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Common Risk Factors and the Macroeconomy: New Evidence from the Japanese Stock Market

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Abstract

Using new data on returns and risk factors the paper considers the stock performance on the Japanese market, which is the second largest in the world and operates under unique macroeconomic conditions. We find that the CAPM model is not an adequate approach for the Japanese market. The Carhart model performs reasonably well but fails to reject the null hypothesis of a zero intercept for the full period. Extended tests reveal a structural change in asset prices in the year 1998. When separating the sample into two periods, the standard four factor model explains market returns much better. We show that the relation between stock returns and risk factors is affected by macroeconomic conditions, especially when considering the momentum strategy. The Japanese case illustrates the necessity of considering structural instability related to the macroeconomic development, which is especially important for countries and time periods with a sluggish economy.

Keywords: Risk factors, value, size, momentum, Japanese stocks, macroeconomic conditions, structural break
JEL Classification: G12, G15, G01, C89

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1 Introduction

The generality and robustness of the widely applied risk-factor models in financial economics are a research topic of highest priority. It is undisputed that the Fama-French three-factor approach (Fama and French 1993) and the momentum effect as proposed by Carhart (Carhart 1997) had a widespread empirical success. However, given the dynamic development of expectations and behavior, further results in different settings seem to be warranted. Moreover, according to recent literature, the book–to–market factor (HML) and the size factor (SMB) are associated with macroeconomic fundamentals, in particular with changes in economic growth expectations, see Liew and Vassalou (2000) and Vassalou (2003) who demonstrate that HML and SMB contain information about changes in growth expectations. In a recent contribution, Aretz, Bartram, and Pope (2010) show that most macroeconomic factors are actually priced and the momentum factor (WML) contains incremental information for asset pricing.

Interestingly, Liu and Lee (2001) find that WML is not observed on the Japanese stock market, where recent macroeconomic conditions differ quite substantially from other countries. In fact, the Japanese economy has experienced a period of absent or very low growth since the 1990s. Moreover, it is characterized by high government debt, amounting to 220 percent of GDP. At the same time, we observe a non-growing labor force, rising unemployment, decreasing savings rates, and near-to-zero (nominal deposit) interest rates. The Japanese experience can be interpreted as a prominent example for a lasting stagnancy, which other leading economies might be confronted with in the future. Still, Japan is ranked among the world's largest economies in terms of real GDP and real GDP per capita; its stock market is the second largest in the world.

The paper contributes to the literature in three different respects. First, we thoroughly test the applicability of the risk factor model à la Fama-French and Carhart to Japan with newly constructed data and up-to-date estimation techniques. In particular, we ask whether and how we can improve the empirical asset pricing models by including additional factors when starting with the basic CAPM approach. Second, we relate our findings to the macroeconomic conditions by testing for the emergence of a structural break in the risk-factor models. Note that, before the non-growth period, Japan experienced a long phase of rapid growth and an impressive catch-up with the leading economies. Accordingly, the switch to a new growth regime and the associated changes in asset pricing appear especially rewarding to be studied. Third, we reassess the momentum effect and interpret it from the perspective of macroeconomic conditions.

We find that the CAPM model is not an adequate approach for the Japanese market, while the Carhart model with the risk factors including WML performs reasonably well. However, for the full period, the null hypothesis of a zero intercept is rejected, revealing that asset pricing is not adequately presented by this approach. We further find that the hypothesis of no structural change is rejected and that the structural break occurred in January 1998. In the two-period approach, the null hypothesis of a zero intercept cannot be rejected in both periods. The addition of SMB and HML to the basic CAPM specification improves the overall performance of the model in the full period as well as in both subperiods significantly. Based on descriptive analysis, we find evidence for the momentum strategy only in the second period but for a reversed momentum effect in the first. We conclude that macroeconomic conditions cumulating in the structural break are crucial especially with regard to the momentum strategy, which contrasts recent findings about macroeconomic fundamentals being unable to explain variations in WML, see Griffin, Ji, and Martin (2003). The results are found to be robust.

Past studies on the performance of the Japanese stock market reflect a mixed performance of the standard risk models. Chan, Hamao, and Lakonishok (1991) conclude that the book-to-market ratio has a big impact on Japanese stock returns, which may also be due to to Japanese accounting standards; the cash flow yield and, to a minor extent, the size effect do also affect the stock performance. Kubota and Takehara (1996) reject the CAPM while Kubota and Takehara (1997) show that the Fama-French three-factor model captures the common risks in the Japanese stocks accurately. In contrast, Daniel, Titman, and Wei (2001) reject the Fama-French three-factor model but not the "characteristic" model, which links expected returns of assets to their characteristics which may have nothing to do with the covariance structure of returns. More recently, Vu Pham (2007) finds a reversal of the size effect for the period 1984-2004. Walid and Ahlem (2009) show that the CAPM is not an appropriate model for the Japanese market and Walid (2009) finds that both the firm size and book-to-market ratio are significantly related to average return premiums but suggests that there is stronger support to the characteristic model rather than the Fama-French three-factor model.

To scrutinize Japanese stock returns in an up-to-date and accurate manner, we use newly constructed monthly data and risk factors (see Schmidt et al., 2011) for the time period 1984-2009. We compare the different base models, in particular the classical CAPM, the Fama-French three-factor model as well as the Carhart four-factor model including WML. In accordance with Japanese macroeconomic development, we suggest the model exhibits structural instability. Therefore, we perform corresponding statistical tests and include breaking points. As regards empirical methods, we use GMM estimation techniques. We also perform extensive robustness tests with regard to portfolio formation by altering the dimension from 5x5 to 4x4 and by alternating between equally weighted (EW) and value weighted (VW) portfolios.

The remainder of the paper is organized as follows. Section 2 describes the data characteristics and the portfolio formation as well as the statistical framework in detail. Section 3 presents the empirical results for the full period, first in terms of descriptive statistics and then of regression results. In section 4, we present the tests for structural change as well as the descriptive statistics and regression results for the two different periods. Section 5 summarizes and concludes.

2 Data and methodology

2.1 Data characteristics and portfolio formation

We use newly constructed market returns and risk factors based on Thomson Reuters Datastream and Thomson Reuters Worldscope data. A detailed documentation is given by Schmidt et al. (2011), who confirm the reliability of the thoroughly screened Thomson Reuters Datastream and Thomson Reuters Worldscope dataset by comparing the constructed market, value, size, and momentum risk factors with important benchmarks. We use monthly data from the Japanese stock market between 1984/7 and 2009/7. In December 1984, the number of firms was 403 while it amounted to 3558 in January 2009.

