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Size, value, and momentum in international stock returns ☆

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ABSTRACT

In the four regions (North America, Europe, Japan, and Asia Pacific) we examine, there are value premiums in average stock returns that, except for Japan, decrease with size. Except for Japan, there is return momentum everywhere, and spreads in average momentum returns also decrease from smaller to bigger stocks. We test whether empirical asset pricing models capture the value and momentum patterns in international average returns and whether asset pricing seems to be integrated across the four regions. Integrated pricing across regions does not get strong support in our tests. For three regions (North America, Europe, and Japan), local models that use local explanatory returns provide passable descriptions of local average returns for portfolios formed on size and value versus growth. Even local models are less successful in tests on portfolios formed on size and momentum.

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1. Introduction

Banz (1981) finds that stocks with lower market capitalization (small stocks) tend to have higher average returns. There is also evidence that value stocks, that is, stocks with high ratios of a fundamental like book value or cash flow to price, have higher average returns than growth stocks, which have low ratios of fundamentals to price (DeBondt and Thaler, 1985; Fama and French, 1992; Lakonishok, Shleifer, and Vishny, 1994). Jegadeesh and Titman (1993) show that U.S. stock returns also exhibit momentum: stocks that have done well over the past year tend to continue to do well. The value premium (higher average returns of value stocks relative to growth stocks) and momentum are also observed in international returns (Chan, Hamao, and Lakonishok, 1991; Fama and French, 1998; Rouwenhorst, 1998; Griffin, Ji, and Martin, 2003; Asness, Moskowitz, and Pedersen, 2009; Chui, Titman, and Wei, 2010).

Fama and French (1993) propose a three-factor model to capture the patterns in U.S. average returns associated with size and value versus growth:

$$R_i(t)-RF(t)=a_i+b_i[RM(t)-RF(t)]+s_iSMB(t)+h_iHML(t)+e_i(t). \quad (1)$$

In this regression, $R_i(t)$ is the return on asset i for month t, $RF(t)$ is the riskfree rate, $RM(t)$ is the market return, $SMB(t)$ is the difference between the returns on diversified portfolios of small stocks and big stocks, and $HML(t)$ is the difference between the returns on diversified portfolios of high book-to-market (value) stocks and low book-to-market (growth) stocks. In an attempt to also capture momentum returns, Carhart (1997) proposes a four-factor model for U.S. returns:

$$R_i(t)-RF(t)=a_i+b_i[RM(t)-RF(t)]+s_iSMB(t)$$
$$+h_iHML(t)+w_iWML(t)+e_i(t), \quad (2)$$

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which is (1) enhanced with a momentum return, $WML(t)$, the difference between the month t returns on diversified portfolios of the winners and losers of the past year.

Regressions (1) and (2) are commonly used in applications, most notably to evaluate portfolio performance (Carhart, 1997; Kosowski, Timmermann, Wermers, and White, 2006; Fama and French, 2010). In the initial paper on the three-factor model, however, Fama and French (1993) find that, although it captures the size and value patterns in post-1962 U.S. average returns better than the capital asset pricing model (CAPM), the model's explanation of average returns is far from complete. Avramov and Chordia (2006) likewise find that the four-factor model fails to absorb all the momentum in U.S. average stock returns.

This paper examines international stock returns, with two goals. The first is to detail the size, value, and momentum patterns in average returns for developed markets. Our main contribution is evidence for size groups. Most prior work on international returns focuses on large stocks. Our sample covers all size groups, and tiny stocks (microcaps) produce challenging results. Our second goal is to examine how well (1) and (2) capture average returns for portfolios formed on size and value or size and momentum. We examine local versions of the models in which the explanatory returns (factors) and the returns to be explained are from the same region. For perspective on whether asset pricing is integrated across regions, we also examine models that use global factors to explain global and regional returns.

There is a literature on integrated international asset pricing, ably reviewed by Karolyi and Stulz (2003). The papers closest to ours are Griffin (2002) and Hou, Karolyi, and Kho (2011). We add to their work. For example, Griffin (2002) examines whether country-specific or aggregate versions of (1) better explain returns on portfolios and individual stocks in four countries, the U.S., the U.K., Canada, and Japan. We use 23 countries. Hou, Karolyi, and Kho (2011) do not examine how value premiums and momentum returns differ across size groups and whether the size patterns in average value premiums and momentum returns are captured by local and international asset pricing models—our main tasks.

Section 2 discusses the motivation for the tests. Section 3 describes the data and variables. Section 4 presents summary statistics for returns. Sections 5 and 6 turn to tests of asset pricing models. Section 7 discusses robustness tests. A summary and conclusions are in Section 8.

2. Motivation

Regressions (1) and (2) are motivated by observed patterns in returns. They are examples of empirical asset-pricing models; that is, they try to capture the cross-section of expected returns without specifying the underlying economic model that governs asset pricing. When we propose regressions like (1) or (2) as empirically motivated asset-pricing models, the hypothesis is that the slopes and explanatory returns capture the cross-section of expected returns, so the true intercepts are zero for all left-hand-side (LHS) assets. This in turn implies that the portfolios on the right-hand side (RHS) span the ex ante minimum-variance (MV) tangency portfolio that can be created from all assets (Huberman and Kandel, 1987). If we find a set of explanatory portfolios that spans the MV tangency portfolio, we capture the cross-section of expected returns, whatever the underlying model generating asset prices.

Empirical asset pricing is empty if the search for the MV tangency portfolio is unrestricted. There is, after all, a tangency portfolio for any set of assets. To make empirical asset pricing interesting, restrictions must be imposed. We focus on parsimony. The models in (1) and (2) ask whether a small set of RHS portfolios, directed at patterns in average returns observed over long periods, capture the MV tangency portfolio implied by the expected returns and return covariances of assets.

We study international returns, and the goal is to shed light on two related issues; (i) whether parsimonious empirical asset pricing models capture the value and momentum patterns in international average returns, and (ii) the extent to which asset pricing is integrated across markets. The task faces bad model problems. Any model is an approximation to the pricing process, and so likely to be rejected in tests that have power. The models in (1) and (2) may fail, for example, because we do a poor job constructing value and momentum factors or because it is impossible to capture all value and momentum patterns with factors constructed using simple value and momentum sorts.

Alternatively, the bad model problem may be the absence of integrated asset pricing in the region covered by the RHS returns. Thus, suppose we have the correct asset pricing model; that is, applied to the broadest region in which pricing is integrated, the model's RHS portfolios span the region's MV tangency portfolio. Then if we regress the excess returns on any assets from the integrated pricing region on the model's RHS returns for the region, the intercepts are indistinguishable from zero. But if the intercept tests have power, we expect rejections if we use RHS returns for narrower or broader regions.

For example, suppose the model generating asset prices is the CAPM and pricing is globally integrated. Then βs with respect to the global market portfolio explain expected returns on all assets, but local versions of the CAPM should not work. For example, βs with respect to the U.S. market portfolio should not explain expected returns on all U.S. assets (unless by chance the U.S. market portfolio is the portfolio of U.S. assets maximally correlated with the global market). On the other hand, if pricing is not globally integrated, the global CAPM should fail even if a local CAPM prices assets in each market.

Power is often a problem in our tests of these predictions. We sometimes have too little and sometimes we have too much. When the LHS and RHS portfolios in our asset pricing regressions are for the same region (local or global), the tests typically have power because the regression fits are tight (R^2 is high). As a result, we shall see some formal rejections of models that in economic terms work rather well. On the other hand, when the RHS portfolios are global and the LHS assets are local (restricted to one of the four regions), the regressions fit less tightly and power is a problem. Perhaps as a result, we sometimes fail to reject global models that seem far off target in explaining local average returns.

Global models fare poorly in our tests, which opens the door for local models. We examine local versions of the three-factor and four-factor models (1) and (2) for each of our four regions. The tests of local models typically have power. Nevertheless, for portfolios formed on size and value versus growth, local models capture local average returns rather well. This is the good news for potential applications of such models. Local models have more problems capturing average returns for portfolios with extreme exposures to momentum. We argue that this may not be important in applications because for real world portfolios (for example, mutual funds), extreme momentum tilts are apparently rare.

Finally, like the tests of Fama and French (1998), Griffin (2002), Hou, Karolyi, and Kho (2011), and others, our tests of international asset pricing models ignore exchange rate risk. This means we implicitly assume either (i) complete purchasing power parity (relative prices of goods are the same everywhere and an exchange rate is just the ratio of the nominal prices of any good in two countries) or (ii) the assets we consider cannot be used to hedge exchange risk. See, e.g., Fama and Farber (1979) and Adler and Dumas (1983), for the theory, and Dumas and Solnik (1995) and Zhang (2006) for empirical tests that allow for exchange risk. Exchange risks are thus a potential problem in our inferences.

3. Data and variables

Our international stock returns and accounting data are primarily from Bloomberg, supplemented by Datastream and Worldscope. The sample period is November 1989 to March 2011. Our goal is to extend the international evidence to small stocks and a large sample of developed countries. The cost is a rather short sample period. Although some data, especially for big stocks, are available earlier, the November 1989 start date gives us broad coverage in all 23 countries we examine. All our returns are in U.S. dollars and monthly excess returns are returns in excess of the one-month U.S. Treasury bill rate (from the Center for Research in Security Prices (CRSP)).

