Direct Investment in Real Estate

Momentum profits and their robustness to trading costs.

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Momentum and contrarian strategies are examples of technical trading rules with respect to investments in equities. The extent to which such strategies are capable of generating excess returns is taken as an indicator of market imperfections (see Fama [1970]).

So far there have been few attempts to test technical trading rules in private real estate portfolios. Real estate markets are generally characterized as relatively inefficient, subject particularly to serial correlation or persistence in return indexes in both the overall market and market segments.

We test whether momentum portfolios can outperform buy-and-hold strategies (i.e., a capital-weighted index). The British market represents an interesting example comparable to the U.S. It is well developed and operates much like the U.S. market. The quality of data collected by Investment Property Databank (a global real estate data provider) is actually more representative of overall institutional investment holdings (covering 45% of the entire market) than the equivalent data collected by the National Council of Real Estate Investment Fiduciaries in the U.S., which covers less than 5% of investment holdings.

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LITERATURE REVIEW

Momentum can be described as a cross-sectional result obtained by exchanging assets (i.e., buying winners and selling losers) that constitute an investment portfolio. This feature differentiates momentum from positive autocorrelation, which reflects a time series property.

Several strategies have been implemented to test momentum effects. Jegadesh and Titman [1993] find that the application of simple filter rules results in outperformance of buy-and-hold strategies even after adjustment for transaction costs (see also Keim and Madhavan [1997, 1998]). Testing a wider set of moving average and volume-weighted trading rules, Lo, Mamaysky, and Wang [2000] also conclude that variants of momentum strategies and technical indicators have the potential to capture opportunities for excess return.

Although there is no complete consensus, research on equity markets normally attributes momentum to either underreaction or overreaction and herding behavior of investors in response to firm-specific news.[1] These findings support the proposition that momentum strategies can add value to investment returns over fairly short time periods (from three months to a year) with mean-reversion processes possibly over a longer horizon, which may vary depending on securities, markets, and industries or sectors, according to Moskowitz and Grinblatt [1999]. This breach of the efficient markets hypothesis has been attributed to information inefficiencies, where price momentum is found to be strongest in small stocks with limited analyst coverage.

Lo and MacKinlay [1990] have shown that three factors may cause momentum extra profits:

- Serial dependence in returns, which allows a certain degree of predictability of future returns.
- A lead-lag structure between stocks or industries and sectors allows the investor to predict future returns from past returns of other stocks.
- Persistent differences in unconditional means, which determine potential benefits for investments in stocks showing a high average return.

Lewellen [2004] argues that firm-specific returns, together with behavioral models, do not explain a significant component of momentum profits. He finds that intertemporal cross-covariance between stocks and not over or underreaction represents the main reason behind momentum profits. If cycles of different securities or market segments are uncorrelated intertemporally, the investor may jump from one asset to the next to beat the market. If securities or market segments are highly integrated, though, the strategy of moving from one asset to the next will not earn any extra profit.

Hence, on the one hand, even in markets with a high level of information efficiency, there is evidence of persistence in returns, because low intertemporal cross-correlation between assets creates potential benefits from cross-sectional predictability. On the other hand, in private real estate markets, highly persistent returns are associated with high cross-correlation between different segments. Thus, momentum may be caused by persistence in returns, but the main factor causing it (cross-covariance) does not contribute and may lead to the erosion of extra profits achievable with such strategies. Conversely, if returns of market segments are unsmoothed, both persistence in returns and cross-correlation are reduced, and the effect on momentum profits may change.

Real estate research has thoroughly investigated the issue of persistence in direct property returns in an ample literature on smoothing in valuation-based performance indexes. At the aggregate level, it is clearly established that returns tend to show strong serial autocorrelation. In U.K. monthly and U.S. quarterly indexes, first-order serial correlation is very high (around 0.8 and 0.6, respectively), decaying to lower but still significant levels at lags up to one year (or four quarters).[2]

The question of strong persistence effects even at the level of sectors or market segments has been the subject of very little research. If there is persistence, there will be sustained differentials in the relative performance of subdivisions of the market, with potential to add value to real estate portfolio returns.

Young and Graff [1996] and Graff and Young [1997] find strong persistence in the top and bottom quartiles of the rankings (but not in the second and third) for both individual REITS and private real estate sectors and metropolitan statistical area (NCREIF indexes) in the U.S. Stevenson [2002] uses monthly returns of aggregate real estate stock indexes for 11 countries, and obtains no evidence of mean-reverting behavior. Strong support for the benefits of momentum strategies is found, however; winner portfolios outperform loser portfolios on a risk-adjusted basis up to horizons of two to four years.

Hahn, Geltner, and Gerardo-Lietz [2005] find relative performance in real estate opportunity funds to be persistent for consecutive funds launched by the same manager (both for winners and for losers). Relative performance is mean-reverting over longer time periods between fund launchings. Finally, when management fees are deducted from gross returns, there is less persistence, because successful managers can probably effectively charge higher fees on subsequent funds.

DATA AND METHODOLOGY

Our empirical tests use property return series from Investment Property Databank (IPD). Other sources such as Jones Lang LaSalle or CB Richard Ellis offer longer time series or higher-frequency results, but their samples are relatively small and cannot be disaggregated to a range of submarkets sufficient for the form of analysis we apply.

The annual IPD index starting in 1980 offers the most comprehensive and widely used annual measure of direct property investment performance in the U.K. As of the end of 2004, this dataset covered 10,986 investments with a market value of £120.7 billion, estimated by IPD as equivalent to 65% of the total assets of institutions and listed property companies, and 45% of the total market including all forms of investors.

While it provides the longest detailed history, the IPD annual series cannot support tests more finely tuned to shorter-term market performance or portfolio allocation. And with only 24 observations, the annual series is unlikely to support statistically strong conclusions on the differences in return generated by alternative trading strategies. We use the annual series to introduce the method of analysis and draw some broad conclusions on the effectiveness of different types of strategy. The main part of our analysis, to which more rigorous statistical tests can be applied, uses the IPD Monthly Index from December 1986 (its base date) through the end of 2004—a total of 216 observations. As of February 2005, the Monthly Index covered 3,230 investments with a total value of £28.6 billion.

