CFR-Working Paper NO. 10-12

The Cross-Section of German Stock Returns: New Data and New Evidence

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First Version: January 2010

This Version: April 2011

Abstract

This paper serves two purposes. First, we introduce a new data set on the German stock market which is publicly available to all researchers. It comprises factor returns (a market factor, a size factor, a book-to-market factor, and a momentum factor) as well as returns of portfolios which are single- and double-sorted according to beta, size, book-to-market, and momentum. Second, we use this data set to perform asset pricing tests for the German equity market. Specifically, we test the standard CAPM, the Fama-French three-factor model, and the Carhart four-factor model. Our tests are based on a more comprehensive data set than earlier studies and we investigate the sensitivity of the results to the choice of test assets. Our results indicate that none of the models is able to consistently explain the cross-section of returns. They also demonstrate that the results of asset pricing tests are sensitive to the choice of test assets.

JEL-Classification Codes: G12, G15

Keywords: Asset Pricing, Fama, French, Carhart, Characteristics, Risk Factors, Value, Size, Momentum, Germany

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Abstract

This paper serves two purposes. First, we introduce a new data set on the German stock market which is publicly available to all researchers. It comprises factor returns (a market factor, a size factor, a book-to-market factor, and a momentum factor) as well as returns of portfolios which are single- and double-sorted according to beta, size, book-to-market, and momentum. Second, we use this data set to perform asset pricing tests for the German equity market. Specifically, we test the standard CAPM, the Fama-French three-factor model, and the Carhart four-factor model. Our tests are based on a more comprehensive data set than earlier studies and we investigate the sensitivity of the results to the choice of test assets. Our results indicate that none of the models is able to consistently explain the cross-section of returns. They also demonstrate that the results of asset pricing tests are sensitive to the choice of test assets.

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1 Introduction

The explanation of the cross-section of stock returns is one of the most important and most frequently researched topics in finance. The starting point for much of this literature was the observations that there are systematic patterns in returns (such as the size effect, the book-to-market effect or return momentum) that are not easily reconciled with the Capital Asset Pricing Model (CAPM). Researchers responded to these findings by developing asset pricing models that include additional factors beyond the market risk premium. The current "industry standard" is the Fama French (1993) three-factor model (market risk premium, size and book-to-market) and the Carhart (1997) four-factor model (the three factors listed above augmented by return momentum[1]).

Unfortunately there is no theory that explains why these factors represent sources of risk that are priced in equilibrium. Fama and French (1993, 1995, 1998) argue that size and book-to-market proxy for default risk. Following their view, investors demand a premium for holding small, near-bankruptcy firms, because of their reduced ability to absorb negative financial shocks. Other papers argue that the size and book-to-market factors compensate for holding illiquid stocks (e.g., Brennan, Chordia, and Subrahmanyam (1998)), can be linked to future economic growth (Liew and Vassalou (2000)) or are related to innovations in state variables that forecast future investment opportunities (Petkova (2006)). Risk-based explanations for the momentum factor are scarce. A notable exception is Chordia and Shivakumar (2002) who argue that profits to momentum strategies can be explained by macroeconomic variables. Griffin, Ji, and Martin (2003), however, find that their results are not robust.

Most of the empirical evidence is based on US data. Among the advantages of US data is that the data is easily available and that the number of listed firms in the US is large and therefore allows for meaningful tests. These advantages come at a cost, however. Because a large number of papers are based on the same data set, any regularity in that data set – be it a characteristic of the underlying population or just a random occurrence – affects the results of

[1] *Jegadeesh and Titman (1993) showed that stocks with an above-average performance over the previous 12 months continue to outperform other stocks over the following months. This is referred to as return momentum. In a study of mutual fund performance, Carhart (1997) constructed a benchmark which adds a momentum factor to the Fama-French three-factor model. The resulting four-factor model is known as the Carhart model. The construction of the momentum factor is described in section 3 below.*

all studies. In this sense, additional studies do not necessarily provide independent new evidence.

Against this background, out-of sample tests using data from other countries than the US are warranted. However, limited data availability is a serious restriction in many cases. For the US, both factor returns (e.g. a market factor, a size factor, and a book-to-market factor) and returns on test assets (usually 25 portfolios double-sorted on size and book-to-market) can be downloaded from Kenneth French's homepage.[2] For many other countries, including Germany, comparable data is either not publicly available and / or spans much shorter sample periods and much fewer firms.

The purpose of the present paper is twofold. We describe a new data set which is freely available to all researchers and perform asset pricing tests using the new data set.[3] The data set covers more than 900 stocks listed at the Frankfurt Stock Exchange in the period 1960-2006. It consists of factor returns and returns of equity portfolios which can be used as test assets in asset pricing tests. However, application of the data is not limited to empirical asset pricing tests. The data may also prove valuable in other applications such as performance measurement and the estimation of cost of capital. Using the new data set, we test three standard models using a time-series regression approach, the CAPM, the Fama-French three factor model, and the Carhart four factor model. Our asset pricing tests add to the literature[4] in two important ways. (1) We perform our tests on different sets of test assets, including a set of industry portfolios. This is in response to a recommendation by Lewellen, Nagel, and Shanken (2010). These authors criticize the current practice of using only 25 size- and book-to-market-sorted portfolios as test assets (p. 190): *“Our basic conclusion is that asset pricing models should not be judged by their success in explaining average returns on size-B/M portfolios [...]”.* One of their suggestions for improved asset pricing tests is "*to include other portfolios in the tests, for example, portfolios sorted by industry [...]*" (p. 190). Our paper is among the first papers to implement this suggestion. (2) When evaluating the results of one-

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[2] *See http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/.*

[3] *The factors and the one- and two-dimensional test assets used in this study can be downloaded from http://www.cfr-cologne.com/.*

[4] *We do not attempt to review the empirical asset pricing literature here. Papers using data from the German equity market include Amel-Zadeh (2011), Artmann, Finter, and Kempf (2010), Breig and Elsas (2009), Elsas, El-Shaer, and Theissen (2003), Hagemeister and Kempf (2010), Koch (2009, 2010), Schlag and Wohlschieß (1997), Schrimpf, Schröder, and Stehle (2007), Stehle (1997), Wallmeier (2000), and Ziegler, Schröder, Schulz, and Stehle (2007).*

dimensional portfolio sorts we employ a test procedure recently proposed by Patton and Timmermann (2010). The traditional procedure is to sort assets into ten portfolios according to a firm characteristic (e.g. size) and then to compare the average returns of the two extreme portfolios using a simple t-test. However, a significant difference between the returns of the extreme portfolios does not allow the conclusion that returns are monotonically increasing or decreasing across the ten portfolios. The monotonic relationship (MR) test developed by Patton and Timmermann (2010) tests the null hypothesis of a flat relation against the alternative of a monotonic relation. When we apply the MR test to one.dimensional portfolio sorts we find that returns increase monotonically across ten portfolios sorted on return momentum. No such relation is found for portfolios sorted on beta, size, or book-to-market. These results are consistent with earlier findings of a momentum effect in the German stock market (e.g. Glaser and Weber 2003), but are inconsistent with the CAPM and the existence of either a size or a book-to-market effect.

Our regression-based asset pricing tests suggest that the test results are indeed sensitive to the choice of the test assets. When we form portfolios sorted according to beta or industry affiliation we find that all models explain the portfolio returns reasonably well. However, all models fail to explain the returns of portfolios sorted according to size and book-to-market. The CAPM and the Fama-French three-factor model also fail to explain the behavior of the momentum portfolios. The Carhart model shows the best results. It performs reasonably well on the momentum portfolios and generally delivers the lowest values of the Gibbons, Ross, and Shanken (1989) test statistic (GRS statistic). When we form portfolios sorted according to two criteria (all combinations of beta, size, book-to-market, and momentum) we obtain results that are rather unfavorable for the models under investigation. With only one exception the GRS statistic rejects all models at the 5% level. The four factor model again performs best, but it may only be the one-eyed man in the land of the blind.

Our results are somewhat less favorable for the standard asset pricing models under investigation than those of other recent studies for the German market (most notably Ziegler, Schröder, Schulz, and Stehle (2007)). This is partly due to differences in the data sets (ours extends from 1960 to 2006 as compared to 1967-1995) and partly due to differences in the test methodology (we base our conclusions on the GRS statistic which tests for joint significance of all regression intercepts while Ziegler, Schröder, Schulz, and Stehle (2007) only report t-statistics for the individual regression intercepts).

The remainder of the paper is organized as follows. In section 2 we describe our data set. Section 3 describes the construction of the factors. Section 4 introduces the test assets and presents the results of return comparisons based on one- and two-dimensional portfolio sorts. Section 5 presents the results of our asset pricing tests. Section 6 concludes.