The used risk factors are (for the details on the construction of the factors, see Schmidt et al. (2011), section 3.1):

- Fama-French risk factors: SMB (small minus big; related to the size, i.e. market capitalization), HML (high minus low; related to book-to-market value)
- Carhart's momentum factor: WML (winner minus loser)
- Market return: RM

In the case of Japan, the market return RM is highly and significantly correlated with the Tokio Stock Price Index (TOPIX); the estimated correlation is 0.996 in the VW (p-value < 0.0001) and 0.838 in the EW (p-value < 0.0001) case. Since there are no treasury bills in Japan, the usual proxy for the risk-free rate Rf is the Gensaki times series. However, Gensaki is not available for the full period; hence, we use the basic discount and loan rate (middle rate) as proxy for the risk-free rate, the data are also from Thomson Reuters. The basic discount and loan rate is highly positively correlated with the Gensaki rate; the correlation estimation yields 0.978 (p-value < 0.0001).

In order to analyze the returns, following the standard procedure in the literature, portfolios are formed each year with regard to size, book-to-market value and momentum. The breakpoints are chosen to be 0.5, see also Schmidt et al. (2011), section 3.2. We consider the following portfolio-structures:

- 5x5 portfolios
    - 5 size-ranges (small to big) / 5 B/M-ranges (low to high)
    - 5 size-ranges (small to big) / 5 momentum-ranges (loser to winner)
- 4x4 portfolios
    - 4 size-ranges (small to big) / 4 B/M-ranges (low to high)
    - 4 size-ranges (small to big) / 4 momentum-ranges (loser to winner)

2.2 Statistical framework

In the empirical analysis we consider three versions of a factor pricing model. The dependent variable in the corresponding regressions is throughout the excess return of portfolio i $(R_{it} - Rf_t)$ which is regressed on different combinations of the four risk factors described above. b_i, s_i, h_i and m_i are the accordant factor sensitivities for each portfolio i which are estimated from the time series regressions. N is the number of portfolios with the index i and T is the number of observations over time indexed by t. Thus, for $i = 1, 2, ..., N$, the following model specifications are considered:

$$R_{it} - Rf_t = a_i + b_i(RM_t - Rf_t) + e_{it}, \tag{1}$$

$$R_{it} - Rf_t = a_i + b_i(RM_t - Rf_t) + s_i SMB_t + h_i HML_t + e_{it}, \tag{2}$$

$$R_{it} - Rf_t = a_i + b_i(RM_t - Rf_t) + s_i SMB_t + h_i HML_t + m_i WML_t + e_{it}. \tag{3}$$

a_i and e_{it} are asset return intercepts and disturbances, respectively. Model (1) is the Sharpe-Lintner version of the CAPM where excess portfolio returns are regressed on a constant and the excess market return only. Model (2) is often referred as the Fama-French three-factor-model including additionally the HML and SMB factor. We refer to model (3) as the four-factor Carhart-like model where the momentum factor (WML) is added to describe portfolio returns. Model (1) is applied to size-B/M-sorted portfolios only, whereas model (2) and (3) are applied to size-B/M-sorted as well as to size-momentum-sorted portfolios[1].

In a first step, we descriptively analyze the sample moments of the variables involved. Then, by estimating the coefficients from the models above, we study common variation in portfolio returns. Additionally, we comparatively evaluate the precision of the different asset pricing specifications by the implication that each element of $\mathbf{a}=(a_1, a_2, ..., a_N)'$ is zero for a single model, which should be the case if the factors involved completely explain excess returns. Therefore, we will form a Wald test statistic of the null hypothesis $\mathbf{a}=\mathbf{0}$ against the alternative hypothesis $\mathbf{a}\neq\mathbf{0}$. That is, we test the joint hypothesis that all intercepts are zero. A rejection of the null hypothesis indicates a deviation from the exact factor pricing model.

Based on MacKinlay and Richardson (1991), inference is refined by applying a GMM approach. For every model (1) to (3), we jointly identify the parameters of interest by estimating a system of equation including all portfolios. Therewith,

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[1] When not mentioned explicitly, the results are reported for model (2) applied to size-B/M-sorted portfolios and model (3) applied to size-momentum-sorted portfolios.

compared to single equation OLS, we are able to relax the assumptions that returns conditional on the factor realizations are IID through time and jointly multivariate normal.

The analysis is focused on the 4x4 sorted portfolios for value weighted returns. We will check the result's robustness by additionally applying the described framework on equally weighted returns as well as on 5x5 sorted portfolios.

Following Bai and Perron (2003), we then test for structural instability of the models and include breaking points into the empirical analysis. Further information is given in the following section. All calculations and estimations are conducted in R, version 2.12.2 (R Development Core Team, 2011).

3 Empirical evidence: full period

3.1 Descriptive statistics

Considering the sample moments of the explanatory returns in table 1, we see that only the mean for the HML factor is significantly different from zero. Furthermore, the correlation matrix shows that the correlation coefficients are generally low and only partly significant[2]. Specifically, we find a negative correlation between RM and HML, RM and WML as well as between SMB and WML.

The calculated means for the portfolios formed on size and book-to-market equity show that the returns increase monotonically and consistently from the lowest to the highest portfolio. Accordingly, as it is shown in table 2 the difference between the return of the highest B/M minus the lowest B/M portfolio is significantly different from zero, which indicates a positive relation between average return and B/M equity. We also find some evidence that there is a negative relationship between returns and size, but in a less consistent way. Specifically, the returns in the biggest fourth portfolio seem to be greater than the next smaller portfolio return. Consequently, for each category, the difference between the smallest and biggest portfolio is not statistically different from zero.

Looking at the portfolios formed on size and momentum in the lower sections of table 1 and table 2, we observe that there is no clear evidence for a momentum effect from the average means. The difference between the returns of the winner and the loser portfolio is not statistically different from zero through every size category. However, forming the portfolios on a size-momentum-basis instead of the size-B/M basis reveals a clear negative relationship between average returns and size, with the difference of the return from the smallest minus the biggest portfolio being partly significantly different from zero.

Generally, the descriptive statistics correspond with established findings from the Japanese stock market, confirming the high quality and reliability of the newly

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[2] In the following, significance is always set at the 5%-level.

constructed market returns and risk factors.

