (0.84)	0.56 (1.44)	0.74 (1.16)	0.78 (1.91)	0.71 (1.75)	
10	0.87 (2.18)	0.04 (0.12)	0.27 (0.67)	0.17 (0.43)	0.60 (1.58)	0.48 (1.37)	0.77 (1.95)	0.86 (1.39)	0.87 (2.17)	0.88 (2.22)	
P10 − P1	0.91 (2.52)	1.44 (4.06)	1.43 (3.48)	0.46 (1.50)	1.09 (3.08)	1.22 (3.73)	1.12 (3.43)	1.00 (2.86)	0.78 (2.21)	0.94 (2.62)	
GRS	2.15 [0.02]	3.97 [0.00]	3.33 [0.00]	1.49 [0.14]	2.32 [0.01]	3.13 [0.00]	2.67 [0.00]	1.81 [0.06]	2.00 [0.03]	2.28 [0.01]	
HJ-distance	0.28 [0.02]	0.15 [0.86]	0.13 [0.72]	0.12 [0.89]	0.24 [0.25]	0.15 [0.91]	0.17 [0.81]	0.25 [0.19]	0.24 [0.22]	0.25 [0.12]	0.22[0.76]
$\overline{\text{Adj}}\ R^2$	0.59	0.76	0.76	0.66	0.65	0.75	0.65	0.06	0.60	0.59	0.62

Table 4
Tests for the equality of the Hansen–Jagannathan distance. This table shows the difference in the Hansen–Jagannathan (HJ) distance between each competing model and FF5 (in Panel A) and between each competing model and CNZ3 (in Panel B). 'FF3' indicates the Fama and French (1993) three-factor model containing the market factor, SMB, and HML; 'FF5' indicates a five-factor model containing Fama and French's three factors plus the default spread (DEF) and the term spread (TERM); 'CNZ3' indicates Chen et al. (2010) three-factor model containing the market factor, an investment factor (INVEST), and a return on asset factor (ROA); 'MKT + LIQ' is a two-factor model containing the market factor and a liquidity factor (LIQ); 'MKT + EIU' is the Kim (2006) two-factor model containing the market factor and an earnings information uncertainty risk factor (EIU); 'MKT + REVSL' is a two-factor model containing the market factor and a long-term price reversal factor (REVSL); 'MKT + GDP' is a two-factor model containing the market factor and a GDP factor; 'MKT + LABOR' is a two-factor model containing the market factor and a labor factor; CCAPM is the Consumption-based CAPM; 'Campbell' indicates the Campbell (1996) five-factor model; and the Jagannathan and Wang (1996) model contains the market factor, the term spread (TERM), and the growth rate in real labor income (LABOR). Numbers in the bracket indicate p-value for the pair-wise equality test by Kan and Robotti (2009).

Test portfolio	CAPM	APT-motivated models					CCAPM	ICAPM-motivated models			Jagannathan–Wang
		FF3	CNZ3	MKT + LIQ	MKT + EIU	MKT + REVSL		MKT + GDP	MKT + LABOR	Campbell	
Panel A: HJ distance of the competing model − HJ distance of FF5											
Size-BM	0.26[0.00]	0.14[0.00]	0.16[0.03]	0.16[0.01]	0.21[0.00]	0.15[0.01]	0.15[0.02]	0.24[0.00]	0.20[0.00]	0.18[0.00]	0.22[0.00]
Size	0.22[0.00]	0.06[0.24]	0.10[0.04]	0.10[0.02]	0.05[0.16]	0.08[0.09]	0.14[0.01]	0.22[0.00]	0.20[0.00]	0.02[0.80]	0.18[0.01]
BM	0.18[0.00]	0.04[0.43]	0.07[0.38]	0.14[0.02]	0.17[0.00]	0.13[0.02]	0.13[0.03]	0.17[0.00]	0.15[0.01]	0.07[0.52]	0.16[0.05]
Liquidity	0.08[0.00]	0.00[0.82]	−0.04[0.28]	0.04[0.10]	0.04[0.03]	0.05[0.02]	0.05[0.06]	0.07[0.02]	0.01[0.83]	0.00[0.97]	0.07[0.01]
STDFE	0.14[0.01]	0.01[0.55]	0.07[0.21]	0.07[0.17]	0.10[0.06]	0.07[0.22]	0.09[0.09]	0.14[0.01]	0.10[0.08]	0.05[0.46]	0.08[0.18]
Asset growth	0.07[0.22]	0.05[0.41]	−0.02[0.76]	0.01[0.91]	0.06[0.34]	0.03[0.69]	0.12[0.05]	0.06[0.33]	0.07[0.24]	−0.15[0.11]	0.04[0.48]
Reversal	0.08[0.07]	0.01[0.56]	0.04[0.44]	0.07[0.13]	0.07[0.08]	0.05[0.14]	0.06[0.17]	0.07[0.12]	0.06[0.09]	0.02[0.79]	0.03[0.56]
SUE	0.14[0.01]	0.02[0.58]	−0.01[0.87]	0.11[0.06]	0.02[0.45]	0.03[0.49]	0.11[0.01]	0.10[0.03]	0.12[0.06]	0.08[0.35]	0.13[0.02]
Panel B: HJ distance of the competing model − HJ distance of CNZ3											
Size-BM	0.10[0.00]	−0.02[0.54]	−0.16[0.03]	0.00[0.90]	0.05[0.01]	−0.02[0.54]	−0.01[0.67]	0.07[0.17]	0.04[0.30]	0.02[0.57]	0.06[0.26]
Size	0.12[0.00]	−0.04[0.42]	−0.10[0.04]	0.00[0.86]	−0.04[0.22]	−0.01[0.54]	0.04[0.20]	0.12[0.00]	0.10[0.00]	−0.07[0.36]	0.09[0.09]
BM	0.11[0.03]	−0.03[0.60]	−0.07[0.38]	0.07[0.10]	0.10[0.03]	0.06[0.23]	0.06[0.21]	0.10[0.05]	0.08[0.07]	−0.00[0.96]	0.09[0.16]
Liquidity	0.12[0.02]	0.05[0.23]	0.04[0.28]	0.08[0.06]	0.09[0.11]	0.09[0.06]	0.09[0.09]	0.12[0.04]	0.05[0.22]	0.05[0.51]	0.11[0.11]
STDFE	0.08[0.01]	−0.05[0.18]	−0.07[0.21]	0.00[0.87]	0.03[0.11]	0.00[0.77]	0.03[0.32]	0.07[0.08]	0.03[0.47]	−0.02[0.58]	0.01[0.80]
Asset growth	0.09[0.01]	0.07[0.14]	0.02[0.76]	0.02[0.47]	0.07[0.04]	0.04[0.29]	0.14[0.00]	0.08[0.11]	0.09[0.02]	−0.13[0.18]	0.06[0.21]
Reversal	0.04[0.16]	−0.03[0.50]	−0.04[0.44]	0.02[0.24]	0.03[0.26]	0.01[0.61]	0.02[0.37]	0.02[0.46]	0.02[0.37]	−0.03[0.54]	−0.01[0.83]
SUE	0.15[0.01]	0.02[0.68]	0.01[0.87]	0.11[0.05]	0.03[0.54]	0.04[0.29]	0.12[0.01]	0.11[0.02]	0.13[0.03]	0.09[0.33]	0.14[0.02]

