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ORIGINAL RESEARCH

Momentum, value, and size strategy returns: the explanatory power of global macroeconomic risks

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Abstract

The work aims to empirically test whether the returns of Fama–French-Carhart (FFC) portfolio strategies can be explained by higher/lower sensitivity to the five macroeconomic factors considered by Chen-Ross-Roll (the industrial production growth index, the unexpected inflation, changes in inflation expectations, the yield curve, and the default spread) and to measure the premiums of the global macroeconomic risk factors. The work extends the definition of the three FFC strategies to equity, bond, and commodity asset classes and expands the sample of countries analyzed (26 countries from geographic areas around the world: Developed Asia, Canada, Continental Europe, Emerging Markets, Japan, the United Kingdom, and the United States). The results show that the returns of the three strategies are influenced by the overall macroeconomic factors. The result is a dataset of more than 43,000 monthly returns that can also be a useful reference for subsequent studies. The results show that the returns of the three strategies are influenced by the overall macroeconomic factors proposed by CRR and thus there are global premiums for the corresponding risks. The signs of the emerging relationships are also economically meaningful. Moreover, it is shown that macroeconomic factors could explain the observed positive returns of negatively correlated combinations of strategies, for example, of value-momentum and size-momentum combinations.

Keywords Value · Momentum · Size · Global macroeconomic risk

JEL Classification G11 · G12 · G15 · F44

1 Introduction

The relationship between asset class returns and macroeconomic factors is significant in the asset management industry. Different asset classes react differently to shocks in macroeconomic variables, and the study of these different reactions can lead to the construction

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of efficient portfolios from the perspective of the risk-return relationship. In this context, although value, size, and momentum effects are three of the most debated anomalies of financial markets, it emerges how the literature has not provided an unambiguous answer on the relationships between the performance of such strategies and the macroeconomic factors yet. The study of the above relationships could further contribute to identifying the best investment portfolio strategy.

The goal of this study is to shed light on these relationships and, therefore, contribute to the puzzle about strategy combinations that minimize the risk-return ratio of investment portfolios. The study starts with a review of the international literature. Since the studies of Banz (1981) about the size effect, Fama and French (1992) about the value effect, and Carhart (1997) about the momentum effect, a series of studies arose with a twofold objective: *i)* to search for more and more new factors to find anomalies; *ii)* to extend the study to more asset classes. About the first point, the literature counts more than 100 identified factors, so many that Cochrane (2011) talked of *factor zoo*. Regarding the second point, although Merton (1974) provided an intuitive approach to linking equity and bond markets, more relevant factors are necessary to describe the bond market behavior. However, it should be pointed out how equity and debt returns are linked to the corporate fundamentals of the issuing company. Therefore, both asset classes could be expected to be sensitive to the same risk factors. This finding has led a strand of the literature to apply the factors that affect the stock market also to the bond market. Among these studies, those on momentum strategy (Jostova et al. 2013), value strategy (Correia et al. 2012), and size (Houweling and van Zundert 2017) are relevant. Regarding the commodity market, the literature agrees with the possibility of extending market risk, momentum, and value factors to this asset class. Asness et al. (2013) introduce the concept of value for this asset class. In their work, they test value and momentum strategies on a large global sample, including not only equities but also equity indices, bond indices, and commodities. Therefore, we decided to assess whether value, size, and momentum are detectable effects in asset classes other than equities and all financial markets worldwide. In this regard, we offer new insights into these three market anomalies by jointly examining their returns across seven macro geographic areas (Asia Pacific Developed, Canada, Continental Europe, the Emerging Markets, Japan, the United Kingdom, and the United States) and four different asset classes (single stocks, equity indexes, government bond indexes, and commodities). Unlike Asness et al. (2013), it was decided to extend the dataset not only to the value and momentum strategy but also to the size strategy. In this regard, although the literature (see Alquist et al. 2018) has shown that the size premium has not been empirically confirmed since its discovery, other studies (for instance, Esakia et al. 2019) found that including exposure to size improves the risk/return profile of a multi-factor portfolio. Therefore, it is challenging to ask whether the empirical findings about the poor performance of the size strategy are the result of a different sensitivity that this strategy has to macroeconomic factors compared to the value and momentum strategies.