IPD indexes represent valuation-based measures of investment returns, drawn from the portfolio records of a range of major investors in the U.K. Details of the construction methods (available on the IPD website) are similar to the methods applied in the U.S. to construct the NCREIF index.[3]

Our primary aim is to evaluate the effectiveness of strategies creating portfolios from a selection of submarkets in the IPD annual or monthly data. The IPD total sample is divided into segments defined by property type and broad regional location. The choice of segments is set by a ten-way categorization of the market (called segments or submarkets henceforth) employed as a primary breakdown in IPD's performance analysis reports to individual investors.[4]

U.K. annual returns are affected by smoothing much less than U.S. performance, and results are obtained without applying any unsmoothing procedure. We do see in monthly returns both stale appraisal and anchoring effects that do not reflect the actual market transaction prices of the underlying trading market. As one may argue that these features could affect results on momentum strategies, for monthly returns we also adopt a correction for smoothing by using a first-order autoregressive filter.[5]

We unsmooth IPD returns for each market segment by adopting five different unsmoothing parameters, corresponding to 100%, 85%, 70%, 55%, and 40% of the first-order autocorrelation coefficient. For example, if the first-order serial correlation is equal to 0.5, a 70% unsmoothing parameter will be equal to 0.35.

The first result we obtain directly from desmoothing is a reduction in the average correlation coefficient between market segments, which drops from 0.65 when we use original appraisal-based indexes to 0.35 when we assume efficient markets (100% of the autocorrelation pattern is taken away).

Portfolio Composition and Benchmark

In our analysis, equally weighted momentum portfolios are composed by five segments for an annual frequency, and either one, three, or five segments for a monthly frequency. As submarkets show significant serial correlation and are highly cross-correlated, we expect momentum profits to drop as the number of segments in a portfolio increases.

As a benchmark for our strategies, we use the IPD index average (termed IPD benchmark). It represents a buy-and-hold strategy. An investor buys the market portfolio at the beginning of the period and keeps it until the end of the period. This is the true benchmark of the IPD average, a universe with weights shifted from year to year by varying capital performance and investment flows, and against which a real portfolio would typically be measured.

Since the mid-1990s, it has been possible to achieve the performance of this index through an index-tracking synthetic instrument, the Barclays Property Index Certificate.[6]

Trading Rules: Decision Periods and Rebalancing Intervals

We use a very simple trading rule. Momentum (i.e., winner) portfolios are made up of investments that have shown strong returns in the past. In other words, an investor holds or buys assets with recent good returns, and sells those with recent poor returns, on the assumption that returns are *persistent*.

Exhibit 1
Annual Ranking Scores of Five Best-Performing Market Segments

	Std Retail South East	Std Retail Rest of UK	Shopping Centres	Retail Warehouses	Offices City	Offices West End	Offices Rest of South East	Offices Rest of UK	Industrials Southern Eastern	Industrials Rest of UK
1981	2	1	5		3	4				
1982	5	2	3	1	4					
1983	1	3	2	4					5	
1984	3	1	2	4	5					
1985	1	3	4	2	5					
1986	4	5		3	1	2				
1987	4				1	2			3	5
1988						1	4	5	2	3
1989						4	5	1	3	2
1990		5	4					2	3	1
1991		4		1				5	3	2
1992		3	4	1				5		2
1993		3		1	4	5				2
1994		5	3	1		4				2
1995			3	1	2	4				5
1996	4		2	1					3	5
1997	5		3	1		4			2	
1998		5	2			4	3		1	
1999			4			2	3		1	5
2000				5	3	1	4		2	
2001				5	1	2		4		3
2002	3	2	4	1						5
2003	4	3	2	1						5
2004	3	2	5	1		4				

Numbers in cells indicate the position achieved in the ranking.

Exhibit 1 gives a visual impression of the persistence in annual returns year by year. All ten IPD segments are ranked annually on the basis of their total return. The exhibit reports only the five best-performing sectors; the numbers in the cells show the rank number of the segment by total return within each year.

The picture suggests substantial persistence in rank score—i.e., ranking above the median is more often part of a run of years rather than randomly distributed. There are especially sustained runs of above-median returns for retail across the board through the early and middle 1980s, and then for provincial office and industrial in the late 1980s to early 1990s. Through the last four years, there has again been a strong run of performance from the retail and industrial segments.

Momentum portfolios are generated directly from the segment returns. In the base year, 1982, the momentum portfolio includes a 20% weight in each of the top five segments ranked by returns in 1981. For an annual frequency, portfolios are rolled forward, with reweightings at each start-year based on segment performance achieved in the previous year. That is, at the beginning of 1983, the momentum portfolio is reallocated to a 20% weight in the top five segments through 1982, and so on.

For a monthly frequency, we also make up portfolios with the three best-performing segments (at 33.3% weights) and with the best-performing sector (at a 100% weight).

Finally, we vary the strategy rules through changes in:

- The calibration period, i.e., the time over which we measure past performance before incorporating it in the decision rule. With annual returns, we test for one, two, three, four, five, and six years.

With monthly returns, we test for 6, 12, 18, and 24 months.

- The holding period, i.e. how often we rebalance the portfolio on the basis of the decision rule. With annual returns, we can test for only one year due to the limited number of observations. With monthly returns, we test for rebalancing intervals of 6, 12, 18, 24, and 36 months.

Testing over different intervals reveals empirically the boundaries between persistence and mean reversion in the time series characteristics of underlying segment returns. If, for instance, segments tend to show excess returns for periods of 12 months, and then fall back toward the market average with a period of weak returns, momentum strategies based on performance running back (no more than) 12 months will pay off.

The intervals at which the portfolio allocation between segments is adjusted govern the trading costs of implementing either form of strategy. More frequent portfolio rebalancing will usually increase the trading cost burden of shifting portfolios between segments, and dilute the gains of the underlying strategy.

Taking the combinations of calibration and rebalancing periods together with the variable number of segments held in the momentum portfolios, a total of 60 strategies are investigated for the monthly analysis.[7]

Finally, in order to prove that our results are not sample-biased and since the minimum step for either the holding period or the calibration period is 6 months, we also compute all strategies 12 times (for a total of 720 strategies) by choosing different starting months (from January to December). Changes in start month do not significantly affect our results, so we report only findings for a January start month.

Trading Costs and Net Returns

For each strategy, we compute both gross and net returns. In the U.K., both purchases and sales normally cost 1.5% of value in *professional fees* (i.e., brokers, surveyors, and lawyers). Larger investors, especially on large deals, would usually expect to see a reduction on fees, but a 3% round-trip cost of buying and selling is assumed throughout. Transaction tax payable by buyers (known as *stamp duty* in the U.K.) has since March 2000 been 4% of value for transactions over £600,000. Although lower rates applied in earlier years (2% before 1998), the current higher rate is used throughout the calculations. These costs reflect the dilution of any benefits of a trading strategy at current levels of cost, rather than those that actually applied for most of the period covered. Finally, recognizing that trading is highly management-intensive, a further 0.5% *internal cost* is added to the round-trip costs of selling out of one segment and buying into another. With these assumptions, we arrive at total trading costs of 7.5%.