The sum of the intercept estimate and the residuals is regarded as the orthogonalized TERM and DEF with respect to SMB and HML, $\text{TERM}^{\perp}$ and $\text{DEF}^{\perp}$, respectively. Then, we estimate the time-series regression model of test portfolio returns on these orthogonalized factors:

$$R_{pt} = \alpha_{\rm p}^{'} + \beta_{\rm p1}^{'}\text{TERM}_{\rm t}^{\perp} + \beta_{\rm p2}^{'}\text{DEF}_{\rm t}^{\perp} + \varepsilon_{pt}, \tag{9}$$

where R_{pt} is test portfolio return at time t.

Table 5 presents the estimation results of Eq. (9) for 16 size-BM-sorted portfolio returns in Korea and 25 size-BM-sorted portfolios in the U.S. during the sample period.[18] The coefficient estimates on $\text{TERM}^{\perp}$ ($\hat{\beta}_{\rm p1}^{'}$) are all statistically significant mostly at the 1% significance level in Korea. On the other hand, these are all statistically insignificant for the case of the U.S. The average values of the estimated coefficients on $\text{TERM}^{\perp}$ are 2.444 and 0.143 in Korea and the U.S., respectively. The coefficient estimates on $\text{DEF}^{\perp}$ ($\hat{\beta}_{\rm p2}^{'}$) are similarly statistically significant in both Korea and the U.S. mostly at the 10% significance level. However, the magnitude of $\hat{\beta}_{\rm p2}^{'}$ is slightly larger in Korea than in the U.S. (−2.007 vs. −1.481). The average (adjusted) R^2 of Eq. (9) is at least 3 times greater in Korea than in the U.S. (0.045 vs. 0.013). These above results indicate that contrary to the case of the U.S., TERM and DEF still have significant explanatory power for stock returns in Korea even after controlling for SMB and HML.[19] In particular, TERM has a stronger explanatory power for stock returns in Korea than does DEF. This result is consistent with the CSR results to be discussed below.

5.5. Cross-sectional regression tests

To examine whether the differences in average return across assets are explained by the differences in their factor loadings (or betas), we estimate the cross-sectional relationship between average returns and factor loadings on the risk factors by using Fama–MacBeth's (1973) two-stage regression methodology. In the first-stage, we estimate betas using time-series regressions. In the second-stage, we use the beta estimates as the explanatory variables in the cross-sectional regressions (CSR). The CSR model to be estimated at each month t is

$$R_{pt} - R_{ft} = \gamma_{0t} + \gamma_{1t}\hat{\beta}_{1p,t} + \cdots + \gamma_{Kt}\hat{\beta}_{Kp,t} + \varepsilon_{pt}, \quad p = 1, \cdots, N, \tag{10}$$

where $\hat{\beta}_{kp,t}$ is portfolio p's beta estimate on the k-th factor that is obtained from the multivariate time-series regression using the whole sample. We estimate month-by-month the above CSR model by the generalized least squares (GLS) method. The error covariance matrix to be needed for the GLS estimation is obtained by using the residual terms generated from the first-stage time-series regressions. As test assets, we use 16 (4×4) size-BM portfolios which is most popular for the CSR test in the literature.[20] We also use individual stocks as test assets in order to obtain robust test results which are not sensitive to the portfolio formation. The use of individual stocks is to utilize unique information of individual stocks which would be otherwise lost and to increase test power.[21] Instead, the errors-in-variables (EIV) bias would be more severe than using portfolios.[22]

Table 6 presents time-series averages ($\bar{\hat{\gamma}}_k$) of the CSR coefficient estimates or gamma estimates, $\hat{\gamma}_{kt}$, of each asset pricing model by using 16 size-BM portfolios. This table also presents two t-statistics; the

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[18] 16 equally-weighted size-BM portfolios in Korea are formed by independently sorting individual stocks according to their market capitalization and book-to-market ratios at the end of every June at the intersection of breakpoints of size and book-to-market ratios. 25 value-weighted size-BM portfolios in the U.S. are obtained from Kenneth French's website at Dartmouth (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/). The reason that only 16 (=4×4) portfolios are constructed in Korea is that when Korean individual stocks are independently sorted in a way of 5×5, some portfolios have only a few stocks since the total number of stocks in Korea is not large enough as in the U.S.