The dataset construction also concerns data on the independent variables, i.e., the global macroeconomic risk factors. In this regard, inspired by the work of Liu and Zhang (2008) and Cooper et al. (2022), we decided to use the macroeconomic factors proposed by Chen et al. (1986) (henceforth, CRR) as explanatory variables in our model. These factors provide a complete description of the various risks arising from the macroeconomic conditions across global markets. Differently from the studies in the field (for example, see Asness et al. 2013 and Cooper et al. 2022), the global factors are measured in terms of market capitalization-weighted averages of the CRR factors of all 26 countries in our sample. The main reason for using the market capitalization instead of GDP per capita (as in Asness et al. 2013 and Cooper et al. 2022), concerns the need to define a measure of relevance of macroeconomic factors consistent with the dependent variable. Since we try to explain the returns on investment portfolios of asset classes listed on financial markets, the relevant perspective is that of investors in financial markets and therefore the weight of macroeconomic factors should be reasonably referred to the perceived relevance of each country from this perspective.

We showed that value, size, and momentum premia exist in all markets and almost all asset classes. What emerged most when analyzing the three strategies together as applied to all asset classes and across international financial markets was the different movements of the three strategies' returns over the sample period considered. Indeed, in all asset classes and all international markets, it was found that the size strategy is negatively correlated with the momentum strategy and has a low correlation with the value strategy. On the other hand, the findings of Asness et al. (2013) are confirmed: the value and the momentum strategies are negatively correlated. Moreover, it was found that an equal combination of negatively correlated, or poorly correlated strategies produces a positive return over time. The emerging movement patterns suggest the presence of common global factors related to value, size, and momentum effects. In addition, the positive return obtained from the combination could represent the market's demand for a remuneration of residual and not diversified common risk.

Our study of the relationships between macroeconomic factors (e.g., industrial production changes, unexpected inflation, changes in expected inflation, term spread, default spread), on the one side, and the returns obtained by factor-based investment strategies (value, momentum, and size), on the other side, could explain the low or negative correlation often found among the returns of various factor strategies, since they show a different exposure to macroeconomic risks [Cooper and Priestley (2009); Avramov et al. (2012); Wisniewski and Jackson (2020); Dahlquist and Hasseltoft (2020)].

Our empirical findings indicate that the global macroeconomic factors explain more than one-third of the cross-sectional variability of returns of value, momentum, and size strategies applied to all asset classes across the world. They indicate that markets are integrated across countries and asset classes and that the returns produced by these strategies price the global macroeconomic risk. The results show that the impact of global macroeconomic factors on pricing value, size, and momentum portfolios is not limited to equities, but it is also observable in nonequity asset classes. Moreover, global macroeconomic factors are important in explaining the returns of combinations between strategies across international markets and asset classes. They account for the negative correlation between size and momentum strategies, the negative correlation between value and momentum strategies, and the positive correlation between value and size strategies. We showed how: *i*) size and value – the two strategies with the highest correlation of returns – have concordant signs of macroeconomic factor loadings; *ii*) value and momentum – the two strategies with the lowest correlation of returns – show discordant signs of macroeconomic factor loadings. In addition, expanding the dataset to include the size strategy has allowed us to strengthen the empirical findings of Cooper et al. (2022): the size strategy neutralizes the effect of some macroeconomic factors on returns when combined with the momentum strategy. This neutralizing effect may explain why the combination of size and momentum strategies produced a lower performance during the sample period: the lower the sensitivity to macroeconomic factors, the lower the risk premium. The power of the macroeconomic risk factors lies in their ability to explain why the combinations between strategies negatively (or scarcely) correlated generate positive returns. In this regard, we showed that the returns of the combination portfolios are not neutral to the macroeconomic risk factors.

