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Limits to arbitrage, investor sentiment, and factor returns in international government bond markets

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ABSTRACT

The perspective of behavioural finance is that anomalies in the cross-section of returns are driven by mispricing that arises from investor irrationality that cannot be easily arbitraged away. In this study, we examine the implications of this for international government bond markets. Using data for 25 countries for the years 1992–2015, we replicate multiple factor strategies that represent four major return drivers: defensive (low-risk), carry, value and momentum. We investigate the relationships between the performance of these strategies and market-wide measures of limits to arbitrage and investor sentiment. We find that the defensive strategy performs best during tight arbitrage conditions whereas severe limits to arbitrage negatively affect momentum profits.

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1. Introduction

Recent finance literature has documented numerous equity anomalies that have parallels in government bond markets. For example, Asness, Moskowitz and Pedersen (2013) demonstrate the profitability of value and momentum strategies in government bond markets and Frazzini and Pedersen (2014) show that defensive or low-risk strategies also work in bonds. Koijen, Moskowitz, Pedersen and Vrugt (2016) report that the carry strategy can be implemented in multiple asset classes – including government bonds. Moreover, numerous other studies have document that these four broad strategies – defensive, carry, value and momentum – are robust return drivers in international government bond markets.[1]

Although the existence of these return patterns is widely acknowledged, the reasons for their existence have not been explored. While the neoclassical explanation suggests underlying risk factors, the behavioural finance explanation is that persistent return regularities are manifestations of asset mispricing that results from investor irrationality which enables the emergence of these anomalies and limits to arbitrage

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and which prevents investors from exploiting mispricing.[2] The behavioural explanation leads to practical implications that can be tested empirically. Specifically, it suggests that inefficiencies should be particularly pronounced during periods of increased investor irrationality and severe arbitrage constraints. An investigation into this issue may not only provide new insights into asset pricing but may also form the underpinnings of practical tools that can be used for asset allocation across investment strategies in government bond markets.

The primary aim of this article is to examine the role of market-wide limits to arbitrage and investor sentiment in returns on factor strategies for government bond markets. Namely, we contribute to the literature by investigating the role of limits to arbitrage and investor sentiment in government bonds returns on factor strategies, a relatively unexplored asset class. In doing so, we address a gap in the literature by focusing on government bond markets and not on equity markets, as most previous studies with a similar theme have done.

We begin the study with a replication of four well-documented strategies for global government bonds, namely the defensive, carry, value and momentum strategies. For each strategy, we use six different specifications and obtain 24 different return predictive signals. Next, using data for 25 countries for the years 1992–2015, we form long–short portfolios based upon 24 return patterns. We also construct composite strategies that represent combinations of defensive, carry, value and momentum sub-strategies.

Subsequently, we design ad hoc indices that proxy for market-wide conditions of investor sentiment and limits to arbitrage. The proxy for investor sentiment is constructed from a combination of four different measures representing business, consumer and investor sentiment in multiple countries. The proxy for arbitrage constraints mirrors the T.E.D. spread, credit spread, expected overall volatility and idiosyncratic volatility. Finally, by utilising a broad set of regressions, we investigate the relationship between the performance of factor strategies for government bonds, arbitrage conditions and/or investor sentiment.

The main findings of this article can be summarised as follows. First, we confirm the profitability of the four bond selection approaches examined; the defensive, carry, value and momentum strategies. All are associated with positive payoffs that are robust to numerous considerations. Second, we find that the defensive strategy is related to limits to arbitrage; profitability increases during periods of severe arbitrage constraints. This effect is robust to numerous considerations and renders the influence of investor sentiment insignificant. Third, contrary to our initial expectation, the momentum effect produces higher returns during periods of low limits to arbitrage. This observation is consistent with the findings of Avramov, Cheng and Hameed (2016), Jacobs (2015) and Zaremba (2016b) who find that high liquidity and abundant availability of financing facilitates momentum profits. The two other strategies show no distinct correlation with market-wide changes in arbitrage constraints or investor sentiment. In summary, these findings produce new insights into the ongoing debate on the nature of cross-sectional return patterns. Our observations support the hypothesis that returns are generated by the application of a low-risk strategy in international government bond markets that is driven by behavioural mispricing. In contrast, our observations suggests that the carry, value and momentum premia potentially reflect underlying risk factors.

The remainder of the article is organised as follows. The next section reviews the literature on the subject. This is then followed by an outline of the data and research methods employed. We then present and discuss the empirical findings. The last section concludes.

2. Literature review

The study draws upon two streams of literature that consider: (1) the influence of limits to arbitrage and sentiment on return predictability in various asset classes; and (2) the return cross-sectional return patterns in government bonds.

Regarding the influence of limits to arbitrage and investor sentiment, the previous literature has focuses almost solely on the equities. Stambaugh, Yu and Yuan investigate the impact of time-varying investor sentiment on eleven equity anomalies in the U.S. market. Kim and Na (2015) extend this to consider macroeconomic variables. Jacobs test a broad range of a 100 equity anomalies and investigate the influence of not only the sentiment, but also of the limits to arbitrage proxies: volatility, bid-ask spreads or liquidity. Zaremba (2016b) replicates these investigation for a country-level framework and tests the influence of limits to arbitrage on country-level cross-sectional return regularities. Selected studies also attempt to examine the influence of limits to arbitrage on emerging markets. The work of Xavier and Machado (2017), which focuses on Brazil, is an example. A focus limited to equity markets presents a gap that calls for further exploration. This research contributes to the literature by examining a set of factor strategies in international government bond markets and testing these for relationships with market-wide proxies for arbitrage constraints and investor sentiment. We emphasise that while the nature of equity anomalies has already been extensively investigated, analogous investigations for government bond markets are limited. As far as we are aware, this is the first study to examine the influence of investor sentiment and limits to arbitrage on factor returns in international government bond markets.

We also contribute to literature on cross-sectional return patterns in government bonds. The majority of earlier studies concentrate on individual return patters. Luu and Yu (2012), Duyvesteyn and Martens (2014), Hambusch, Hong and Webster (2015) consider the momentum effect. Beekhuizen, Duyvesteyn, Martens and Zomerdijk (2016), de Carvalho, Dugnolle, Lu and Moulin (2014) and Durham (2016) examine defensive strategies based upon duration or volatility. Asness, Ilmanen, Israel and Moskowitz (2015), Beekhuizen, Duyvesteyn, Martens and Zomerdijk (2016) and Bolla (2017) research yield-based strategies that are linked to the concept of carry investing. Finally, Asness, Ilmanen, Israel and Moskowitz (2015) and Asness, Moskowitz and Pedersen also discuss value effects. This article examines a number of different strategies jointly in the style of Zaremba and Czapkiewicz (2017) and thus permitting comparison.