[19] Jung and Kim (2011) report that a factor related with innovations in the expectation of future money growth is priced on stock returns in Korea even after controlling for the Fama and French three factors and the momentum factor. We conjecture that innovations in future money growth might be related with the significant role of TERM and DEF in Korea.

[20] We sort all stocks into one of (5×5) size-BM portfolios in a two-by-two independent sorting way. However, only a small number of stocks are assigned into some portfolios.

[21] Kim and Qi (2010) show how the CSR results are sensitive to the portfolio formation.

[22] See Kim (1995, 1997) for the EIV-bias correction for CSR coefficients themselves rather than their standard errors.

Table 5
Time-series regressions of portfolio returns on the orthogonalized term spreads and default spreads. This table reports the time-series regression estimation results of size-BM-sorted portfolio returns on the orthogonalized term spread and default spread with respect to SMB and HML. The orthogonalized term spread, $TERM^{\perp}$, is obtained as the sum of the intercept estimate and the residuals from regressing the term spread on SMB and HML. The orthogonalized default spread, $DEF^{\perp}$, is similarly obtained. 16 ($=4\times4$) size-BM portfolios in Korea are formed by sorting individual stocks according to their market capitalization and boon-to-market ratios at the end of every June at the intersection of breakpoints of size and book-to-market ratios. 25 ($=5\times5$) size-BM portfolios in the U.S. are obtained from Kenneth French's website at Dartmouth. 'SiBj' indicates the *i*-th largest size and *j*-th highest BM portfolio. "Average" is the simple average of the coefficient estimates and the adjusted R^2. Numbers in parentheses indicate *t*-statistics.

Size-BM portfolio	Intercept	$TERM^{\perp}$	$DEF^{\perp}$	Adj R^2	Size-BM portfolio	Intercept	$TERM^{\perp}$	$DEF^{\perp}$	Adj R^2
Korea					U.S.				
S1B1	0.010 (1.03)	2.375 (2.76)	−2.313 (−1.72)	0.033	S1B1	0.018 (1.33)	−0.026 (−0.06)	−1.851 (−1.37)	0.009
S1B2	0.023 (2.17)	3.812 (3.93)	−1.796 (−1.18)	0.062	S1B2	0.024 (2.09)	0.022 (0.06)	−1.744 (−1.54)	0.011
S1B3	0.020 (2.24)	2.911 (3.47)	−2.467 (−1.88)	0.049	S1B3	0.023 (2.49)	0.049 (0.16)	−1.609 (−1.80)	0.015
S1B4	0.022 (2.26)	2.036 (2.21)	−1.276 (−0.88)	0.020	S1B4	0.024 (2.85)	0.147 (0.51)	−1.804 (−2.16)	0.020
S2B1	0.001 (0.08)	1.971 (2.58)	−1.672 (−1.40)	0.028	S1B5	0.023 (2.43)	0.394 (1.23)	−2.058 (−2.23)	0.021
S2B2	0.006 (0.76)	2.215 (2.94)	−2.245 (−1.90)	0.038	S2B1	0.018 (1.53)	0.159 (0.39)	−1.864 (−1.59)	0.011
S2B3	0.010 (1.23)	2.148 (2.99)	−1.919 (−1.70)	0.037	S2B2	0.018 (1.93)	−0.004 (−0.01)	−1.249 (−1.38)	0.009
S2B4	0.017 (1.95)	2.343 (2.92)	−2.191 (−1.74)	0.036	S2B3	0.016 (1.98)	0.139 (0.50)	−1.067 (−1.33)	0.007
S3B1	−0.003 (−0.32)	2.008 (2.77)	−1.766 (−1.55)	0.032	S2B4	0.023 (2.72)	0.039 (0.14)	−1.618 (−1.99)	0.018
S3B2	0.002 (0.29)	2.594 (3.63)	−2.163 (−1.93)	0.054	S2B5	0.020 (2.04)	0.254 (0.77)	−1.753 (−1.83)	0.014
S3B3	0.009 (1.24)	2.518 (3.73)	−2.833 (−2.68)	0.062	S3B1	0.018 (1.59)	0.238 (0.63)	−1.920 (−1.75)	0.013
S3B4	0.012 (1.36)	2.275 (2.89)	−2.015 (−1.63)	0.035	S3B2	0.016 (1.83)	0.146 (0.51)	−1.248 (−1.49)	0.009
S4B1	0.000 (−0.02)	2.568 (4.06)	−1.894 (−1.91)	0.065	S3B3	0.015 (1.91)	0.040 (0.16)	−0.783 (−1.05)	0.005
S4B2	0.002 (0.30)	2.438 (3.82)	−1.779 (−1.78)	0.058	S3B4	0.013 (1.70)	0.254 (0.96)	−1.134 (−1.48)	0.010
S4B3	0.005 (0.58)	2.472 (3.34)	−1.360 (−1.17)	0.045	S3B5	0.013 (1.56)	0.283 (0.98)	−0.841 (−1.01)	0.006
S4B4	0.011 (1.33)	2.413 (3.04)	−2.415 (−1.94)	0.040	S4B1	0.020 (2.03)	0.179 (0.54)	−1.784 (−1.85)	0.014
					S4B2	0.015 (1.84)	0.104 (0.39)	−1.049 (−1.36)	0.008
					S4B3	0.014 (1.72)	0.218 (0.77)	−1.300 (−1.60)	0.011
					S4B4	0.020 (2.60)	0.103 (0.40)	−1.509 (−2.00)	0.017
					S4B5	0.015 (1.77)	0.236 (0.81)	−1.426 (−1.69)	0.012
					S5B1	0.017 (2.22)	0.153 (0.60)	−1.518 (−2.07)	0.018
					S5B2	0.016 (2.35)	0.185 (0.80)	−1.438 (−2.14)	0.019
					S5B3	0.015 (2.18)	0.131 (0.55)	−1.418 (−2.04)	0.017
					S5B4	0.020 (2.77)	0.024 (0.10)	−1.719 (−2.43)	0.027
					S5B5	0.016 (1.88)	0.102 (0.36)	−1.315 (−1.59)	0.011
Average	0.009	2.444	−2.007	0.045	Average	0.018	0.143	−1.481	0.013