3.2 Regression results

The estimated parameters of model (1) are visualized in table 3. The b_is have the expected sign and magnitude, ranging around 1. They are highly significant for every portfolio i. However, the b_is cannot sufficiently explain the differences in returns between the portfolios. Moreover, in 4 out of 16 cases, the null-hypothesis of a_i being equal to zero is rejected. The hypothesis for a_i being jointly zero throughout all portfolios is rejected indicating a misspecification of the CAPM.

As expected, we see from the left section of table 4 that the three factors in model (2) capture common variation in stock returns. The b_is are all highly significant. s_i and h_i (except for a few exceptions) are also significant. The slopes of HML_t and SMB_t are related to size and B/M respectively. s_i decreases with size and h_i increases with a higher B/M ratio explaining the variation in portfolio returns described in the descriptive analysis. All estimates for a_i are significantly different from zero, and the joint hypothesis cannot be rejected which, compared to model (1), indicates an improvement of the asset pricing specification.

The 16 estimated b_is in model (1) range from 0.773 and 1.077 with a sample variance of 0.006, whereas in model (2) they lie between 0.907 and 1.090 with a sample variance of 0.002. This shows that with regard to the excess market return the factor sensitivities in the three-factor model exhibit some form of convergence over the different portfolios. According to Fama and French (1993)"(...) Adding SMB and HML to the regressions collapses the betas for stocks toward 1 (...). This behavior is due, of course, to the correlation between the market and SMB or HML." Consistently, we can see in the correlation matrix from table 1 that the correlation between HML and SMB is low and not significant, whereas it is significant between RM and HML. Furthermore, the estimates for b_i seem to be systematically lower in model (1). Adding the momentum factor to the regression (2) does not change the results. b_i, s_i and h_i are robust with regard to sign and magnitude. According to table 11, the values of the Wald statistics of the null hypothesis are slightly higher for the four-factor model, indicating some improvement in the description of portfolio returns. The momentum factor WML is negative and partly significant, especially for the portfolios with a low B/M ratio[3].

The results for model (3) are presented in the right section of table 4. The portfolios are now formed on size and momentum factors. The b_is are still highly significant and range around 1. The s_i and h_i coefficients are still significant in most cases. Both factor sensitivities, however, show less significance for the biggest portfolio category.

Except for two portfolios, the momentum-factor m_i is significant in explaining

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[3] The corresponding results can be obtained from the authors upon request.

common variation. We observe that m_i is monotonically increasing from loser to winner portfolios, which, however, is not reflected in the returns described in the descriptive statistics above. The reasons are possibly the effect of additional factors. From the regression results, we find that for the winner portfolio h_is are consistently lowest within the corresponding size category.

Remarkably, the null hypothesis $\mathbf{a}=\mathbf{0}$ is rejected at a very low significance level. Thus, although model (3) consists of four risk factors, the asset pricing process is described poorly (or in an incomplete manner, to put it more mildly).

Applying model (2) to size-momentum-sorted portfolios does not change the results related to b_i, s_i and h_i [4]. Comparing the corresponding values of the Wald statistic of the null hypothesis $\mathbf{a}=\mathbf{0}$ for model (2) and (3) in table 11 we see that, compared to the three-factor model, the inclusion of the momentum factor improves the description of portfolio returns only marginally.

4 Estimations for two periods

4.1 Structural change

Macroeconomic development of the Japanese economy suggests that the structure of the main economic time series does not necessarily remain the same throughout the full sample period. Therefore, with regard to the empirical models, we expect the parameters to be unstable over time. In this section, we statistically address the issue of possible structural changes. We compute F-statistics in order to compare the unsegmented full period model against every possible single-shift alternative. Following Andrews and Ploberg (1994), we reject the null hypothesis of structural stability if the supremum of these statistics is too large. The test is applied for every model and for every portfolio based on OLS estimations. From table 5 we derive that, apart from two exceptions, the null hypothesis of no structural change is rejected in any case.

In the next step, given the evidence for a structural change, we assess the timing of the structural break by using the dating procedure of Bai and Perron (2003). Although the test is conducted for every regression specifically, we generalize the specific results from the 64 models such that we get a representative single breaking point. That is, in order to keep the design of the empirical analysis straight, we apply the same two sample periods to every model under examination.

The number of breaks is determined in advance by choosing the models with the minimal Bayesian information criterion (BIC) throughout different number of breakpoints. For 50% of the analyzed models the BIC is minimal at a single breaking point. Thus, given one breakpoint, the optimal sample segmentations are presented in table 6. In roughly 65% of the models the breaking point lies in the time period between 1997 and 2000. Excluding model (1) from the analysis

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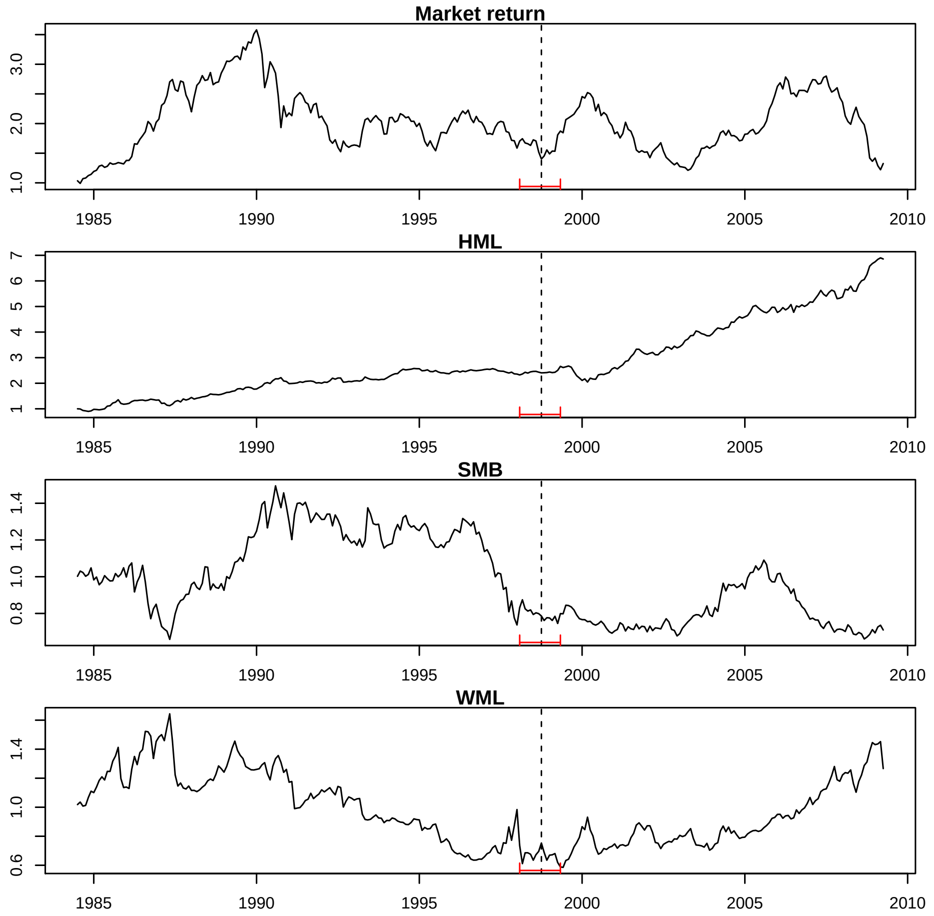
[4] The corresponding results can be obtained from the authors upon request.