The IPD index benchmark is reported gross of trading costs, and therefore crudely represents a buy-and-hold strategy. Some trading would be required to maintain the benchmark portfolios, to follow investment shifts within the IPD index, and to adjust for differential capital growth across segments. The comparison of net returns from momentum strategies against gross benchmark returns is therefore a demanding test of the potential to generate excess returns.

High transaction costs will add volatility to returns if costs are assessed at the time the trades are made, particularly for the analysis at a monthly frequency. A strategy with portfolio rebalancing will inevitably appear riskier than a benchmark without rebalancing.[8]

It may be argued, however, that the costs of rebalancing should be treated as a fixed cost spread over the investment period rather than a point cost at the time of the transaction. We therefore calculate net returns both by incorporating transaction costs at the point of the transaction and by spreading them over the period as follows.

For each strategy, we calculate the total amount of transaction costs (in percentage) for the whole history:

$$TC = \sum_{i=1}^{n} TC_i$$

We then obtain the average transaction cost per period:

$$\overline{TC} = \frac{TC}{n}$$

which is subtracted from gross returns.

Since all results obtained using the first method of incorporating trading costs do not yield insightful results, we discuss only net returns computed by spreading transaction costs over the sample period.

Statistical Tests

To compare strategy results with the chosen benchmark, we use several tests. First, we apply a t-test on the mean with a null hypothesis that the average of our strategy is equal to the average of the benchmark. Since the two series may have unequal variances (and this is mostly true when we introduce trading costs and use net returns), we allow for this in our t-test.[9]

Second, we also compute a normal t-test to show that the difference in variances is significant, and a correction in the t-test is needed because this difference often makes us reject the equality of means when we would not otherwise.[10]

Since our strategies imply a higher standard deviation than the IPD index, we base our conclusions about the equality of means on a Behrens-Fisher specification ($ttest_{B-F}$) with a Satterthwaite's approximation for the effective degrees of freedom. If we apply either a Jarque-Bera or Lilliefors test, we always reject the null hypothesis that the time series is normally distributed. Non-normality is mainly due to kurtosis (always above 4.5) rather than skewness (slightly positive). This factor, along with the robustness of the t-test, gives us confidence in the significance of our t-test.

In a cross-check, we also apply non-parametric tests to allow for non-normality. The first test is represented by the Wilcoxon signed rank test (*wsr*), which is a two-sided test of the hypothesis that the difference between our strategy and the benchmark comes from a distribution whose median is zero.

We should note that a null hypothesis with zero median for $X_s - X_b$ is not equivalent to the hypothesis of equal medians for X_s and X_b. Therefore we also use the Wilcoxon rank sum test (*wsum*), which is equivalent to the Mann-Whitney U-test. This is a two-sided rank sum test of the hypothesis that two independent samples come from distributions with equal medians. The two distributions are assumed to be identical except for a location shift.

Moreover, since the assumption of the two distributions being identical except for a location shift is not realistic (we also register a difference in variances), we perform a two-sided sign test (*signtest*) of the hypothesis that the difference between the median of our trading rule and the median of the benchmark is equal to zero. This test is a less powerful alternative to the Wilcoxon signed rank test, but it allows for inequality of variances and at the same time does not assume (as the *wrs* test does) that the population probability distribution is symmetric.

Finally, since an investor is normally concerned with risk-adjusted returns rather than absolute performance, we test for differences in Sharpe ratios.[11] The null hypothesis that there is no difference between our strategy's and the benchmark's Sharpe ratios is tested under two specifications, following either Jobson and Korkie [1981] or Jorion [1985].[12]

RESULTS

We use an example of the inputs and outputs for a specific test to demonstrate the method in full. We summarize and discuss the results for a range of calibration periods and portfolio adjustment frequencies.

Annual Returns

Annual returns for the benchmark and the momentum portfolio with a one-year calibration period and a one-year holding period (both gross and net returns) are shown in Exhibit 2. Measured by gross returns, momentum strategies give strong confirmation of persistence effects in segment returns. At first glance, the results suggest strong potential gains to investors following a simple momentum strategy, producing average returns not only 3.2 percentage points per year above the market benchmark, but also with lower risk than the benchmark, and outperforming the benchmark in every individual year except for 2002. Sustained over 23 years, this margin of return over the benchmark would rank a fund's performance in the top 1% of all IPD funds.

Figuring trading costs in the analysis, of course, reduces the gains (or increases the losses) from the rule-driven strategy to the extent that portfolios are reallocated each year and according to the assumed costs of trading. In the first case, readjusting the momentum portfolio each year demands a high rate of trading. On average, the required portfolio turnover runs at 58% per year—well above the rate of around 20% actually seen for IPD funds in recent years. Over the long run, IPD figures suggest trading has actually added extra profits to average returns over and above trading costs. That is, trading has on average generated a profit on the standard measures of portfolio performance even when trading costs are taken into account.

For those reasons, comparing net returns on the momentum strategy with the benchmark returns is very much a worst case example of the benefits of the strategy. It nonetheless leaves a 1.0 percentage point per year margin in favor of the momentum portfolio against the IPD main benchmark, with a similar level of risk (8.6% volatility).

We then apply the same procedure of portfolio construction using calibration periods from one to six years. In all cases, portfolios are reweighted each year. Summary results for the period December 1986 through December 2004 common to all runs of the simulation are given in Exhibit 3. In all cases, momentum strategies show returns

EXHIBIT 2

Annual Returns of Momentum Strategy with One-Year Calibration Period and Annual Reweighting

	IPD Benchmark	Momentum Strategies	
		Gross Returns	Net Returns
1982	7.5	9.1	7.6
1983	7.6	10.3	8.8
1984	8.8	12.3	10.8
1985	8.3	12.3	12.3
1986	11.3	14.3	12.8
1987	26.0	28.0	25.0
1988	29.5	33.7	30.7
1989	15.4	26.6	26.6
1990	-8.4	-4.5	-7.5
1991	-3.1	6.7	5.2
1992	-1.6	5.2	3.7
1993	20.2	23.4	20.4
1994	11.9	13.7	12.2
1995	3.6	4.8	3.3
1996	10.0	10.7	7.7
1997	16.8	18.4	16.9
1998	11.8	12.5	9.5
1999	14.5	15.8	14.3
2000	10.5	13.3	10.3
2001	6.8	8.0	5.0
2002	9.6	8.0	3.5
2003	10.9	14.6	14.6
2004	18.3	20.0	18.5
Geometric	10.0	13.2	11.0
Average	10.7	13.8	11.8
Std Deviation	8.6	8.5	8.6

different from the IPD benchmark, but the differences are not always significant at the 95% confidence level.