3. Data and methods

This study aims to investigate the effects of market-wide limits to arbitrage and investor sentiment on the performance of factor strategies for government bonds.

Therefore, we first form a set of 24 different bond strategies and subsequently examine whether their performance is influenced by changes in sentiment and arbitrage conditions. We then employ regressions to investigate the relationship between the performance of factor strategies, arbitrage conditions and investor sentiment. This section presents the data sources and the methodology employed in the preparation of the sample and the factor strategies that we investigate. We then present our proxy measures of limits to arbitrage and investor sentiment and the methodology used to examine the role of these proxies. Finally, we outline the robustness checks employed.

3.1. Data sources and sample preparation

The sample used in this study employs monthly returns on the Bloomberg/EFFAS Total Return Bond Indices for 25 countries for the period between January 1992 and October 2015. Our return sample begins in December 1994 (251 monthly observations in total) and we use earlier data to construct sorting variables for the purposes of portfolio formation. The sample includes all countries and the entire period covered by Bloomberg/EFFAS. Indices are determined separately for five maturity buckets, namely 1–3 years, 3–5 years, 5–7 years, 7–10 years and more than 10 years. This produces a total of 125 international government bond buckets that we use in our investigation. The present sample is broader than that used by most earlier studies of return regularities in international government bonds (e.g., Asness et al., 2013; Frazzini & Pedersen, 2014; Beekhuizen, Duyvesteyn, Martens & Zomerdijk, 2016) and includes a unique default event: Greece.

To disentangle returns associated with currency fluctuations and actual bond returns and to ensure currency consistency across multiple markets, we employ returns hedged against the U.S. dollar. We gather data denominated in local currencies and then adjust for hedging costs using 1-month forward points quoted by Bloomberg. Table A1 in the Online Appendix provides a summary of the research sample.[3] All other data that we use in this study, such as index characteristics, sovereign ratings and macroeconomic data, are also sourced from Bloomberg. For cash rates, we use T-Bill rates from Kenneth French's website.[4]

3.2. Factor strategies

To derive returns on factor strategies in government bond markets, we follow Asness et al. (2015) and investigate four major strategy types: defensive (or low-risk), carry, value and momentum. To ensure robustness, we replicate six different return predictive signals, relying primarily upon the variants used by Zaremba (2017). We implement a uniform portfolio formation procedure for all strategies. For each month, we rank all bond buckets on a sorting variable related to a return determinant. Next, we form zero-investment equal-weighted portfolios that are long (short) in the bucket quantiles with the highest (lowest) values of the sorting variable.[5]

The first category – defensive – assumes going long in low-beta assets and short in high-beta assets. We take into account the observations of Beekhuizen, Duyvesteyn, Martens and Zomerdijk (2016) and de Carvalho, Dugnolle, Lu and Moulin (2014), who indicate that beta signals may also be proxied by duration-based measures that tend to be more stable. Consequently, the variables for the defensive strategy include: (1) adjusted duration; (2) life; (3) duration and three different betas based upon; (4) 36-month; (5) 48-month; and (6) 60-month formation periods. The second group – carry – assumes investment in higher yielding markets that is financed by shorting (or borrowing) in lower yielding markets (Asness et al., 2015). This category includes various yield measures, either raw or adjusted for local hedging costs, duration and credit risk: (7) yield-to-maturity; (8) term premium; (9) term relative value; (10) credit relative value; (11) term-and-credit relative value; and (12) term-and-sovereign relative value. For the value strategies, we follow the approach of Asness, Moskowitz and Pedersen (2013) and use long-run changes in yields as a proxy for the value-based return predictive signals. To establish robustness, we again use six different variants: changes in: (13) 30-month; (14) 36-month; (15) 42-month; (16) 48-month; (17) 54-month; and (18) 60-month yields. Finally, the last category includes six measures that proxy for the momentum effect that are also employed by Zaremba (2017): (19) the six-month price momentum; (20) the 12-month price momentum; (21) the six-month yield momentum; (22) the 12-month yield momentum; (23) the six-month moving average; and (24) the 12-month moving average.

3.3. The role of investor sentiment and limits to arbitrage

To investigate the influence of market-wide limits to arbitrage and investor sentiment, we broadly follow the approach of Jacobs (2015) and Zaremba (2016b) and develop ad hoc measures of both phenomena based upon the four subcomponents.

3.3.1. Investor sentiment

Following Stambaugh, Yu, and Yuan (2012) and Jacobs (2015), as a first indicator, we employ the basic Baker and Wurgler (2006) market-level investor sentiment index (S_{BW}). This is a monthly index composed of various components that reflect aspects such as I.P.O. volume and discounts, closed-end fund discounts and N.Y.S.E. turnover.[6] The second metric is the University of Michigan Consumer Sentiment Index (S_{MC}), which is an interview-based indicator published by the University of Michigan.[7] This metric is also employed by Jacobs (2015). As a third measure, we use AAII Investor Sentiment Surveys (S_{AAI})[8] conducted among U.S. market participants by the American Association of Individual Investors. Specifically, for each month, we calculate the difference between bullish and bearish readings and employed this difference as a sentiment indicator. Fourth, we use the Economic Sentiment Indicator (S_{ESI}) provided by the European Commission.[9] This is a composite indicator comprising of five sectoral confidence indicators related to industry, services, consumers, construction and retail trade. Values are based upon a selection of questions closely related to the reference variable that each indicator tracks.

To facilitate the interpretation results, each of the measures above is normalised before further analysis. Subsequently, we also calculate a composite sentiment indicator (*SENT*), that is the normalised value of the averaged z-scores of all of the sentiment subcomponents (S_{BW}, S_{MC}, S_{AAI}, S_{ESI}).