Hence, the combination of strategies exhibits positive returns that could be interpreted in terms of a remuneration of these combinations' macroeconomic risks.

The work proceeds as follows. Section II discusses recent literature on return premia across countries and asset classes. Section III describes the dataset and portfolio construction and examines value, size, and momentum performance across asset classes, showing their global co-movements. In Section IV, we present the econometric model and the resulting cross-sectional tests, by comparing the correlations between value, size, and momentum return premia implied by the global CRR model. Finally, the empirical results are discussed. Section V reports the robustness tests.

2 Macroeconomic risk factors and portfolio strategy returns: literature review

The work is grounded in the debate on determining factors affecting stock and portfolio returns, starting with the research carried out by Fama and French (1992). They kicked off a series of research into factor analysis concerning investment decisions that led to numerous new tested factors (above all, Carhart 1997, with the momentum effect).

A recent strand of literature has tested whether the performance obtained from these strategies could be explained through their higher/lower correlation with macroeconomic factors. For the momentum and value strategies, the key question of the debate is the statistical significance of the relationships between strategy returns and macroeconomic factors (for an in-depth analysis, see Matteucci, and Venanzi 2023).

As far as the momentum strategy, Griffin et al. (2003) assess whether its returns represent rewards for the macroeconomic risks proposed by CRR in the empirical test of Ross Arbitrage Pricing Theory (1976) – a pricing model that can be considered an alternative to the Capital Asset Pricing Model in terms of the assumptions required for its derivation, but not necessarily in the conclusions it reaches (Caprio 1989). The obtained results show that the relationships with macroeconomic variables are not statistically significant. However, Liu and Zhang (2008), by using Griffin et al. (2003) sample, studied the relationship between the strategy momentum returns applied to the U.S. stocks and the industrial production index and found that there is a positive relationship, which is statistically significant, between the two variables. The differences obtained between the two papers can be attributed to a different methodology for estimating risk premiums (constant betas vs variable betas). Asness et al. (2013) show how momentum strategy returns cannot be explained by the industrial production index, the liquidity risk, or inflation expectations. Only a weak sensitivity of momentum returns to the yield curve and the default spread emerges. This is also true for the bond asset classes, in which the authors detected a low statistical significance of the industrial production index. Cooper et al. (2022) test the five CRR macroeconomic factors on Asness et al. (2013) dataset. They found statistically significant relationships. However, we should point out how Cooper et al. (2022) stated that they would use the Fama–Macbeth (1973) estimation procedure (the same used by Asness et al. 2013), which consisted of a cross-section regression estimation every month. However, in the end, they used Black et al. (1972) estimation procedure. Therefore, it is possible to affirm that the differences in the results between the two papers can be attributed either to the different macroeconomic factors considered or to a different estimation methodology for risk premiums. Goyal et al. (2025) offer a thorough examination of the empirical drivers of momentum strategy in a comprehensive international dataset. Their study explores the influence of market conditions, which are potentially linked to broader macroeconomic factors. They observe that momentum strategy tends to be stronger in rising markets and during periods of low volatility – patterns that are consistent with U.S. evidence and suggest that investor overconfidence may be amplified in bullish and stable environments.