The short sample period reduces the power of our tests, but we can mitigate the loss by using diversified LHS portfolios in our regressions. Diversification enhances regression fits, which increases the precision of the intercepts that are the focus of the tests of competing asset pricing models. To ensure that we have lots of stocks in each LHS portfolio, we combine our 23 developed markets into four regions: (i) North America (NA), which includes the United States and Canada; (ii) Japan; (iii) Asia Pacific, including Australia, New Zealand, Hong Kong, and Singapore (but not Japan); and (iv) Europe, including Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. We also examine global portfolios that combine the four regions. On average, North America, Europe, Japan, and Asia Pacific account for 47.3%, 30.0%, 18.4%, and 4.3% of global market capitalization.

Parsimony in the choice of regions is important in the power of our tests, but we also want regions in which market integration is a reasonable assumption. It is reasonable to assume that the U.S. and Canada are close to one market for goods and securities during our sample period (Mittoo, 1992). The countries of Europe are almost all members of the European Union (EU), and those that are not formal members (e.g., Switzerland) participate in most of the EU's open market provisions. Our tests suggest that market integration is most questionable in the rather small Asia Pacific region.

In each region, we sort stocks on size (market capitalization or market cap) and momentum and on size and the ratio of book equity to market equity (B/M). In our previous work on U.S. stocks (e.g., Fama and French, 1993) we use NYSE breakpoints for size and B/M, to avoid sorts that are dominated by the plentiful but less important tiny Amex and Nasdaq stocks. For the same reason, in our current tests we use B/M and momentum breakpoints based on large stocks and size breakpoints that are percents of aggregate market cap chosen to avoid undo weight on tiny stocks.

Specifically, the explanatory returns in our asset pricing tests are for portfolios constructed from 2×3 sorts on size and B/M or size and momentum. At the end of June of each year t we sort the stocks in a region on market cap and B/M. Big stocks are those in the top 90% of market cap for the region, and small stocks are those in the bottom 10%. For North America, 90% of market cap corresponds roughly to the NYSE median, used to define small and big stocks in Fama and French (1993). The B/M breakpoints in the 2×3 sorts for the four regions are the 30th and 70th percentiles of B/M for the big stocks of a region, where, as in Fama and French (1993), book value is for the fiscal year ending in calendar year $t-1$ and market cap is for the end of December of calendar year $t-1$. The global portfolios use global size breaks, but to mitigate any effects of differences in accounting rules across the four regions, we use each region's B/M breakpoints to allocate its stocks to the global portfolios. We also use regional momentum breakpoints (described below) when forming global size-momentum portfolios.

For each region, the intersection of the independent 2×3 sorts on size and B/M produces six portfolios, *SG*, *SN*, *SV*, *BG*, *BN*, and *BV*, where S and B indicate small or big and G, N, and V indicate growth, neutral, and value (bottom 30%, middle 40%, and top 30% of B/M), respectively. We compute monthly value-weight returns for each portfolio from July of year t to June of $t+1$. The size factor, *SMB*, for a region is the equal-weight average of the returns on the three small stock portfolios from the 2×3 size-B/M sorts for the region minus the average of the returns on the three big stock portfolios. For each region, we construct value—growth returns for small and big stocks, $HML_S = SV - SG$ and $HML_B = BV - BG$, and *HML* is the equal-weight average of HML_S and HML_B.

As in Fama and French (1993), at the end of June of each year we also construct 25 size-B/M portfolios for each region, to use as LHS assets in asset pricing regressions. The size breakpoints for a region are the 3rd, 7th, 13th, and 25th percentiles of the region's aggregate market capitalization. These correspond roughly to the average market caps for the NYSE quintile breakpoints for size used in Fama and French (1993). The B/M breakpoints in the 5×5 sorts follow the same rules as the 2×3 sorts, except we use the separate quintile B/M breakpoints (rather than 30–40–30 splits) for big (top 90% of market cap) stocks in each region to allocate the region's big and small stocks. The 25 value-weight size-B/M portfolios for the region are the intersections of the independent 5×5 size and B/M sorts.

We do 2×3 and 5×5 sorts on size and momentum using the same breakpoint conventions as the size-B/M sorts, except that the size-momentum portfolios are formed monthly and the lagged momentum return takes the place of B/M. For portfolios formed at the end of month t, the lagged momentum return is a stock's cumulative return for $t-11$ to $t-1$. (Skipping the sort month is standard in momentum tests.) The intersection of the independent 2×3 sorts on size and momentum produces six value-weight portfolios, *SL*, *SN*, *SW*, *BL*, *BN*, and *BW*, where S and B indicate small and big, and L, N, and W indicate losers, neutral, and winners (bottom 30%, middle 40%, and top 30% of lagged momentum). In the 2×3 sorts we construct winner – loser returns for small and big stocks, $WML_S = SW - SL$ and $WML_B = BW - BL$, and *WML* is the equal-weight average of WML_S and WML_B. The intersections of the independent 5×5 size and momentum sorts for a region produce 25 value-weight portfolios, which we use as LHS assets in the regressions. The first momentum sort absorbs a year of data, so the 20+ year sample period for all tests is November 1990 through March 2011 (henceforth 1991–2010).

When the LHS and RHS portfolios in regressions (1) and (2) are for the same (global or local) region, the LHS portfolios are from finer versions of the size, B/M, and momentum sorts that produce the *SMB*, *HML*, and *WML* explanatory returns in (1) and (2). In effect, the models are playing home games. As suggested by Lewellen, Nagel, and Shanken (2010), it would be interesting to see how the models perform when the LHS portfolios are formed differently. An advantage of our LHS portfolios is that variation through time in regression slopes is likely to be minor precisely because the portfolios are from finer versions of the sorts that produce the RHS returns. We can thus avoid the thorny estimation problems posed by time-varying regression slopes. If, for example, we ask the models to explain the returns on industry portfolios, time-varying slopes can be a problem, as in Fama and French (1997). It is also important to note that even in the home games played here, our models often lose, that is, they are rejected in tests on size-B/M and size-momentum portfolios.

The bottom line, nevertheless, is that our inferences about the successes and failures of global and local versions of the three-factor and four-factor models are for the size-B/M and size-momentum portfolios we use as LHS assets. Models that do well in our tests may fail in tests on other LHS assets, and vice versa. The restricted nature of our inferences is thus a potential problem in applications (for example, evaluating mutual fund performance) in which the LHS portfolios may have tilts toward other firm characteristics that are related to average returns but are not covered by our tests.

4. Summary statistics

We begin by examining summary statistics for the RHS explanatory returns in our asset pricing regressions. We then turn to the 25 portfolios formed on size and B/M, and the 25 size-momentum portfolios that are the LHS assets in the regressions.

4.1. Explanatory returns

Equity premiums for 1991–2010 (the average differences between monthly value-weight market returns and the one-month U.S. Treasury bill rate) are large in three of the four regions, ranging from 0.56% per month for Europe to 0.86% for Asia Pacific (Table 1). Japan is the exception, with a negative premium of -0.12% per month. As usual, the estimates of equity premiums are imprecise. The estimates for our sample period of 20+ years are above the traditional two-standard-error bound in only two of the four regions, Asia Pacific and North America. The global premium, a respectable 0.44% per month despite Japan's poor return, is 1.57 standard errors from zero.

There is no size premium in any region during our sample period. Average *SMB* returns are all close to zero (Table 1). In contrast, there are value premiums in all regions. Average *HML* returns range from 0.33% per month ($t=1.48$) for North America to 0.62% ($t=3.04$) for Asia Pacific. As in the U.S. results of Fama and French (1993), Kothari, Shanken, and Sloan (1995), and Loughran (1997), value premiums are larger for small stocks. The only exception is Japan, where the value premium is similar for small and big stocks, 0.47% ($t=2.38$) and 0.50% per month ($t=2.02$). The average global *HML* return is 0.45% per month ($t=2.85$), but the premium for small stocks, 0.66% ($t=3.78$), is larger than the premium for big stocks, 0.24% ($t=1.36$), and the difference, 0.42%, is 2.76 standard errors from zero.

The evidence that international value premiums are larger for small stocks seems contrary to the results in Fama and French (2006). The sample of the earlier paper is, however, thin on small stocks. The more complete current sample suggests that larger value premiums for small stocks are typical.

There are similar size patterns in momentum returns. Like Asness, Moskowitz, and Pedersen (2009) and Chui, Titman, and Wei (2010), we find strong momentum returns everywhere, except Japan. Average *WML* returns for the other regions range from 0.64% per month ($t=1.91$) for North America to 0.92% ($t=3.38$) for Europe (Table 1). Echoing the results for the U.S. in Hong, Stein, and Lim (2000), average *WML* returns for all regions except Japan are larger for small stocks. The global results are a summary. The average global *WML* return is 0.62% per month ($t=2.30$), the result of 0.82% ($t=3.14$) for small stocks and 0.41% ($t=1.38$) for big stocks. The difference between average *WML* returns for small and

Table 1
Summary statistics for explanatory returns: November 1990–March 2011, 245 months.