Table 6

Time-series averages of the cross-sectional regression estimates using portfolios' whole-period betas. This table presents times-series averages ($\hat{\gamma}_j$) of the month-by-month cross-sectional regression GLS coefficient estimates of test portfolios' excess returns on the factor loading (or beta) estimates. The factor loadings are estimated from multivariate time-series regressions of raw returns of the portfolio on the factor by using the whole period returns. The test period is January 1990 through December 2009. Numbers in the top parentheses indicate t-values by the Fama–MacBeth method and those in the bottom parentheses indicate t-values by Shanken's (1992) errors-in-variables bias corrected standard errors based on the Newey and West (1987, 1994) heteroskedasticity and autocorrelation-consistent covariance matrix estimation with the automatic lag selection procedure. $\beta_{e,k}$ is the factor loading on the k-th innovations from VAR(1) of the four factors in the Campbell model. R^2_{KS} is the R-square by Kandel and Stambaugh (1995).

Explanatory variable	CAPM	FF3	FF5	CNZ3	Campbell	CAPM	FF3	FF5	CNZ3	Campbell
	Using equally-weighted 16 size-BM portfolios					Using value-weighted 16 size-BM portfolios				
Intercept	−1.34 (−1.29) (−1.31)	−1.99 (−1.67) (−1.66)	−0.97 (−0.58) (−0.60)	−2.17 (−2.05) (−1.76)	−1.74 (−1.49) (−1.09)	−2.95 (−2.77) (−2.69)	−3.51 (−2.90) (−2.76)	−2.89 (−2.15) (−2.03)	−3.69 (−3.28) (−2.98)	−3.11 (−2.53) (−1.94)
β_{MKT}	1.47 (1.19) (1.29)	2.16 (1.56) (1.63)	0.71 (0.38) (0.41)	2.28 (1.81) (1.72)	1.78 (1.34) (1.09)	3.32 (2.61) (2.99)	3.91 (2.77) (2.86)	3.13 (2.02) (2.07)	4.20 (3.10) (3.26)	3.38 (2.41) (1.91)
β_{SMB}		0.80 (2.24) (2.33)	0.79 (2.21) (2.26)				0.53 (1.41) (1.35)	0.62 (1.62) (1.58)		
β_{HML}		1.34 (3.92) (3.87)	1.38 (4.04) (3.87)				1.31 (3.50) (3.15)	1.36 (3.48) (3.18)		
β_{TERM}			0.95 (4.48) (4.07)					0.64 (2.58) (2.53)		
β_{DEF}			0.38 (1.94) (1.81)					0.22 (1.33) (1.21)		
β_{INVEST}				0.75 (1.28) (1.12)					−0.01 (−0.02) (−0.02)	
β_{ROA}				−2.17(−2.50) (−2.20)					−1.78 (−2.17) (−2.73)	
β_{eLABOR}					0.57 (0.25) (0.25)					0.37 (0.16) (0.16)
β_{eDIV}					−0.00 (−0.53) (−0.56)					−0.00 (−0.27) (−0.27)
β_{eRTB}					−0.12 (−1.27) (−1.35)					0.06 (0.41) (0.30)
β_{eTERM}					0.20 (2.29) (2.11)					0.240 (2.44) (2.08)
R^2_{KS}	0.0277	0.4718	0.8189	0.4026	0.3254	0.1769	0.5921	0.7148	0.2838	0.3445

Fama–MacBeth *t*-statistic (in the top parenthesis) and the Shanken (1992) EIV-corrected *t*-statistic based on the Newey and West (1987, 1994) heteroskedasticity and autocorrelation-consistent covariance matrix estimation with the automatic lag selection procedure (in the bottom parenthesis). Since the time-series tests show that FF5, CNZ3, FF3, and the Campbell five-factor model performs relatively well over the other models, we include only these four models for the CSR tests. In addition, we include CAPM for the CSR tests as a benchmark model. In the CSR tests, FF5 also performs the best among these five models in explaining the cross-sectional behavior of stock returns in Korea. When equally-weighted 16 size-BM portfolios are used, the time-series averages (or risk premia estimates) of the CSR coefficient estimates on the FF5 factor loadings are all positive; $\hat{\bar{\gamma}}_{MKT} = 0.71\%$ with *t*-statistic of 0.38, $\hat{\bar{\gamma}}_{SMB} = 0.79\%$ with *t*-statistic of 2.21, $\hat{\bar{\gamma}}_{HML} = 1.38\%$ with *t*-statistic of 4.04, $\hat{\bar{\gamma}}_{TERM} = 0.95\%$ with *t*-statistic of 4.48, and $\hat{\bar{\gamma}}_{DEF} = 0.38\%$ with *t*-statistic of 1.94. Four among the five risk premia estimates are statistically positively significant. This result also shows that among the two bond portfolios, TERM captures more cross-sectional variation of stock returns than does DEF. Some of the risk premia estimates of CNZ3 and the Campbell model are negatively significant, which is inconsistent with the risk-return tradeoff principle. For example, the risk premium estimate on ROA of CNZ3 ($\hat{\bar{\gamma}}_{ROA}$) is −2.17% with *t*-statistic of −2.50. Two risk premia estimates of the Campbell model are also negative. The risk premia estimates of FF3 are all positive and statistically significant. However, its intercept estimate is statistically negatively significant at the 10% level. When value-weighted 16 size-BM portfolios are used, we also obtain the similar statistical and economic significance of the coefficient estimates, although the intercept estimates are more negatively significant.