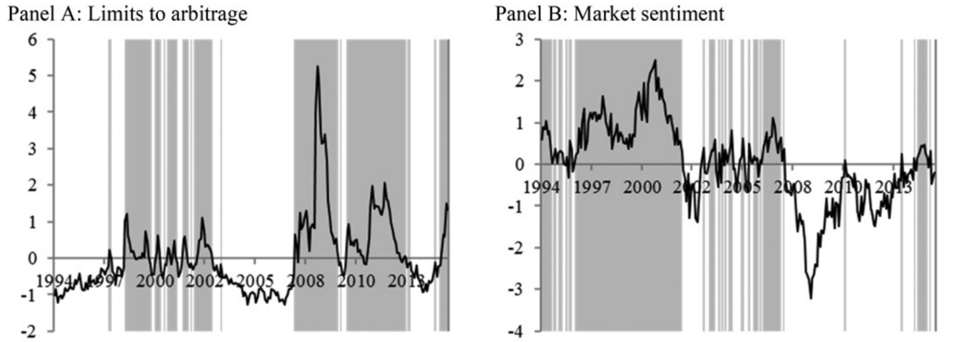
A limitation of these sentiment indicators is that they do not directly measure worldwide sentiment but only that of markets in the U.S. and the European Union. There are no global sentiment indicators available that coincide with the present sample period to our knowledge. We therefore assume that sentiment for the two largest economic areas in the world provides a sufficient representation of general sentiment relevant for the present international sample. Furthermore, by using a combination of indicators covering financial markets and real economies for various countries, we hope to eliminate the influence of noise and to better extract pure investor sentiment.

3.3.2. Limits to arbitrage

Our composite measure of limits to arbitrage also broadly follows that of Jacobs (2015) and comprises of four components: T.E.D. spread, credit spread, expected total volatility and idiosyncratic volatility. T.E.D. spread is defined as the difference between the three-month L.I.B.O.R. Eurodollar rate and the three-month T-Bill rate (A_{TED}). It is assumed to reflect perceived credit risk in interbank loans relative to riskless U.S. short-term government bonds. The spread usually widens during market distress due to the 'flight-to-liquidity' phenomenon (Brunnermeier & Pedersen, 2009) and is frequently used as a proxy for funding liquidity (Ang, Gorovyy, & van Inwegen, 2011; Asness et al., 2013; Brunnermeier & Pedersen, 2009; Frazzini & Pedersen, 2014; Moskowitz, Ooi, & Pedersen, 2012). Arguments similar to those setting out the mechanism of the T.E.D. spread can be put forward for a credit spread proxy (Akbas, Armstrong, Sorescu, & Subrahmanyam, 2016; Engelberg, Gao, & Jagannathan, 2008). We measure the credit spread as the difference between Moody's corporate yields for bonds rated BAA and the benchmark 10-year U.S. government bond yields (A_{BAA}).

Another indicator of the limits to arbitrage that we employ is the Chicago Board Options Exchange Market Volatility Index (V.I.X.), which expresses the implied volatility of short-term index options on the S&P500 index (A_{VIX}).[10] The increased limits to arbitrage faced by investors in times of high V.I.X. values may stem from several sources. Vayanos (2004) provides evidence of higher risk aversion and 'flight-to-quality' effects when the V.I.X. is elevated. Also, several papers indicate that periods of high expected volatility lead to tighter funding constraints for investors, difficulties in borrowing or raising money or even fund withdrawals by investors leading to forced position unwinding (Shleifer & Vishny, 1997; Brunnermeier & Pedersen, 2009; Gromb & Vayanos, 2002). Finally, Ang et al. (2011) and Ben-David, Franzoni, and Moussawi (2012) demonstrate that hedge funds may face the necessity of reducing leverage during high-V.I.X. periods.

While the V.I.X. is an equity-oriented measure of overall risk, Pontiff (1996), McLean (2010) and Akbas et al. (2016) argue that idiosyncratic risk should also be related to the diversification concerns of arbitrageurs – the higher the idiosyncratic volatility, the higher the limits to arbitrage. Therefore, we use this variable as the fourth component of our composite measure of limits to arbitrage and derive it using international bond returns (A_{IVOL}). Specifically, we first define the idiosyncratic volatility of a given bond bucket as the standard deviation of the residual obtained from regressing monthly excess returns on the market portfolio of all of the bond buckets in the sample, weighted according to their market value. Subsequently, for each



Note. These figures are the time-series of proxies for market-wide limits to arbitrage (Panel A) and investor sentiment (Panel B) as set out in the section on methods. The shaded (blank) areas represent periods of above-median (below-median) limits to arbitrage and above-median (below-median) market sentiment in Panels A and B respectively.

Figure 1. Proxies of limits to arbitrage and investor sentiment.
Note. These figures are the time-series of proxies for market-wide limits to arbitrage (Panel A) and investor sentiment (Panel B) as set out in the section on methods. The shaded (blank) areas represent periods of above-median (below-median) limits to arbitrage and above-median (below-median) market sentiment in Panels A and B respectively.

bucket, we calculate the equally weighted average idiosyncratic risk for our bond universe, which fulfills the role of a composite measure of idiosyncratic risk.

As with the sentiment measures, all of these variables are normalised. Subsequently, we compute a composite indicator of limits to arbitrage (*ARB*), a normalised value of the averaged *z*-scores of all four subcomponents: A_{TED}, A_{BAA}, A_{VIX}, and A_{IVOL}. The time series of composite measures of sentiment and of limits to arbitrage are plotted in Figure 1. The measures presented exhibit some negative correlation, with the Pearson's coefficient equaling -0.57.

After obtaining proxies for market-wide limits to arbitrage and sentiment, we investigate their role in bond strategies by conducting regression tests as in Jacobs (2015). For robustness, we use both standard continuous variables as well as dummy (binary) variables that represent current conditions. The dummy variables take the value of one (zero) in month *t* when a given indicator (of sentiment or limits to arbitrage) is above (below) its median at the end of month *t*-1.

We then employ a two-stage regression approach. First, for each long–short portfolio of bonds, we regress raw monthly excess returns on the excess return on the market portfolio, i.e., the value-weighted portfolio of all bonds in our sample. This approach estimates a bond equivalent of the C.A.P.M. model (Sharpe, 1964). Then, we define the benchmark-adjusted monthly return in month *t* as the sum of the intercept of a portfolio *i* and the residual from the regression model in month *t*. Second, we regress the time series of benchmark-adjusted returns on variables that represent limits to arbitrage or investor sentiment.

3.2. Robustness checks

To ensure the validity of the results, we conduct a set of robustness checks at various stages.

3.2.1. Alternative breakpoints

We form three types of portfolios based upon different breakpoints: quintile, quartile, and tertile portfolios. We employ quartile portfolios as the default approach and use the other two portfolios for the purposes of robustness checks.

3.2.2. Alternative weighting methods

Our base approach assumes equal-weighted portfolios. For robustness checks, we also consider a value-weighted scheme.