As far as bond asset class, Hutchinson and O'Brien's (2020) and Baltussen et al. (2021) found various evidence that pointed to the relationships between the momentum strategy returns applied to the bond asset classes both with an industrial production index and inflation expectations. The differences between the results of the two studies can be attributed to a different length of the analyzed time frame. In this regard, Baltussen et al. (2021) pointed out that studies carried out in recent years may be distorted since they are influenced by quite favorable historical phases (no world wars, growing economic prosperity, and a few phases of high recession). This spurred the authors to analyze a period forecast of 147 years, characterized by 43 years of bear markets and 74 years of recession, and to draw more convincing conclusions based on the evidence of the revealed links. Neville et al. (2021) and Baltussen et al. (2023) studied the performances given by the momentum strategy in the bond market in different inflationary regimes. Baltussen et al. (2023) detected how the momentum strategy in the bond market gives a positive performance in all periods except for those of high inflation (inflation rate higher than 4%) and how its variation over time among different inflationary regimes is statistically significant. However, the results of the two papers are conflicting. This is probably due to: *i)* the length of the time frame in question (93 vs 146 years); *ii)* the countries included in the sample (Japan, U.K., and U.S. versus Europe, U.K., U.S., Developed Asia, and Emerging Markets).

The study of the relationships between macroeconomic variables and the value strategy returns traced its origins from Fama and French's research (1993). Their research pointed out that the value strategy applied to equity and bond asset classes has a positive relationship with the yield curve and the default spread. Among the many cross-sectional studies, the most relevant studies are those of Asness et al. (2013) and of Cooper et al. (2022), carried out on both asset classes. Asness et al. (2013) confirmed the positive relationship, and the default spread for the U.S. market. They found different evidence from Fama and French (1993) about the relationship between value strategy returns applied to international bond markets and the yield curve. A possible explanation for such a divergence could be attributed to the wide range of bonds considered in the samples of the two studies. Fama and French's study (1993) also included corporate bonds, while Asness et al. (2013) only analyzed government bonds. Cooper et al. (2022) tested CRR factors by using Asness et al. (2013) sample. Although the authors did not provide information about the statistical significance of the time-series regressions in the case of the value strategy, it is worth noting that by changing the regressors and testing the model on the same sample as Asness et al. (2013), the relationship between returns in the value strategy applied to the bond asset class and the yield curve changes sign again, returning to the evidence of Fama and French (1993).

Baltussen et al. (2021) showed that the strategy produces positive and statistically significant performances with the equity asset class in the context of an economic recession and bear markets. In addition, they showed that the value strategy produces better results in the bond asset classes during expansive phases of the economic cycle, which are characterized by no crisis and bull markets. On the contrary, regression on CRR macroeconomic factors showed that there is a negative relationship with the industrial production growth index, which is statistically significant. Neville et al. (2021) find that the value strategy produces negative returns during periods of high inflation but is still resilient when compared to the returns of long-only strategies. Baltussen et al. (2023)

found that over 146 years (from 1875 to 2021), the value strategy produced positive results in all considered inflationary contexts. However, the differences among returns in various inflationary scenarios are not statistically significant, therefore inflation is a macroeconomic factor that doesn't affect value strategy returns. Maloney and Moskowitz (2021) investigate the relationship between value factor performance and the slope of the yield curve. They find that while changes in the yield curve slope exhibit some statistically significant positive correlation with value returns, the economic magnitude of this relationship is modest. In particular, even during major value drawdowns (e.g., 2017–2019), changes in the slope explain only a small fraction of the underperformance. Beccalli et al. (2023) examine the relationship between the value premium and macroeconomic expectations by using a decomposition of the market-to-book ratio based on the Rhodes-Kropf, Robinson, and Viswanathan (2005) framework. Analyzing U.S. stock market data from 1975 to 2016, they find that approximately 17% of the value premium can be attributed to macroeconomic conditions, particularly the term spread and long-term Treasury yields. Specifically, improving economic prospects – characterized by economic expansion, a steeper term spread, and rising Purchasing Managers Index and Leading Economic Indicator indices – tend to benefit value stocks. In contrast, higher interest rates negatively impact on value stocks, particularly those with high financial leverage, as they increase the cost of capital and make value firms less attractive than growth stocks. Recent research has emphasized the importance of firm-level characteristics that interact with macroeconomic conditions in shaping cross-sectional return premia. Hu et al. (2024) provide compelling evidence that the product life cycle (PLC) plays a critical role in amplifying the book-to-market effect, especially under macroeconomic regimes characterized by high investor sentiment or economic downturns. Specifically, the authors show that firms with longer PLCs – typically operating in more concentrated industries and receiving lower investor attention – exhibit significantly stronger value premia. This is particularly true during recessions, when investor mispricing is likely to be exacerbated due to heightened uncertainty and limited processing of intangible signals. Their findings support the view that macro-financial uncertainty interacts with informational frictions to drive misevaluation, and ultimately, return differentials across book-to-market portfolios.