There is, however, a clear pattern. Gains from the momentum strategy fall off progressively with lengthening calibration periods. The comparison indicates that persistence characteristics in segment returns are far more useful for portfolio construction applications than mean reversion. Persistence or momentum effects are consistent throughout all calibration periods, but diminish steadily as are consistent throughout of the calibration period is extended.

One effect of extending the calibration period is to reduce asset turnover and trading costs, since the longer moving average series of segment returns is more stable than the annual returns. At the six- year calibration period, the rate of portfolio turnover required to maintain the strategy is half that at the one-year calibration period.

EXHIBIT 3

Average Return and Standard Deviation of Momentum Strategies with Varying Calibration Periods

	Geometric Mean	Average Return	Standard Deviation
Benchmark Portfolios			
IPD	10.0	10.7	8.6
Momentum Portfolios by Calibration Period – Gross Returns			
One Year	13.2	13.8	8.5
Two Years	13.1	13.4	9.2
Three Years	12.3	12.6	8.8
Four Years	11.7	12.1	8.7
Five Years	11.5	11.9	9.2
Six Years	11.1	11.5	8.7
Momentum Portfolios by Calibration Period – Net of 7.5% Trading Costs			
One Year	11.0	11.8	8.6
Two Years	11.3	11.6	9.2
Three Years	10.6	11.0	9.2
Four Years	10.1	10.5	9.0
Five Years	10.3	10.7	9.5
Six Years	10.0	10.3	9.0

Portfolio returns after adjustment for trading costs at 7.5% are shown in the last panel of Exhibit 3. Because the asset turnover is reduced, the dilution of return by costs falls with a longer calibration period, from –2 percentage points per year for the one-year period to –1.2 points per year for the six-year period. Savings through trading costs are not, however, enough to change the decay in returns added through the momentum strategy. After deducting trading costs, the maximum gains from momentum investing are cut to 1.1 percentage points per year, decaying to –0.4% with a six-year calibration period.

Broad conclusions from the annual analysis are consistent with those in other studies focused on both other asset classes and the securitized real estate markets. Portfolio simulations show there are strong persistence effects in relative returns at the segment level, which (before adjustment for trading costs) yield potentially large gains from momentum investment strategies. These effects are strongest at the shortest horizon available in the annual data (one year), but are sustained out to six years.

Monthly Returns

The annual analysis describes the longest time period and the most broadly based sample for the strategy simulations. Applying the same process to monthly series running from December 1986 through December 2004 offers two additional refinements. First, the total of 216 monthly observations allows statistically robust tests of the impact of varying strategies. Second, the monthly frequency makes it possible to test the impacts of shorter calibration periods, which would reveal more complex persistence patterns than can be seen in the annual data, and more frequent portfolio reweightings. Since the annual analysis establishes the minimal benefits of momentum strategies with longer calibration periods, monthly results are generated only for a set of momentum strategies calibrated for 24 months.

Exhibit 4 reports the average return and its standard deviations for all 60 strategies and the benchmark based on gross returns. The general pattern in the results is similar but not identical to that in the annual analysis because IPD monthly returns are slightly different from the annual index, and weightings in the monthly dataset are significantly different from weightings in the annual dataset.

All momentum strategies except those with a 36-month holding period produce returns significantly different from the IPD benchmark, mostly at the 99% confidence level (*see Exhibit 5*). They show a similar overall pattern to the annual analysis, in that excess returns decline if the calibration period is lengthened from one to two years. If we then look at frequencies longer than 12 months, average excess returns tend to increase slightly, but they are in line with those in a one-year period. Consequently, the maximum gain in return appears with a calibration period of either 6 or 12 months; the former shows slightly higher average returns. Thereafter, as in the annual analysis, the return gains diminish with lengthening calibration periods.

Although the standard deviations in returns for the momentum portfolios tend to be slightly higher than the IPD benchmark, only few of the differences in risk are significant at the 10% level (measured by an F-test for unequal variances). Almost all momentum strategies, therefore, generate added gross returns without a significant risk penalty.

Lengthening the holding period produces a reduction in returns and a rise in their standard deviation, revealing the decaying nature of the momentum effect. We also find that a 36-month holding period underperforms the index when the calibration period is 18 months or longer, probably revealing the extent of a mean-reversion process.

Moreover, diversification (i.e., including more segments in the momentum portfolio) does not add value to portfolio management. Moving from one to five segments produces a reduction in both average excess return and standard deviation. The former has a higher impact

EXHIBIT 4
Monthly Benchmark and Simulated Strategies (gross returns)

	Sector	IPD	6m6	6m12	6m18	6m24	6m36	12m6	12m12	12m18	12m24	12m36	18m6	18m12	18m18	18m24	18m36	24m6	24m12	24m18	24m24	24m36
Average	1	9.34	16.86	15.83	14.65	14.98	12.97	16.31	15.69	14.54	15.43	12.66	14.98	13.41	13.45	12.06	9.28	13.88	13.78	10.87	12.06	9.28
	3		14.18	13.74	13.31	12.69	12.11	13.55	12.69	12.97	12.34	11.29	13.35	12.77	12.50	12.18	11.29	13.01	12.64	12.06	12.03	10.99
	5		12.73	12.11	11.93	11.77	10.58	12.40	11.72	11.69	11.49	10.83	12.08	11.54	11.39	11.24	10.66	11.67	11.24	11.05	10.50	10.04
Standard Deviation	1	2.44	3.20	3.11	3.33	3.11	3.17	3.19	3.15	3.22	3.09	2.96	3.11	3.13	3.28	3.56	3.71	3.12	3.01	3.27	3.56	3.71
	3		2.68	2.71	2.66	2.83	2.79	2.54	2.53	2.65	2.79	2.77	2.56	2.58	2.58	2.71	2.76	2.55	2.56	2.61	2.68	2.74
	5		2.55	2.61	2.53	2.60	2.65	2.55	2.58	2.67	2.67	2.67	2.53	2.54	2.58	2.60	2.56	2.60	2.61	2.64	2.80	2.82

Average return and standard deviation of benchmark (IPD) and momentum portfolios of either one, three, or five sectors.
The momentum strategy 6m12 indicates a 6-month calibration period and a 12-month holding period.