2 Data

Our sample includes 955 non-financial German firms.[5] We restrict our analysis to non-financial firms because financial firms are subject to special accounting standards and risk factors (see Viale, Kolari, and Fraser (2009)). A considerable number of firms have issued different classes of shares (e.g. common shares and non-voting preferred shares). We include only one class per firm in the sample and use the class for which the longer data history is available.[6] The sample period extends from January 1960 to December 2006.

Table 1 shows the average number of firms for several sub-periods. In the first three decades of our sample period, the number of firms remains generally constant at around 200. In the 1990s numerous IPOs more than doubled the sample size. The maximum (598 firms) is reached in the year 2000.

< Please insert Table 1 approximately here >

We obtain daily stock prices from Karlsruher Kapitalmarktdatenbank (KKMDB) in Karlsruhe (Germany) and adjust these prices for dividends, splits, and equity offerings using data from KKMDB and Saling/Hoppenstedt Aktienführer.[7] Based on this data, we calculate discrete monthly stock returns. In order to reduce the impact of outliers we exclude the 0.25% smallest and largest return observations from the sample.

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[5] *We include all firms listed on the market segments "Amtlicher Handel" or "Neuer Markt". In addition, we consider stocks of firms listed on "Geregelter Markt" if they were listed on "Amtlicher Handel" or "Neuer Markt" at any time during our sample period. Firms listed in the OTC segment "Freiverkehr" only are not included in the sample.*

[6] *When the sample periods for both classes are identical we include the common shares.*

[7] *Saling/Hoppenstedt Aktienführer is an annual publication which contains information about all listed German firms such as balance sheet and profit and loss statement items.*

Betas of individual stocks are estimated at the end of June of each year τ. To estimate beta, we use rolling five year time series regressions based on monthly returns. We require that at least 24 of the 60 return observations are available and, thus, calculate beta at the end of June 1962 for the first time. Betas are calculated relative to the Deutscher Aktienforschungsindex (DAFOX), a value-weighted performance index designed for research purposes by KKMDB.[8] In 2005 and 2006 we use the CDAX, a value-weighted performance index of Deutsche Börse AG, as our market portfolio. Using two indices is necessary because the DAFOX is available only until 12/2004 while the CDAX is only available from 1970 onwards.[9] We use the one-month money market rate reported by Deutsche Bundesbank (series SU0104) as our proxy for the monthly risk-free rate of return.

Besides the market index we also use value-weighted industry performance indices calculated by Thomson Financial Datastream for the period 01/1973 to 12/2006. The sectors under scrutiny are: Basic Materials, Consumer Goods, Consumer Services, Financials, Healthcare, Industrials, and Utilities.[10]

Following Jegadeesh and Titman (1993) the momentum of a stock in month t is calculated as the cumulative past return from month t-12 to month t-2. The one month lag is imposed to avoid the short-term reversal effect first documented by Jegadeesh (1990).

In order to construct the size and book-to-market factors we use hand-collected data on common book equity and shares outstanding obtained from Saling/Hoppenstedt Aktienführer. This data is cross-checked with hand-collected information from annual reports and with data on stock splits and equity offerings from KKMDB. If a firm publishes individual and consolidated financial statements, we use consolidated balance sheet data on common book equity. Firm-years with negative book-values and short fiscal years (i.e., a fiscal year with less than 12 months) are excluded from the analysis.

We measure size by the market value of equity (stock price times shares outstanding) at the end of June of year τ. As mentioned above, some firms have issued different classes of shares. In some cases the classes are identical except for their par value. In this case we simply scale

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[8] *For the calculation of DAFOX see Göppl and Schütz (1995).*

[9] *DAFOX and CDAX are very similar with respect to the firms they cover and the weighting schemes they apply. A comparison of the two time series yields a Theil U coefficient of only 0.022 and a correlation of 0,98. Therefore, we consider the DAFOX/CDAX as an appropriate market proxy for our stock universe.*

[10] *Due to the inadequately low number of constituents we do not consider the sector index "Telecommunications". We further exclude the sector "Technology" because it is only available after 10/1988.*

the prices of unlisted classes appropriately. 117 of the sample firms have issued both common and preferred shares. When both classes are listed we calculate the market value of equity from the prices of both classes. When only one class is listed we assume that the value of the unlisted class is equal to the price of the listed class.

To calculate book-to-market equity (BE/ME) in year τ we divide book equity for the fiscal year ending in calendar year τ-1 by the market value of equity at the end of December in calendar year τ-1.[11] To avoid the effect of outliers, BE/ME is winsorized by setting the bottom (top) 1% values equal to the value corresponding to the 1st (99th) percentile of the empirical distribution.

< Please insert Table 2 approximately here >

Table 2 shows summary statistics of firm characteristics. Beta, size, and BE/ME are measured at a yearly frequency whereas momentum is calculated on a monthly basis. The distribution of firm size is heavily skewed. There are many small and micro caps in our sample: 25% of yearly firm size observations are below € 28 million. Even the 75th percentile is considerably smaller than the mean firm size. The average BE/ME is 0.69. The mean beta is 0.72, well below the value of one. This is due to the fact that, unlike in the US, smaller firms in Germany tend to have relatively lower betas (see, e.g., Stehle (1997) and Hagemeister and Kempf (2010)). Momentum, defined as the return over the past eleven months lagged by one month, averages 6.80%.

3 Factors

We follow Fama and French (1993) when constructing our SMB and HML factors, long-short portfolios designed to mimic risk factors associated with size and BE/ME characteristics. In June of each year from 1962 to 2006 all firms are ranked on size and BE/ME. The conservative six month lag is imposed to ensure that BE/ME of the previous year is known before ranking. Then, we employ independent sorts to allocate firms to two size groups and three BE/ME groups. We use the median size to split the sample into the group of small

[11] *We follow Fama and French (1992) and use December market equity for firms that do not have December fiscal year ends.*

stocks (S) and the group of big stocks (B). In a similar way (independent of size), the 30th and 70th percentiles of BE/ME serve as breakpoints for the three BE/ME groups: Low BE/ME stocks (L) are below the 30th percentile, high BE/ME stocks (H) are above the 70th percentile, medium BE/ME stocks (M) are in the middle 40%.

In the next step we form six portfolios, S/L, S/M, S/H, B/L, B/M, B/H, as the intersections of the size and BE/ME groups, and calculate the corresponding monthly value-weighted portfolio returns from July of year τ to June of year τ+1.[12] SMB ("Small Minus Big") is the difference in returns of the three small-stock portfolios ($r_{S/L}$, $r_{S/M}$, $r_{S/H}$) and the returns of the three big-stock portfolios ($r_{B/L}$, $r_{B/M}$, $r_{B/H}$):

$$SMB = \frac{1}{3}\left(r_{S/L} + r_{S/M} + r_{S/H}\right) - \frac{1}{3}\left(r_{B/L} + r_{B/M} + r_{B/H}\right). \tag{1}$$

HML ("High Minus Low"), a hedge-portfolio constructed to be size-neutral, is the difference in returns of the two high-BE/ME portfolios ($r_{S/H}$, $r_{B/H}$) and the returns of the two low-BE/ME portfolios ($r_{S/L}$, $r_{B/L}$):

$$HML = \frac{1}{2}\left(r_{S/H} + r_{B/H}\right) - \frac{1}{2}\left(r_{S/L} + r_{B/L}\right). \tag{2}$$

The construction of WML ("Winner Minus Loser"), the momentum factor, follows Carhart (1997). Each month t we rank stocks based on their past eleven-months return lagged one month. To provide an example, the ranking for the month of January is performed based on the return from January to November of the previous year. In the next step we form two equally-weighted portfolios: The loser portfolio contains the 30% stocks with the lowest past return, the winner portfolio includes the 30% stocks with the highest past return. WML is then simply the return difference between the winner and the loser portfolio.

The excess market return (RMRF) is calculated as the difference between the return of the market proxy and the risk-free rate. We use the value-weighted DAFOX/CDAX performance

[12] *For example, the firms in portfolio S/L are thus firms that are simultaneously among the 50% of firms with the lowest market capitalization and among the 30% of firms with the lowest book-to-market ratio.*

index (see Section 2), as our proxy for the market portfolio. The one-month money market rate serves as our proxy for the risk-free rate.

Descriptive statistics for the factors are reported in Panel A of Table 3. The premium on WML is the most pronounced with an average return of 0.90% per month, statistically different from zero at the 1% level. The average value premium (i.e., the premium on HML) is 0.49% per month and is also highly significant. The average market risk premium, RMRF, is 0.40% per month. It has the highest standard deviation of all four factors (4.96% per month) and is significantly different from zero only at the 10% level. The size factor, SMB, has an insignificant average return of -0.18% per month (the median is virtually 0% per month).

< Please insert Table 3 approximately here >

Pairwise cross-correlations between RMRF, SMB, HML, and WML are presented in Panel B of Table 3. Overall the correlations are weak, suggesting that the four hedge portfolios proxy for separate factors. By construction, the two Fama and French (1993) factors, SMB and HML, are almost uncorrelated (-0.04). WML shows no noticeable relation to SMB (-0.10) and low correlations with RMRF (-0.23) and HML (0.19). RMRF and SMB exhibit a strong negative correlation (-0.56).