We examine regional portfolios for North America, Europe, Japan, and Asia Pacific (excluding Japan) and Global portfolios that combine the four regions. We form portfolios at the end of June of each year t by sorting stocks in a region into two market cap and three book-to-market equity (B/M) groups. Big stocks are those in the top 90% of June market cap for the region, and small stocks are those in the bottom 10%. The B/M breakpoints for the four regions are the 30th and 70th percentiles of B/M for the big stocks of a region. The global portfolios use global size breaks, but we use the B/M breakpoints for the four regions to allocate the stocks of these regions to the global portfolios. The independent 2×3 sorts on size and B/M produce six value-weight portfolios, *SG*, *SN*, *SV*, *BG*, *BN*, and *BV*, where S and B indicate small or big and G, N, and V indicate growth, neutral, and value (bottom 30%, middle 40%, and top 30% of B/M). *SMB* is the equal-weight average of the returns on the three small stock portfolios for the region minus the average of the returns on the three big stock portfolios. We construct value—growth returns for small and big stocks, $HML_S=SV-SG$ and $HML_B=BV-BG$, and *HML* is the equal-weight average of HML_S and HML_B. The 2×3 sorts on size and lagged momentum are similar, but the size-momentum portfolios are formed monthly. For portfolios formed at the end of month t, the lagged momentum return is a stock's cumulative return for $t-11$ *to* $t-1$. The independent 2×3 sorts on size and momentum produce six value-weight portfolios, *SL*, *SN*, *SW*, *BL*, *BN*, and *BW*, where S and B indicate small and big and L, N, and W indicate losers, neutral, and winners (bottom 30%, middle 40%, and top 30% of lagged momentum). We construct winner—loser returns for small and big stocks, $WML_S=SW-SL$ and $WML_B=BW-BL$, and *WML* is the equal-weight average of WML_S and WML_B. $HML_{S\text{-}B}$ ($WML_{S\text{-}B}$) is the difference between HML_S and HML_B (WML_S and WML_B). All returns are in U.S. dollars. Market is the return on a region's value-weight market portfolio minus the U.S. one-month T-bill rate. The mean value of the T-bill rate is 0.28%. Mean and Std dev are the mean and standard deviation of the return, and *t*-Mean is the ratio of Mean to its standard error.

	Market	*SMB*	*HML*	HML_S	HML_B	HML_{S-B}	*WML*	WML_S	WML_B	WML_{S-B}
Global										
Mean	0.44	0.10	0.45	0.66	0.24	0.42	0.62	0.82	0.41	0.41
Std dev	4.37	2.19	2.46	2.73	2.74	2.39	4.20	4.09	4.68	2.60
t-Mean	1.57	0.69	2.85	3.78	1.36	2.76	2.30	3.14	1.38	2.46
North America										
Mean	0.66	0.24	0.33	0.56	0.10	0.46	0.64	0.85	0.44	0.40
Std dev	4.39	3.28	3.54	4.38	3.31	3.22	5.27	5.35	5.61	3.03
t-Mean	2.35	1.16	1.48	2.01	0.49	2.23	1.91	2.47	1.23	2.09
Europe										
Mean	0.56	−0.06	0.55	0.69	0.42	0.27	0.92	1.34	0.50	0.85
Std dev	4.95	2.39	2.48	2.83	2.98	3.05	4.26	3.98	4.99	2.98
t-Mean	1.77	−0.38	3.51	3.81	2.21	1.38	3.38	5.29	1.56	4.44
Japan										
Mean	−0.12	−0.09	0.48	0.47	0.50	−0.03	0.08	0.00	0.15	−0.14
Std dev	6.03	3.46	2.93	3.08	3.87	3.81	4.74	4.34	5.88	4.12
t-Mean	−0.31	−0.42	2.59	2.38	2.02	−0.13	0.25	0.02	0.39	−0.54
Asia Pacific										
Mean	0.86	−0.21	0.62	0.93	0.32	0.61	0.69	0.99	0.39	0.61
Std dev	6.14	3.07	3.22	3.29	4.22	3.98	4.81	4.49	5.93	4.23
t-Mean	2.19	−1.05	3.04	4.42	1.19	2.39	2.24	3.47	1.02	2.25

big stocks exceeds two standard errors for all regions, except Japan. For Japan, average *WML* returns are close to zero for small and big stocks.

Chui, Titman, and Wei (2010) argue that momentum returns are stronger in cultures that value individualism. They argue that Japan ranks low on individualism, and this explains the absence of momentum returns. We are skeptical since it seems the argument could go the other way; that is, low individualism might produce momentum because stock prices react slowly to information. A simple alternative is that the absence of momentum returns in Japan is a chance result. Chance is a serious contender; the Hotelling T^2 test (not shown) of whether expected *WML* returns differ across regions fails to reject at the 90% level. Chance might also explain the low Japanese market portfolio return; the test of whether expected market returns differ across regions barely rejects at the 90% level.

4.2. Excess returns for the 25 size-B/M and the 25 size-momentum portfolios

For a sample period preceding that used here, Fama and French (1993) find that the low returns of small U.S. growth stocks are a problem for the three-factor model (1). Panel A of Table 2 shows that for our new 1991–2010 sample, low returns for small growth stocks are common to all regions except Japan. Japan aside, for extreme growth stocks (the left column of the 5×5 size-B/M matrices), the small stock portfolios tend to have lower average returns than the big stock portfolios—a reverse size effect.

Japan aside, there is a standard size effect in the right column of the 5×5 size-B/M matrices; the small extreme value (high B/M) portfolios have higher average returns than the big extreme value portfolios. For every region including Japan, there are value premiums in all size groups; average returns increase from left to right in every row of all the size-B/M matrices. But the lower average returns of small stocks in the left column of the matrices for North America, Europe, and Asia Pacific combine with a typical size effect in the right column to produce larger value premiums for small stocks, especially microcaps. This common size pattern in value premiums poses an interesting challenge for our asset pricing models.

Panel B of Table 2 shows matrices of average excess returns for the 25 size-momentum portfolios of our four

Table 2

Summary statistics for the 25 size-B/M and size-momentum excess returns for November 1990–March 2011, 245 months.

At the end of June of each year, we construct 25 size-B/M portfolios for each region. The size breakpoints are the 3rd, 7th, 13th, and 25th percentiles of aggregate market cap for a region. The B/M quintile breakpoints use the big stocks (top 90% of market cap) of a region. The global portfolios use global size breakpoints, but the separate quintile B/M breakpoints for North America, Europe, Japan, and Asia Pacific are used to allocate the stocks of these regions to the global portfolios. The intersections of the 5×5 independent size and B/M sorts for a region produce 25 value-weight size-B/M portfolios. The 5×5 sorts on size and momentum use the same breakpoint conventions as the size-B/M sorts, except that the size-momentum portfolios are formed monthly. For portfolios formed at the end of month t, the lagged momentum return is a stock's cumulative monthly return for $t-11$ to $t-1$. The intersections of the independent 5×5 size and momentum sorts produce 25 value-weight portfolios for each region.

Panel A: Monthly excess returns for 25 portfolios formed on size and B/M

	Mean					Standard deviation				
	Low	2	3	4	High	Low	2	3	4	High
Global										
Small	0.07	0.48	0.77	0.83	1.12	5.94	5.48	5.09	4.64	4.38
2	0.09	0.46	0.59	0.69	0.79	5.87	5.21	4.68	4.40	4.56
3	0.21	0.40	0.52	0.57	0.74	5.78	5.19	4.64	4.47	4.65
4	0.37	0.43	0.52	0.60	0.69	5.66	4.61	4.50	4.47	4.78
Big	0.29	0.36	0.49	0.53	0.53	4.62	4.29	4.41	4.45	5.40
North America										
Small	0.50	0.75	1.13	1.04	1.42	8.48	7.15	6.42	5.50	5.43
2	0.34	0.73	0.95	0.94	1.08	7.77	6.82	5.73	4.90	5.24
3	0.90	0.70	0.87	0.86	1.08	7.34	6.02	5.14	4.67	5.03
4	0.80	0.73	0.89	0.84	0.96	6.97	5.29	4.76	4.75	4.79
Big	0.54	0.56	0.62	0.66	0.64	4.84	4.35	4.32	4.35	5.48
Europe										
Small	−0.13	0.29	0.44	0.66	0.88	5.79	5.50	5.21	4.94	4.89
2	0.10	0.42	0.53	0.78	0.89	6.13	5.40	5.15	5.14	5.26
3	0.21	0.54	0.62	0.62	0.86	6.01	5.32	5.10	5.30	5.47
4	0.39	0.57	0.66	0.64	0.88	5.57	4.90	5.10	5.29	5.81
Big	0.31	0.52	0.65	0.76	0.73	5.09	4.83	5.16	5.56	6.44
Japan										
Small	−0.17	−0.08	0.02	0.08	0.22	9.32	7.81	7.58	7.31	7.25
2	−0.45	−0.37	−0.13	0.01	0.03	8.30	7.78	7.17	7.08	7.23
3	−0.42	−0.39	−0.27	−0.16	0.13	7.93	7.06	6.72	6.46	6.97
4	−0.50	−0.18	−0.21	0.00	0.05	7.51	6.44	6.06	6.05	6.84
Big	−0.33	−0.10	−0.10	0.18	0.35	6.95	5.99	6.15	6.02	7.44
Asia Pacific										
Small	0.39	0.61	0.87	1.17	1.61	8.18	8.03	7.36	7.34	7.42
2	0.17	0.51	0.63	0.79	1.06	7.21	7.72	6.91	7.23	7.94
3	0.10	0.77	0.88	1.00	0.92	7.37	6.88	6.76	7.04	8.04
4	0.90	0.96	0.66	1.08	1.16	6.67	6.20	6.35	6.95	8.49
Big	0.69	0.97	0.95	0.94	1.13	6.52	6.25	6.45	6.90	8.11