EXHIBIT 5

Tests for Equality of Means and Medians (gross returns)

Independence	Sectors	6m6	6m12	6m18	6m24	6m36	12m6	12m12	12m18	12m24	12m36	18m6	18m12	18m18	18m24	18m36	24m6	24m12	24m18	24m24	24m36
T-test	1	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		**0.00**	**0.00**	**0.00**	**0.00**	
	3	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	5	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	***0.01***
T-test Behrens-Fisher	1	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	***0.02***		**0.00**	**0.00**	0.17	***0.02***	
	3	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	*0.05*	**0.00**	**0.00**	**0.00**	**0.00**	*0.05*	**0.00**	**0.00**	**0.01**	**0.01**	0.10
	5	**0.00**	**0.01**	**0.01**	***0.01***	0.21	**0.00**	***0.01***	***0.02***	***0.03***	0.13	**0.00**	***0.02***	***0.04***	*0.05*	0.17	***0.02***	*0.05*	*0.08*	0.25	0.49
Wilcoxon signed rank	1	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		**0.00**	**0.00**	**0.00**	**0.00**	
	3	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	5	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Wilcoxon rank sum	1	**0.00**	**0.00**	**0.00**	**0.00**	***0.01***	**0.00**	**0.00**	**0.00**	**0.00**	***0.02***	**0.00**	**0.00**	**0.00**	***0.02***		**0.00**	**0.00**	0.23	***0.02***	
	3	**0.00**	**0.00**	**0.00**	**0.01**	***0.04***	**0.00**	**0.00**	**0.00**	**0.00**	0.11	**0.00**	**0.00**	**0.00**	**0.01**	0.13	**0.00**	**0.00**	***0.01***	***0.01***	0.26
	5	**0.00**	**0.01**	***0.01***	***0.02***	0.50	**0.00**	***0.02***	***0.02***	***0.05***	0.30	**0.00**	***0.03***	***0.04***	*0.07*	0.35	***0.02***	*0.06*	0.11	0.20	0.61
Sign test	1	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		**0.00**	**0.00**	**0.00**	**0.00**	
	3	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	5	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

No test statistic is reported when the momentum strategy yields an average return below the benchmark. Strategies in boldface are significant at the 99% level. Strategies in boldface and italics are significant at the 95% level. Strategies in italics are significant at the 90% level.

than the latter and causes an overall reduction in the risk-adjusted measure of returns (Sharpe ratio). This result occurs because of the high cross-correlation between different market segments.

When we deduct transaction costs in Exhibit 6, the maximum net profit of 13.30% is achieved by investing in one sector and using a momentum strategy constructed with a 12-month calibration period and a 24-month holding period. Standard deviations are similar to those of gross returns and range between 2.53% and 3.71%, with several figures around 2.60%.

As for gross returns, when the calibration period is lengthened, the average performance tends to decay starting at 18 months. During the first year, there is not a clear pattern; either 6- or 12-month calibration periods show the highest figures for different portfolio compositions. Average net returns assume a concave shape if plotted against the holding period, with a maximum ranging between 18 and 24 months (depending on the number of segments in the momentum portfolio). When the calibration period increases, the optimum holding period is reduced.

Finally, there is no clear relationship between the number of segments in the portfolio and the average net return. This result can be explained by the trade-off between the persistence of real estate returns and the level of trading costs associated with portfolio shifts. So far, we find the average gross return declines as the number of segments increases because of a high positive serial correlation. If returns are highly persistent, it is easier to outperform the benchmark by investing 100% in the best-performing asset than by investing 1/*n*th in each of the *n* best-performing segments. The best-performing segment will produce a higher return than the return achieved with a mixed portfolio.

Moreover, for net returns there is not a monotonic relationship between transaction costs and the number of segments. A one-segment portfolio, for example, will have relatively infrequent trades of 100% of the portfolio. On the other hand, a five-segment portfolio will trade a smaller fraction of the total portfolio (e.g., perhaps only one or two sectors corresponding to 20% or 40% are substituted each time), but this shift will occur more often than for a one-asset portfolio.

Exhibit 6

Monthly Benchmarks and Simulated Strategies (net returns)

	Sector	IPD	6m6	6m12	6m18	6m24	6m36	12m6	12m12	12m18	12m24	12m36	18m6	18m12	18m18	18m24	18m36	24m6	24m12	24m18	24m24	24m36
Average	1	9.34	8.97	10.04	10.96	11.81	10.36	11.53	11.46	11.38	13.30	11.09	10.25	9.25	10.31	9.99	7.26	9.19	10.13	6.80	9.99	7.26
	3		8.81	10.60	10.52	10.61	10.37	9.38	9.75	10.54	10.43	9.91	10.05	10.16	10.41	10.45	9.91	10.05	10.04	10.16	10.30	9.62
	5		8.90	9.31	9.55	10.11	9.24	9.81	9.35	9.73	10.04	9.49	9.70	9.48	9.53	9.90	9.32	9.70	9.39	9.40	9.06	8.81
Standard Deviation	1	2.44	3.20	3.11	3.33	3.11	3.17	3.19	3.15	3.22	3.09	2.96	3.11	3.13	3.28	3.56	3.71	3.12	3.01	3.27	3.56	3.71
	3		2.68	2.71	2.66	2.83	2.79	2.54	2.53	2.65	2.79	2.77	2.56	2.58	2.58	2.71	2.76	2.55	2.56	2.61	2.68	2.74
	5		2.55	2.61	2.53	2.60	2.65	2.55	2.58	2.67	2.67	2.67	2.53	2.54	2.58	2.60	2.56	2.60	2.61	2.64	2.80	2.82

Average return and standard deviation of benchmark (IPD) and momentum portfolios of either one, three, or five sectors.
The momentum strategy 6m12 indicates a 6-month calibration period and a 12-month holding period.

The standard t-test in Exhibit 7 shows high significance for strategies with a 24-month holding period and either a 6- or 12-month calibration period, whatever the number of sectors held in the portfolio. The t-test under a Behrens-Fisher specification, however, rejects the inequality of means for all but six strategies, all using a one-sector portfolio (6m24, 12m6, 12m12, 12m18, 12m24, and 12m36).

We then conclude that momentum strategies yield extra profits even after adjusting for transaction costs when the portfolio is not diversified (one sector) and we use a 12-month calibration period and a 24-month holding period.