this rate increases to 75% indicating a high degree of homogeneity in structural behavior throughout the models (2) and (3).

Fixing the breaking point at October 1998, we can visually recover the structural change by looking at the four cumulated risk factors in figure 1. The market return in the upper section shows only a slight structural modification, whereas the two segments are clearly distinguishable for the other three risk factors. For the HML factor, the process shows a rather stationary behavior in the first period, whereas the second period seems to be governed by a positive trend. Compared to the first period, the SMB factor fluctuates around a lower average in the second period. For the WML factor, we can visually assess a distinct break around the year 1998 with the factor changing from a negative to a positive trend. For the following empirical analysis, we thus set the breaking point at January 1998.

Figure 1: Breakingpoints and cumulated risk factors



4.2 Descriptive statistics

Considering the explanatory returns, from the descriptive statistics presented in table 7 and table 8, we see that the calculated moments are quite similar to the full period sample. With regard to the dependent returns, we see that for the portfolios formed on size and book-to-market equity returns increase from the lowest to the highest portfolio for both time periods.

The returns of the portfolios formed on size and momentum show some revealing properties. From table 9 and table 10 we find evidence for the momentum strategy in period 2 because the winner portfolio significantly outperforms the loser portfolio for two size-categories. On the other hand, there is evidence for a reversed momentum effect in period 1, with the loser portfolio exhibiting a higher average return than the winner portfolio for one size-category at the 15% significance level. Thus, based on this descriptive analysis, the breaking point seems to be especially meaningful with regard to the momentum strategy.

4.3 Regression results

For model (1) presented in table 12 we cannot reject the null hypothesis $\mathbf{a}=\mathbf{0}$ for period 1, indicating a satisfying performance of the CAPM between 1984 and 1998. As for the full period, the same hypothesis is rejected for period 2. The estimates for b_i are systematically higher in period 2.

Similar to the estimates for the full time period, the inclusion of the SMB and HML risk factors in table 13 improves the performance of the asset pricing model. In both cases we cannot reject the null hypothesis $\mathbf{a}=\mathbf{0}$. Also, the corresponding factor sensitivities explain common variation with s_i decreasing in size and h_i increasing with a higher B/M ratio. Generally, the estimates for s_i and h_i tend to be lower in period 1 then in period 2, whereas the estimates from the full period lie in between. There is some evidence that the b_is collapse towards 1 in model (3), however, this property is less pronounced and less consistent than for the full sample period.

The estimates from model (2) are robust to the inclusion of the WML factor. However, the estimated factor sensitivity m_i is not significant in period 2 and only partly significant in period 1.

In contrast to the full period estimates, the null hypothesis $\mathbf{a}=\mathbf{0}$ cannot be rejected for model (3) in both periods. That is, compared to the last section, we find a clear improvement of the four factor model when applied separately for the two time periods. We see from table 14 that the estimated factor sensitivities b_i, s_i, h_i and m_i behave in a similar way as for the full period. Similar to model (2), s_i and h_i tend to be lower for period 1. The momentum sensitivity m_i increases monotonically from loser to winner portfolios for both time periods. As for the full period, the application of the three-factor model to size-momentum-sorted portfolios does not notably change the results with regard to b_i, s_i and h_i[5]. Other than for the full period, the comparison of the test statistics in table 11 reveals a more considerable improvement in the description of portfolio returns when the momentum factor is included.

The regression results as well as the descriptive statistics are mostly robust when applied to equally weighted portfolios sorted on a 4x4 and 5x5 basis as well as for value weighted portfolios sorted on a 5x5 basis. An exception are the equally weighted portfolios, where the null hypothesis $\mathbf{a}=\mathbf{0}$ for model (3) in period 2 is rejected, weakening somewhat the general result of the four factor model performing better when applied to the splitted sample. Furthermore, for equally weighted 5x5 portfolios in period 2, we do not find significant evidence for the momentum strategy calculated from the difference in average portfolio returns. The corresponding tables containing the complete set of calculations and estimations can be obtained from the authors on request.

5 Conclusions

Using a new set of data and risk factors, our results for the Japanese stock market confirm that the commonly used risk factors à la Fama-French or à la Carhart are superior to CAPM and perform reasonably well. However, specific testing reveals that we have a structural break in 1998, indicating the change from a growing to a mainly stagnant economy. It turns out that splitting the data sample is especially important in several respects. First, other than for the full period, the hypothesis for the intercepts being jointly zero in the CAPM cannot be rejected for the first period indicating a more satisfying performance of the basic model specification. Furthermore, considering the momentum strategy, descriptive statistics reveal a reversed effect with the loser portfolio exhibiting a higher average return than the winner portfolio in the first period. With regard to regression analysis we find that the Wald test for the intercepts being jointly zero cannot be rejected for the Carhart model after splitting the data sample, whereas the same test indicates that intercepts are not jointly zero for the full period. Hence, considering the structural break, the standard four factor model explains returns more adequately. This shows that the relation between risk factors and stock returns is influenced by macroeconomic conditions, especially when including the momentum effect.

We conclude that, given the current sluggishness of the world economy, researchers and practitioners should be increasingly alert for structural breaks, following the growth expectations in the economy. Overall, the paper is another proof for the robustness of the Fama-French approach, for both periods of high and low economic growth. It also shows that the momentum effect is vulnerable when macroeconomic conditions change.