To judge the overall fit of the asset pricing models in the CSR, we use the cross-sectional R^2 measure by Kandel and Stambaugh (1995). This measure is computed as

$$R^2_{KS} = 1 - \frac{\bar{\varepsilon}' \widehat{\sum}_{\varepsilon}^{-1} \bar{\varepsilon}}{\bar{r}' \widehat{\sum}_{\varepsilon}^{-1} \bar{r}}, \tag{11}$$

where $\widehat{\sum}_{\varepsilon}$ is the residual covariance matrix, $\bar{\varepsilon}$ is an $(N \times 1)$ vector of time-series averages of the residuals generated from the CSR estimation, and $\bar{r}$ is an $(N \times 1)$ vector of time-series averages of the excess returns $(R_{pt} - R_{ft})$. With respect to the Kandel and Stambaugh R-square measure, FF5 also performs the best among the five models. It has the largest R-square. The R-squares of FF5, FF3, CNZ3, the Campbell model, and CAPM are 0.8189, 0.4718, 0.4026, 0.3254, and 0.0277, respectively. Table 7 shows the differences in the Kandel and Stambaugh R-square between FF5 and the other competing models for all the test (equally-weighted and value-weighted) portfolios that are previously used in the time-series tests. FF5 still dominates the other competing models with respect to the Kandel and Stambaugh *R*-square.

As a robustness check, we compute the Kan et al. (2009) misspecification robust *t*-statistics of the CSR coefficient estimates. In the CSR models, there can be misspecification issues that are caused by missing factors or ignoring possible firm-specific effects.[23] The results are presented in Table A1 in the Appendix. This table shows that our results are robust to possible misspecifications. We also use the portfolios used in the time-series tests of Table 3 as test portfolios in the CSR tests; portfolios sorted by liquidity, FESTD, long-term reversal, asset growth, and SUE. The results are reported in Table 8. The number of test portfolios is 20 in each case to increase the test power, since the CSR sample size of 10 can be too small to maintain reasonable test power. This table also presents two *t*-statistics; the Fama–MacBeth *t*-statistic (in the top parenthesis) and the Shanken (1992) EIV-corrected *t*-statistic based on the Newey and West (1987, 1994) heteroskedasticity and autocorrelation-consistent covariance matrix estimation with the automatic lag selection procedure (in the bottom parenthesis). The results are qualitatively similar to those in Table 6 when test portfolios are 16 size-BM portfolios. We report the CSR estimation results using equally-weighted portfolios only in this table to save the space.[24]

Table 9 presents time-series averages ($\hat{\bar{\gamma}}_k$) of the CSR of excess returns of individual stocks on their beta estimates and their *t*-statistics based on the Newey and West (1994) heteroskedasticity and autocorrelation-consistent covariance matrix estimation with the automatic lag selection procedure. When

[23] See Petersen (2009) for the case that the fixed effect of each test asset in the Fama and MacBeth two-pass methodology is allowed.

[24] The CSR estimation results using value-weighted portfolios are not reported, since the results are similar to those of using the 16 size-BM value-weighted portfolios. The results are available upon request.

Table 7
Tests of equality of the cross-sectional regression R-squares. This table shows the difference in the cross-sectional regression R-square by Kandel and Stambaugh (1995) between the Fama and French 5-factor model and the competing model. R^2_{FF5}, R^2_{CAPM}, R^2_{FF3}, R^2_{CNZ3}, and $R^2_{Campbell}$ are the cross-sectional regression R-squares of the Fama and French 5-factor model, the CAPM, the Fama and French 3-factor model, Chen et al.'s (2010) three-factor model, and the Campbell model, respectively. Numbers in bracket indicates *p*-values for the test of equality of the R-squares, $H_0: R^2_{FF5} = R^2_k$, where *k* is the competing model.