3.2.3. Adjusted vs raw returns

In addition to examining the effects of the limits to arbitrage and investor sentiment on benchmark-adjusted returns, we examine these effects on raw returns.

3.2.4. Binary vs continuous variables

As indicated, we examine the effects of market-wide arbitrage constraints and investor sentiment using both binary and continuous variables.

3.2.5. Composite vs component measures

In addition to composite measures of the limits to arbitrage and sentiment, we investigate the role of individual subcomponents.

3.2.6. Composite vs individual strategies

We apply regression tests to the composite defensive, carry, value and momentum strategies and also to the 24 individual underlying sub-strategies.

4. Results

Table 1 provides an overview of the performance of portfolios of international government bonds. The majority of the strategies tested are profitable; the means of returns are positive and significantly different from zero for almost all strategies. This is the case irrespective of whether quintile, quartile or tertile portfolios are considered (Table 1, Panels A–D). The only exceptions are the long–short portfolios formed on betas for: (4) 36-month; (5) 48-month; and (6) 60-month formation periods and the yield momentum strategies for: (15) 42-month; and (16) 48-month yields; in these cases, although positive, the means are low and, in consequence, predominantly insignificant.

All mean returns on the composite defensive, carry, value and momentum strategies are both positive and highly significant, irrespective of the breakpoint used to form quartile portfolios (Table 1, Panel E). Profitability is however not equal across strategies. The highest mean returns are recorded for the carry strategy (0.30–0.38% per month) and the lowest are recorded for the defensive strategy (0.08–0.10% per month).

Returns on certain factors are not fully independent, particularly within each of the four groups formed upon the basis of similar underlying economic concepts. Nevertheless, the average Pearson correlation coefficient for factor returns is

Table 1. Mean monthly returns on zero-investment portfolios of government bonds.

	Quintiles			Quartiles			Tertiles		
	R	*t*-stat	Vol	R	*t*-stat	Vol	R	*t*-stat	Vol
Panel A: Defensive									
Adjusted duration	**0.10*****	***(3.18)***	0.53	**0.11*****	***(2.96)***	0.63	**0.09*****	***(3.23)***	0.47
Life	**0.08*****	***(2.80)***	0.51	**0.10*****	***(3.46)***	0.47	**0.07*****	***(3.04)***	0.39
Duration	**0.09*****	***(3.05)***	0.52	**0.10*****	***(3.03)***	0.57	**0.10*****	***(3.48)***	0.46
36-month beta	0.04	*(0.92)*	1.02	0.06	*(1.35)*	0.88	0.04	*(1.28)*	0.70
48-month beta	0.07	*(1.25)*	1.06	0.06	*(1.37)*	0.90	0.05	*(1.41)*	0.68
60-month beta	0.09	*(1.58)*	1.11	**0.10***	***(1.88)***	0.93	0.06	*(1.58)*	0.71
Panel B: Carry									
Yield-to-maturity	**0.34*****	***(3.26)***	1.62	**0.31*****	***(3.25)***	1.44	**0.27*****	***(3.25)***	1.23
Term premium	**0.46*****	***(4.05)***	1.71	**0.43*****	***(4.34)***	1.48	**0.38*****	***(4.57)***	1.26
Term relative value	**0.41*****	***(4.03)***	1.58	**0.37*****	***(4.11)***	1.36	**0.31*****	***(4.33)***	1.11
Rating relative value	**0.42*****	***(4.52)***	1.46	**0.39*****	***(4.56)***	1.33	**0.33*****	***(4.48)***	1.14
Term & rating rel. value	**0.33*****	***(4.23)***	1.28	**0.29*****	***(4.43)***	1.08	**0.25*****	***(4.46)***	0.93
Sov. risk relative value	**0.31*****	***(3.64)***	1.35	**0.30*****	***(4.38)***	1.11	**0.25*****	***(4.37)***	0.91
Panel C: Value									
30-month reversal	**0.19****	***(2.36)***	1.31	**0.17****	***(2.45)***	1.16	**0.13****	***(2.36)***	0.97
36-month reversal	0.12	*(1.58)*	1.33	**0.11***	***(1.65)***	1.17	**0.10***	***(1.84)***	0.99
42-month reversal	0.13	*(1.51)*	1.38	**0.15****	***(1.96)***	1.20	**0.12***	***(1.87)***	1.03
48-month reversal	**0.19****	***(2.28)***	1.44	**0.18****	***(2.51)***	1.26	**0.17*****	***(2.84)***	1.07
54-month reversal	**0.16***	***(1.87)***	1.49	**0.15****	***(2.06)***	1.32	**0.14****	***(2.34)***	1.09
60-month reversal	0.14	*(1.58)*	1.52	**0.14***	***(1.66)***	1.38	**0.12***	***(1.75)***	1.15
Panel D: Momentum									
6-month price momentum	**0.28****	***(2.35)***	1.67	**0.27****	***(2.53)***	1.46	**0.23*****	***(2.62)***	1.22
12-month price momentum	**0.30****	***(2.40)***	1.64	**0.26****	***(2.43)***	1.43	**0.22****	***(2.42)***	1.20
6-month yield momentum	0.17	*(1.57)*	1.49	0.15	*(1.64)*	1.31	**0.13***	***(1.67)***	1.11
12-month yield momentum	0.14	*(1.29)*	1.49	0.14	*(1.40)*	1.32	0.12	*(1.52)*	1.10
6-month moving average	**0.32*****	***(2.70)***	1.67	**0.28*****	***(2.64)***	1.47	**0.25*****	***(2.79)***	1.23
12-month moving average	**0.33****	***(2.57)***	1.68	**0.30*****	***(2.66)***	1.46	**0.25*****	***(2.68)***	1.22
Panel E: Composite Strategies									
Defensive	**0.09****	***(2.32)***	0.69	**0.10*****	***(2.66)***	0.65	**0.08*****	***(2.69)***	0.51
Carry	**0.38*****	***(4.66)***	1.29	**0.35*****	***(4.91)***	1.11	**0.30*****	***(5.06)***	0.93
Value	**0.16****	***(2.15)***	1.30	**0.15****	***(2.37)***	1.15	**0.13****	***(2.53)***	0.96
Momentum	**0.26****	***(2.42)***	1.43	**0.23****	***(2.51)***	1.25	**0.20*****	***(2.62)***	1.03