Additionally, we compare the factor premia for the German market to the premia of other major stock markets such as Canada, Japan, the UK, and the US. Results are taken from L'Her, Masmoudi, and Suret (2004) for Canada, Daniel, Titman, and Wei (2001) for Japan, Gregory and Michou (2009) for the UK, and from Kenneth French's homepage[13] for the US (07/1962-12/2006).

With respect to RMRF, HML, and WML, our results are in line with the international evidence. The premium on RMRF ranges between 0.33% and 0.53% (to be compared to 0.40% for Germany) and the premium on HML ranges between 0.42% and 0.68% (compared to 0.49% for Germany). Evidence with respect to the momentum factor is somewhat mixed. The premium for the US (0.81%) has the same order of magnitude as the 0.90% we find, while Canada (1.34%) exhibits a larger premium. In the UK, however, the momentum factor exhibits a surprisingly low and insignificant premium (0.14%). Germany is not the only

[13] *Kenneth French's data library is located at http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/.*

country with an insignificant size premium. Similar findings have been documented for Japan (0.26%), the UK (0.01%) and the US (0.16%); only Canada shows a significant size premium (0.42%).

< Please insert Table 4 approximately here >

Booth and Keim (2000) demonstrate that the size and value premia tend to be concentrated in January. As documented in Table 4, such a seasonal pattern does not exist in the German market. January returns on HML tend to be lower than the average of the monthly returns from February to December. Even for SMB, we do not find a significant return difference, although returns are indeed higher in January (+0.21% as compared to -0.21% over the remaining 11 months).

Jegadeesh and Titman (2001) document that momentum profits also stand out in January where past losers earn significantly higher returns than past winners. Our findings are similar to theirs in that the WML returns are lower in January than in the other months. Contrary to their findings, however, we do not observe a significantly negative premium on WML in January.

The market factor displays a strong January effect: Market excess returns average 1.48% in January as compared to only 0.29% per month over the remainder of the year. The January return is statistically different from zero as well as statistically different from the value for February to December.

4 Test Portfolios

In this section we provide summary statistics for the portfolios that we use as test assets in our empirical analysis. The portfolios are sorted according to the criteria beta, size, BE/ME, and momentum. Beta, size, and BE/ME portfolios are formed at the end of June of each year τ and are held constant throughout the following twelve months. Portfolios sorted by momentum are rebalanced every month t.

4.1 One-Dimensional Portfolio Sorts

For the one-dimensional sorts we group stocks into ten equally-weighted portfolios. The average monthly returns as well as the standard deviations of the returns of these portfolios are shown in Table 5. In order to explore the relationship between the sorting characteristics and average returns, we use two approaches. First, we calculate the difference between the average returns of portfolios 10 and 1 and then use a standard t-test to test the difference against zero. The return differences are presented in the column labeled '10-1'. Second, we implement the Monotonic Relationship (MR) test recently proposed by Patton and Timmermann (2010). This procedure tests whether a monotonic relation between the sorting characteristic and average returns exists across the ten portfolios. Specifically, it tests the null hypothesis of a flat relation against the alternative of a monotonic relation. The alternative hypothesis can be formulated in two ways, namely, a monotonically increasing or decreasing relation. We specify the alternative hypothesis such that it is consistent with the evidence from the US. We test whether average returns are positively related to beta, book-to-market ratios and momentum, and negatively related to firm size. The last column of Table 5 shows the test statistics of the MR test.

< Please insert Table 5 approximately here >

At first sight the results are consistent with the existence of a BE/ME effect. The book-to-market ratio delivers a significant spread in average returns. The average return of portfolio 10 (highest book-to-market ratio) amounts to 1.18% per month as compared to an average return of portfolio 1 (lowest book-to-market ratio) of only 0.33% per month. The return difference is highly significant. These results are consistent with previous results for the German market (see, e.g., Schlag and Wohlschieß (1997), Wallmeier (2000)). However, the MR test does not reject the null hypothesis of a flat relation. Thus, when we impose the stricter requirement of a monotonic relation between book-to-market ratios and return (rather than the requirement of a significant return difference between the extreme portfolios) the evidence in favor of a book-to-market effect disappears.[14]

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[14] *We note that all tests presented in this section are univariate tests that disregard the effect that a third variable may have on the returns.*

The results in Table 5 provide strong support for the existence of a momentum effect. Past winners clearly outperform past losers. The return difference between the extreme portfolios amounts to 1.3% per month and is also highly significant. The MR test clearly rejects the null hypothesis of a flat relation in favor of the alternative of a monotonically increasing relation. The finding of a strong momentum effect in the German stock market is consistent with previous evidence (see, e.g., Glaser and Weber (2003), Schiereck, DeBondt, and Weber (1999)).

We do not find evidence in favor of a size effect. The return difference between the portfolios of the smallest and the largest stocks is only 0.05% per month, far from being significant. The MR test does not reject the null hypothesis of a flat relation. These results are in line with previous findings by Breig and Elsas (2009) and Schlag and Wohlschieß (1997), but stand in contrast to results reported in Stehle (1997) and Wallmeier (2000). These different findings are most likely caused by different sample periods. For example, in the last ten years of our sample period (1997-2006), large caps outperformed small caps significantly (1.03% per month for the largest portfolio as compared to 0.39% for the smallest portfolio). Studies that include this period are therefore unlikely to find a size effect.

Finally, our results do not support the Capital Asset Pricing Model. The relation between beta and return is essentially flat. The average return on the highest beta portfolio is smaller (by an insignificant 0.15% per month) than the return on the lowest beta portfolio. The MR test does not reject the null hypothesis of a flat relation. Our results are consistent with several earlier studies which also rejected the CAPM (see, e.g., Schlag and Wohlschieß (1997), Hagemeister and Kempf (2010)).

4.2 Two-Dimensional Portfolio Sorts

In this section we consider portfolios formed on two characteristics simultaneously. This enables us to analyze the interrelation of the four characteristics. We construct portfolios according to all possible combinations of the four characteristics: size & BE/ME, size & beta, beta & momentum, BE/ME & beta, BE/ME & momentum, and size & momentum. Portfolios are independently sorted. In order to have a sufficient number of observations in each portfolio we categorize stocks into 16 (4x4) portfolios based on the quartile breakpoints.[15] We then calculate the equally-weighted monthly returns of the resulting portfolios.

< Please insert Table 6 approximately here >

Table 6 displays the average returns of all 96 test portfolios (6 double sorts with 4x4 portfolios each). In line with our findings in the previous subsection we find that high momentum stocks outperform low momentum stocks and high BE/ME stocks generate higher returns than low BE/ME stocks, independent of the second sorting criterion. Double-sorting on BE/ME and momentum results in the largest return spread of all six double-sorts. The portfolio containing the highest momentum and highest BE/ME stocks performs best among all 96 portfolios (1.33% per month), whereas the portfolios containing the lowest momentum and the lowest BE/ME stocks performs worst (-0.10% per month). The return spread is thus 1.43% per month, corresponding to an annualized return of 17%.

On the other hand, size and beta create little variation in average returns across portfolios, irrespective of the second sorting criterion. Consider the size & beta sort as an illustration. The portfolio with the highest average return (0.93% per month) is the lowest-beta smallest-size portfolio. The other extreme portfolio (highest-beta largest-size) returns 0.73% on average, resulting in a spread of a meager 0.20% per month. Actually, the highest-beta second-smallest-size portfolio has the lowest average return (0.45%). However, the spread is still only 0.48% per month, far below the 1.43% spread produced by the BE/ME & momentum sort.

5 Regressions

In this section we test the CAPM, the Fama-French model and the Carhart model using different sets of test assets. We use a time-series approach in the spirit of Black, Jensen, and Scholes (1972) and Fama and French (1993) to test the models. A time-series approach is well suited to evaluate the performance of asset pricing models (see, e.g., Chen, Novy-Marx, and Zhang (2010) and Fama and French (1996)). The cross-sectional approach of Fama and

[15] *Conducting a 5x5 sorting scheme as is usually done in US studies results in an inadequately low number of stocks per portfolio.*

MacBeth (1973) and Fama and French (1992), on the other hand, is better suited to determine the factor risk premia (see, e.g., Harvey and Siddique (2000) and Ang, Hodrick, Xing, and Zhang (2006)).

We run time series regressions from July 1962 to December 2006[16] that use excess returns of test portfolios as the dependent variable and factor returns as explanatory variables:

$$r_t - r_{f,t} = \alpha + \beta' F_t + \varepsilon_t, \tag{3}$$

where r_t denotes the return of the test portfolio in month t, $r_{f,t}$ is the risk free rate in month t, and F_t denotes the vector of factor returns in month t. We run regression (3) for each test portfolio j and thus get a cross-section of $\hat{\alpha}_j$. If an asset pricing model is well-specified, i.e. if the model captures the cross-section of average returns, we should find that the null hypothesis that all $\hat{\alpha}_j$ are jointly equal to zero cannot be rejected. In order to test this hypothesis, we employ an F-test as proposed by Gibbons, Ross, and Shanken (1989) (GRS).