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[5] The corresponding results can be obtained from the authors upon request.

It would be interesting to see whether the new evidence for the Japanese market can be corroborated when performing similar tests for other markets. In addition, the international links between financial markets with regard to the momentum effect would be interesting to study. This is left for further research.

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Appendix

Table 1: Descriptive statistics: 16 portfolios, full period (1984-2009)

Explanatory returns

	Sample moments					Correlation matrix			
	Rm	SMB	HML	WML		RM	SMB	HML	WML
Mean	0.115	-0.027	0.690	0.206	RM	1.000	-0.088	-0.244**	-0.177**
Median	0.280	-0.173	0.636	0.766	SMB	-0.088	1.000	0.088	-0.236**
Maximum	18.405	15.014	10.522	15.058	HML	-0.244**	0.088	1.000	0.045
Minimum	-22.000	-14.711	-10.777	-25.299	WML	-0.177**	0.236**	0.045	1.000
t-value	0.344	-0.110	4.093	0.718					

Dependent returns: portfolios formed on size and book-to-market equity

	Mean				t values			
	Low	2	3	High	Low	2	3	High
Small	0.139	0.421	0.526	0.652	0.294	1.023	1.356	1.697
2	-0.201	0.806	0.403	0.582	-0.460	0.208	1.050	1.474
3	-0.128	0.221	0.366	0.517	-0.310	0.598	1.022	1.330
Big	-0.203	0.404	0.646	0.593	-0.542	1.177	1.884	1.648

Dependent returns: portfolios formed on size and momentum

	Mean				t values			
	Losers	2	3	Winner	Losers	2	3	Winner
Small	0.688	0.704	0.886	0.605	1.449	1.746	2.331	1.554
2	0.155	0.363	0.477	0.347	0.336	0.924	1.296	0.913
3	0.047	0.183	0.372	0.352	0.101	0.473	1.050	0.954
Big	0.044	0.174	-0.118	0.345	0.091	0.453	-0.342	0.929

Notes:

For correlation matrix: *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table 2: Differences in means for extreme portfolios: full period (1984-2009)

Portfolios formed on size and book-to-market equity

	Difference in means				t values			
	Small	2	3	Big	Small	2	3	Big
High-low	0.514	0.784	0.645	0.796	2.374	3.561	3.473	2.878
	Low	2	3	High	Low	2	3	High
Small-big	0.342	0.017	-0.012	0.059	0.908	0.053	-0.430	0.191

Portfolios formed on size and momentum

	Difference in means				t values			
	Small	2	3	Big	Small	2	3	Big
Winner-losers	-0.082	0.192	0.305	0.302	-0.290	0.714	1.0281	0.737
	Loser	2	3	Winner	Loser	2	3	Winner
Small-big	0.644	0.531	1.004	0.260	1.953	1.688	3.435	0.748

Table 3: Model (1): 16 portfolios, full period (1984-2009)

	b_i				$t(b_i)$			
	Low	2	3	High	Low	2	3	High
Small	0.977	0.850	0.819	0.773	13.037	12.687	12.961	12.362
2	0.955	0.912	0.893	0.894	14.319	15.936	14.096	15.526
3	1.034	0.953	0.904	0.979	19.088	17.552	21.468	20.099
Big	1.077	0.961	0.960	0.870	37.069	27.090	33.160	18.749

	a_i				$t(a_i)$			
	Low	2	3	High	Low	2	3	High
Small	0.000	0.003	0.004	0.006	0.081	0.979	1.404	1.641
2	-0.003	0.000	0.003	0.005	-1.058	-0.096	1.189	1.609
3	-0.002	0.001	0.003	0.004	-1.175	0.582	1.144	1.562
Big	-0.003	0.003	0.005	0.005	-2.642	2.009	3.965	2.323

Linear hypothesis test for $\mathbf{a}=\mathbf{0}$

p-value	0.001

Table 4: Model (2) and (3): 16 portfolios, full period (1984-2009)

Model (2)

	b_i				$t(b_i)$			
	Low	2	3	High	Low	2	3	High
Small	1.057	0.937	0.911	0.907	33.849	33.307	31.853	34.244
2	0.990	0.989	0.985	1.037	35.254	46.340	44.694	69.298
3	1.059	1.013	0.987	1.090	40.815	31.579	39.312	41.308
Big	1.016	0.968	1.005	0.973	59.105	30.218	43.264	30.036
	s_i				$t(s_i)$			
	Low	2	3	High	Low	2	3	High
Small	1.235	1.069	0.977	0.962	24.051	36.578	21.759	25.511
2	1.105	0.891	0.891	0.879	22.321	33.253	42.908	41.878
3	0.744	0.591	0.548	0.589	15.996	17.547	15.421	16.263
Big	-0.138	-0.201	-0.011	-0.097	-5.787	-4.459	-0.302	-1.864
	h_i				$t(h_i)$			
	Low	2	3	High	Low	2	3	High
Small	0.001	0.152	0.240	0.582	0.013	1.756	2.709	7.230
2	-0.292	0.161	0.283	0.702	-3.924	3.495	5.405	11.219
3	-0.186	0.180	0.391	0.597	-2.794	2.7898	5.391	8.222
Big	-0.419	0.164	0.372	0.892	-6.636	2.387	6.633	9.198
	a_i				$t(a_i)$			
	Low	2	3	High	Low	2	3	High
Small	0.001	0.002	0.003	0.002	0.247	1.361	1.604	1.205
2	-0.001	-0.001	0.001	0.000	-0.491	-0.950	0.953	0.026
3	-0.001	-0.000	-0.000	-0.000	-0.614	-0.025	-0.017	-0.030
Big	-0.000	0.002	0.003	-0.001	-0.321	1.241	2.076	-0.758