Note. Table 1 reports mean monthly returns (R) along with corresponding bootstrap t-statistics (t-stat) and standard deviations for returns (Vol) on zero-investment long/short portfolios of government bonds. The portfolios are long (short) in the quintiles, quartiles or tertiles of bond buckets of the highest (lowest) sorting variables, as described in the Factor Strategies section. Means and volatilities are expressed in percentages Asterisks *, **, and *** indicate values significantly different from zero at the 10%, 5%, and 1% levels of significance respectively; values significantly different from zero are additionally denoted in bold.

approximately 0.17 (for the basic quartile approach) indicating that the sample captures a diverse set of return phenomena (see Tables A3 and A4 in the Online Appendix for details).[11]

Table 2 reports the influence of aggregate limits to arbitrage and investor sentiment on the composite strategies. First, considering the continuous variables (Table 2, Panel A), the outcomes of our calculations indicate that only two of the strategies – defensive and momentum – are significantly affected by variables considered. Changes in returns are predominantly driven by limits to arbitrage. When a univariate regression is applied, the defensive strategy is found to be influenced by market-wide sentiment as well as limits to arbitrage. In a bivariate regression, the effect of the limits to arbitrage prevails and the role of investor sentiment becomes insignificant. Interestingly, the time variation of market-wide arbitrage constraints appears to impact the defensive and momentum strategies in different ways. While the defensive strategy delivers higher returns when limits to arbitrage are elevated,

Table 2. The effect of aggregate limits to arbitrage and investor sentiment on composite bond strategies.

	Panel A: Continuous Variables				*Panel B: Binary Variables*			
	Bivariate regressions		Univariate regressions		Bivariate regressions		Univariate regressions	
	Investor sentiment	Limits to arbitrage	Investor sentiment	Limits to arbitrage	Investor sentiment	Limits to arbitrage	Investor sentiment	Limits to arbitrage
Defensive	−0.05	**0.10****	**−0.11****	**0.13****	−0.06	0.15	−0.11	0.17
	(−1.43)	***(1.97)***	***(−2.25)***	***(2.44)***	*(−0.71)*	*(1.36)*	*(−1.19)*	*(1.49)*
Carry	0.04	0.04	0.02	0.02	0.08	−0.02	0.09	−0.04
	(0.57)	*(0.48)*	*(0.23)*	*(0.19)*	*(0.64)*	*(−0.13)*	*(0.63)*	*(−0.31)*
Value	−0.04	−0.03	−0.02	−0.01	0.04	0.00	0.04	−0.02
	(−0.49)	*(−0.27)*	*(−0.22)*	*(−0.08)*	*(0.27)*	*(−0.02)*	*(0.26)*	*(−0.09)*
Momentum	−0.12	**−0.25*****	0.03	**−0.18****	−0.16	−0.15	−0.12	−0.10
	(−1.63)	***(−2.76)***	*(0.29)*	***(−2.19)***	*(−1.08)*	*(−0.90)*	*(−0.73)*	*(−0.57)*

Note. This table presents coefficients from bivariate and univariate regressions of model-adjusted returns on government bond composite strategies (*defensive*, *carry*, *value* and *momentum*) in month *t* on composite measures of market-wide sentiment and limits to arbitrage as outlined in the Factor Strategies section, at the end of month *t*-1. The numbers in brackets are Newey and West (1987) adjusted *t*-statistics. Asterisks *, ** and *** indicate values significantly different from zero at the 10%, 5%, and 1% levels of significance respectively; values significantly different from zero are additionally denoted in bold.

consistent with the behavioural explanation of return regularities, the momentum strategy performs better when arbitrage constraints are low. This latter observation is consistent with the findings of Avramov, Cheng and Hameed (2016), Jacobs (2015) and Zaremba (2016b) who find that the momentum strategy actually performs particularly well during periods of high liquidity and financing availability.

The two other strategies – carry and value – seem unaffected by changes in market-wide sentiment or limits to arbitrage; no regression coefficients are statistically significant. In summary, only the defensive strategy behaves in a manner that is supported by the behavioural explanation of return regularities. The three remaining strategies – carry, value, and momentum – do not behave is such a manner. This observation may potentially provide support for the hypothesis that these latter three phenomena are driven by underlying risk factors rather than behavioural mispricing.[12]

Interestingly, when we consider dummy variables instead of continuous variables, all regression coefficients were insignificant. This observation suggests that the profitability of the strategies investigated is only affected by extreme levels of investor sentiment and arbitrage constraints. Moderately high levels do not appear to play a key role.

Table 3 provides additional insights into which sub-components of the composite proxies of limits to arbitrage and investor sentiment play a crucial role in determining the dynamics of bond strategies. The defensive strategy exhibits negative correlation with some of the sentiment proxies (S_{BW}, S_{AAI}, S_{ESI}) in either the binary or continuous approach (Table 3, Panel A). However as already reported in Table 2, this relationship disappears after controlling for time-varying limits to arbitrage. When it comes to arbitrage constraints (Table 3, Panel B), the defensive strategy is most strongly impacted by the credit spread (A_{BAA}) and idiosyncratic volatility (A_{IVOL}). In these instances, coefficients are positive and significant. Furthermore, the momentum strategy is negatively influenced by the T.E.D. spread, credit spread and V.I.X. levels.

Table 3. The role of the individual components of the measures of limits to arbitrage and investor sentiment for the composite bond strategies.

	Continuous variables				Binary variables			
	SMC	SAAI	SESI	SBW	SMC	SAAI	SESI	SBW
Panel A: Investor Sentiment								
Defensive	−0.03	**−0.11*****	**−0.13*****	−0.04	0.01	**−0.15***	−0.08	**−0.17****
	(−0.44)	**(−2.73)**	**(−3.93)**	(−1.18)	(0.12)	**(−1.95)**	(−0.85)	**(−2.04)**
Carry	0.08	0.06	−0.13	0.04	0.05	0.07	−0.18	−0.06
	(1.12)	(0.84)	(−1.57)	(0.86)	(0.34)	(0.53)	(−1.23)	(−0.43)
Value	0.09	0.03	**−0.17***	−0.01	0.01	−0.09	−0.21	−0.16
	(0.93)	(0.47)	**(−1.75)**	(−0.14)	(0.04)	(−0.62)	(−1.34)	(−0.93)
Momentum	−0.02	0.08	0.02	0.00	−0.19	0.08	−0.17	0.07
	(−0.22)	(1.18)	(0.25)	(−0.05)	(−1.23)	(0.58)	(−0.97)	(0.41)
Panel B: Limits to Arbitrage								
	A_{TED}	A_{BAA}	A_{VIX}	A_{IVOL}	A_{TED}	A_{BAA}	A_{VIX}	A_{IVOL}
Defensive	0.05	**0.12*****	0.04	**0.14***	−0.01	0.16	0.01	0.12
	(1.02)	**(2.88)**	(0.77)	**(1.74)**	(−0.11)	(1.56)	(0.14)	(1.27)
Carry	−0.05	0.00	−0.07	**0.16***	0.02	−0.13	−0.18	0.10
	(−0.97)	(−0.01)	(−1.22)	**(1.92)**	(0.12)	(−0.89)	(−1.26)	(0.65)
Value	**0.02*****	−0.01	−0.15	0.12	0.17	−0.05	−0.25	0.03
	(2.64)	(−0.15)	(−1.60)	(0.68)	(1.35)	(−0.32)	(−1.53)	(0.16)
Momentum	**−0.17*****	**−0.16****	**−0.18****	0.00	**−0.32****	−0.08	−0.27	0.19
	(−2.84)	**(−2.09)**	**(−2.16)**	(0.01)	**(−2.13)**	(−0.46)	(−1.54)	(1.16)