5.1 Using Factors to Explain One-Dimensional Test Assets

Initially, we concentrate on the four one-dimensionally sorted test portfolios as introduced in Section 4.1. The results are summarized in Table 7. For each of the 120 time-series regressions (3 models, 4 sorts with 10 test assets each), the table shows the intercept and its t-statistic, all slope coefficients[17] and the adjusted R^2. It also shows the GRS test statistic and the associated p-value.

< Please insert Table 7 approximately here >

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[16] *We additionally split the sample period into two sub-periods of equal length (07/1962-09/1984 and 10/1984-12/2006) and re-estimate all models (i.e. the CAPM, the three-factor model and the four-factor model for four one-dimensional and six two-dimensional portfolio sorts) for both sub-periods. The CAPM is almost always rejected in both sub-periods. The Fama-French model is rejected in about half of the cases in the first sub-period and is always rejected in the second-sub-period. The Carhart model is hardly rejected in the first sub-period (one rejection at the 5% level for the beta-momentum sort) but is always rejected in the second sub-period. These results lead to the conclusion that the Carhart model explains the cross-section of returns in Germany reasonably well in the first sub-period but fails in the second sub-period. The difference between the results for the two sub-periods may be due to institutional changes or to the increased number of listed firms. We have omitted the results for the sub-periods from the paper. They are available from the authors.*

[17] *To conserve space we do not report t-statistics for the slope coefficients. They are available upon request.*

We start by considering the ten beta portfolios (Panel A). The GRS test statistic (F_{GRS} = 1.393) does not reject the CAPM, i.e., the null hypothesis that all intercept coefficients are jointly equal to zero is not rejected. The individual intercept coefficients are numerically small and (with one exception) insignificant. The beta increases monotonically across the ten portfolios, but this is of course a natural result given that we are using ten beta-sorted portfolios as test assets. We next turn to the Fama-French model. Adding the size and BE/ME factor improves the explanatory power of the regression. Although several of the individual intercept coefficients are significant (one at the 5% level and three at the 10% level) they are numerically small. The GRS statistic does not reject the null hypothesis that they are jointly equal to zero. The Carhart four-factor model performs best. The individual intercept estimates are numerically small and (with one exception) insignificant and the GRS-statistic almost halves. Momentum betas decrease across the beta portfolios, mirroring the earlier finding that WML and RMRF are negatively correlated (see Table 3). We thus conclude that all three models explain the returns on beta-sorted test assets reasonably well.

Next, we consider test assets sorted by size (Panel B). The GRS statistic rejects the CAPM at the 1% level. Thus, the CAPM is unable to explain the returns of the size portfolios. This result, although consistent with the US evidence, is remarkable given our earlier finding that there is no pronounced size effect in Germany. The Fama-French model and the Carhart model do not perform better than the CAPM. Both models are rejected at the 5% level. Further, both have difficulties to explain the small firm portfolios as is evidenced by the numerically large and (in the case of the Carhart model) significant intercepts for the two smallest size portfolios. Thus, even though these models do include a size factor they are unable to fully explain the return pattern across size deciles.

The performance of the models becomes even more unfavorable when we consider the BE/ME portfolios (Panel C). All three models are rejected at the 1% level. In particular, none of the models is able to explain the return on the highest BE/ME portfolios, as is evidenced by the large and significant intercept coefficients.

Our last set of test assets consists of ten portfolios sorted on momentum (Panel D). The CAPM and the three-factor model are clearly rejected at the 1% level. In both cases six of the ten individual intercept coefficients are significantly different from zero at the 5% level. The four-factor model which includes a momentum factor performs much better. Only one individual intercept coefficient is significant at the 5% level, and the GRS test also does not reject the model at the 5% level.

So far, our results are not very favorable for the three models under investigation. All models are able to explain the returns of beta-sorted test assets. On the other hand, however, when we use portfolios sorted on size or BE/ME as test assets all models are rejected at (at least) the 5% level (in fact, the largest p-value is 0.013). Only the four-factor model stands the test when we use momentum-sorted test portfolios. In summary, the Carhart model performs best, but it is still far from providing a satisfactory explanation of the cross-section of returns.

5.2 Using Factors to Explain Two-Dimensional Test Assets

The current "industry standard" in the empirical asset pricing literature is to use portfolios double-sorted on size and BE/ME as test assets. In this section we report the results we obtain from our double-sorted test portfolios. However, we do not only double-sort according to size and BE/ME but rather implement all six independent double-sorts obtainable from the criteria beta, size, BE/ME, and momentum. As explained in Section 4.2, we sort stocks into 16 (4x4) portfolios. The results are documented in Table 8. The table displays, for each of the 18 tests (6 sets of test assets and 3 models), the test statistic and p-value of the GRS test as well as the mean, median, minimum and maximum adjusted R^2. It also shows the intercepts of the 288 individual time series regressions (16 for each of the 18 tests). [18]

We structure the presentation of the results according to the three models we test, starting with the CAPM. The GRS statistic indicates that the CAPM is rejected irrespective of the set of test assets we use. The least unfavorable result is obtained for the beta-size-sort. Here, the CAPM is only rejected at the 5% level (p-value 0.031). This is not very surprising because size and beta portfolios only deliver a small spread in average returns. Hence, there is not much to explain for the asset pricing model (see Cochrane (2005)). When considering the intercept coefficients in the individual time-series regressions, we find large and significant alphas for the lowest and highest momentum and BE/ME portfolios, indicating that the CAPM fails to properly explain the returns of these portfolios.

< Please insert Table 8 approximately here >

[18] *To conserve space we omit the slope coefficients and their t-values. These results are available upon request.*

The Fama-French model also does a poor job of explaining the two-dimensional portfolio sorts. Although the values of the GRS statistic are lower than those for the CAPM, the model is rejected, too. Again the least unfavorable result (with a p-value of 0.041) is the one for the beta-size-sort. Considering the individual regression intercepts, it appears that the Fama-French model has the most difficulties in explaining the returns of the extreme momentum portfolios. This is evidenced by a considerable number of large and significant intercept coefficients.

Finally, we examine the Carhart four-factor model. According to the GRS statistic this model performs best; the GRS-statistic is distinctly lower as compared to the other models. However, for five out of six sets of test assets the model is still rejected at the 5% level. The one exception is the beta-size sort. Considering the individual regression alphas we find that the Carhart model is incapable of explaining the return of the highest BE/ME portfolios. Most alphas for these portfolios are large and significant irrespective of the second sorting criterion.

5.3 Using Factors to Explain Industry Portfolios

Up to this point we followed the established practice of using test assets that are sorted according to the same variables (namely, beta, size, BE/ME, and momentum) that also underlie the construction of the factors. As an additional "reality check" we now consider industry portfolios. These have the additional advantage that the sorting of stocks into portfolios is independent of the share price.[19] Therefore, using industry portfolios provides a good yardstick to evaluate the performance of asset pricing models.

< Please insert Table 9 approximately here >

Table 9 presents the empirical results. The first two lines of the table show the monthly mean return and return standard deviation of the seven industry portfolios. The portfolios do not display much cross-sectional variation in average returns. The difference between the portfolio with the highest average monthly return (utilities: 1.01%) and the lowest average

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[19]*Both size and BE/ME are directly related to share price. Momentum is related to the share's previous return and thus to the change in share price.*

monthly return (consumer services: 0.74%) amounts to 0.27%. The standard deviation is lowest for utilities (3.62%) and highest for consumer goods (7.29%).

The lower part of Table 9 shows the test results for the three models under investigation. For each of the 21 time-series regressions (3 models, 7 industry portfolios) the table shows the intercept and its t-statistic, all slope coefficients[20] and the adjusted R^2. The first line of each sub-table shows two values of the GRS test statistic and the associated p-values. The first value is for a test which includes all seven industry portfolios. The second value is for a test which excludes financial firms.[21]

None of the three models is rejected. The four-factor model yields the lowest values of the GRS statistic (0.68 as compared to 1.12 for the three-factor model and 1.04 for the CAPM). Individual regression intercepts are small and insignificant for all industries except utilities. Tests excluding the financial sector result in slightly higher values of the GRS statistic but yield otherwise very similar conclusions. We should note that the good performance of the models in this test is likely to be due to the low cross-sectional variation in average industry portfolio returns. As Cochrane (2005, p. 444) puts it, "[i]f your portfolios have no spread in average returns [...], then there will be nothing for the asset pricing model to test".