Model (3)

	b_i				$t(b_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	0.977	0.905	0.917	0.915	35.390	27.052	22.601	23.624
2	1.011	0.806	0.965	0.966	46.478	38.504	30.485	27.895
3	1.063	0.983	0.978	1.025	38.914	27.103	26.641	25.749
Big	1.010	0.951	0.964	1.058	29.347	26.515	28.046	42.885
	s_i				$t(s_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	1.097	1.028	0.986	1.012	27.721	24.925	23.192	19.540
2	0.886	0.808	0.808	0.919	30.060	27.658	24.922	22.012
3	0.611	0.563	0.539	0.610	14.910	14.798	14.248	12.725
Big	-0.050	-0.138	-0.084	-0.066	-0.954	-2.331	-1.877	-1.351
	h_i				$t(h_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	0.219	0.261	0.291	0.151	3.263	4.106	3.819	1.682
2	0.227	0.306	0.306	0.209	4.298	4.969	4.749	2.637
3	0.257	0.361	0.321	0.149	3.338	6.206	4.592	1.870
Big	0.060	0.070	0.325	0.052	0.706	0.681	4.101	0.941
	m_i				$t(m_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	-0.484	-0.173	0.097	0.285	-11.628	-4.726	1.929	4.444
2	-0.551	-0.236	0.032	0.267	-16.829	-6.544	0.748	4.549
3	-0.659	-0.303	-0.014	0.230	-15.997	-7.685	-0.280	5.117
Big	-0.914	-0.420	-0.125	0.453	-15.676	-8.658	-2.179	8.613
	a_i				$t(a_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	0.006	0.005	0.006	0.004	3.947	3.300	3.278	1.724
2	0.000	0.001	0.002	0.001	0.162	0.851	1.092	0.342
3	-0.001	-0.001	0.001	0.001	-0.645	-0.733	0.333	0.538
Big	0.001	0.001	-0.004	0.001	0.424	0.522	-2.765	0.660

Linear hypothesis test for $\mathbf{a}=\mathbf{0}$

Model (2)		Model (3)	
p-value	0.279	p-value	<2.2e-03

Table 5: Structural stability: F tests

	Model (1)				**Model (2)**			
p-values	Low	2	3	High	Low	2	3	High
Small	<2.2e-03	0.018	0.001	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	*0.064*
2	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03
3	<2.2e-03	0.030	0.024	0.050	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03
Big	<2.2e-03	<2.2e-03	0.038	*0.872*	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03

	Model (3)*				**Model (3)**			
p-values	Low	2	3	High	Loser	2	3	Winner
Small	<2.2e-03	<2.2e-03	<2.2e-03	0.023	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03
2	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03
3	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03	<2.2e-03
Big	<2.2e-03	<2.2e-03	<2.2e-03)	<2.2e-03	0.018	<2.2e-03	<2.2e-03	<2.2e-03

Notes: p-value>0.05 are set in italics

* Applied to portfolios formed on size and book-to-market equity.

Table 6: Breaking points

	Model (1)				**Model (2)**			
p-values	Low	2	3	High	Low	2	3	High
Small	1990(3)	1987(8	1990(3)	1990(3)	1997(8)	1990(10	1987(2)	1986(11)
2	1990(5)	1987(8)	1990(3)	1990(8)	1997(5)	1999(2)	1999(10)	1998(10)
3	1989(1)	1998(12)	1999(10)	1990(8)	1997(10)	1997(6)	1999(10)	1997(2)
Big	1990(8)	1986(11)	2000(3)	1999(6)	1998(8)	1993(4)	2000(5)	2002(10)

	Model (3)*				**Model (3)**			
p-values	Low	2	3	High	Loser	2	3	Winner
Small	2002(10)	1990(4	1990(10)	1999(9)	1992(11)	1998(2)	1998(7)	1999(10
2	2000(12)	1999(2)	1999(10)	1999(4)	1999(11)	1998(3)	1998(3)	1999(10
3	1999(5)	1997(6)	1999(10)	1997(2)	1999(10)	1998(7)	1997(7)	1997(10)
Big	1999(1)	1993(5)	2000(6)	2002(10)	2000(6)	1987(2)	2000(6)	1997(5)

Notes: The breakingpoint is defined as the last observation of the first period.

* Applied to portfolios formed on size and book-to-market equity.

Table 7: Descriptive statistics: 16 portfolios, period 1 (1984-1998)

Explanatory returns

	Sample moments				Correlation matrix				
	Rm	SMB	HML	WML		RM	SMB	HML	WML
Mean	0.220	-0.072	0.574	0.107	RM	1.000	-0.088	-0.221**	-0.099**
Median	0.253	0.194	0.510	0.345	SMB	-0.088	1.000	0.119	-0.344**
Maximum	18.405	15.014	10.522	15.058	HML	-0.221**	0.119	1.000	0.088
Minimum	-22.000	-14.711	-10.777	-25.299	WML	-0.099**	-0.344**	0.088	1.000
t-value	0.468	-0.192	2.407	0.284					

Dependent returns: portfolios formed on size and book-to-market equity

	Mean				t values			
	Low	2	3	High	Low	2	3	High
Small	0.191	0.412	0.524	0.725	0.295	0.678	0.906	1.265
2	-0.161	0.005	0.306	0.507	-0.269	0.010	0.531	0.892
3	-0.316	0.131	0.221	0.314	-0.560	0.240	0.418	0.569
Big	-0.107	0.529	0.493	0.593	-0.193	1.013	1.017	1.213

Dependent returns: portfolios formed on size and momentum

	Mean				t values			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	0.673	0.765	0.988	0.273	1.014	1.231	1.685	0.482
2	0.165	0.374	0.408	0.088	0.261	0.634	0.727	0.1661
3	0.063	0.090	0.302	0.157	0.098	0.158	0.567	0.305
Big	0.014	0.332	0.053	0.454	0.024	0.602	0.106	0.847

Notes:

For correlation matrix: *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table 8: Descriptive statistics: 16 portfolios, period 2 (1998-2009)

Explanatory returns

	Sample moments					Correlation matrix			
	Rm	SMB	HML	WML		RM	SMB	HML	WML
Mean	-0.144	-0.250	0.714	0.603	RM	1.000	-0.091	-0.262**	-0.255**
Median	0.052	-0.527	0.880	1.241	SMB	-0.091	1.000	0.085	-0.262**
Maximum	17.924	12.795	7.950	15.058	HML	-0.262**	0.085	1.000	-0.046
Minimum	-20.371	-14.072	-6.663	-25.299	WML	-0.255**	-0.262**	0.046	1.000
t-value	-0.325	-0.807	3.226	1.324					

Dependent returns: portfolios formed on size and book-to-market equity

	Mean				t values			
	Low	2	3	High	Low	2	3	High
Small	-0.399	-0.034	0.086	0.124	-0.585	-0.064	0.176	0.258
2	-0.693	-0.259	0.078	0.197	-1.102	-0.517	0.163	0.371
3	-0.244	-0.026	0.159	0.297	-0.417	-0.055	0.347	0.561
Big	-0.376	0.144	0.627	0.370	-0.799	0.359	1.366	0.722