Note. This table presents coefficients from bivariate and univariate regressions of model-adjusted returns on government bond composite strategies (*defensive*, *carry*, *value* and *momentum*) in month *t* on individual components of measures of market-wide sentiment and limits to arbitrage, as outlined in the Factor Strategies section, at the end of month *t*-1. SBW, SMC, SAAI, SESI are sentiment variables based upon Baker and Wurgler's (2006) sentiment measures, the University of Michigan Consumer Sentiment Index, the surveys of the American Association of Individual Investors, and the Economic Sentiment Indicator, respectively; A_{TED}, A_{BAA}, A_{VIX}, and A_{IVOL} represent limits to arbitrage proxied by T.E.D. spread, credit spread, V.I.X., and idiosyncratic volatility, respectively. The numbers in brackets are Newey and West (1987) adjusted *t*-statistics. Asterisks *, ** and *** indicate values significantly different from zero at the 10%, 5%, and 1% levels of significance respectively; values significantly different from zero are additionally denoted in bold.

This suggests that the damaging effect of elevated limits to arbitrage is visible in almost all of the examined measures with the only exception being the idiosyncratic volatility. Finally, as in Table 2, in the binary variable approach, the roles of market-wide sentiment and limits to arbitrage are predominantly insignificant.[13]

Table 4 reports the effects of investor sentiment and limits to arbitrage on the specific individual strategies that are used to form composite strategies. As the carry and value strategies (Table 4, Panels B and C) show no relationships with these variables, we focus first on the defensive strategy (Table 4, Panel A). When we consider continuous variables, all strategies exhibit significant positive exposure to limits to arbitrage. Investor sentiment also proves to be important in univariate regressions. However, its effect becomes insignificant when we control for arbitrage constraints. The influence of limits to arbitrage on the low-beta strategies is found to be particularly robust. It is found to be significant when binary variables are used in both univariate and bivariate regressions.[14]

In line with the results reported in Tables 2 and 3, nearly all individual momentum sub-strategies (Table 4, Panel D) are negatively influenced by elevated limits to arbitrage. The only exceptions are the yield-based momentum portfolios, for which coefficients remain negative but are not statistically significant. The effects of arbitrage constraints also outweigh the effects of investor sentiment although they are

Table 4. The effect of aggregate limits to arbitrage and investor sentiment on individual bond strategies.