Comparison Using Risk-Adjusted Returns

So far we have evaluated differences in return and risk across trading strategies separately. Now we look at differences in Sharpe ratios, applying the tests under the Jobson and Korkie [1981] and Jorion [1985] specifications. Statistical results of the two different tests are almost the same, so they are not separately discussed.

Exhibit 8 (Panel A) shows for gross returns a Sharpe ratio lower than the IPD benchmark for all but four momentum strategies. If transaction costs are deducted from gross returns, there are significant excess risk-adjusted returns on 11 momentum strategies, with the best results from a one-sector portfolio composition and a 24-month holding period.

Panel B shows that 6 of 20 strategies for a one-sector portfolio outperform the benchmark on a risk-adjusted basis. Moreover, all 12-month calibration period strategies for a one-sector portfolio yield a Sharpe ratio that is higher than the IPD one.

Finally, as we increase the number of segments in the portfolio, we obtain reduced statistical significance. This finding justifies an increase in the number of specialized real estate vehicles because it suggests that diversification between segments adds little to overall risk-adjusted returns.

Impact of Smoothing

When we unsmooth valuation-based indexes, we still obtain extra risk-adjusted profits at a gross level. We also find diversification has a greater impact than for original IPD returns, with three- and five-sector strategies yielding similar results. These profits are partially but not totally eroded by unsmoothing, which tends to diminish their significance and extent.

When we deduct trading costs, these strategies do not always reward the investor, even if several strategies still outperform the benchmark on a risk-adjusted basis (*see Exhibit 9*). Portfolios composed of three sectors generate higher profits for several strategies for unsmoothing at a 40% to 85% level.

Particularly, three-sector strategies with a calibration period of 12 months and a rebalancing period of 2 years yield a higher Sharpe ratio

EXHIBIT 7

Tests for Equality of Means and Medians (net returns)

Independence	Sectors	6m6	6m12	6m18	6m24	6m36	12m6	12m12	12m18	12m24	12m36	18m6	18m12	18m18	18m24	18m36	24m6	24m12	24m18	24m24	24m36
T-test	1		0.18	**0.00**	**0.00**	0.12	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	*0.06*		***0.03***	0.21			0.11		0.21	
	3		**0.00**	**0.00**	**0.00**	***0.02***	0.88	0.13	**0.00**	**0.00**	*0.08*	***0.01***	**0.00**	**0.00**	**0.00**	*0.07*	***0.01***	***0.01***	**0.01**	**0.00**	0.36
	5			0.33	**0.00**		***0.04***	0.96	*0.07*	**0.00**	0.59	*0.08*	0.50	0.32	**0.01**		*0.08*	0.82	0.77		
T-test Behrens-Fisher	1		0.52	0.15	***0.02***	0.35	***0.05***	*0.05*	*0.07*	**0.00**	*0.10*	0.40		0.38	0.58			0.46		0.58	
	3		0.21	0.23	0.21	0.31	0.96	0.67	0.22	0.28	0.57	0.46	0.39	0.27	0.27	0.57	0.46	0.46	0.40	0.33	0.78
	5			0.83	0.43		0.62	0.99	0.69	0.47	0.88	0.70	0.88	0.84	0.57		0.71	0.96	0.95		
Wilcoxon signed rank	1	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.59	**0.00**	**0.00**	***0.02***	**0.00**	0.59
	3	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	5	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	***0.01***
Wilcoxon rank sum	1	**0.00**	**0.00**	**0.00**	**0.00**	*0.07*	**0.00**	**0.00**	**0.00**	**0.00**	***0.05***	**0.00**	***0.01***	**0.00**	***0.05***	0.94	**0.00**	**0.00**	0.83	***0.05***	0.94
	3	***0.03***	**0.00**	***0.01***	***0.04***	0.15	*0.09*	*0.06*	***0.01***	***0.02***	0.32	***0.04***	*0.06*	***0.05***	***0.03***	0.35	*0.08*	*0.08*	0.15	***0.04***	0.58
	5	0.20	0.14	0.16	*0.08*	0.88	0.13	0.33	0.19	0.12	0.59	0.27	0.28	0.27	0.18	0.67	0.33	0.43	0.50	0.44	0.99
Sign test	1	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.19	**0.00**	**0.00**	**0.00**	**0.00**	0.19
	3	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	5	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

No test statistic is reported when the momentum strategy yields an average return below the benchmark. Strategies in boldface are significant at the 99% level. Strategies in boldface and italics are significant at the 95% level. Strategies in italics are significant at the 90% level.

for any unsmoothing level. This finding reinforces our conclusion about a three-year mean-reversion process.

CONCLUSIONS

We have demonstrated that momentum strategies have the potential to generate significant excess returns in direct investment in real estate, although these potential gains are likely to be partially (but not completely) offset by the additional trading costs required to implement such a strategy. This has a policy implication as to the extent of transaction costs (stamp duty) and an implication for the level of efficiency in real estate markets. If taxes on property transactions are reduced by only 50 basis points, huge potential gains might be achieved by actively trading investors.

We find 12 months to be the best calibration period, and 24 months to be the best holding (or rebalancing) period. This suggests that mean reversion starts after 36 months (the sum of the calibration and holding periods), so that differences in the Sharpe ratio are not significant for this holding period, even in the case of gross returns.

We also show how smoothing induces an integration of real estate markets. If we unsmooth valuation-based returns, markets tend to be much less integrated, showing lower cross-correlation coefficients. This positive effect (i.e., reduction of the portfolio risk when portfolios with more than one segment are considered) partially counterbalances the negative impact of a reduced persistence of returns.

Finally, the analysis points to some areas that may be ripe for innovation. We see that the ability to achieve excess returns is heavily tempered by transaction costs. In practical application, such strategies would also be limited by liquidity, i.e., the ability of an investor to change the portfolio frequently and precisely. The development of segment-specific index-based derivatives, which may be in sight in both the U.K. and U.S. markets, would remove these barriers to the use of momentum strategies, given sufficient liquidity.