Dependent returns: portfolios formed on size and momentum

	Mean				t values			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	0.203	0.180	0.334	0.600	0.298	0.369	0.749	1.180
2	-0.389	-0.137	0.161	0.308	-0.270	0.924	0.363	0.597
3	-0.512	-0.166	0.090	0.330	-0.737	-0.324	0.202	0.661
Big	-0.313	-0.387	-0.508	0.219	-0.423	-0.743	-1.126	0.454

Notes:

For correlation matrix: *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table 9: Differences in means for extreme portfolios: period 1 (1984-1998)

Portfolios formed on size and book-to-market equity

	Difference in means				t values			
	Small	2	3	Big	Small	2	3	Big
High-low	0.534	0.668	0.630	0.700	2.479	3.468	3.924	2.472
	Low	2	3	High	Low	2	3	High
Small-big	0.298	-0.118	0.031	0.132	0.758	-0.312	0.100	0.368

Portfolios formed on size and momentum

	Difference in means				t values			
	Small	2	3	Big	Small	2	3	Big
Winner-Loser	-0.400	-0.077	0.094	0.440	-1.463	-0.300	1.318	1.148
	Loser	2	3	Winner	Loser	2	3	Winner
Small-big	0.659	0.432	0.935	-0.181	2.035	1.231	2.816	-0.479

Table 10: Differences in means for extreme portfolios: period 2 (1998-2009)

Portfolios formed on size and book-to-market equity

	Difference in means				t values			
	Small	2	3	Big	Small	2	3	Big
High-low	0.523	0.889	0.541	0.746	2.381	3.670	2.590	2.866
	Low	2	3	High	Low	2	3	High
Small-big	-0.022	-0.178	-0.540	-0.245	0.058	-0.636	-2.218	-0.997

Portfolios formed on size and momentum

	Difference in means				t values			
	Small	2	3	Big	Small	2	3	Big
Winner-Loser	0.387	0.696	0.842	0.531	1.244	2.372	2.690	1.182
	Loser	2	3	Winner	Loser	2	3	Winner
Small-big	0.516	0.567	0.841	0.371	1.531	2.133	3.555	1.161

Table 11: Comparison of tests: $\mathbf{a}=\mathbf{0}$

	Size-value-sorted portfolios		Size-momentum-sorted portfolios	
	Model (2)	Model (3)	Model (2)	Model (3)
Full period	0.279	0.332	9.5e-0.6	6.5e-0.6
Period 1	0.775	0.842	0.016	0.074
Period 2	0.687	0.883	0.038	0.104

Table 12: Model (1): 16 portfolios, period 1 and period 2

Model (1): period 1 (1984-1998)									**Model (1): period 2 (1998-2009)**								
	b_i				$t(b_i)$					b_i				$t(b_i)$			
	Low	2	3	High	Low	2	3	High		Loser	2	3	Winner	Loser	2	3	Winner
Small	0.964	0.899	0.865	0.807	9.307	9.695	9.753	9.057	Small	0.993	0.789	0.760	0.732	8.391	8.425	8.913	8.353
2	0.955	0.967	0.961	0.919	11.259	13.274	10.970	11.382	2	0.953	0.845	0.801	0.863	8.226	9.915	10.175	10.552
3	1.043	1.027	0.968	1.025	14.888	15.322	20.422	18.633	3	1.034	0.862	0.824	0.921	11.536	11.678	12.172	11.136
Big	1.100	1.054	0.978	0.877	26.620	23.223	31.015	15.348	Big	1.045	0.829	0.938	0.882	55.064	17.603	18.105	10.404
	a_i				$t(a_i)$					a_i				$t(a_i)$			
	Low	2	3	High	Low	2	3	High		Loser	2	3	Winner	Loser	2	3	Winner
Small	-0.000	0.002	0.003	0.005	-0.044	0.423	0.696	1.020	Small	-0.003	0.000	0.002	0.002	-0.553	0.364	3.278	0.426
2	-0.004	-0.002	0.001	0.003	-0.886	-0.538	0.250	0.674	2	-0.006	-0.002	0.002	0.002	-1.210	-0.479	0.415	0.630
3	-0.005	-0.001	0.000	0.001	-2.035	-0.361	0.024	0.262	3	-0.001	0.001	0.002	0.004	-0.316	0.214	0.682	0.909
Big	-0.003	0.003	0.003	0.004	-1.573	1.621	1.900	1.532	Big	-0.002	0.003	0.008	0.005	-2.289	1.300	3.324	1.354
Linear hypothesis test for $\mathbf{a}=\mathbf{0}$																	
p-value	0.192								p-value	0.008							