To summarize our regression results, the Carhart four-factor model clearly performs best while the Fama-French three-factor model only performs slightly better than the parsimonious CAPM. The CAPM and the Fama-French model have difficulties in capturing the momentum effect. This is in line with previous US evidence (see, e.g., Fama and French (1996)). Moving to the Carhart model which incorporates a momentum factor distinctly improves the explanatory power. Even this best performing model, however, is far from satisfactorily explaining the cross-section of returns. Like the other two models it fails to explain the return on the high BE/ME portfolios in spite of the inclusion of the HML factor among the regressors.

[20] *To conserve space we do not report t-statistics for the slope coefficients. They are available upon request.*

[21] *Excluding financial firms from asset pricing tests is common practice. The usual justification is that accounting information for financial firms is not comparable to that for non-financial firms. In the present context, however, we do not use accounting information and therefore do not see much reason to exclude financial firms. Still, to enhance comparability to other studies we also report results that are obtained after the exclusion of financial firms.*

6 Conclusion

In this paper we introduce a new data set which is publicly available to all researchers and use it to run several asset pricing tests. The data set covers factor returns (a market factor, a size factor, a book-to-market factor, and a momentum factor) as well as returns of portfolios which are single- and double-sorted according to beta, size, book-to-market, and momentum.

We use this data set to test the CAPM, the Fama-French three-factor model, and the Carhart four-factor model for the German stock market. Our study improves upon previous studies by using a more extensive data set, by basing the results on different sets of test assets, and by implementing recently proposed statistical test procedures (the Patton and Timmermann (2010) test for monotonicity). Based on this test procedure we confirm earlier findings that there is a strong momentum effect in the German stock market. We do not find evidence of a book-to-market or a size effect.

The results of our asset pricing tests are not very favorable for the models under investigation. None of the models is able to consistently explain the cross-section of returns. The four-factor model performs best. It always delivers the lowest values of the GRS statistic, and it is able to explain the return pattern across momentum portfolios. Even this model, however, is rejected more often than not and thus does not provide a satisfactory explanation of the cross-section of stock returns in Germany.

Our results also indicate that the results of asset pricing tests are sensitive to the choice of test assets, a point which has also been made by Lewellen, Nagel, and Shanken (2010). Future research should take this into account and test the robustness of results to the selection of the test assets.

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Table 1
Number of Firms

Period	Average Number of Firms	Period	Average Number of Firms
1960-1962	210	1984-1986	223
1963-1965	206	1987-1989	258
1966-1968	192	1990-1992	300
1969-1971	173	1993-1995	317
1972-1974	189	1996-1998	363
1975-1977	215	1999-2001	569
1978-1980	215	2002-2004	524
1981-1983	207	2005-2006	482

Notes: This table shows the average number of firms in our sample for different sub-periods. All firms are listed at the Frankfurt Stock Exchange. The number of firms reported is equal to the number of firms used in the construction of the factors. Financial firms are excluded.

Table 2
Summary Statistics for Beta, Size, BE/ME, and Momentum: 1962 – 2005 (44 Years)

	Mean	Std. Dev.	Median	25th Percentile	75th Percentile
Beta	0.72	0.48	0.68	0.35	1.01
Size (million €)	892.22	5204.17	93.45	27.99	335.71
BE/ME	0.69	0.57	0.54	0.35	0.84
Momentum	6.80%	39.22%	2.90%	-14.56%	23.64%

Notes: This table shows summary statistics for the firm characteristics used in our analysis. Beta is estimated relative to the DAFOX (CDAX from 2005 onwards) at the end of June of each year τ using rolling five year time series regressions with monthly returns. Size is measured by market value of equity (stock price multiplied by shares outstanding) at the end of June of year τ. To calculate book-to-market equity (BE/ME) in year τ we divide book equity for the fiscal year ending in calendar year τ-1 by the market value of equity at the end of December of calendar year τ-1. Firm-years with negative book-values and short fiscal years are excluded. Momentum is defined as the return from month t-12 to month t-2 and is calculated on a monthly basis.

Table 3
Descriptive Statistics and Cross-Correlations for Factors, 07/1962 to 12/2006 (534 Months)

Panel A Descriptive Statistics	RMRF	SMB	HML	WML
Mean	0.40%*	-0.18%	0.49%***	0.90%***
Std. Dev.	4.96%	3.02%	2.85%	3.51%
Skewness	-0.25	-0.41	0.41	-0.35
Kurtosis	5.13	4.40	8.64	9.92
Minimum	-22.13%	-12.96%	-12.24%	-17.78%
25th Percentile	-2.46%	-1.91%	-1.05%	-0.67%
Median	0.47%	-0.06%	0.37%	0.99%
75th Percentile	3.27%	1.79%	1.94%	2.44%
Maximum	19.05%	10.61%	19.23%	17.55%

Panel B Cross-Correlations	RMRF	SMB	HML	WML
RMRF	1.00			
SMB	-0.56	1.00		
HML	0.01	-0.04	1.00	
WML	-0.23	-0.10	0.19	1.00

*Notes: This table shows descriptive statistics (Panel A) and cross-correlations (Panel B) for the market factor (RMRF), the size factor (SMB), the value factor (HML), and the momentum factor (WML). RMRF is calculated as the return difference between the DAFOX (CDAX from 2005 onwards) and the risk free rate. SMB and HML are calculated as in Fama and French (1993), WML is calculated as in Carhart (1997). SMB (HML) goes long in small (high BE/ME) stocks and short in large (low BE/ME) stocks. WML goes long in past winners and short in past losers. * denotes significance at 10%, *** denotes significance at 1%.*

Table 4
January Seasonality of Factor Premiums,
01/1963 to 12/2006 (528 Months)

		January	NonJan (Feb - Dec)	Jan - NonJan
RMRF	Mean	1.48%**	0.29%	1.19%*
	Std. Dev.	4.30%	4.93%	4.48%
SMB	Mean	0.21%	-0.21%	0.42%
	Std. Dev.	3.39%	2.99%	3.39%
HML	Mean	0.31%	0.55%***	-0.24%
	Std. Dev.	4.12%	2.69%	4.60%
WML	Mean	0.20%	0.98%***	-0.78%
	Std. Dev.	4.51%	3.38%	5.32%

*Notes: This table shows average monthly returns and standard deviations of RMRF, SMB, HML, and WML for January and February to December (NonJan). The last column presents the mean and the standard deviation of the difference in returns between the January return and the average monthly returns between February and December. RMRF is calculated as the return difference between the DAFOX (CDAX from 2005 onwards) and the risk free rate. SMB and HML are calculated as in Fama and French (1993), WML is calculated as in Carhart (1997). SMB (HML) goes long in small (high BE/ME) stocks and short in large (low BE/ME) stocks. WML goes long in past winners and short in past losers. * denotes significant at 10%, ** denotes significance at 5%, *** denotes significance at 1%.*

Table 5
Monthly Percentage Average Returns and Standard Deviations for Portfolios Formed on Beta, Size, BE/ME, and Momentum: 07/1962 – 12/2006 (534 Months)

		Deciles										Overall	
		1 (low)	2	3	4	5	6	7	8	9	10 (high)	10-1	MR-Test
Beta	Return	0.76	0.80	0.82	0.81	0.74	0.79	0.73	0.83	0.71	0.61	-0.15	-0.12
	Std. Dev.	2.65	2.85	3.32	3.55	3.89	4.23	4.54	4.77	5.54	6.16		
Size	Return	0.81	0.82	0.63	0.56	0.60	0.63	0.68	0.56	0.84	0.76	-0.05	-0.29
	Std. Dev.	3.98	4.08	4.00	4.30	4.21	4.49	4.20	4.36	4.34	4.91		
BE/ME	Return	0.33	0.41	0.54	0.49	0.69	0.58	0.83	0.88	0.94	1.18	0.85***	-0.11
	Std. Dev.	4.48	4.35	4.17	4.13	4.11	4.18	4.04	4.22	4.47	4.61		
Momentum	Return	0.14	0.22	0.37	0.52	0.58	0.76	0.78	1.00	1.03	1.45	1.30***	0.03***
	Std. Dev.	6.24	5.26	4.67	4.23	4.09	3.70	3.68	3.62	3.88	4.46		

*Notes: This table shows average monthly returns and return standard deviations for equally-weighted portfolios sorted on beta, size, BE/ME, and momentum. Portfolios for beta, size, and BE/ME are rearranged at the end of June of each year τ and are held constant throughout the following twelve months. Portfolios formed on momentum are rearranged each month. Beta is estimated relative to the DAFOX (CDAX for 2005 and 2006) at the end of June of each year τ using rolling five year time series regressions with monthly returns. Size is measured by the market value of equity (stock price multiplied by shares outstanding) at the end of June of year τ. To calculate BE/ME in year τ we divide book equity for the fiscal year ending in calendar year τ-1 by the market value of equity at the end of December in calendar year τ-1. Firm-years with negative book-values and short fiscal years are excluded. Momentum is defined as the return from month t-12 to month t-2. The column labeled "Overall" shows the return difference between portfolio 10 and portfolio 1 and the test statistic of the Patton and Timmermann (2010) Monotonic Relationship (MR) test. We test if average returns are monotonically increasing in betas, book-to-market ratios, and momentum and monotonically decreasing in firm size. *** denotes significance at 1%.*