	Continuous variables				Binary variables			
	Bivariate regressions		Univariate regressions		Bivariate regressions		Univariate regressions	
	Investor sentiment	Limits to arbitrage	Investor sentiment	Limits to arbitrage	Investor sentiment	Limits to arbitrage	Investor sentiment	Limits to arbitrage
Panel A: Defensive								
Adjusted duration	−0.03	**0.12****	**−0.09***	**0.13****	−0.05	0.12	−0.08	0.13
	(−0.77)	**(2.21)**	**(−1.86)**	**(2.47)**	(−0.58)	(1.17)	(−0.96)	(1.25)
Life	−0.04	**0.12*****	**−0.10****	**0.14*****	−0.08	0.12	**−0.12***	0.14
	(−1.22)	**(2.88)**	**(−2.34)**	**(3.48)**	(−1.27)	(1.41)	**(−1.66)**	(1.62)
Duration	−0.02	**0.12*****	**−0.09***	**0.14*****	−0.04	0.12	−0.07	0.13
	(−0.67)	**(2.64)**	**(−1.95)**	**(2.92)**	(−0.49)	(1.32)	(−0.96)	(1.44)
36-month beta	−0.06	**0.11***	**−0.13****	**0.15****	−0.05	**0.22***	−0.12	**0.24***
	(−1.35)	**(1.80)**	**(−2.09)**	**(2.47)**	(−0.40)	**(1.70)**	(−0.90)	**(1.78)**
48-month beta	−0.06	0.11	**−0.12****	**0.15****	−0.08	**0.25***	−0.16	**0.28****
	(−1.43)	(1.63)	**(−2.27)**	**(2.35)**	(−0.66)	**(1.81)**	(−1.31)	**(2.07)**
60-month beta	−0.08*	**0.14****	**−0.16*****	**0.19*****	−0.14	**0.27***	**−0.22***	**0.32****
	(−1.69)	**(2.09)**	**(−2.85)**	**(2.85)**	(−1.17)	**(1.94)**	**(−1.87)**	**(2.30)**
Panel B: Carry								
Yield-to-maturity	0.04	0.04	0.02	0.01	0.08	−0.08	0.11	−0.11
	(0.52)	(0.35)	(0.23)	(0.13)	(0.50)	(−0.48)	(0.64)	(−0.56)
Term premium	0.05	0.04	0.03	0.01	0.06	−0.09	0.09	−0.11
	(0.68)	(0.36)	(0.33)	(0.06)	(0.34)	(−0.55)	(0.47)	(−0.59)
Term relative value	0.06	0.08	0.01	0.05	0.10	0.03	0.09	0.00
	(0.62)	(0.70)	(0.10)	(0.42)	(0.54)	(0.18)	(0.49)	(0.00)
Rating relative value	0.03	−0.02	0.04	−0.04	0.07	−0.09	0.10	−0.12
	(0.37)	(−0.37)	(0.58)	(−0.88)	(0.55)	(−0.80)	(0.72)	(−0.94)
Term & rating relative value	0.01	0.04	−0.01	0.03	0.04	0.05	0.03	0.04
	(0.12)	(0.52)	(−0.19)	(0.61)	(0.38)	(0.43)	(0.21)	(0.28)
Sov. risk relative value	0.06	0.08	0.02	0.04	0.17	0.14	0.12	0.09
	(0.76)	(1.03)	(0.21)	(0.64)	(1.14)	(0.91)	(0.86)	(0.61)
Panel C: Value								
30-month reversal	−0.04	0.01	−0.05	0.03	0.00	0.06	−0.01	0.06
	(−0.58)	(0.06)	(−0.52)	(0.35)	(0.03)	(0.35)	(−0.09)	(0.31)
36-month reversal	−0.03	−0.05	0.00	−0.03	0.03	−0.03	0.04	−0.04
	(−0.36)	(−0.49)	(0.01)	(−0.36)	(0.22)	(−0.22)	(0.23)	(−0.25)
42-month reversal	−0.05	−0.03	−0.03	0.00	0.04	0.01	0.03	0.00
	(−0.69)	(−0.27)	(−0.39)	(−0.03)	(0.25)	(0.06)	(0.19)	(−0.01)
48-month reversal	−0.08	−0.04	−0.05	0.00	−0.06	−0.08	−0.03	−0.06
	(−0.98)	(−0.36)	(−0.59)	(0.00)	(−0.38)	(−0.52)	(−0.20)	(−0.35)
54-month reversal	−0.06	−0.05	−0.04	−0.01	−0.06	−0.04	−0.04	−0.03
	(−0.75)	(−0.34)	(−0.41)	(−0.09)	(−0.38)	(−0.28)	(−0.25)	(−0.15)
60-month reversal	−0.01	0.02	−0.02	0.03	0.01	0.02	0.00	0.02
	(−0.09)	(0.14)	(−0.21)	(0.23)	(0.04)	(0.13)	(0.00)	(0.10)
Panel D: Momentum								
6-month price momentum	**−0.17****	**−0.34*****	0.02	**−0.24****	−0.20	−0.23	−0.13	−0.16
	(−1.97)	**(−3.13)**	(0.17)	**(−2.19)**	(−1.04)	(−1.13)	(−0.66)	(−0.78)
12-month price momentum	−0.07	**−0.22****	0.05	**−0.18***	−0.08	−0.12	−0.04	−0.10
	(−0.86)	**(−2.30)**	(0.59)	**(−1.94)**	(−0.54)	(−0.76)	(−0.24)	(−0.58)
6-month yield momentum	**−0.15***	−0.22	−0.03	−0.13	−0.23	−0.13	−0.19	−0.05
	(−1.95)	(−1.54)	(−0.39)	(−1.34)	(−1.48)	(−0.70)	(−1.17)	(−0.29)
12-month yield momentum	0.01	−0.11	0.08	−0.12	−0.06	−0.06	−0.04	−0.04
	(0.12)	(−1.10)	(0.89)	(−1.52)	(−0.41)	(−0.42)	(−0.24)	(−0.28)
6-month moving average	**−0.15***	**−0.28*****	0.01	**−0.19****	−0.21	−0.14	−0.17	−0.07
	(−1.82)	**(−2.93)**	(0.09)	**(−2.10)**	(−1.00)	(−0.71)	(−0.81)	(−0.38)
12-month moving average	**−0.16***	**−0.33*****	0.03	**−0.24****	−0.21	−0.23	−0.13	−0.16
	(−1.95)	**(−3.22)**	(0.22)	**(−2.19)**	(−1.15)	(−1.13)	(−0.73)	(−0.76)

Note. This table presents coefficients from bivariate and univariate regressions of model-adjusted returns on government bond individual strategies (as detailed in Table A2 in the Online Appendix) in month t on composite measures of market-wide sentiment and limits to arbitrage, as outlined in the Factor Strategies section, at the end of month t-1. The numbers in brackets are Newey and West (1987) adjusted t-statistics. Asterisks *, ** and *** indicate values significantly different from zero at the 10%, 5%, and 1% levels of significance respectively; values significantly different from zero are additionally denoted in bold.

Table 5. The impact of aggregate limits to arbitrage and investor sentiment on the composite bonds strategies—alternative portfolio construction methods.

	Continuous variables				Binary variables			
	Bivariate regressions		Univariate regressions		Bivariate regressions		Univariate regressions	
	Investor sentiment	Limits to arbitrage	Investor sentiment	Limits to arbitrage	Investor sentiment	Limits to arbitrage	Investor sentiment	Limits to arbitrage
Panel A: Quintile Portfolios								
Defensive	−0.05	**0.11***	**−0.11****	**0.14****	−0.06	0.17	−0.11	0.18
	(−1.20)	***(1.94)***	***(−2.11)***	***(2.47)***	*(−0.68)*	*(1.43)*	*(−1.24)*	*(1.63)*
Carry	0.05	0.04	0.02	0.02	0.11	−0.03	0.12	−0.07
	(0.60)	*(0.49)*	*(0.24)*	*(0.20)*	*(0.72)*	*(−0.22)*	*(0.72)*	*(−0.40)*
Value	−0.06	−0.02	−0.04	0.01	0.02	0.03	0.01	0.02
	(−0.66)	*(−0.19)*	*(−0.41)*	*(0.05)*	*(0.10)*	*(0.16)*	*(0.05)*	*(0.11)*
Momentum	−0.13	**−0.27*****	0.02	**−0.19****	−0.20	−0.15	−0.15	−0.09
	(−1.63)	***(−2.59)***	*(0.18)*	***(−2.07)***	*(−1.10)*	*(−0.74)*	*(−0.79)*	*(−0.43)*
Panel B: Tertile Portfolios								
Defensive	−0.04	**0.08****	**−0.09****	**0.10****	−0.05	0.11	−0.09	0.13
	(−1.38)	***(1.97)***	***(−2.20)***	***(2.51)***	*(−0.81)*	*(1.36)*	*(−1.26)*	*(1.49)*
Carry	0.03	0.02	0.01	0.01	0.06	−0.01	0.06	−0.03
	(0.49)	*(0.35)*	*(0.22)*	*(0.11)*	*(0.55)*	*(−0.07)*	*(0.52)*	*(−0.22)*
Value	−0.04	−0.05	−0.01	−0.03	0.05	−0.02	0.06	−0.04
	(−0.59)	*(−0.55)*	*(−0.11)*	*(−0.35)*	*(0.45)*	*(−0.21)*	*(0.46)*	*(−0.30)*
Momentum	−0.09	**−0.22*****	0.03	**−0.16****	−0.13	−0.13	−0.09	−0.09
	(−1.62)	***(−2.89)***	*(0.40)*	***(−2.36)***	*(−1.03)*	*(−0.96)*	*(−0.67)*	*(−0.65)*
Panel C: Value-Weighted Portfolios								
Defensive	−0.03	**0.05****	**−0.06****	**0.07*****	−0.03	0.08	−0.06	**0.09***
	(−1.36)	***(2.02)***	***(−2.48)***	***(3.10)***	*(−0.72)*	*(1.58)*	*(−1.25)*	***(1.79)***
Carry	0.05	0.05	0.03	0.02	−0.05	**−0.18***	0.00	**−0.16***
	(0.89)	*(0.72)*	*(0.61)*	*(0.33)*	*(−0.40)*	***(−1.78)***	*(0.03)*	***(−1.68)***
Value	−0.01	−0.02	0.00	−0.01	0.07	0.03	0.06	0.01
	(−0.18)	*(−0.18)*	*(0.03)*	*(−0.21)*	*(0.70)*	*(0.31)*	*(0.63)*	*(0.09)*
Momentum	−0.01	**−0.20*****	**0.11***	**−0.20*****	−0.03	−0.21	0.04	−0.20
	(−0.13)	***(−2.93)***	***(1.92)***	***(−3.46)***	*(−0.19)*	*(−1.61)*	*(0.33)*	*(−1.58)*