Panel B: Monthly excess returns for 25 portfolios formed on size and momentum

	Mean					Standard deviation				
	Low	2	3	4	High	Low	2	3	4	High
Global										
Small	0.20	0.66	0.80	1.15	1.57	6.42	4.36	3.95	4.07	5.43
2	0.17	0.52	0.54	0.78	1.12	6.72	4.65	4.19	4.19	5.54
3	0.28	0.46	0.55	0.57	0.85	6.64	4.87	4.26	4.18	5.51
4	0.26	0.46	0.52	0.57	0.86	6.59	4.78	4.18	4.20	5.35
Big	0.12	0.32	0.38	0.55	0.61	6.26	4.57	4.09	4.15	5.36
North America										
Small	0.54	0.96	1.19	1.51	1.96	7.71	5.05	4.73	5.26	7.09
2	0.52	0.95	0.95	1.00	1.50	7.94	5.17	4.81	4.88	7.47
3	0.57	0.75	0.90	1.07	1.27	7.45	5.13	4.49	4.71	6.91
4	0.54	0.79	0.84	0.82	1.29	7.35	4.76	4.30	4.41	6.54
Big	0.36	0.52	0.44	0.74	0.97	6.55	4.55	3.96	4.21	6.22
Europe										
Small	−0.28	0.38	0.61	1.03	1.75	6.53	4.85	4.52	4.41	5.51
2	−0.16	0.46	0.66	0.88	1.45	6.90	5.34	4.86	4.71	5.60
3	0.19	0.43	0.63	0.77	1.11	6.97	5.37	4.95	4.84	5.65
4	0.27	0.52	0.65	0.77	1.11	7.22	5.45	4.92	4.96	5.37
Big	0.22	0.47	0.69	0.65	0.77	7.46	5.64	4.77	4.74	5.51
Japan										
Small	0.17	0.26	0.15	0.24	−0.05	8.87	7.20	6.65	6.48	7.88
2	−0.10	−0.03	−0.06	0.03	−0.09	8.71	7.10	6.59	6.64	7.35
3	−0.14	−0.22	−0.12	−0.02	−0.05	8.09	6.86	6.12	6.22	6.92
4	−0.11	−0.11	−0.18	−0.16	−0.05	7.99	6.57	6.10	5.91	6.68
Big	−0.10	−0.28	−0.31	−0.12	−0.06	8.31	6.53	6.17	5.89	6.84
Asia Pacific										
Small	0.60	1.04	1.31	1.95	1.73	8.56	6.88	6.48	6.86	8.03
2	−0.14	0.83	0.85	1.08	1.18	9.01	7.20	6.35	6.48	7.72
3	0.18	0.60	0.71	1.19	1.24	8.77	6.78	6.15	6.58	7.85
4	0.48	0.96	0.85	0.99	1.23	8.59	7.29	5.83	5.98	7.74
Big	1.11	0.72	1.07	1.06	1.12	8.74	7.24	6.61	6.35	7.00

Table 3
Summary statistics for regressions to explain monthly excess returns on portfolios from sorts on size and B/M, with (5 × 5) and without (4 × 5) microcaps: November 1990 to March 2011.

The regressions use the CAPM, three-factor (1), and four-factor (2) models with global or local factors to explain the returns on Global, North American, European, Japanese, and Asia Pacific portfolios formed on size and B/M. The 5 × 5 results include all five size quintiles; the 4 × 5 results exclude microcap portfolios. The GRS statistic tests whether all intercepts in a set of 25 (5 × 5) or 20 (4 × 5) regressions are zero; $|a|$ is the average absolute intercept for a set of regressions; R^2 is the average adjusted R^2; $s(a)$ is the average standard error of the intercepts; and $SR(a)$ is the Sharpe ratio for the intercepts. With 25 portfolios and 245 monthly returns, critical values of the GRS statistic for all models are: *90%:* 1.41; *95%:* 1.56; *97.5%:* 1.69; *99%:* 1.86; and *99.9%:* 2.25.

	Global factors								Local factors							
	5 × 5					4 × 5			5 × 5					4 × 5		
	GRS	$\|a\|$	R^2	$s(a)$	$SR(a)$	GRS	$\|a\|$	$SR(a)$	GRS	$\|a\|$	R^2	$s(a)$	$SR(a)$	GRS	$\|a\|$	$SR(a)$
Global																
CAPM	4.07	0.21	0.81	0.13	0.68	1.72	0.17	0.39								
Three-factor	3.62	0.12	0.95	0.07	0.66	2.19	0.09	0.45								
Four-factor	3.22	0.11	0.95	0.07	0.64	1.82	0.07	0.42								
North America																
CAPM	3.25	0.40	0.62	0.23	0.61	1.77	0.37	0.40	3.00	0.23	0.73	0.19	0.59	1.41	0.19	0.36
Three-factor	2.95	0.39	0.74	0.19	0.59	2.16	0.36	0.45	2.88	0.13	0.93	0.10	0.59	1.55	0.10	0.38
Four-factor	2.40	0.41	0.75	0.19	0.55	1.74	0.39	0.41	2.57	0.12	0.93	0.10	0.56	1.25	0.08	0.35
Europe																
CAPM	1.65	0.24	0.66	0.20	0.43	1.20	0.23	0.33	1.63	0.20	0.80	0.15	0.43	1.19	0.17	0.33
Three-factor	1.43	0.13	0.76	0.17	0.41	0.84	0.11	0.28	1.23	0.09	0.94	0.09	0.38	1.13	0.08	0.33
Four-factor	1.28	0.10	0.76	0.18	0.40	0.59	0.08	0.24	1.07	0.07	0.94	0.09	0.38	0.94	0.06	0.31
Japan																
CAPM	1.48	0.49	0.29	0.39	0.41	1.56	0.52	0.37	1.11	0.18	0.78	0.21	0.35	1.12	0.18	0.31
Three-factor	1.27	0.69	0.36	0.37	0.39	1.31	0.70	0.35	0.88	0.11	0.93	0.12	0.32	0.99	0.10	0.30
Four-factor	1.19	0.63	0.36	0.38	0.39	1.19	0.66	0.34	0.86	0.10	0.93	0.12	0.32	0.96	0.09	0.30
Asia Pacific																
CAPM	2.84	0.41	0.49	0.33	0.57	1.52	0.39	0.37	2.85	0.23	0.78	0.22	0.57	1.40	0.19	0.36
Three-factor	2.50	0.26	0.56	0.32	0.55	1.25	0.24	0.34	2.59	0.22	0.89	0.16	0.56	1.83	0.20	0.41
Four-factor	2.08	0.24	0.56	0.32	0.51	0.90	0.21	0.30	2.22	0.19	0.89	0.16	0.53	1.47	0.17	0.38

regions. For Japan there is no hint of momentum in any size group. For all other regions there are momentum returns in all size groups; average returns increase from left (last year's losers) to right (winners) in all rows of the 5 × 5 matrices. There is no consistent relation between average return and size in the first two columns of the matrices. A typical size effect (higher average returns for small stocks) shows up in the fourth column of the matrices, and it is more evident in the fifth column. Thus, last year's winners show positive momentum returns in all size groups, but persistence is stronger for small stocks, especially microcaps. The size pattern in momentum returns is also an interesting challenge for our asset pricing models.

Why are the spreads in momentum and value versus growth average returns larger for small stocks? Liquidity and sensitivity to liquidity factors in returns of the type discussed by Amihud and Mendelson (1986), Pastor and Stambaugh (2003), and Acharya and Pedersen (2005) are a possibility, suggested by a referee. For a liquidity story to work, small growth stocks and small momentum losers must be more liquid and/or have lower sensitivity to liquidity factors than small value stocks and small momentum winners. The results of Pastor and Stambaugh (2003) and Acharya and Pedersen (2005) suggest that this is unlikely. Moreover, since any persistent differences in expected return affect price ratios like B/M, our asset pricing models do not necessarily miss liquidity effects in expected returns.

5. Asset pricing tests for size-B/M portfolios

Tables 3 and 4 summarize regressions to explain excess returns on the portfolios from the 5 × 5 sorts on size and B/M. Table 3 shows the *F*-test of Gibbons, Ross, and Shanken (GRS, 1989) and summary statistics for the regression intercepts that help us interpret the GRS test. Table 4 shows matrices of the intercepts and their *t*-statistics for selected models. (Detailed regression results are available on request.) For the 25 global LHS portfolios, we use only global explanatory returns. For the four regions, we examine results for local and global explanatory returns.