	Test portfolios							
	Size-BM	Size	BM	Liquidity	Past returns	STDFE	SUE	Asset growth
Panel A: using equally-weighted portfolio								
$R^2_{FF5} - R^2_{CAPM}$	0.79	0.84	0.67	0.59	0.66	0.88	0.74	0.36
	(0.00)	(0.02)	(0.24)	(0.59)	(0.45)	(0.36)	(0.22)	(0.68)
$R^2_{FF5} - R^2_{FF3}$	0.35	0.12	0.11	0.01	0.09	0.04	0.05	0.23
	(0.01)	(0.38)	(0.66)	(0.97)	(0.84)	(0.89)	(0.77)	(0.57)
$R^2_{FF5} - R^2_{CNZ3}$	0.42	0.26	0.23	−0.18	0.28	0.29	−0.04	0.00
	(0.02)	(0.23)	(0.89)	(0.06)	(0.89)	(0.73)	(0.24)	(0.08)
$R^2_{FF5} - R^2_{Campbell}$	0.49	0.04	0.24	0.02	0.07	0.16	0.34	−0.31
	(0.01)	(0.14)	(0.36)	(0.75)	(0.47)	(0.78)	(0.05)	(0.53)
Panel B: using value-weighted portfolios								
$R^2_{FF5} - R^2_{CAPM}$	0.54	0.68	0.29	0.84	0.18	0.12	0.42	0.50
	(0.05)	(0.37)	(0.77)	(0.41)	(0.97)	(0.94)	(0.67)	(0.57)
$R^2_{FF5} - R^2_{FF3}$	0.12	0.21	0.00	0.52	0.17	0.11	0.22	0.30
	(0.26)	(0.53)	(0.99)	(0.39)	(0.77)	(0.70)	(0.52)	(0.60)
$R^2_{FF5} - R^2_{CNZ3}$	0.43	0.49	0.15	0.56	−0.07	0.10	−0.07	−0.01
	(0.07)	(0.60)	(0.98)	(0.85)	(0.11)	(0.51)	(0.68)	(0.26)
$R^2_{FF5} - R^2_{Campbell}$	0.37	0.00	0.17	0.29	−0.61	−0.32	−0.01	0.18
	(0.05)	(0.93)	(0.06)	(0.56)	(0.63)	(0.43)	(0.46)	(0.51)

individual stocks are used as test assets, the CSR is estimated by the ordinary least squares (OLS) method, since the inverse of the error covariance matrix cannot be computed. Also, Shanken *t*-statistics cannot be computed. The beta variables of individual stocks used in the CSR are the portfolio beta estimates which are assigned to the stock. As a compromise between the greater testing power from using individual stocks and the smaller errors-in-variables problem from using portfolios, Fama and French (1992) adopt an allocation-beta approach. In this approach, we first construct 16 size-BM portfolios which are the same portfolios used in the CSR tests. Post-ranking betas of the portfolios using the whole-period returns are assigned into individual stocks which were contained in the portfolio.

The CSR estimation results using individual stocks are overall similar to those of using portfolios. When the betas assigned from equally-weighted 16 size-BM portfolios are used, FF5 has mostly positive risk premia estimates and has no significantly negative risk premia estimates; $\hat{\hat{\gamma}}_{MKT} = -0.33\%$ with *t*-statistic of −0.18, $\hat{\hat{\gamma}}_{SMB} = 1.13\%$ with *t*-statistic of 2.67, $\hat{\hat{\gamma}}_{HML} = 0.85\%$ with *t*-statistic of 2.32, $\hat{\hat{\gamma}}_{TERM} = 1.04\%$ with *t*-statistic of 4.03, and $\hat{\hat{\gamma}}_{DEF} = 0.13\%$ with *t*-statistic of 0.69. On the other hand, CNZ3 and the Campbell model have negatively significant risk premia estimates, which is inconsistent with the risk-return trade-off principle. In particular, four among the five risk premia estimates in the Campbell model are negative. The risk premia estimates of FF3 are also all positive and statistically significant. However, its intercept estimate is negatively statistically significant. Nonetheless, it would be argued that FF3 is the second most acceptable model in the CSR tests. To compare the overall fit of the asset pricing models in the CSR, we use the time-series average of the month-by-month CSR adjusted R^2 measure. FF5 has the largest average of adjusted R-squares. FF3, CNZ3, and the Campbell model are the next in order. We also find the similar CSR results when using the betas assigned from value-weighted 16 size-BM portfolios.

6. Summary remarks and conclusions

This paper comprehensively evaluates and compares asset pricing models in the Korean stock market. The asset pricing models considered are the CAPM, several APT-motivated models, the CCAPM, several ICAPM-motivated models, and the Jagannathan and Wang model. To evaluate and compare these asset pricing models, we conduct time-series tests and cross-sectional tests based on individual *t*-tests, the

Table 8

Time-series averages of the cross-sectional regression estimates using various test portfolios. This table shows times-series averages ($\hat{\hat{\gamma}}_j$) of the month-by-month cross-sectional regression GLS coefficient estimates of test portfolios' excess returns on the factor loading (or beta) estimates. The factor loadings are estimated from multivariate time-series regressions of raw returns of the portfolio on the factor by using the whole period returns. All test portfolios are equally-weighted. The test period is January 1990 through December 2009. Numbers in the top parentheses indicate *t*-values by the Fama–MacBeth method and those in the bottom parentheses indicate *t*-values by Shanken's (1992) errors-in-variables bias corrected standard errors based on the Newey and West (1987, 1994) heteroskedasticity and autocorrelation-consistent covariance matrix estimation with the automatic lag selection procedure. $\beta_{e.k}$ is the factor loading on the *k*-th innovations from VAR (1) of the four factors in the Campbell model. $R^2_{KS}$is the R-square by Kandel and Stambaugh (1995).