EXHIBIT 8

Tests for Equality of Sharpe Ratio

Panel A: Gross Returns

Sharpe Ratio	Sector	6m6	6m12	6m18	6m24	6m36	12m6	12m12	12m18	12m24	12m36	18m6	18m12	18m18	18m24	18m36	24m6	24m12	24m18	24m24	24m36
Jorion	1	**12.02**	**11.12**	**8.24**	**9.75**	**4.85**	**11.84**	**11.45**	**10.26**	**10.67**	**5.68**	**10.10**	**6.73**	**7.79**	**3.70**	-1.64	**7.66**	**7.98**	*1.80*	**3.70**	-1.64
	3	**14.66**	**13.41**	**11.33**	**8.84**	**6.11**	**14.91**	**12.53**	**14.26**	**9.91**	**5.51**	**14.63**	**11.84**	**11.90**	**9.85**	**5.71**	**12.91**	**11.63**	**9.10**	**9.44**	**4.95**
	5	**14.58**	**11.91**	**12.10**	**9.83**	**4.48**	**13.17**	**10.64**	**10.33**	**8.66**	**5.01**	**13.29**	**10.67**	**10.30**	**8.72**	**5.25**	**10.78**	**8.57**	**7.56**	**4.20**	*1.74*
Jobson and Korkie	1	**9.99**	**9.44**	**7.42**	**8.52**	**4.61**	**9.89**	**9.65**	**8.90**	**9.15**	**5.35**	**8.77**	**6.24**	**7.10**	**3.58**	-1.63	**6.99**	**7.23**	*1.77*	**3.58**	-1.63
	3	**11.50**	**10.84**	**9.60**	**7.90**	**5.72**	**11.63**	**10.36**	**11.33**	**8.68**	**5.22**	**11.50**	**9.94**	**9.99**	**8.64**	**5.39**	**10.57**	**9.81**	**8.10**	**8.35**	**4.72**
	5	**11.49**	**10.01**	**10.12**	**8.63**	**4.30**	**10.74**	**9.19**	**8.99**	**7.79**	**4.78**	**10.82**	**9.22**	**8.97**	**7.84**	**4.99**	**9.29**	**7.73**	**6.94**	**4.05**	*1.71*

Panel B: Net Returns

Sharpe Ratio	Sector	6m6	6m12	6m18	6m24	6m36	12m6	12m12	12m18	12m24	12m36	18m6	18m12	18m18	18m24	18m36	24m6	24m12	24m18	24m24	24m36
Jorion	1	-0.91	0.44	1.23	**2.70**	0.89	***2.14***	***2.07***	*1.90*	**4.49**	*2.18*	0.58	-0.63	0.38	-0.21	-3.07	-0.70	0.51	-3.51	-0.21	-3.07
	3	-0.86	*1.86*	*1.79*	*1.68*	1.49	0.14	0.73	*1.69*	1.32	0.65	1.16	1.29	*1.67*	1.45	0.66	1.15	1.15	1.27	1.28	0.26
	5	-0.66	-0.07	0.38	1.19	-0.18	0.77	0.02	0.46	0.96	0.17	0.61	0.24	0.24	0.79	0.00	0.50	-0.02	-0.01	-0.72	-1.05
Jobson and Korkie	1	-0.90	0.43	1.21	**2.63**	0.88	***2.10***	***2.03***	*1.86*	**4.29**	*2.13*	0.58	-0.62	0.38	-0.21	-3.03	-0.69	0.51	-3.46	-0.21	-3.03
	3	-0.85	*1.83*	*1.76*	*1.65*	1.47	0.14	0.72	*1.66*	1.30	0.64	1.14	1.28	1.64	1.42	0.66	1.14	1.13	1.26	1.26	0.26
	5	-0.66	-0.07	0.38	1.17	-0.17	0.76	0.02	0.45	0.95	0.17	0.60	0.23	0.24	0.78	0.00	0.49	-0.02	-0.01	-0.71	-1.04

Strategies in boldface are momentum strategies with a Sharpe ratio that is significantly higher than the ratio of the benchmark at a 99% confidence level.
Strategies in italics and boldface are momentum strategies with a Sharpe ratio that is significantly higher than the ratio of the benchmark at a 95% confidence level.
Strategies in italics are momentum strategies with a Sharpe ratio that is significantly higher than the ratio of the benchmark at a 90% confidence level.

ENDNOTES

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[1]See Hong, Lim, and Stein [2000] and Johnson [2002] for under- or overreaction theories. For herding behavior, see Jegadeesh and Titman [2001]. In some cases behavioral models are used; see Barberis, Shleifer, and Vishny [1998], Daniel, Hirshleifer, and Subrahmanyam [1998], and Hong and Stein [1999].

[2]See Quan and Quigley [1991], Geltner [1991, 1993a, 1993b], Fisher, Geltner, and Webb [1994], Chaplin [1997], Brown and Matysiak [1998], Cho, Kawaguchi, and Shilling [2003], and Geltner, MacGregor, and Schwann [2003].

[3]See www.ipdindex.co.uk.

[4]Note that an 11th segment normally shown by IPD has been excluded (other property). It represents a small but highly heterogeneous set of properties covering development land, residential, agricultural, and other property types. Its weight in the IPD benchmark universe is less than 2%, and its returns have been highly erratic. Because of its widespread use in the industry, this segmentation has become a market standard for setting allocation strategies. Moreover, tests reported by IPD suggest it is a categorization that maximizes the explanation of variance in returns across individual properties for a given number of segments. Therefore it is the most effective split of the market for the optimization of asset allocation. See Frodsham and Key [1996].

[5]Geltner [1993a], or Barkham and Geltner [1995].

[6]It is not really possible for any investor to buy the index, because the property composition of the index changes over time, the properties in the index are not for sale at all times, and the Barclays derivative product has not been very liquid.

[7]That is, number of sectors composing the portfolio (3) times the number of calibration periods (4) times the number of holding periods (5).

[8]Let us assume an average monthly return of 1%. If during the 12th month we have a gross return of 2%, and the portfolio is entirely traded (all segments are sold), we will incur a 7.5% cost during that month, making the return a negative 5.5%, well below the average return. Thus, when-

EXHIBIT 9
Tests for Equality of Sharpe Ratio—Unsmoothed Net Returns

Panel A: One Sector

One sector	Unsm	6m6	6m12	6m18	6m24	6m36	12m6	12m12	12m18	12m24	12m36	18m6	18m12	18m18	18m24	18m36	24m6	24m12	24m18	24m24	24m36
Jorion Sharpe Ratio	40%	-1.01	1.14	**2.21**	*1.83*	-0.29	2.62	*1.90*	**1.98**	3.10	0.57	0.64	-0.14	-0.46	1.00	-4.88	-0.75	0.73	-5.62	-0.94	-4.88
	55%	-0.29	-0.10	2.97	1.34	-0.40	*1.90*	1.37	1.48	**2.41**	0.33	0.24	-0.24	-0.67	0.65	-4.25	-0.53	0.49	-3.13	-0.93	-4.25
	70%	-0.12	0.53	**2.27**	0.98	-0.41	-0.31	-0.35	1.11	*1.71*	0.19	0.28	-0.13	-0.71	0.54	-3.57	-0.71	-0.89	-2.66	-0.80	-3.57
	85%	-1.46	-0.88	1.60	0.69	-0.33	-0.51	-0.40	0.33	0.44	-0.68	0.55	0.28	0.66	**2.44**	1.04	-0.26	-0.12	-1.98	0.37	-2.65
	100%	-2.25	-1.68	0.53	-0.06	-0.14	-0.43	-0.41	0.63	0.31	-0.42	0.29	-0.06	-0.24	0.90	-0.07	-0.14	0.14	-0.93	1.09	-0.18