Table 6

Monthly Percentage Average Returns for Six Different (4x4) Independently Double-Sorted Portfolios on Beta, Size, BE/ME, and Momentum: 07/1962 – 12/2006 (534 Months)

		BE/ME						Beta			
		1 (low)	2	3	4 (high)			1 (low)	2	3	4 (high)
Size	1 (low)	0.45	0.55	0.78	1.04	BE/ME	1 (low)	0.58	0.62	0.55	0.40
	2	0.27	0.59	0.53	0.95		2	0.86	0.64	0.69	0.55
	3	0.36	0.48	0.75	1.16		3	0.98	0.71	0.78	0.72
	4 (high)	0.48	0.71	0.88	1.08		4 (high)	1.18	0.97	1.11	0.95
		Beta						Momentum			
Size	1 (low)	0.93	0.59	0.86	0.73	BE/ME	1 (low)	-0.10	0.28	0.63	0.98
	2	0.81	0.76	0.69	0.45		2	0.03	0.37	0.74	1.16
	3	0.69	0.76	0.81	0.75		3	0.20	0.56	0.86	1.20
	4 (high)	0.72	0.86	0.86	0.73		4 (high)	0.58	0.94	1.18	1.33
		Momentum						Momentum			
Size	1 (low)	0.37	0.71	0.98	1.26	Beta	1 (low)	0.39	0.65	0.92	1.17
	2	0.01	0.52	0.71	1.20		2	0.49	0.53	0.74	1.22
	3	-0.09	0.44	0.93	1.15		3	0.21	0.68	0.93	1.20
	4 (high)	0.30	0.51	0.77	1.03		4 (high)	0.08	0.55	0.95	1.07

Notes: This table shows average monthly returns for equally-weighted double-sorted portfolios. Stocks are independently categorized into 16 (4x4) portfolios based on the quartile breakpoints. Portfolios sorted on momentum as one characteristic are formed every month, while the other portfolios are rebalanced in June of each year τ. Beta is estimated relative to DAFOX (CDAX from 2005 onwards) at the end of June of each year τ using rolling five year time series regressions with monthly returns. Size is measured by the market value of equity (stock price multiplied by shares outstanding) at the end of June of year τ. To calculate BE/ME in year τ we divide book equity for the fiscal year ending in calendar year τ-1 by the market value of equity at the end of December in calendar year τ-1. Firm-years with negative book-values and short fiscal years are excluded. Momentum is defined as the return from month t-12 to month t-2.

Table 7

Time Series Regressions on Single Sorted Test Assets Formed on Beta, Size, BE/ME, Momentum: 07/1962 – 12/2006 (534 Months)

	1 (low)	2	3	4	5	6	7	8	9	10 (high)
Panel A: Beta Deciles										
CAPM (F_{GRS} = 1.393, p_{GRS} = 0.180)										
Alpha	0.188	0.206	0.189	0.159	0.050	0.062	-0.017	0.053	-0.113	-0.254
T-Statistic$_{Alpha}$	1.521	1.770	1.501	1.162	0.424	0.492	-0.126	0.398	-0.746	-1.531
Beta	0.300	0.358	0.461	0.500	0.611	0.687	0.755	0.819	0.934	1.044
adj. R^2	0.305	0.375	0.465	0.476	0.594	0.635	0.670	0.714	0.690	0.700
Fama-French Model (F_{GRS} = 1.414, p_{GRS} = 0.170)										
Alpha$_{Fama\ French}$	0.175	0.214	0.136	0.136	0.010	0.032	-0.058	0.011	-0.192	-0.223
T-Statistic$_{Alpha}$	1.670	2.277	1.517	1.334	0.126	0.356	-0.607	0.134	-1.763	-1.828
Beta	0.452	0.526	0.647	0.700	0.822	0.896	0.967	1.023	1.153	1.267
Beta$_{SMB}$	0.450	0.498	0.552	0.592	0.627	0.622	0.628	0.604	0.650	0.658
Beta$_{HML}$	0.072	0.035	0.165	0.107	0.146	0.124	0.148	0.146	0.227	0.003
adj. R^2	0.485	0.560	0.651	0.651	0.762	0.773	0.795	0.819	0.787	0.771
Carhart Model (F_{GRS} = 0.765, p_{GRS} = 0.663)										
Alpha$_{Carhart}$	0.145	0.185	0.123	0.114	0.066	0.067	0.016	0.084	0.045	0.098
T-Statistic$_{Alpha}$	1.330	1.883	1.406	1.129	0.826	0.756	0.171	1.036	0.379	0.666
Beta	0.462	0.536	0.651	0.708	0.803	0.884	0.942	0.998	1.072	1.157
Beta$_{SMB}$	0.463	0.510	0.558	0.602	0.603	0.607	0.596	0.573	0.547	0.519
Beta$_{HML}$	0.064	0.027	0.161	0.100	0.162	0.133	0.169	0.166	0.292	0.092
Beta$_{WML}$	0.036	0.034	0.015	0.027	-0.067	-0.043	-0.089	-0.088	-0.285	-0.385
adj. R^2	0.486	0.561	0.651	0.651	0.765	0.774	0.799	0.822	0.814	0.811
Panel B: Size Deciles										
CAPM (F_{GRS} = 2.602, p_{GRS} = 0.004)										
Alpha	0.183	0.159	-0.048	-0.144	-0.114	-0.111	-0.047	-0.191	0.079	-0.070
T-Statistic$_{Alpha}$	1.003	0.897	-0.317	-0.894	-0.815	-0.818	-0.371	-1.632	0.909	-1.127
Beta	0.446	0.534	0.570	0.639	0.662	0.719	0.689	0.746	0.785	0.954
adj. R^2	0.303	0.411	0.491	0.532	0.597	0.622	0.652	0.709	0.789	0.915
Fama-French Model (F_{GRS} = 2.323, p_{GRS} = 0.011)										
Alpha$_{Fama\ French}$	0.193	0.174	-0.055	-0.116	-0.018	-0.045	0.019	-0.139	0.092	-0.100
T-Statistic$_{Alpha}$	1.591	1.604	-0.712	-1.398	-0.264	-0.508	0.212	-1.603	1.142	-1.624
Beta	0.736	0.828	0.851	0.940	0.945	0.940	0.876	0.899	0.863	0.938
Beta$_{SMB}$	0.859	0.869	0.830	0.890	0.834	0.650	0.550	0.450	0.232	-0.046
Beta$_{HML}$	0.067	0.058	0.099	0.033	-0.111	-0.066	-0.079	-0.061	-0.003	0.057
adj. R^2	0.593	0.692	0.761	0.797	0.849	0.755	0.762	0.777	0.806	0.917
Carhart Model (F_{GRS} = 2.271, p_{GRS} = 0.013)										
Alpha$_{Carhart}$	0.331	0.316	0.091	-0.005	0.095	0.144	0.144	-0.005	0.137	-0.019
T-Statistic$_{Alpha}$	2.741	2.828	1.039	-0.054	1.263	1.661	1.580	-0.064	1.734	-0.321
Beta	0.689	0.779	0.801	0.902	0.907	0.875	0.833	0.854	0.848	0.910
Beta$_{SMB}$	0.800	0.808	0.767	0.841	0.785	0.568	0.496	0.392	0.213	-0.082
Beta$_{HML}$	0.105	0.097	0.139	0.064	-0.080	-0.014	-0.044	-0.024	0.009	0.079
Beta$_{WML}$	-0.165	-0.171	-0.175	-0.133	-0.135	-0.228	-0.151	-0.160	-0.053	-0.098
adj. R^2	0.610	0.709	0.780	0.806	0.859	0.781	0.775	0.790	0.807	0.921

Table 7 (continued)
Time Series Regressions on Single Sorted Test Assets Formed on Beta, Size, BE/ME, Momentum: 07/1962 – 12/2006 (534 Months)