Explanatory variable	CAPM	FF3	FF5	CNZ3	Campbell	CAPM	FF3	FF5	CNZ3	Campbell	CAPM	FF3
	Using 20 liquidity portfolios					Using 20 FESTD portfolios					Using 20 long-term reversal portfolios	
Intercept	4.36(3.56) (2.92)	1.19(0.71) (0.69)	0.10(0.05) (0.05)	4.27(2.93) (2.62)	4.30(2.80) (1.95)	−1.48 (−1.40) (−1.47)	−1.19 (−1.12) (−1.19)	−1.49 (−1.38) (−1.19)	−1.45 (−1.32) (−1.42)	−2.08 (−1.80) (−1.96)	−1.46 (−1.1) (−1.14)	−1.32 (−0.96) (−1.02)
β_{MKT}	−4.24 (−3.20) (−2.58)	−1.25 (−0.73) (−0.71)	−0.26 (−0.14) (−0.12)	−4.14 (−2.75) (−2.41)	−4.11 (−2.71) (−1.99)	1.79(1.25) (1.39)	1.05(0.71) (0.77)	1.29(0.88) (0.81)	1.72(1.19) (1.33)	2.51(1.57) (1.74)	1.98(1.22) (1.34)	1.59(0.98) (1.06)
β_{SMB}		1.62(3.23) (3.00)	1.43(2.78) (2.38)				0.95(1.54) (1.69)	1.29(2.01) (1.84)				0.06(0.07) (0.08)
β_{HML}		0.09(0.13) (0.15)	0.20(0.28) (0.30)				0.60(0.77) (0.80)	0.14(0.17) (0.14)				1.47(1.82) (1.87)
β_{TERM}			1.05(4.00) (3.17)					−0.52 (−1.84) (−1.57)				
β_{DEF}			0.29(2.30) (2.11)					−0.16 (−1.25) (−1.04)				
β_{INVEST}				0.29(0.67) (0.60)					0.13(0.32) (0.34)			
β_{ROA}				0.68(0.81) (0.71)					−0.53 (−1.00) (−0.95)			
β_{eLABOR}					−2.38 (−1.17) (−0.88)					−1.31 (−0.84) (−0.75)		
β_{eDIV}					0.00(0.28) (0.21)					0.00(−0.66) (−1.02)		
β_{eRTB}					0.05(0.65) (0.45)					0.20(2.42) (1.83)		
β_{eTERM}					0.02(2.90) (2.10)					0.00(0.68) (0.88)		
R^2_{KS}	0.15	0.26	0.57	0.15	0.35	0.08	0.47	0.66	0.12	0.38	0.09	0.51

(*continued on next page*)

Table 8 (*continued*)

Explanatory variable	FF5	CNZ3	Campbell	CAPM	FF3	FF5	CNZ3	Campbell	CAPM	FF3	FF5	CNZ3	Campbell
	Using 20 long-term reversal portfolios			Using 20 asset growth portfolios					Using 20 SUE portfolios				
Intercept	−1.28 (−0.81) (−0.91)	−2.05 (−1.43) (−1.45)	−1.15 (−0.83) (−0.65)	1.99(1.47) (1.36)	−0.95 (−0.60) (−0.54)	−6.48 (−3.00) (−1.73)	1.63(1.18) (0.92)	1.82(1.32) (0.74)	−1.39 (−0.89) (−0.94)	−1.47 (−0.94) (−0.89)	−1.42 (−0.90) (−0.75)	−3.73 (−2.2) (−1.56)	−1.71 (−1.08) (−1.11)
β_{MKT}	1.69(1.03) (1.27)	2.38(1.38) (1.54)	1.44(0.87) (0.72)	−2.13 (−1.27) (−1.13)	−0.13 (−0.07) (−0.07)	4.82(2.17) (1.32)	−1.59 (−0.94) (−0.72)	−1.52 (−0.86) (−0.53)	2.58(1.36) (1.48)	2.95(1.52) (1.51)	2.72(1.38) (1.13)	5.08(2.53) (1.91)	3.00(1.52) (1.58)
β_{SMB}	−0.30 (−0.28) (−0.26)				1.30(2.45) (2.39)	1.51(2.76) (2.88)				−0.89 (−1.32) (−1.36)	−0.87 (−1.25) (−1.08)		
β_{HML}	1.79(2.04) (1.96)				2.42(2.70) (2.43)	3.60(3.79) (2.45)				0.38(0.69) (0.67)	0.55(1.01) (0.84)		
β_{TERM}	0.35(1.19) (1.08)					0.69(2.13) (2.24)					1.41(3.78) (3.39)		
β_{DEF}	0.04(0.22) (0.19)					−0.39 (−2.10) (−1.41)					0.43(3.11) (2.73)		
β_{INVEST}		0.70(1.72) (2.02)					1.22(4.41) (4.63)					0.87(1.95) (1.92)	
β_{ROA}		−0.32 (−0.63) (−0.64)					1.52(2.05) (1.69)					1.02(2.13) (1.73)	
β_{eLABOR}			2.34(1.00) (0.78)					6.51(4.07) (2.38)					−1.28 (−0.55) (−0.57)
β_{eDIV}			−0.01 (−1.34) (−1.33)					0.00(0.53) (0.37)					0.00 (−0.02) (−0.02)
β_{eRTB}			−0.18 (−2.09) (−1.85)					−0.21 (−2.31) (−1.49)					−0.10 (−0.98) (−1.03)
β_{eTERM}			−0.01 (−0.86) (−0.86)					−0.02 (−1.83) (−1.45)					0.00(0.10) (0.11)
R^2_{KS}	0.6	0.32	0.62	0.03	0.29	0.57	0.37	0.37	0.04	0.07	0.4	0.47	0.09

Table 9

Time-series averages of the cross-sectional regression estimates using individual stocks. This table shows times-series averages ($\hat{\gamma}_j$) of the month-by-month cross-sectional regression OLS coefficient estimates of individual test stocks' excess returns on the factor loading (or beta) estimates. The factor loadings are estimated from single time-series regressions of individual stock's raw returns on the factor by using the whole period returns. The test period is January 1990 through December 2009. Numbers in parentheses indicate t-values by the Fama–MacBeth method based on the Newey and West (1987, 1994) heteroskedasticity and autocorrelation-consistent covariance matrix estimation with the automatic lag selection procedure. $\overline{\text{Adj}}\ R^2$ is the time-series average of month-by-month CSR's.