Panel B: Three Sectors

Three sectors	Unsm	6m6	6m12	6m18	6m24	6m36	12m6	12m12	12m18	12m24	12m36	18m6	18m12	18m18	18m24	18m36	24m6	24m12	24m18	24m24	24m36
Jorion Sharpe Ratio	40%	-0.11	**2.14**	3.16	3.12	3.03	-1.65	-0.26	**2.17**	3.45	0.20	*1.85*	1.64	4.32	**2.43**	0.69	*1.67*	*1.70*	*1.91*	**2.07**	0.69
	55%	-1.35	1.10	0.32	1.50	0.62	-1.08	-0.28	*1.83*	2.81	0.09	*1.77*	*1.72*	2.66	*1.95*	0.50	*1.87*	1.47	2.64	*1.64*	0.37
	70%	-0.77	0.32	0.62	1.23	0.55	-0.54	0.00	1.43	**2.30**	0.07	0.91	1.40	**2.07**	1.59	0.41	0.99	1.20	*1.85*	1.34	0.29
	85%	-3.00	-0.95	-0.01	1.30	0.15	-0.25	0.30	**2.03**	3.07	**2.40**	0.25	1.19	*1.66*	1.28	0.30	1.12	1.34	0.94	0.67	0.28
	100%	-5.40	-2.94	-0.49	0.25	-0.04	-2.13	0.30	-0.50	**1.98**	1.39	-1.17	-0.51	1.46	1.39	0.81	0.66	1.57	0.67	0.74	0.73

Panel C: Five Sectors

Five sectors	Unsm	6m6	6m12	6m18	6m24	6m36	12m6	12m12	12m18	12m24	12m36	18m6	18m12	18m18	18m24	18m36	24m6	24m12	24m18	24m24	24m36
Jorion Sharpe Ratio	40%	-0.19	0.41	0.73	**2.43**	0.59	1.53	0.53	**2.31**	2.61	-0.07	0.66	0.20	*1.85*	**2.14**	-0.07	1.21	0.47	-0.09	0.40	-2.49
	55%	-1.54	-0.59	-0.38	**2.05**	0.51	0.44	0.37	*1.72*	**2.25**	-0.05	0.58	0.07	0.72	*1.85*	-0.05	0.85	0.37	-0.86	0.35	-2.14
	70%	-2.72	-0.81	-1.04	1.51	0.23	-0.44	-0.15	0.77	**1.96**	-0.15	0.27	0.07	2.77	*1.64*	0.06	0.37	0.39	-1.20	0.43	-1.66
	85%	-3.46	-0.84	-0.78	1.22	0.14	-1.27	-0.39	0.62	1.50	0.36	0.25	0.51	**2.28**	*1.88*	0.28	0.26	1.05	0.25	0.89	-0.63
	100%	-4.97	-2.72	-0.09	0.22	-0.29	-1.83	-0.14	-0.61	1.31	0.70	-0.91	-0.44	1.44	1.15	0.77	-0.34	1.21	*1.64*	1.36	0.25

Strategies in gray boxes are momentum strategies with a Sharpe ratio that is significantly higher than the ratio of the benchmark at a 99% confidence level.
Strategies in boldface are momentum strategies with a Sharpe ratio that is significantly higher than the ratio of the benchmark at a 95% confidence level.
Strategies in talics are momentum strategies with a Sharpe ratio that is significantly higher than the ratio of the benchmark at a 90% confidence level.

ever a transaction happens (even if it refers to a portion of the overall portfolio), since trading costs are very high, we would obtain a significantly negative return and thus an increase in volatility. The higher risk is mainly caused by the impact of trading costs and does not represent a pure property risk.

[9]If X, SE, Var, and n represent average, standard error, variance, and number of observations of our time series, and the two subscripts s and b refer to our strategy and the benchmark, we obtain the t-statistic as follows:

$$ttest_{B-F} = \frac{\overline{X}_s - \overline{X}_b}{SE(\overline{X}_s - \overline{X}_b)},$$

where

$$SE(\overline{X}_s - \overline{X}_b) = \sqrt{\frac{Var_s}{n_s} + \frac{Var_b}{n_b}}$$

[10]The normal t-test is computed as follows:

$$ttest = \frac{\overline{X}_s - \overline{X}_b}{\sqrt{Var_{pooled} * \left(\frac{1}{n_s} + \frac{1}{n_b}\right)}}$$

[11]The Sharpe ratio (SR) is derived, for i equal to s (strategy) or b (benchmark), from the formula:

$$SR_i = \frac{\overline{X}_i - \overline{R}_f}{\sigma_i}$$

where R_f represents the risk-free rate (three-month T-bill rate) and σ_i is the standard deviation of the portfolio.

[12]Risk premiums rather than nominal returns are tested. Risk premiums are obtained by subtracting the average risk-free rate from the nominal return for each strategy. The tests for differences in the Sharpe ratio under the two specifications are *srtest1* and *srtest2*:

$$srtest1 = \frac{\overline{X}_s\sigma_b - \overline{X}_b\sigma_s}{\sqrt{\frac{2}{n}\left(\sigma_b^2\sigma_s^2 - \sigma_b\sigma_s\sigma_{bs}\right)}}$$

$$srtest2 = \frac{\overline{X}_s\sigma_b - \overline{X}_b\sigma_s}{\sqrt{\frac{1}{n}\left[2\sigma_s^2\sigma_b^2 - 2\sigma_s\sigma_b\sigma_{sb} + \frac{1}{2}\overline{X}_s^2\sigma_b^2 + \frac{1}{2}\overline{X}_b^2\sigma_s^2 - \frac{\overline{X}_s\overline{X}_b}{2\sigma_s\sigma_b}\left(\sigma_{sb}^2 + \sigma_s^2\sigma_b^2\right)\right]}}$$

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