In addition to the GRS test, the summary statistics in Table 3 include the average absolute value of the 25 intercepts from each set of regressions, the average of the standard errors of the intercepts, and the average of the 25 regression R^2. Following the recommendation of Lewellen, Nagel, and Shanken (2010), Table 3 also shows $SR(a)$, the core of the GRS statistic:

$$SR(a) = (a'S^{-1}a)^{1/2}, \tag{3}$$

where a is the column vector of the 25 regression intercepts produced by a model when applied to 25 global or local size-B/M portfolios, and S is the covariance matrix of regression residuals.

Gibbons, Ross, and Shanken (1989) show that $SR(a)^2$ is the difference between (i) the square of the maximum

Table 4
Intercepts from CAPM, three-factor (1), and four-factor (2) regressions to explain monthly excess returns on portfolios from 5 × 5 sorts on size and B/M, November 1990 to March 2011.

The regressions use the CAPM, three-factor (1), and four-factor (2) models with global and local factors to explain the excess returns on Global, North American, European, Japanese, and Asia Pacific portfolios formed from independent size and B/M sorts. The table reports intercepts, *a*, and *t*-statistics, *t*(*a*), for the intercepts.

	a					*t*(*a*)				
	Low	2	3	4	High	Low	2	3	4	High
Global size-B/M returns regressed on global factors										
CAPM										
Small	−0.41	0.01	0.33	0.44	0.75	−1.81	0.07	1.91	2.81	4.77
2	−0.41	−0.01	0.17	0.29	0.39	−2.09	−0.10	1.25	2.36	2.65
3	−0.31	−0.08	0.09	0.16	0.32	−1.90	−0.54	0.82	1.36	2.40
4	−0.15	−0.01	0.08	0.19	0.26	−0.98	−0.11	0.97	1.75	2.00
Big	−0.14	−0.06	0.06	0.11	0.04	−1.26	−0.90	0.90	1.24	0.25
Three-factor										
Small	−0.32	0.00	0.23	0.22	0.44	−3.15	0.03	2.70	3.28	6.08
2	−0.30	−0.04	0.03	−0.00	−0.00	−3.77	−0.59	0.47	−0.02	−0.03
3	−0.13	−0.09	−0.10	−0.14	−0.06	−1.71	−1.28	−1.42	−2.15	−0.94
4	0.07	−0.08	−0.10	−0.08	−0.12	0.82	−1.12	−1.55	−1.17	−1.75
Big	0.18	0.00	−0.04	−0.07	−0.26	3.11	0.04	−0.76	−1.14	−3.06
Four-factor										
Small	−0.33	0.01	0.22	0.21	0.41	−3.16	0.14	2.52	3.09	5.59
2	−0.22	0.02	0.03	0.02	0.01	−2.88	0.33	0.51	0.46	0.19
3	−0.08	−0.09	−0.06	−0.09	−0.05	−1.13	−1.30	−0.79	−1.36	−0.71
4	0.06	−0.04	−0.08	−0.03	−0.07	0.74	−0.57	−1.18	−0.41	−1.01
Big	0.21	−0.03	−0.02	−0.07	−0.15	3.57	−0.56	−0.38	−1.14	−1.89

	a					*t*(*a*)				
	Low	2	3	4	High	Low	2	3	4	High
North American size-B/M returns regressed on North American factors										
Three-factor										
Small	−0.45	−0.15	0.17	0.11	0.38	−2.75	−1.16	1.58	1.37	4.43
2	−0.45	−0.14	0.02	−0.01	−0.02	−3.71	−1.39	0.26	−0.12	−0.25
3	0.13	−0.18	0.01	−0.04	0.06	1.07	−1.64	0.12	−0.44	0.72
4	0.14	−0.05	0.05	−0.03	0.01	1.08	−0.46	0.46	−0.32	0.07
Big	0.15	−0.00	−0.08	−0.09	−0.34	2.05	−0.00	−0.97	−0.99	−3.20
Four-factor										
Small	−0.44	−0.13	0.17	0.13	0.35	−2.67	−0.94	1.52	1.53	4.03
2	−0.33	−0.12	0.02	0.04	0.00	−2.91	−1.15	0.24	0.55	0.02
3	0.07	−0.14	0.07	0.02	0.07	0.58	−1.29	0.71	0.23	0.87
4	0.11	−0.00	0.07	0.00	0.05	0.82	−0.04	0.64	0.03	0.65
Big	0.17	−0.01	−0.04	−0.06	−0.27	2.23	−0.07	−0.52	−0.66	−2.59
European size-B/M Returns regressed on European factors										
Three-factor										
Small	−0.32	−0.05	0.01	0.10	0.20	−2.63	−0.55	0.13	1.45	2.97
2	−0.12	−0.05	−0.05	0.09	0.06	−0.90	−0.59	−0.61	1.29	0.91
3	−0.05	0.04	−0.04	−0.15	−0.01	−0.42	0.46	−0.42	−1.74	−0.11
4	0.09	0.03	−0.01	−0.17	−0.08	0.82	0.35	−0.09	−1.90	−0.86
Big	0.10	0.07	0.04	0.00	−0.27	1.22	0.80	0.61	0.04	−2.23
Japanese size-B/M returns regressed on Japanese factors										
Three-factor										
Small	0.15	0.09	0.17	0.17	0.18	0.77	0.61	1.18	1.77	1.87
2	−0.10	−0.16	−0.03	0.05	−0.07	−0.66	−1.41	−0.26	0.62	−1.05
3	−0.05	−0.14	−0.21	−0.18	0.01	−0.32	−1.12	−2.07	−1.94	0.09
4	−0.14	−0.02	−0.17	−0.08	−0.12	−0.94	−0.13	−1.40	−0.72	−1.24
Big	0.09	−0.03	−0.12	0.08	0.11	0.82	−0.25	−1.07	0.60	0.59
Asia Pacific size-B/M returns regressed on Asia Pacific factors										
Three-factor										
Small	−0.10	−0.02	0.22	0.41	0.76	−0.44	−0.10	1.56	3.07	5.48
2	−0.39	−0.22	−0.03	−0.06	−0.12	−2.27	−1.58	−0.26	−0.45	−0.87
3	−0.47	0.15	0.16	0.14	−0.33	−2.61	0.89	0.99	0.81	−1.75
4	0.25	0.32	−0.02	0.12	−0.25	1.52	1.98	−0.10	0.66	−1.37
Big	0.11	0.20	0.03	−0.31	−0.36	0.75	1.67	0.26	−2.54	−1.80

Sharpe ratio for the portfolios that can be constructed from the LHS and RHS assets in a set of time-series regression tests of an asset pricing model and (ii) the square of the maximum Sharpe ratio for the portfolios that can be constructed from the RHS assets alone. More directly, $SR(a)$ is the maximum Sharpe ratio for excess returns on portfolios of the LHS assets constructed to have zero slopes on the RHS returns. We often refer to $SR(a)$, somewhat loosely, as the Sharpe ratio for the intercepts (unexplained average returns) of a model.

The advantage of $SR(a)$ as a summary statistic is that it combines the regression intercepts with the covariance matrix of the regression residuals, which is an important determinant of the precision of the alphas. This advantage, however, is also a disadvantage: because $SR(a)$ combines information about both the magnitude of the intercepts and their precision, it is useful to have the information about the two pieces provided by the average absolute intercept, the average R^2, and the average standard error of the intercepts.

5.1. *Global models for global size-B/M portfolio returns*

The regressions in which global portfolios provide both dependent and explanatory returns illustrate many of the asset pricing problems we encounter. Because the global LHS size-B/M portfolios are quite diversified, they identify the problems with precision. Moreover, if we use the correct asset pricing model, the tests to explain global returns with global factors provide evidence on whether asset pricing is integrated across our four developed regions. The tests that use global factors to explain returns for the four regions then give details about sources of success and failure.

The global CAPM, which includes only the global excess market return as an explanatory variable, fares poorly in our tests. The GRS statistic for the CAPM regressions, 4.07 in Table 3, is far into the right tail of the relevant *F*-distribution, and the CAPM intercepts (Table 4) are always negative for extreme growth portfolios and positive for extreme value portfolios. The CAPM fails because market betas for the 25 global size-B/M portfolios (not shown) are, if anything, higher for growth than for value portfolios, the reverse of what is needed to explain the value premium in global returns.

Switching to the three-factor model (1) improves the description of average returns on the global size-B/M portfolios. The GRS statistic falls to 3.62 and the average absolute intercept falls from 0.21% to 0.12%. Nevertheless, the GRS statistic is above the 99.9% threshold, 2.25, and we confidently reject the global three-factor model. The rejection is due in part to tight regression fits. Adding the global *SMB* and *HML* returns raises the average R^2 from 0.81 for the CAPM to 0.95 for the three-factor model, and the average standard error of the intercepts falls by almost half, from 0.13% to 0.07%. But there are also three-factor pricing problems. The global model leaves a strong value pattern in the intercepts for global microcaps (first row of the intercept matrix in Table 4), and it creates a milder reverse value pattern (positive intercepts for growth portfolios and negative for value portfolios) among megacaps (the last row). The explanation follows from two facts. (i) Value-growth spreads in global average returns are larger for small stocks, especially microcaps (Table 2), and (ii) the spreads in three-factor *HML* slopes (not shown) are not wider for small stocks. As a result, the global three-factor model underestimates the value-growth spread in global microcap average returns and overestimates the spread for megacaps.