Explanatory variable	CAPM	FF3	FF5	CNZ3	Campbell	CAPM	FF3	FF5	CNZ3	Campbell
	Using betas allocated from equally-weighted 16 size-BM portfolios					Using betas allocated from value-weighted 16 size-BM portfolios				
Intercept	3.34 (1.44)	−5.36 (−2.96)	−1.86 (−1.42)	−6.93 (−3.73)	−5.24 (−2.38)	2.81 (0.92)	−6.68 (−3.65)	−4.84 (−3.53)	−7.78 (−4.28)	−5.73 (−3.29)
β_{MKT}	−3.06 (−1.33)	5.76 (2.75)	−0.33 (−0.32)	5.62 (2.88)	5.16 (1.92)	−2.43 (−0.66)	7.62 (3.75)	3.86 (2.02)	7.20 (3.77)	5.61 (2.77)
β_{SMB}		1.63 (2.82)	1.13 (2.93)				1.92 (3.57)	2.00 (2.59)		
β_{HML}		0.96 (2.43)	0.85 (1.90)				0.91 (2.38)	0.64 (2.74)		
β_{TERM}			1.04 (4.71)					0.88 (3.06)		
β_{DEF}			0.13 (0.93)					0.09 (1.48)		
β_{INVEST}				−015 (−0.00)					0.74 (2.66)	
β_{ROA}				−4.49 (−3.25)					−4.00 (−0.50)	
β_{eLABOR}					−5.61 (−0.98)					−0.22 (−2.70)
β_{eDIV}					−0.04 (−2.58)					−0.03 (−3.25)
β_{eRTB}					−0.50 (−2.14)					−0.46 (−2.43)
β_{eTERM}					−0.03 (−0.14)					0.27 (0.11)
$\overline{\text{Adj}}\ R^2$	0.0206	0.0387	0.0412	0.0329	0.0364	0.0215	0.0389	0.0408	0.0335	0.0328

Table A1
Time-series averages of the cross-sectional regression estimates using portfolios under the misspecification. This table presents times-series averages ($\hat{\bar{\gamma}}_j$) of the month-by-month GLS coefficient estimates of the CSR of test portfolios' excess returns on the factor loading (or beta) estimates. The factor loadings are estimated from multivariate time-series regressions of raw returns of the portfolio on the factor by using the whole period returns. The test period is January 1990 through December 2009. Numbers in the parentheses indicate the misspecification robust *t*-values by Kan and Robotti (2009) based on the Newey and West (1987, 1994) heteroskedasticity and autocorrelation-consistent covariance matrix estimation with the automatic lag selection procedure. $\beta_{e.k}$ is the factor loading on the *k*-th innovations from VAR(1) of the four factors in the Campbell model. R^2_{KS} is the R-square by Kandel and Stambaugh (1995).

Explanatory variable	CAPM	FF3	FF5	CNZ3	Campbell	CAPM	FF3	FF5	CNZ3	Campbell
	Using equally-weighted 16 size-BM portfolios					Using value-weighted 16 size-BM portfolios				
Intercept	−1.34 (−1.08)	−1.99 (−1.28)	−0.97 (−0.41)	−2.17 (−1.62)	−1.74 (−0.68)	−2.95 (−2.25)	−3.51 (−2.21)	−2.89 (−1.57)	−3.69 (−2.59)	−3.11 (−1.28)
β_{MKT}	1.47 (1.04)	2.16 (1.35)	0.71 (0.29)	2.28 (1.62)	1.78 (0.68)	3.32 (2.35)	3.91 (2.26)	3.13 (1.62)	4.20 (2.65)	3.38 (1.38)
β_{SMB}		0.80 (2.29)	0.79 (2.22)				0.53 (1.36)	0.62 (1.54)		
β_{HML}		1.34 (3.79)	1.38 (3.84)				1.31 (3.18)	1.36 (2.88)		
β_{TERM}			0.95 (3.60)					0.64 (2.05)		
β_{DEF}			0.38 (1.14)					0.22 (0.87)		
β_{INVEST}				0.75 (0.62)					−0.01 (−0.01)	
β_{ROA}				−2.1 (−1.24)					−1.78 (−1.35)	
β_{eLABOR}					0.57 (0.17)					0.37 (0.09)
β_{eDIV}					0.00 (−0.37)					0.00 (−0.21)
β_{eRTB}					−0.12 (−0.71)					0.06 (0.21)
β_{eTERM}					0.20 (1.65)					0.24 (1.15)
R^2_{KS}	2.77	47.18	81.89	40.26	32.54	17.69	59.21	71.48	28.38	34.45

GRS *F*-tests, the HJ distance, and R-squares. Since test results could be sensitive to the choice of test portfolios, various test portfolios as well as individual stocks are used.

Overall, time-series tests and cross-sectional regression tests show that FF5 performs most satisfactorily among the asset pricing models considered in explaining the intertemporal and cross-sectional behavior of stock returns in Korea. FF3, CNZ3, and the Campbell model are the next. We also obtain the similar results for two subperiods before and after the Asian foreign currency crisis; 1990–1998 and 1999–2009. The results that FF5 outperforms FF3 in many aspects indicate that the bond portfolios, TERM and DEF, play an important role in explaining stock returns in Korea.

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