Table 13: Model (2): 16 portfolios, period 1 and period 2

	Model (2): period 1 (1984-1998)									**Model (2): period 2 (1998-2009)**							
	b_i				$t(b_i)$					b_i				$t(b_i)$			
	Low	2	3	High	Low	2	3	High		Low	2	3	High	Low	2	3	High
Small	1.037	0.971	0.948	0.934	29.857	24.300	28.194	24.065	Small	1.094	0.907	0.868	0.870	16.531	19.180	14.598	18.610
2	0.982	1.041	1.041	1.038	30.237	45.261	55.082	51.168	2	1.014	0.932	0.913	1.044	19.226	22.592	24.556	50.399
3	1.061	1.069	1.031	1.108	30.316	28.616	34.448	35.884	3	1.078	0.956	0.943	1.081	23.529	17.630	19.735	22.464
Big	1.024	1.043	1.011	0.961	43.108	25.279	39.744	23.558	Big	1.015	0.865	1.001	1.012	68.083	18.255	21.354	15.747
	s_i				$t(s_i)$					s_i				$t(s_i)$			
	Low	2	3	High	Low	2	3	High		Low	2	3	High	Low	2	3	High
Small	1.133	1.062	0.988	0.957	19.537	27.550	15.803	17.505	Small	1.467	1.095	0.954	0.931	17.046	17.414	14.638	15.882
2	0.981	0.860	0.914	0.870	17.296	28.120	39.486	30.085	2	1.372	0.977	0.870	0.918	20.907	20.353	24.800	28.810
3	0.616	0.583	0.572	0.574	12.015	13.348	10.427	11.348	3	0.998	0.663	0.565	0.677	15.120	12.286	11.637	14.873
Big	-0.141	-0.233	-0.041	-0.193	-4.173	-3.674	0.861	-3.117	Big	-0.126	-0.116	0.062	0.097	-4.199	-3.176	0.924	1.131
	h_i				$t(h_i)$					h_i				$t(h_i)$			
	Low	2	3	High	Low	2	3	High		Low	2	3	High	Low	2	3	High
Small	-0.060	-0.018	0.134	0.540	-0.489	-0.159	1.094	4.060	Small	0.107	0.404	0.391	0.633	0.582	3.069	2.464	5.692
2	-0.371	0.123	0.151	0.519	-4.279	2.120	3.184	9.059	2	-0.153	0.218	0.465	0.965	-1.083	2.350	4.128	10.867
3	-0.224	0.012	0.206	0.380	-2.289	0.176	2.441	5.513	3	-0.118	0.420	0.658	0.918	-0.998	3.496	5.619	7.363
Big	-0.597	0.051	0.323	0.869	-7.245	0.597	3.619	6.373	Big	-0.170	0.328	0.449	0.950	-3.216	3.013	4.694	5.188
	a_i				$t(a_i)$					a_i				$t(a_i)$			
	Low	2	3	High	Low	2	3	High		Low	2	3	High	Low	2	3	High
Small	0.001	0.003	0.003	0.002	0.322	1.412	1.310	1.459	Small	0.001	0.001	0.002	0.000	0.140	0.225	0.572	0.131
2	-0.001	-0.002	0.001	0.000	-0.461	-1.414	0.510	0.378	2	-0.001	-0.000	0.001	-0.001	-0.266	-0.185	0.390	-0.818
3	-0.004	-0.001	-0.001	-0.001	-1.844	-0.410	-0.441	-0.815	3	0.002	-0.000	-0.000	-0.000	0.864	-0.097	-0.195	-0.169
Big	0.000	0.002	0.001	-0.001	0.001	1.565	0.479	-0.661	Big	-0.001	0.000	0.005	-0.001	-1.292	0.018	1.945	-0.330
									Linear hypothesis test for **a**=**0**								
p-value	0.775								p-value	0.687							

Table 14: Model (3): 16 portfolios, period 1 and period 2

Model (3): period 1 (1984-1998)

	b_i				$t(b_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	0.995	1.003	1.006	0.944	26.948	33.552	25.650	20.959
2	1.015	1.040	1.052	0.967	37.249	50.240	38.607	33.531
3	1.064	1.059	1.060	1.024	28.401	28.552	24.254	24.325
Big	0.977	0.991	1.004	1.047	26.736	18.004	21.999	30.067
	s_i				$t(s_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	1.027	1.068	1.040	1.006	20.015	21.644	18.689	17.741
2	0.805	0.831	0.815	0.878	27.613	23.611	39.486	20.705
3	0.530	0.557	0.540	0.540	10.595	12.200	10.153	9.767
Big	-0.071	-0.184	-0.119	-0.143	-1.247	-2.232	-2.034	-3.117
	h_i				$t(h_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	0.157	0.127	0.165	0.021	1.658	1.417	1.619	0.183
2	0.206	0.149	0.166	0.093	3.484	2.008	2.638	1.181
3	0.211	0.227	0.177	0.009	1.720	3.270	2.127	0.096
Big	0.069	0.119	0.398	0.126	0.438	0.647	3.578	1.309
	m_i				$t(m_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	-0.454	-0.147	0.169	0.328	-8.953	-3.334	3.111	4.635
2	-0.528	-0.212	0.053	0.323	-16.023	-6.085	1.137	6.628
3	-0.676	-0.320	0.010	0.327	-12.859	-7.637	0.157	5.021
Big	-0.845	-0.475	-0.089	0.450	-9.289	-5.089	-1.259	6.146
	a_i				$t(a_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	0.004	0.006	0.007	0.001	2.920	2.864	3.391	0.374
2	-0.001	0.001	0.001	-0.002	-0.419	0.983	0.812	-0.800
3	-0.002	-0.002	0.000	-0.001	-0.795	-1.234	0.024	-0.395
Big	-0.002	0.001	-0.004	0.001	-0.587	0.238	-1.787	0.426

Model (3): period 2 (1998-2009)

	b_i				$t(b_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	0.945	0.771	0.795	0.887	16.495	13.209	9.046	9.105
2	1.002	0.863	0.846	0.970	20.015	14.509	11.615	10.648
3	1.066	0.891	0.876	1.037	18.057	14.115	10.748	11.062
Big	1.056	0.914	0.887	1.063	13.059	11.926	13.150	24.275
	s_i				$t(s_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	1.223	0.946	0.889	1.037	13.459	15.978	9.530	7.246
2	1.031	0.794	0.795	1.012	14.618	14.046	11.100	9.970
3	0.772	0.593	0.580	0.774	11.835	8.175	8.087	8.902
Big	-0.015	-0.015	0.019	0.088	-0.127	-0.185	0.260	1.236
	h_i				$t(h_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	0.285	0.431	0.438	0.319	2.108	4.759	3.607	1.961
2	0.252	0.514	0.483	0.359	2.067	5.090	3.882	2.000
3	0.334	0.554	0.514	0.346	2.632	4.680	3.629	2.300
Big	0.017	0.051	0.194	-0.044	0.137	0.352	1.288	-0.480
	m_i				$t(m_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	-0.504	-0.197	0.045	0.271	-7.439	-3.218	0.494	2.136
2	-0.557	-0.267	0.016	0.245	-9.250	-4.766	0.205	2.065
3	-0.648	-0.313	-0.062	0.277	-9.409	-4.368	-0.753	2.641
Big	-0.949	-0.422	-0.194	0.425	-9.968	-7.077	-2.153	5.970
	a_i				$t(a_i)$			
	Loser	2	3	Winner	Loser	2	3	Winner
Small	0.007	0.003	0.003	0.005	2.478	1.326	1.004	1.237
2	0.001	0.000	0.001	0.003	0.659	-0.099	0.419	0.779
3	-0.000	-0.001	0.000	0.003	-0.057	-0.390	0.066	0.794
Big	0.004	-0.000	-0.004	0.002	1.356	-0.117	-1.404	0.755

Linear hypothesis test for **a**=**0**

	Period 1		Period 2
p-value	0.074	p-value	0.104

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