The global version of Carhart's (1997) four-factor model (2), which adds the global *WML* momentum return to the three-factor model (1), lowers the GRS statistic from 3.62 (three-factor model) to 3.22, but the four-factor model is still rejected, and its intercepts (Table 4) are similar to those from the three-factor model. Adding *WML* to the three-factor model slightly shrinks the average absolute intercept from 0.12% to 0.11% and $SR(a)$, the Sharpe ratio for the intercepts (where smaller is better), only falls from 0.66 to 0.64.

The $SR(a)$ produced by the global CAPM, 0.68, is close to those of the global three- and four-factor models, 0.66 and 0.64. Keep in mind, however, that $SR(a)$ depends on the precision of the intercepts as well as their magnitude, and precision (as measured by average R^2 and the average standard error of the intercepts) is much lower in the CAPM regressions.

The serious intercept problems of the four-factor model in the tests on global returns center largely on microcaps. Thus, perhaps integrated global pricing does not extend to microcaps or perhaps other bad model problems are just more apparent among microcaps. To see how our models do without microcaps, Table 3 summarizes intercept tests for the global size-B/M portfolios when the microcap (first) row of the intercept matrices is deleted. For the four-factor model, dropping microcaps produces a large decline in $SR(a)$, from 0.64 to 0.42. The GRS statistic also falls, from 3.22 to 1.82, which (using the degrees of freedom for the test that includes microcaps) still rejects at the 97.5% level—despite the bias in favor of model acceptance created by hindsight omission of the quintile with the biggest problems. The tests, however, have substantial power (average R^2 is 0.95), and microcaps aside, the performance of the four-factor model seems acceptable. For example, without microcaps the average absolute intercept in (2) is 0.07%, among the lowest in Table 3. These results suggest that, except for microcaps, integrated global pricing and the four-factor model are a passable story for global size-B/M portfolio returns.

It is possible that global LHS portfolios, which mix assets from our four basic regions, conceal asset pricing problems. For example, the expected returns of the assets of a region (e.g., North America) may not be captured well by global RHS portfolios, but this information may be buried in tests that use global LHS portfolios. To check this possibility, we turn now to regressions that use global RHS returns to explain the returns on LHS portfolios for each of the four basic regions.

5.2. *Global models for regional size-B/M portfolio returns*

When the tests include microcaps, the GRS statistic (Table 3) cleanly rejects the global versions of our three models when applied to the 25 size-B/M portfolios of North America and Asia Pacific. If we drop microcaps, the GRS statistics improve and only the tests for North

America reject the global CAPM, three-factor, and four-factor models. Again, however, dropping the portfolios known to cause the biggest problems creates a bias toward accepting the models.

There are power problems in the tests of global models on regional returns. Japan is the extreme case. The three global models pass the GRS test easily when asked to explain Japanese size-B/M portfolio returns. The largest GRS statistic, 1.48 for the global CAPM, is barely above 1.41, the 90th percentile of the relevant *F*-distribution. But the power of the tests is low. Average R^2 is only 0.29 for the CAPM and 0.36 for the three-factor and four-factor models, and the standard error of the intercepts averages 0.37% or higher. Moreover, the intercepts (not shown) in the regressions for all Japanese portfolios and all global models are strongly negative, so average intercepts are the negatives of the average absolute intercepts, which are huge, from 0.49% to 0.69% per month. The problem traces to low average excess returns on the 25 Japanese size-B/M portfolios (Table 2) combined with slopes close to 1.0 (not shown) on the global market excess return and a large average global market premium (Table 1). As a result, average returns on the Japanese size-B/M portfolios are far lower than the global models predict. We can't reject global CAPM, three-factor, or four-factor pricing for Japan, but in economic terms, the global models fail badly there.

Though less severe, global models also have power problems (witnessed by low R^2 and high intercept standard errors) in the regressions to explain size-B/M returns for other regions. Moreover, with global explanatory returns, there is an intercept problem in the regressions for North America like that in the Japanese tests, but of opposite sign. The NA average intercepts (not shown) are systematically positive and large (0.38–0.41%), and as in Japan, extreme NA intercepts are common to all size groups, not just microcaps. The poor economic performance of the global models makes them unattractive for applications focused on North American or Japanese returns (markets that together account on average for about 60% of global market cap).

Systematically extreme intercepts in the estimates of global models on the size-B/M portfolio returns of Japan and North America suggest that regional differences in the level of average returns are a problem for the global models. As a check, we use the global models to explain the market portfolio returns of the four regions. Despite poor regression fits (average R^2 is 0.68), the GRS test (Table 5) rejects the global CAPM for the market returns of the four regions at the 90% level. The GRS test rejects the global three-factor and four-factor models for regional market returns at the 95% level. Once again, the intercepts for the North American market return are large and positive (0.26–0.37%) in the three global models, and the intercepts for Japan are large and negative (-0.53% to -0.60%).

Solnik (1974), Harvey (1991), and Fama and French (1998) fail to reject the global CAPM as a model for country market portfolio returns. Our stronger evidence against global models for regional market portfolios may be specific to our sample period, but enhanced power is also a possibility. Previous papers typically use LHS market portfolios for many countries. In multiple comparisons tests like GRS, more LHS portfolios can imply less power. Collapsing countries into four regions, with a presumption of integrated pricing in each region, can reduce the power loss.

In short, global models fare poorly when asked to explain the returns on regional size-B/M portfolios. We see next that local (regional) models are better for that task.

5.3. Local models for regional size-B/M portfolio returns

The GRS statistic (Table 3) testing whether the Japanese market, *SMB*, and *HML* returns capture the average returns for the 25 Japanese size-B/M portfolios, 0.88, is below the median of the relevant *F*-distribution, there are no notable patterns in the matrix of three-factor regression intercepts (Table 4), the intercepts are almost all

Table 5
Summary statistics and intercepts for CAPM, three-factor (1), and four-factor (2) regressions to explain monthly excess returns on value-weight market portfolios for North America, Europe, Japan, and Asia Pacific with global factors, November 1990 to March 2011.

The GRS statistic, in Panel A, tests whether all intercepts in a set of four regressions are zero; $|a|$ is the average absolute intercept; R^2 is the average adjusted R^2; $s(a)$ is the average standard error of the intercepts; and $SR(a)$ is the Sharpe ratio for the intercepts. With four portfolios and 245 monthly returns, critical values of the GRS statistic for all four models are: *90%:* 1.97; *95%:* 2.41; *97.5%:* 2.84; and *99%:* 3.40. In Panel B, a is the intercept for a region and $t(a)$ is its t-statistic.

Panel A: Summary statistics

	GRS	$\|a\|$	R^2	$s(a)$	$SR(a)$
CAPM	2.27	0.32	0.68	0.19	0.19
Three-factor	2.63	0.30	0.70	0.19	0.21
Four-factor	2.69	0.30	0.70	0.20	0.22

Panel B: Intercepts

	a				$t(a)$			
	NA	Europe	Japan	AP	NA	Europe	Japan	AP
CAPM	0.26	0.11	−0.53	0.37	2.20	0.82	−1.85	1.54
Three-factor	0.35	0.01	−0.57	0.25	3.06	0.05	−2.00	1.03
Four-factor	0.37	−0.01	−0.60	0.24	3.13	−0.05	−2.03	0.95

economically and statistically close to zero, and the Sharpe ratio for the 25 intercepts, 0.32, is the lowest in Table 3 tests that include microcaps. In short, the local three-factor model works well for the Japanese size-B/M portfolios.

The GRS test suggests that the local CAPM also works in Japan, but the test has low power. The average R^2 for the CAPM regressions is only 0.78, the average standard error of the intercepts is 0.21%, and the CAPM leaves a strong value pattern in the (unreported) intercepts for all five size groups. Adding the three-factor model's *SMB* and *HML* returns pushes the average R^2 up to 0.93, shrinks the average standard error of the intercepts to 0.12%, and lowers the average absolute intercept from 0.18% to 0.11%. The local four-factor model does not improve the local three-factor model's explanation of the average returns on the Japanese size-B/M portfolios. This is not surprising since Japan is the only region where there is no return momentum (Table 2).

The local three-factor model also works well for the 25 European size-B/M portfolios. The model leaves a value pattern in the intercepts for microcaps (Table 4), and it creates a mild reverse value pattern for megacaps. But the GRS statistic, 1.23, does not come close to producing a rejection, and $SR(a)$ and the average absolute intercept are among the lowest in the tests that include microcaps. The local four-factor model also works well for the 25 European size-B/M portfolios, indeed a bit better than the three-factor model.