	1 (low)	2	3	4	5	6	7	8	9	10 (high)
Panel C: BE/ME Deciles										
CAPM (F_{GRS} = 4.143, p_{GRS} = 0.000)										
Alpha	-0.376	-0.310	-0.176	-0.230	-0.028	-0.146	0.132	0.154	0.211	0.465
T-Statistic$_{Alpha}$	-2.146	-2.008	-1.410	-1.856	-0.245	-1.182	1.039	1.140	1.274	2.673
Beta	0.651	0.676	0.678	0.684	0.683	0.694	0.630	0.682	0.693	0.670
adj. R^2	0.511	0.588	0.640	0.664	0.667	0.666	0.588	0.630	0.582	0.511
Fama-French Model (F_{GRS} = 2.652, p_{GRS} = 0.004)										
Alpha$_{Fama\ French}$	-0.101	-0.095	-0.050	-0.171	-0.031	-0.164	0.090	0.034	0.070	0.335
T-Statistic$_{Alpha}$	-0.907	-1.153	-0.635	-2.050	-0.409	-1.933	0.996	0.430	0.750	2.781
Beta	0.824	0.876	0.870	0.865	0.880	0.891	0.851	0.890	0.943	0.939
Beta$_{SMB}$	0.500	0.581	0.562	0.534	0.584	0.584	0.655	0.623	0.747	0.804
Beta$_{HML}$	-0.508	-0.380	-0.198	-0.064	0.065	0.096	0.151	0.308	0.362	0.345
adj. R^2	0.698	0.766	0.773	0.771	0.793	0.789	0.760	0.802	0.802	0.738
Carhart Model (F_{GRS} = 2.724, p_{GRS} = 0.003)										
Alpha$_{Carhart}$	0.101	0.098	0.127	-0.021	0.038	-0.085	0.168	0.129	0.193	0.447
T-Statistic$_{Alpha}$	0.894	1.176	1.485	-0.248	0.510	-1.006	1.893	1.598	2.047	3.574
Beta	0.755	0.811	0.810	0.814	0.857	0.864	0.824	0.858	0.901	0.901
Beta$_{SMB}$	0.413	0.498	0.485	0.469	0.554	0.549	0.621	0.582	0.694	0.755
Beta$_{HML}$	-0.452	-0.327	-0.149	-0.023	0.084	0.117	0.173	0.334	0.396	0.376
Beta$_{WML}$	-0.242	-0.230	-0.212	-0.180	-0.082	-0.095	-0.093	-0.113	-0.148	-0.135
adj. R^2	0.727	0.795	0.800	0.790	0.797	0.794	0.765	0.810	0.813	0.747
Panel D: Momentum Deciles										
CAPM (F_{GRS} = 6.016, p_{GRS} = 0.000)										
Alpha	-0.643	-0.534	-0.362	-0.201	-0.134	0.065	0.094	0.316	0.333	0.732
T-Statistic$_{Alpha}$	-3.052	-2.861	-2.124	-1.452	-0.987	0.595	0.825	2.808	2.774	4.897
Beta	0.844	0.773	0.713	0.685	0.663	0.614	0.603	0.592	0.614	0.664
adj. R^2	0.445	0.526	0.563	0.636	0.636	0.665	0.646	0.643	0.601	0.533
Fama-French Model (F_{GRS} = 5.279, p_{GRS} = 0.000)										
Alpha$_{Fama\ French}$	-0.474	-0.397	-0.289	-0.171	-0.136	0.061	0.053	0.277	0.309	0.763
T-Statistic$_{Alpha}$	-3.050	-3.413	-2.879	-1.712	-1.512	0.804	0.675	3.298	3.235	5.189
Beta	1.163	1.050	0.967	0.888	0.874	0.791	0.774	0.752	0.783	0.820
Beta$_{SMB}$	0.935	0.811	0.749	0.599	0.623	0.522	0.508	0.475	0.501	0.459
Beta$_{HML}$	-0.250	-0.197	-0.071	0.000	0.068	0.061	0.136	0.128	0.100	-0.016
adj. R^2	0.601	0.689	0.726	0.760	0.780	0.789	0.772	0.756	0.707	0.598
Carhart Model (F_{GRS} = 1.793, p_{GRS} = 0.059)										
Alpha$_{Carhart}$	0.271	0.169	0.139	0.074	-0.029	0.106	-0.003	0.102	0.074	0.429
T-Statistic$_{Alpha}$	1.859	1.603	1.592	0.774	-0.343	1.334	-0.033	1.288	0.857	3.287
Beta	0.909	0.857	0.821	0.804	0.837	0.776	0.793	0.811	0.863	0.933
Beta$_{SMB}$	0.612	0.566	0.564	0.493	0.577	0.503	0.532	0.551	0.603	0.604
Beta$_{HML}$	-0.045	-0.041	0.047	0.067	0.097	0.073	0.121	0.080	0.035	-0.108
Beta$_{WML}$	-0.893	-0.678	-0.514	-0.293	-0.129	-0.054	0.066	0.210	0.282	0.400
adj. R^2	0.813	0.861	0.850	0.809	0.790	0.791	0.775	0.790	0.760	0.680

Notes: This table shows the results of the CAPM regressions, the Fama-French three-factor regressions, and the Carhart four-factor regressions on one-dimensionally sorted test assets. For each asset pricing model, the Gibbons, Ross, and Shanken (1989) F-statistic (FGRS) and its p-value (pGRS) is reported. Standard errors are adjusted for heteroscedasticity and autocorrelations. Portfolios for beta, size, and BE/ME (Panels A, B, C) are rearranged at the end of June of each year τ and are held constant throughout the following twelve months. Portfolios formed on momentum (Panel D) are rearranged every month. RMRF is calculated as the return difference between the DAFOX (CDAX from 2005 onwards) and the risk free rate. SMB and HML are calculated as in Fama and French (1993), WML is calculated as in Carhart (1997). SMB (HML) goes long in small (high BE/ME) stocks and short in large (low BE/ME) stocks. WML goes long in past winners and short in past losers

Table 8
Time Series Regressions on Independent Double Sorted Test Assets: 07/1962 – 12/2006 (534 Months)

Panel A: Size (Rows) and BE/ME (Columns) Portfolios

	(a) CAPM (F_{GRS} = 3.056, p_{GRS} = 0.000)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	-0.178	-0.091	0.124	0.363*
2	-0.429**	-0.105	-0.186	0.241
3	-0.352*	-0.251*	0.028	0.403**
4 (high)	-0.296**	-0.090	0.090	0.294*
	Mean	Median	Min.	Max.
adj. R^2	0.526	0.521	0.266	0.806
	(b) Fama-French Model (F_{GRS} = 2.046, p_{GRS} = 0.010)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	-0.111	-0.021	0.117	0.307**
2	-0.168*	-0.033	-0.194**	0.078
3	-0.089	-0.179*	-0.023	0.255**
4 (high)	-0.096	-0.086	-0.052	0.042
	Mean	Median	Min.	Max.
adj. R^2	0.696	0.717	0.474	0.816
	(c) Carhart Model (F_{GRS} = 2.014, p_{GRS} = 0.011)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	0.069	0.130	0.327***	0.416***
2	0.101	0.091	-0.144	0.157
3	0.140	-0.050	0.036	0.361***
4 (high)	0.013	0.004	-0.014	0.156
	Mean	Median	Min.	Max.
adj. R^2	0.710	0.743	0.499	0.821

Panel B: Size (Rows) and Beta (Columns) Portfolios

	(a) CAPM (F_{GRS} = 1.781, p_{GRS} = 0.031)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	0.358**	-0.049	0.175	-0.057
2	0.206*	0.096	-0.048	-0.351*
3	0.086	0.089	0.074	-0.070
4 (high)	0.104	0.170	0.062	-0.154
	Mean	Median	Min.	Max.
adj. R^2	0.483	0.499	0.224	0.834
	(b) Fama-French Model (F_{GRS} = 1.712, p_{GRS} = 0.041)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	0.341***	-0.065	0.107	-0.013
2	0.212**	0.063	-0.079	-0.371***
3	0.065	0.033	0.066	-0.093
4 (high)	0.083	0.104	-0.017	-0.195**
	Mean	Median	Min.	Max.
adj. R^2	0.620	0.604	0.247	0.839
	(c) Carhart Model (F_{GRS} = 1.144, p_{GRS} = 0.311)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	0.338**	-0.038	0.234*	0.235
2	0.130	0.048	-0.027	-0.094
3	0.035	0.055	0.067	0.161
4 (high)	0.113	0.112	0.035	0.050
	Mean	Median	Min.	Max.
adj. R^2	0.627	0.604	0.246	0.864

Table 8 (continued)

Time Series Regressions on Independent Double Sorted Test Assets: 07/1962 – 12/2006 (534 Months)