Although the size factor has a solid place in academic asset pricing models, the literature, over time, showed that the size premium has failed to materialize since its discovery. This has led the literature to place less emphasis on the size strategy than on more popular strategies. Only three studies have analyzed the relationship between size premium and macroeconomic factors. Vassalou and Xing (2004) analyzed the relationship between size strategy returns and default spread. They found that the size effect is present only in the market segment with the highest default risk. Within this segment, the difference in performance between small and large stocks can be explained by the difference in their default risk. Neville et al. (2021) found that smaller companies perform poorly in inflationary regimes. In real terms, the difference between small cap and large cap premium is −4% annually in inflationary periods, compared to +1% in normal times. It proves that larger companies are more suited to react to inflationary periods (the costs of inflation are likely to show some economies of scale), due to their larger adaptability. Finally, Blitz (2022) examined the size performance distinguishing between *i)* expansion vs recession phases; *ii)* normal vs inflationary regimes; *iii)* periods with an ISM (Institute for Supply Management) purchasing managers sentiment index (a widely followed sentiment indicator on the state of US economy) above and below 50. He found that size performs better during expansion and normal (in terms of inflation) periods rather than during recession and inflationary regimes. Moreover, differently from value and momentum strategies, size does better when sentiment is negative (ISM below 50), concluding that rather than being a reward for macroeconomic risks, the size premium is basically a behavioral phenomenon.

3 Research questions and tested hypotheses

From the literature review, it emerges that the returns on value and momentum strategies applied to developed markets and to asset classes other than equities are positive. However, there are doubts regarding the size strategy, both in terms of its applicability to different asset classes and its persistence in returns. Hence, the primary objective of our research is to investigate whether value, momentum, and size strategies, when applied to global markets and across all asset classes, generate positive returns. Once this is established, our goal is to test whether the performances of these strategies can be attributed to a macroeconomic risk premium. To address this, it has been shown that the CRR model most effectively explains the relationship between the returns of value and momentum strategies in developed countries and macroeconomic factors. Based on this observation, our aim is to determine whether the macroeconomic factors proposed by CRR can explain the returns generated by value, momentum, and size strategies across global financial markets and all asset classes.

Our study aims not only to verify the existence of a macroeconomic risk premium but also to investigate the economic significance of the results. Regarding the momentum strategy, the literature agrees that it generates performance based on investor enthusiasm. Therefore, we expect a positive relationship between the returns of this strategy and favorable macroeconomic conditions (e.g., an increase in the industrial production index or an upward yield curve, indicating an entry into an expansionary phase of the economic cycle) and a negative impact during adverse macroeconomic conditions (e.g., rising inflation expectations or increasing default spread are expected to negatively impact momentum strategy performance). These hypotheses are extendable to the bond market, except for the relationship with the term spread, for which a negative relationship is expected: in the case of an increase in the yield spread between 10-year bonds and short-term bonds, markets may sell the so-called high-yield bonds in favor of safer bonds that still offer good interest rates in the long term.