Local models fare poorly in tests on Asia Pacific size-B/M portfolios. Average absolute intercepts for all models are 0.17% or greater, with or without microcaps. With microcaps, the local four-factor model produces the smallest GRS statistic, 2.22, which rejects at the 99% level. The model rejections are impressive since the precision of the tests is low. Average R^2 is 0.89 or less, and the average standard errors of the intercepts are 0.16% or greater. Given the imprecision of the tests, the improvements in the GRS statistics when microcaps are dropped do not redeem the local Asia Pacific models.

The three-factor model was developed to explain the returns on U.S. size-B/M portfolios, but in the tests of local three-factor models the GRS test rejects most strongly for North America. The rejection is not news (Fama and French, 1993). The patterns in the NA three-factor intercepts are like those that show up in the local three-factor models for all regions except Japan; that is, the three-factor model leaves a value pattern in the intercepts for microcap portfolios and it creates a milder reverse value pattern in the intercepts for megacaps (Table 4). The patterns are, however, typically stronger in the NA tests. The local NA four-factor model produces a marginal improvement in the GRS statistic, but it is still rejected at the 99.9% level, and it leaves similar microcap and megacap patterns in the regression intercepts. Dropping microcaps produces a big improvement in the performance of the NA three-factor and four-factor models. For example, the average absolute intercept for the four-factor model falls from 0.12% to 0.08%, the GRS statistic falls from 2.57 to 1.25, and $SR(a)$ declines to 0.35, versus 0.56 with microcaps.

In sum, local three-factor models are quite passable for average returns on size-B/M portfolios in Japan and Europe, with or without microcaps. Microcaps are important in the rejections of local models for North America. Microcaps aside, the local four-factor model does a reasonable job capturing average returns on North American size-B/M portfolios, and it is tempting to conclude that North America is an important contributor to the same conclusion from the earlier tests of global models on global size-B/M portfolios. For Europe and Japan, nothing much is gained or lost in switching from local three-factor to four-factor models, so if it is desirable to settle on one model, local four-factor models can be the choice for Europe, Japan, and North America. None of our models do well on Asia Pacific size-B/M returns.

6. Asset pricing tests for size-momentum portfolios

Table 6 summarizes regressions to explain excess returns on size-momentum portfolios. The intercepts for selected models are in Table 7. Preliminary tests on international returns confirmed the earlier U.S. results of Fama and French (1996) that the CAPM and the three-factor model (1) fare poorly when the returns to be explained have momentum tilts. To save space, we show results here only for the four-factor model (2), which

Table 6

Summary statistics for four-factor regressions to explain monthly excess returns on portfolios from sorts on size and momentum, with (5×5) and without (4×5) microcaps, November 1990 to March 2011.

The regressions use the four-factor model (2) with global or local factors to explain the returns on Global, North American, European, Japanese, and Asia Pacific portfolios formed on size and momentum. The 5×5 results include all five size quintiles, the 4×5 results exclude microcaps. The GRS statistic tests whether all intercepts in a set of 25 or 20 regressions are zero; $|a|$ is the average absolute intercept; R^2 is the average adjusted R^2; $s(a)$ is the average standard error of the intercepts; and $SR(a)$ is the Sharpe ratio for the intercepts. With 25 portfolios and 245 monthly returns, critical values of the GRS statistic for all four models are: *90%:* 1.41; *95%:* 1.56; *97.5%:* 1.69; *99%:* 1.86; and *99.9%:* 2.25.

	Global factors								Local factors							
	5×5					4×5			5×5					4×5		
	GRS	$\lvert a\rvert$	R^2	$s(a)$	$SR(a)$	GRS	$\lvert a\rvert$	$SR(a)$	GRS	$\lvert a\rvert$	R^2	$s(a)$	$SR(a)$	GRS	$\lvert a\rvert$	$SR(a)$
Global	4.44	0.14	0.94	0.08	0.75	2.29	0.09	0.48								
North America	2.72	0.48	0.74	0.19	0.59	1.23	0.43	0.35	2.87	0.14	0.91	0.11	0.59	1.16	0.09	0.33
Europe	3.25	0.20	0.75	0.18	0.64	2.58	0.14	0.50	3.14	0.18	0.93	0.10	0.64	2.57	0.14	0.52
Japan	1.43	0.57	0.37	0.37	0.43	1.24	0.62	0.35	0.92	0.10	0.92	0.12	0.33	0.74	0.08	0.26
Asia Pacific	3.06	0.35	0.55	0.33	0.62	2.49	0.29	0.50	3.44	0.27	0.89	0.16	0.66	2.37	0.19	0.48

Table 7
Intercepts from four-factor (2) regressions to explain monthly excess returns on portfolios from 5×5 sorts on size and momentum, November 1990 to March 2011.

The regressions use the four-factor model (2) with global and local factors to explain the excess returns on Global, North American, European, Japanese, and Asia Pacific portfolios formed from independent size and momentum sorts. The table reports intercepts, a, and t-statistics, $t(a)$.

	a					$t(a)$				
	Losers	2	3	4	Winners	Losers	2	3	4	Winners
Global size-momentum returns regressed on global factors										
Small	−0.03	0.15	0.20	0.50	0.77	−0.25	1.86	2.47	6.54	6.38
2	−0.04	0.02	−0.08	0.09	0.28	−0.44	0.29	−1.09	1.38	3.63
3	0.08	−0.04	−0.07	−0.14	−0.03	0.93	−0.62	−0.96	−2.13	−0.33
4	0.12	0.01	−0.04	−0.13	0.01	1.24	0.18	−0.60	−1.95	0.08
Big	0.19	0.03	−0.11	−0.11	−0.19	1.97	0.45	−1.49	−1.89	−2.07
North American size-momentum returns regressed on North American factors										
Small	−0.15	0.15	0.31	0.53	0.68	−1.08	1.66	3.39	4.90	4.60
2	−0.12	0.18	0.08	0.03	0.09	−1.08	1.98	0.75	0.35	0.91
3	0.05	0.07	0.10	0.10	−0.00	0.36	0.72	1.01	0.95	−0.03
4	0.06	0.16	0.11	−0.04	0.03	0.41	1.79	1.14	−0.46	0.24
Big	0.09	0.09	−0.13	−0.04	−0.19	0.70	0.93	−1.33	−0.46	−1.78
European size-momentum returns regressed on European factors										
Small	−0.24	−0.02	0.01	0.34	0.94	−2.25	−0.17	0.06	3.94	6.35
2	−0.13	0.06	0.04	0.12	0.54	−1.44	0.56	0.50	1.39	4.97
3	0.15	−0.00	−0.02	−0.07	0.09	1.37	−0.02	−0.22	−0.88	0.78
4	0.31	0.13	−0.03	−0.12	0.05	2.30	1.52	−0.34	−1.29	0.47
Big	0.37	0.10	0.02	−0.24	−0.29	2.96	0.94	0.29	−3.07	−2.50
Japanese size-momentum returns regressed on Japanese factors										
Small	0.31	0.30	0.16	0.20	0.01	2.14	2.34	1.43	1.76	0.03
2	0.07	0.01	−0.07	0.02	−0.01	0.55	0.06	−0.61	0.17	−0.04
3	−0.00	−0.20	−0.12	−0.01	0.02	−0.02	−1.99	−1.05	−0.07	0.15
4	0.02	−0.08	−0.17	−0.13	0.01	0.16	−0.73	−1.38	−1.11	0.10
Big	0.08	−0.16	−0.26	−0.14	0.03	0.51	−1.30	−2.13	−1.32	0.25
Asia Pacific size-momentum returns regressed on Asia Pacific factors										
Small	0.08	0.51	0.61	1.10	0.60	0.55	3.63	4.48	6.08	3.39
2	−0.64	0.19	0.04	0.20	−0.07	−4.63	1.25	0.27	1.30	−0.40
3	−0.29	−0.03	0.04	0.29	0.03	−1.70	−0.17	0.32	1.94	0.20
4	−0.08	0.23	0.25	0.10	0.01	−0.47	1.29	1.66	0.64	0.06
Big	0.69	0.14	0.23	−0.05	−0.24	3.42	0.95	1.67	−0.36	−1.30

includes a momentum explanatory return. We begin again with the results for the global region.

6.1. A global four-factor model for global size-momentum portfolio returns

In the regressions to explain returns on the 25 global size-momentum portfolios with global factors, the GRS test (Table 6) rejects the four-factor model. Table 7 shows that the model leaves a momentum pattern in the intercepts for microcaps and creates a reverse momentum pattern (positive intercepts for losers and negative for winners) for megacaps. The patterns are due to (i) stronger momentum returns for microcaps (Table 2) and (ii) spreads in the *WML* slopes, from losers to winners, (not shown) that are at least as extreme for megacaps as for microcaps.

When microcaps are dropped, the performance of the global four-factor model improves. The average absolute intercept falls from 0.14% to a respectable 0.09%, and $SR(a)$ falls from 0.75 to 0.48. Even without microcaps, however, the four-factor model is strongly rejected by the GRS test on the 25 global size-momentum portfolios.