Note. This table presents coefficients from bivariate and univariate regressions of model-adjusted returns on government bond composite strategies (*defensive*, *carry*, *value* and *momentum*) in month t on composite measures of market-wide sentiment and limits to arbitrage, as outlined in the Factor Strategies section, at the end of month t-1. The numbers in brackets are Newey and West (1987) adjusted t-statistics. Asterisks *, ** and *** indicate values significantly different from zero at the 10%, 5%, and 1% levels of significance respectively; values significantly different from zero are additionally denoted in bold. Panels A and B report the results for equal-weighted quintile and tertile portfolios and panel C shows quartile value-weighted portfolios.

only significant when continuous variables are used in regressions. In summary, the results presented in Table 4 confirm the robustness of the negative influence of limits to arbitrage on defensive strategies and the positive influence on momentum portfolios.

Finally, in Table 5 we report the results of additional robustness checks that employ alternative breakpoints for portfolio formation (Panels A and B) and alternative weighting approaches (Panel C). In general, the outcomes of these tests fully support the earlier results. In all specifications, high levels of limits to arbitrage exert a positive influence on the defensive strategy in both binary and univariate regressions, outweighing any influence of market-wide sentiment that is much more pronounced when continuous variables are used. Similarly, high levels of limits to arbitrage display a detrimental effect on the profitability of bond momentum strategies. Again, this effect is present in both bivariate and univariate regressions but is significant only for continuous variables.[15]

5. Conclusion

The purpose of this study is to examine the effects of limits to arbitrage and investor sentiment on major factor strategies used in investing in government bond markets. We find that of the four investment strategies examined – defensive, carry, value and momentum strategies – two are influenced by elevated limits to arbitrage. In line with propositions of the behavioural explanation of mispricing, the defensive strategy is more profitable during periods of elevated limits to arbitrage. On the other hand, the momentum strategy performs well when arbitrage constraints are low. In conclusion, our observations contribute new insights to an ongoing debate; the results support the hypothesis that profits from low-risk bond strategies are driven by behavioural mispricing, whereas carry, value and momentum profits are more likely to be attributable to underlying risk factors.

This has implications for bond traders, fund managers and investors at large; profitable strategies that take into consideration limits to arbitrage can be devised for bond markets and not only equity markets. Furthermore, this implies that market participants should closely monitor arbitrage conditions and should act accordingly by entering into an appropriate strategy at the appropriate time. In other words, market timing may prove to be profitable.

Our study is subject to limitations, which may be worth keeping in mind. We have not taken into account trading costs and limitations to cross-country capital mobility which is likely to be imperfect. We have also not considered the effectiveness of these strategies during important economic events, such as the global financial crisis, the European debt crisis. Furthermore, our sample does not consider a large number of emerging markets.

Further studies of the issues discussed in this article may be pursued. Firstly, our findings could be used as a starting point in the search for other factors that drive anomaly returns. Secondly, given the weak links between arbitrage constraints and investor sentiment and carry and value strategies, it would be potentially worthwhile to investigate the possible risk factors that contribute to the development of these return patterns. Finally, while we focus on market-wide proxies for investor sentiment and arbitrage constraints, an examination of strategy-level variables may be another point of departure for future research.

Notes

1. See, for value effect: Asness et al. (2015); for momentum: Luu and Yo (2012), Duyvesteyn and Martens (2014), Hambusch et al. (2015) and Zaremba and Czapkiewicz, (2017); for carry: Asness, Ilmanen, Israel and Moskowitz (2015), Beekhuizen et al. (2016), and Bolla (2017); for defensive: Beekhuizen, Duyvesteyn Martens, and Zomerdijk (2016), de Carvalho et al., (2014) and Durham (2016).
2. For further discussion and empirical evidence, see: Barberis and Thaler (2003), Brav, Heaton, and Li (2010), Stambaugh et al. (2012), Hanson and Sunderam (2014), and Jacobs (2015). Also, Zaremba (2015, 2016a) indicated that investor activity may influence the performance of return patterns in commodity markets.
3. The Online Appendix is available on request.
4. Http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

5. The variable and portfolio formation procedures employed for the defensive, carry, value and momentum strategies are outlined in Table A2 of the Online Appendix.
6. This data is sourced from Jeffrey Wurgler's website: http://people.stern.nyu.edu/jwurgler/.
7. For further information and data see: http://www.sca.isr.umich.edu/.
8. For further information and data see: http://www.aaii.com/sentimentsurvey.
9. For further details and accompanying, see: http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Economic_sentiment_indicator_(ESI).
10. For further information on V.I.X. see http://www.cboe.com/micro/vix/vixwhite.pdf.
11. The Online Appendix is available on request.
12. The results of the robustness check using raw returns is presented in Table A5 in the Online Appendix (available on request).
13. Analogous results for raw returns are presented in Table A6 in the Online Appendix (available on request).
14. Analogous results for raw returns are presented in Table A7 in the Online Appendix (available on request).
15. Analogous results for raw returns are presented in Table A8 in the Online Appendix (available on request).

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