It is different when we talk about the value strategy. This is because there is still a debate in the literature (see Asness et al. 2015) regarding the definition of value companies. On one hand, some literature views these companies as having limited future growth opportunities and being in a phase of harvesting returns from existing investments, thus being more exposed to systematic risk. On the other hand, another stream of literature considers them undervalued by investors due to the over-extrapolation bias, which is the tendency to believe that growth rates can be sustained over a long period. Depending on which definition is adopted, the expected relationships with macroeconomic factors change. If companies are considered undervalued due to behavioral distortions, an inverse relationship with favorable macroeconomic scenarios is expected. For instance, in the case of an increase in the industrial production index or in the yield curve, markets tend to purchase more glamorous stocks, leaving value stocks undervalued. Conversely, in adverse economic scenarios, such as rising inflation expectations or an increase in the credit spread, we expect the value strategy to generate positive performance. In these circumstances, markets are likely to sell stocks of companies previously thought to have long-term earnings growth and seek returns in undervalued stocks, thus generating a positive performance of the value strategy. This logic can be applied to the bond market as well. On the contrary, if value companies are defined as those with higher risk, the expected relationships with macroeconomic factors would be opposite.

As far as the expected relationship between the returns of the size strategy and macroeconomic factors, we anticipate that the strategy will perform well in positive economic scenarios (e.g., growth in the industrial production index and the yield curve). Conversely, we expect it to produce negative performance in adverse economic contexts. For example, in the case of rising inflation expectations, large cap companies, often in a relevant competitive position, have greater bargaining power and competitive strength than smaller firms in adjusting the prices of their products/services to inflation, suffering less from the shock due to a rise in inflation expectations. Additionally, in the event of widening credit spreads, there would be an increased probability of default for these firms, which could lead to a negative performance of the size strategy. The relationship between the size strategy returns in the bond market and rising inflation expectations is different: here, a positive relationship is expected, as inflation erodes the nominal value of debt, benefiting companies with significant liabilities relative to total assets. Similarly, the relationship with the term spread is expected to differ from that in the equity market. An increase in the yield curve could lead to higher financing costs, making it more difficult for smaller firms to access credit to finance their investment projects.

Finally, Asness et al. (2013) found that the returns of value and momentum strategies are negatively correlated and that a portfolio equally combining these two strategies produces positive returns. In this scenario, our objective is to verify whether these correlations and returns hold with our global dataset and to examine the impact of incorporating the size strategy. Upon confirming the correlations and returns of the combined strategies, we aim to explore whether these correlations can be attributed to differential sensitivities to macroeconomic risk factors. Furthermore, we seek to verify if the positive returns from the combined strategies represent a compensation for the macroeconomic risks.

4 Dataset, portfolio construction and global macroeconomic risk factors

The dataset aims to extend that of Asness et al. (2013), from the perspective of: *i)* strategies considered; *ii)* countries considered; and *iii)* length of sample period. The aim is to further contribute to the research on this topic to improve the understanding of the impact of macroeconomic factors on the returns of value, size, and momentum strategies. As regard the first point, it was decided to extend the dataset to the size strategy. In fact, although the literature (see Alquist et al. 2018) has shown that the size premium has yet to be empirically confirmed, Esakia et al. (2019) found that including exposure to size improves a multifactor portfolio's risk/return. In particular, the size factor contributes to the Sharpe ratio because it has a particularly low correlation with the other traditional factors, making it an effective portfolio diversifier. Therefore, it is helpful to ask whether what the literature has shown about the poor performance of the size strategy results from a different sensitivity that this strategy has to macroeconomic factors compared to the value and momentum strategies. Moreover, the work expands the sample of countries analyzed (26 countries from geographic areas around the world: Developed Asia, Canada, Continental Europe, Emerging Markets, Japan, the United Kingdom, and the United States) from June 1980 to June 2022.