The patterns in the intercepts for microcaps and megacaps in the global size-momentum four-factor regressions (Table 7) parallel those in the tests on global size-B/M returns (Table 4). There are also parallels between the regressions that use the global model to explain regional size-momentum and regional size-B/M returns. Moreover, if anything, the rejections of the global model for regional size-momentum returns are stronger and more prevalent than for regional size-B/M returns. The GRS test rejects the global four-factor model for the size-momentum portfolio returns of North America, Europe, and Asia Pacific. The GRS statistic for Japan is smaller, but echoing our earlier results, low average R^2 (0.37) and a high average standard error for the intercepts (0.37%) indicate low power. The Japanese four-factor intercepts are again far from zero, with an average absolute value of 0.57% per month. The average absolute intercepts for the other regions are smaller, but all are far from zero.

In sum, microcaps aside, the global four-factor model may be acceptable for global size-momentum portfolio returns, but it performs poorly on regional size-momentum portfolio returns. Thus, as in the tests on size-B/M portfolio returns, size-momentum portfolios provide little support for integrated global pricing, at least with our asset pricing models.

6.2. Local four-factor models for regional size-momentum portfolio returns

The four-factor model (2) is commonly used in research on U.S. returns. Table 6 says the GRS test rejects the local four-factor model in tests on the 25 North American size-momentum portfolios. The intercepts in Table 7 suggest that microcaps are again the problem. The four-factor model leaves a momentum pattern in the intercepts for microcaps; the intercepts increase from -0.15% for the prior year's biggest losers to 0.68% ($t=4.60$) for the biggest winners. The intercepts for the four larger size groups are much smaller. There is a mild reverse momentum pattern in the intercepts for megacaps, but the average absolute intercept for the four larger quintiles is only 0.09%, all intercepts are within 0.19% of zero, and the GRS statistic for these 20 portfolios is only 1.16. We conclude that the local four-factor model is reasonable for applications to North American portfolios that are not tilted toward microcaps.

There is no evidence of momentum in Japanese returns (Table 2), so it is not surprising that Japan provides the only case where the local three-factor model captures average returns on size-momentum portfolios as well as the four-factor model. The GRS statistic and $SR(a)$, not shown, are 0.89 and 0.32 for the local three-factor model versus 0.92 and 0.33 for the local four-factor model (Table 6). Thus, from an asset pricing perspective, there is no reason to prefer the four-factor model for average returns on the Japanese size-momentum portfolios. When estimating the expected return on one of the portfolios, for example, these results suggest the three-factor model will be at least as accurate as the four-factor model.

The local momentum factor does, however, capture variation in monthly Japanese size-momentum portfolio returns. Adding *WML* increases the average R^2 from 0.87 in the three-factor regressions (unreported) to 0.92 in the four-factor regressions. This is similar to the marginal explanatory power of local *WML* returns in the other regions, which show strong positive average *WML* returns. There is thus a good case for using the four-factor model when measuring the abnormal performance of Japanese portfolios in which there may be momentum tilts. The local momentum factor can improve model fit and the precision of the estimated intercept.

The bad news for local models for size-momentum returns comes from Asia Pacific and Europe. As in the size-B/M tests, the local Asia Pacific factors have low power in regressions to explain returns on the 25 Asia Pacific size-momentum portfolios. The average standard error of the four-factor intercepts is 0.16%. The average absolute intercept is, however, quite large (0.27% with microcaps and 0.19% when microcaps are dropped), and despite low power, the GRS test rejects the local four-factor model, with or without microcaps.

The European results are also disappointing. The local four-factor model leaves a huge spread of 1.18% per month between winner and loser intercepts for microcaps, the spread is 0.67% in quintile two, and the model creates a reverse momentum spread of -0.66% for megacaps (Table 7). As a result, even when microcaps are dropped, the GRS test rejects the local four-factor model for the 25 European size-momentum portfolio returns. These results imply that in applications involving European portfolios with momentum tilts, the local four-factor model is likely to have rather general problems.

The concluding Section 8 provides a summary and interpretation of the tests to explain size-momentum returns. First, however, we briefly summarize two robustness checks.

7. Robustness

Hou, Karolyi, and Kho (HKK, 2011) find that the choice of price ratio used to construct *HML* is important in asset pricing tests on international returns. Specifically, *HML* factors formed on cashflow to price, C/P, produce fewer model rejections than factors constructed from sorts on B/M. We have examined 5×5 and 2×3 sorts on size and earnings-price (E/P) ratios as well as C/P. Details differ, but the patterns in size-B/M average returns show up with the other value variables. For example, there is a size pattern in average value premiums in the sorts on E/P and C/P, though it is somewhat weaker than in the sorts on B/M. The *SMB* and *HML* explanatory returns from each of the 2×3 sorts on the different value variables also lead to similar conclusions when used in tests on 5×5 size-B/M, size-E/P, size-C/P, and size-momentum portfolios, except that (not surprisingly) regression fits are a little tighter when the tests use the same value variable to construct the LHS and RHS returns.

Why are these results different from those of HKK? Their methodology for constructing *HML* is quite different. Their *HML* factors are the spreads between the returns on the stocks in the top and bottom 20% of a price ratio from sorts of all stocks. Fama and French (2008) find that the extremes in sorts that use all stocks are dominated by small stocks because (i) they are more plentiful than big stocks, and (ii) the fundamentals of small firms are typically more disperse. In short, it is likely that the *HML* factors of HKK are dominated by small stocks. The breakpoints for price ratios in our sorts use only big stocks, and we control for size by constructing an *HML* factor as the average of its small and big components, HML_S and HML_B.

Like Griffin (2002), HKK also test hybrid models that explain the local returns for a region with global factors and the region's local factors, so, for example, the three-factor model (1) becomes a six-factor model. HKK conclude that global factors add non-trivially to the explanation of local returns provided by local factors. We have replicated all the tests of local models in Tables 3 and 6 with tests of their hybrid analogues. The changes in the GRS statistic and the average absolute intercept produced by the hybrid models are tiny and random in sign, and the average R^2 values are typically unchanged. Like Griffin (2002), we conclude that the hybrid models add nothing to the explanation of returns and average returns provided by their purely local counterparts.

8. Summary and conclusions

There are common patterns in average returns in developed markets. Echoing earlier studies, we find value premiums in average returns in all four regions we examine (North America, Europe, Japan, and Asia Pacific), and there are strong momentum returns in all regions except Japan. Our new evidence centers on how international value and momentum returns vary with firm size. Except for Japan, value premiums are larger for small stocks. The winner minus loser spreads in momentum returns also decrease from smaller to bigger stocks. In Japan there is no hint of momentum returns in any size group.

We test whether the value and momentum patterns in average returns are captured by empirical asset pricing models and whether such models suggest that asset pricing is integrated across regions. For evidence on market integration, we examine how well global explanatory returns capture average returns for global portfolios and for portfolios of the four regions.

In the tests of the global CAPM, three-factor, and four-factor models on global size-B/M and size-momentum portfolio returns, the GRS test rejects the hypothesis that the true intercepts are zero, but microcaps aside, the intercepts for the global four-factor model suggest that it is passable for average returns on global size-B/M and size-momentum portfolios. We would be comfortable using the global four-factor model in applications to explain the returns on global portfolios – for example, to evaluate the performance of a mutual fund that holds a global portfolio of stocks – as long as the portfolio does not have a strong tilt toward microcaps or toward the stocks of a particular region. This is the good news about global models and integrated asset pricing.

Unfortunately, rejections on the GRS test and large average absolute intercepts suggest that the global models do not do well when asked to explain average returns on regional size-B/M or size-momentum portfolios. This is the bad, probably damning, news for the global models. It suggests shortcomings of integrated pricing across the four regions—or other bad model problems. We would not use the global models in applications to explain regional portfolio returns.

The failure of the three global models in tests to explain regional returns motivates us to examine local models. There is a common bottom line. Thus, when any local model is acceptable for the 25 size-B/M or size-momentum portfolios of a region, the local four-factor model performs as well or better than the three-factor model or the CAPM. The assets covered by this conclusion include the size-BM portfolios of Japan, Europe, North America (without NA microcaps), and perhaps Asia Pacific, and the size-momentum portfolios of Japan and North America (again without NA microcaps). Even the local models perform poorly on the size-momentum portfolios of Europe and Asia Pacific.

Our local four-factor asset pricing models are rather successful in capturing average returns on local size-B/M portfolios, but they are less successful when applied to local size-momentum portfolios. The momentum problems of the models are, however, largely concentrated in the extremes, that is, portfolios with extreme tilts toward winners or losers, and such tilts are probably rare in applications. For example, there are mutual funds with strong tilts toward value or growth, so to properly evaluate the performance of such funds, empirical asset pricing models must work well in the extremes of the value-growth spectrum. The results of Carhart (1997) and Fama and French (2010) suggest, however, that few mutual funds have extreme momentum tilts. In short, the shortcomings of the four-factor model in the extremes of momentum may rarely be a serious problem in applications.

Finally, the LHS assets in our tests are restricted to portfolios formed on size and B/M or size and momentum. The asset pricing models considered here may have less success with portfolios formed in other ways. For example, portfolios with tilts toward other variables ("anomalies") that seem to be related to historical average returns (see, e.g., Fama and French, 2008) may be more troublesome for the models.

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