	Panel C: BE/ME (Rows) and Beta (Columns) Portfolios				**Panel D: BE/ME (Rows) and Momentum (Columns) Portfolios**			
	(a) CAPM (F_{GRS} = 3.488, p_{GRS} = 0.000)				**(a) CAPM (F_{GRS} = 5.299, p_{GRS} = 0.000)**			
Alpha	1 (low)	2	3	4 (high)	1 (low)	2	3	4 (high)
1 (low)	0.006	-0.018	-0.190	-0.455***	-0.860***	-0.450***	-0.047	0.287*
2	0.268**	-0.026	-0.072	-0.280*	-0.742***	-0.356**	0.053	0.456***
3	0.387***	0.053	0.043	-0.106	-0.556**	-0.160	0.162	0.508***
4 (high)	0.550***	0.286*	0.383**	0.143	-0.178	0.221	0.482***	0.629***
	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.
adj. R^2	0.499	0.519	0.238	0.698	0.527	0.524	0.424	0.619
	(b) Fama-French Model (F_{GRS} = 2.725, p_{GRS} = 0.000)				**(b) Fama-French Model (F_{GRS} = 4.272, p_{GRS} = 0.000)**			
Alpha	1 (low)	2	3	4 (high)	1 (low)	2	3	4 (high)
1 (low)	0.077	-0.007	-0.148	-0.328***	-0.563***	-0.270**	0.074	0.479***
2	0.278***	-0.047	-0.060	-0.236**	-0.608***	-0.301***	0.064	0.455***
3	0.341***	0.010	-0.030	-0.181*	-0.456***	-0.220**	0.080	0.424***
4 (high)	0.462***	0.161	0.212*	-0.001	-0.258*	0.119	0.327***	0.487***
	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.
adj. R^2	0.630	0.674	0.404	0.782	0.665	0.662	0.571	0.753
	(c) Carhart Model (F_{GRS} = 2.331, p_{GRS} = 0.002)				**(c) Carhart Model (F_{GRS} = 2.264, p_{GRS} = 0.003)**			
Alpha	1 (low)	2	3	4 (high)	1 (low)	2	3	4 (high)
1 (low)	0.065	-0.010	-0.210	-0.097	0.051	0.054	0.033	0.198
2	0.228**	-0.016	0.020	0.025	-0.068	-0.077	0.033	0.188*
3	0.309**	-0.001	0.029	0.024	0.208*	-0.083	0.033	0.174
4 (high)	0.427***	0.180	0.307***	0.244	0.308**	0.286**	0.309***	0.282**
	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.
adj. R^2	0.637	0.679	0.404	0.802	0.727	0.731	0.630	0.819

Table 8 (continued)

Time Series Regressions on Independent Double Sorted Test Assets: 07/1962 – 12/2006 (534 Months)

Panel E: Size (Rows) and Momentum (Columns) Portfolios

	(a) CAPM (F_{GRS} = 4.633, p_{GRS} = 0.000)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	-0.319	0.063	0.362**	0.620***
2	-0.744***	-0.185	0.048	0.518***
3	-0.892***	-0.294*	0.233*	0.453***
4 (high)	-0.564***	-0.293**	0.002	0.273**
	Mean	Median	Min.	Max.
adj. R^2	0.512	0.511	0.290	0.795
	(b) Fama-French Model (F_{GRS} = 3.993, p_{GRS} = 0.000)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	-0.234	0.052	0.308**	0.568***
2	-0.601***	-0.148	0.052	0.482***
3	-0.720***	-0.239**	0.201**	0.464***
4 (high)	-0.484***	-0.329***	-0.054	0.283**
	Mean	Median	Min.	Max.
adj. R^2	0.653	0.658	0.472	0.816
	(c) Carhart Model (F_{GRS} = 1.778, p_{GRS} = 0.031)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	0.315**	0.204*	0.230*	0.357**
2	0.006	0.039	0.001	0.184*
3	-0.056	0.024	0.142	0.225**
4 (high)	0.197	-0.013	-0.022	-0.021
	Mean	Median	Min.	Max.
adj. R^2	0.718	0.744	0.501	0.841

Panel F: Beta (Rows) and Momentum (Columns) Portfolios

	(a) CAPM (F_{GRS} = 5.581, p_{GRS} = 0.000)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	-0.253	0.050	0.346**	0.576***
2	-0.223	-0.152	0.097	0.561***
3	-0.573***	-0.072	0.192	0.483***
4 (high)	-0.763***	-0.289*	0.138	0.279*
	Mean	Median	Min.	Max.
adj. R^2	0.489	0.518	0.210	0.715
	(b) Fama-French Model (F_{GRS} = 4.86, p_{GRS} = 0.000)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	-0.212	0.057	0.317***	0.572***
2	-0.241	-0.190*	0.064	0.490***
3	-0.523***	-0.116	0.134	0.414***
4 (high)	-0.734***	-0.300**	0.086	0.196*
	Mean	Median	Min.	Max.
adj. R^2	0.616	0.653	0.386	0.772
	(c) Carhart Model (F_{GRS} = 2.567, p_{GRS} = 0.001)			
Alpha	1 (low)	2	3	4 (high)
1 (low)	0.227	0.118	0.226*	0.339**
2	0.108	-0.095	-0.022	0.324***
3	-0.076	-0.012	0.114	0.189
4 (high)	-0.120	-0.016	0.202	-0.002
	Mean	Median	Min.	Max.
adj. R^2	0.655	0.695	0.404	0.779

*Notes: This table shows the results of the CAPM regressions, the Fama-French three-factor regressions, and the Carhart four-factor regressions on two-dimensionally sorted test assets. For each asset pricing model, the Gibbons, Ross and Shanken (1989) F-statistic (FGRS) and its p-value (pGRS) is reported. Standard errors are adjusted for heteroscedasticity and autocorrelations. Portfolios for beta, size, and BE/ME (Panels A, B, C) are rearranged at end of June of each year τ and are held constant throughout the following twelve months. Portfolios formed on momentum as one characteristic (Panels D, E, F) are rearranged every month. RMRF is calculated as the return difference between the DAFOX (CDAX from 2005 onwards) and the risk free rate. SMB and HML are calculated as in Fama and French (1993), WML is calculated as in Carhart (1997). SMB (HML) goes long in small (high BE/ME) stocks and short in large (low BE/ME) stocks. WML goes long in past winners and short in past losers. * denotes significance at 10%, ** denotes significance at 5%, *** denotes significance at 1%*

Table 9

Time Series Regressions on Industry Portfolios: 01/1973 – 12/2006 (408 Months)

.	Basic Materials	Industrials	Consumer Goods	Healthcare	Consumer Services	Utilities	Financials
Mean Return	0.98%	0.93%	0.84%	0.84%	0.74%	1.01%	0.96%
Std. Dev.	5.44%	5.51%	7.29%	4.47%	5.77%	3.62%	6.27%
	CAPM (F_{GRS} = 1.039, p_{GRS} = 0.402; Non-Financials Only: F_{GRS} = 1.216, p_{GRS} = 0.297)						
Alpha	0.123	0.027	-0.080	0.085	-0.114	0.387	0.000
T-Statistic$_{Alpha}$	0.842	0.236	-0.342	0.523	-0.680	2.364	0.004
Beta	0.903	0.998	1.044	0.659	0.892	0.376	1.121
adj. R^2	0.690	0.822	0.512	0.543	0.598	0.265	0.804
	Fama-French Model (F_{GRS} = 1.119, p_{GRS} = 0.350; Non-Financials Only: F_{GRS} = 1.297, p_{GRS} = 0.257)						
Alpha$_{Fama\ French}$	-0.151	-0.050	-0.206	0.013	-0.134	0.349	-0.000
T-Statistic$_{Alpha}$	-1.177	-0.450	-0.875	0.083	-0.790	2.179	-0.001
Beta	0.824	0.953	1.095	0.703	0.951	0.449	1.174
Beta$_{SMB}$	-0.209	-0.128	0.164	0.139	0.179	0.223	0.157
Beta$_{HML}$	0.403	0.093	0.263	0.164	0.089	0.131	0.048
adj. R^2	0.748	0.828	0.525	0.559	0.605	0.299	0.808
	Carhart Model (F_{GRS} = 0.682, p_{GRS} = 0.687; Non-Financials Only: F_{GRS} = 0.796, p_{GRS} = 0.574)						
Alpha$_{Carhart}$	-0.058	0.055	0.001	-0.039	-0.116	0.316	-0.021
T-Statistic$_{Alpha}$	-0.468	0.549	0.002	-0.250	-0.691	1.856	-0.149
Beta	0.794	0.919	1.029	0.720	0.945	0.460	1.180
Beta$_{SMB}$	-0.250	-0.174	0.074	0.162	0.170	0.237	0.166
Beta$_{HML}$	0.429	0.122	0.320	0.150	0.094	0.122	0.042
Beta$_{WML}$	-0.100	-0.114	-0.224	0.056	-0.020	0.036	0.023
adj. R^2	0.752	0.833	0.535	0.560	0.604	0.298	0.808

Notes: This table shows average monthly returns and standard deviations for industry portfolios and the results of the CAPM regressions, the Fama-French three-factor regressions, and the Carhart four-factor regressions on industry portfolios. For each asset pricing model, the table reports the Gibbons, Ross and Shanken (1989) F-statistic (F_{GRS}) and its p-value (p_{GRS}) for (a) a regression model including all industry portfolios and (b) a model including all industry portfolios excluding "Financials". Standard errors are adjusted for heteroscedasticity and autocorrelations. RMRF is calculated as the return difference between the DAFOX (CDAX from 2005 onwards) and the risk free rate. SMB and HML are calculated as in Fama and French (1993), WML is calculated as in Carhart (1997). SMB (HML) goes long in small (high BE/ME) stocks and short in large (low BE/ME) stocks. WML goes long in past winners and short in past losers.

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