4.1 Dataset: the asset classes considered

We examine value, size, and momentum portfolios of individual stocks globally traded across seven equity macro-markets: the Asia Pacific Developed, Canada, Continental Europe, the Emerging Markets, Japan, the United Kingdom, and the United States. We selected securities with a positive price-to-book ratio for all stock markets, an available market capitalization, and at least 12 months of past total return[1] (including dividends) history from June 1980 to June 2021 (all series are monthly). By excluding stocks with non-positive price-to-book ratio might lead to a survivorship bias and consequently to distorted estimation results (Heckman, 1979). However, it is consistent with previous studies on this kind of analysis (Fama and French 1993; Asness et al. 2013; Cooper et al., 2022) and it is explained in terms of the specific objectives of the analysis here (and in these studies) conducted. In fact, these studies aim to analyze the effect of macroeconomic factors on value strategy. According with Fama–French (1993), firms with a negative price-to-book ratio are characterized by a negative equity and therefore by cumulated high losses. Therefore, no investors should be oriented to select this kind of stocks and hence a realistic portfolio value strategy should exclude them. The sample under consideration is an open sample, meaning that, over the years, it may include firms that are later excluded due to a negative price-to-book ratio, as well as firms that were initially excluded but later returned to financial health. The impact on survivorship bias depends on the purpose of the analysis. Since the objective is to construct a robust model for explaining cross-sectional returns based on the price-to-book ratio such exclusions are justified. Data are derived from the Refinitiv Eikon Datastream dataset. The sample consists of companies that are active in the years under investigation, regardless of any subsequent delisting during the following period. We exclude ADRs, REITs, financials, closed-end funds, foreign shares, and merged stocks. Following Asness et al. (2013), we rank stocks in descending order based on their market capitalization at the beginning of the month and include in the selection the number of stocks whose cumulative market capitalization constitutes 90% of the total market capitalization of the entire stock market. We narrow the sample to a considerably more liquid universe to offer practical and conservative estimates for implementable trading strategies. This allows for a more effective comparison with the strategies employed in equity market indexes, government bond indexes, and commodity futures – financial instruments that are generally more liquid. Moreover, it allows us to assess whether the size strategy succeeds in producing a positive performance even without the presence of the so-called micro-cap firms (for instance, see Alquist et al. 2018). As far as the definition/aggregation of markets in geographical groups is concerned, the MSCI[2] market classification is followed. The Asia Pacific Developed stock universe consists of common equity listed respectively in Australia, Hong Kong and Singapore Security Exchanges. Differently from the MSCI classification, in this case, Japan has been considered a standalone market, given the size and development of the Japanese financial market. Furthermore, New Zealand had to be excluded from the subsample, due to a lack of monthly macroeconomic

[1] Total returns are calculated using the RI formula in Eikon Datastream.

[2] https://www.msci.com/our-solutions/indexes/market-classification

data. At the beginning of the sample period (June 1980), the Asia Pacific Developed stock universe consisted of 64 firms, and by the end of the sample period (June 2021), the universe comprised 2,083 stocks. Unlike the MSCI classification, we have chosen to consider Canada as a standalone market for the same reasons that led use to exclude Japan from the Developed Asia sub-sample. At the beginning of the sample period, the subsample consists of 76 firms, and by the end of the sample period, it comprised 618 stocks. The Continental Europe stock universe consists of common equity listed respectively on Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Portugal, Spain, Sweden. At the beginning of the sample period, the subsample consists of 190 Continental Europe firms, and by the end of the sample period, the universe comprises 1,702 stocks. The Emerging Market stock universe consists of common equity listed respectively on Brazil, China, India, Russia, South Africa, South Korea, and Taiwan. The subsample consists of the 17 largest Emerging Markets firms at the beginning of the sample period. By the end of the sample period, the universe comprises 6,196 stocks, proving the growing significance, that financial markets have gained in these countries over the last 40 years and how the omission of these financial markets from the datasets used in literature could be controversial. At the beginning of the sample period, the Japan stock universe consists of 267 firms, and by the end of the sample period, it comprised 2,187 stocks, while, at the beginning of the sample period, the United Kingdom stock universe consists of 154 firms, and by the end of the sample period, it comprised 578 stocks. Finally, the United States stock universe consists of common equity listed on the New York Stock Exchange and NASDAQ. At the beginning of the sample period, it consisted of 938 firms, and by the end of the sample period, it comprised 2,354 stocks. The maximum (minimum) number of analyzed stocks is 15,718 (1,706), belonging to 26 countries around the world for a period of 41 years (corresponding to 492 months).

The universe of country equity index futures consists of the following 24 equity markets: Australia, Austria, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, Hong Kong, India, Italy, Japan, Netherlands, Norway, Portugal, Singapore, South Africa, South Korea, Spain, Sweden, the United Kingdom, and the United States.[3] Total returns (including dividends), market capitalization, and book values are obtained from Datastream. According to Bali and Cakici (2010) and Umutlu (2015), the Datastream indices assure a broad and consistent international representation, and in certain periods, their coverage has been better than MSCI. The sample covers the period June 1980 – June 2021, with a minimum number of 14 equity indices in 1980 and 24 indices from 1995.

The bond index monthly total returns and market capitalization are derived from Intercontinental Exchange – Bank of America Merrill Lynch, while short rates and 10-year government bond yields are from Datastream. We obtain government bond data for the following 18 countries: Australia, Austria, Belgium, Canada, China, Denmark, Finland, France, Germany, India, Italy, Japan, Netherlands, Portugal, Spain, Sweden, the United Kingdom, and the United States over the period June 1989 to June 2021, with a minimum number of 5 country bond returns and 18 country bonds from 2007. As in Asness et al. (2013), our study only analyzes strategies applied to government bond indices without any maturity distinction and without extending the analysis to the set of corporate bond indices as well, since the related data result to be scarce and insufficient to test portfolio construction

[3] Data on Russia and Taiwan indices were not available.

despite data provided by the world's largest bond dataset of Bank of America Merrill Lynch.

The dataset includes information on 27 commodity futures (aluminum, natural gas, heating oil, copper, nickel, zinc, lead, tin, platinum, brent crude oil, diesel, live cattle, feeder cattle, lean hogs, corn, soybeans, wheat, WTI crude oil, RBOB gasoline, gold, silver, cotton, cocoa, coffee, sugar, soybean meal, and soybean oil). In the sample period, we have a minimum number of 11 commodities and 27 from 1995. The collected information includes monthly prices and details on trading and production volumes to define size, which Bloomberg commonly uses in constructing the most widely used commodity index. As for price and trading volume information, data were collected from London Metal Exchange, Intercontinental Exchange, Chicago Mercantile Exchange, Chicago Board of Trade, New York Mercantile Exchange, and New York Mercantile Exchange. The production data of commodities have been derived as indicated in Table 1.

Since the unit used to measure commodity production often differs from that of futures contracts (for example, crude oil production is measured in metric tons while crude oil futures are in barrels), a conversion factor has been derived for each commodity. Table 2 shows the sources from which the conversion factors were obtained.

Table 1 Sources used for production data of commodities

Commodity	Source	Table
Natural Gas	U.S. EIA Annual Statistical Supplement	Gross Natural Gas Production
Crude Oil	U.S. EIA Annual Statistical Supplement	World Crude Oil Production
Live Cattle	Food and Agriculture Organization of the UN Statistical Data Service ("FAOSTAT")	Cattle Meat
Lean Hogs	FAOSTAT	Pig Meat
Wheat	FAOSTAT	Wheat Production
Corn	FAOSTAT	Maize
Soybeans	FAOSTAT	Soybeans
Aluminium	U.S. Geological Survey, National Minerals Information Center ("MYDI")	Aluminum Primary World Production
Copper	MYDI	Copper, World Refinery Production
Zinc	MYDI	Zinc World Smelter Production
Nickel	MYDI	Nickel World Plant Production
Lead	MYDI	Lead World Refinery Production
Tin	MYDI	Tin World Smelter Production
Gold	MYDI	World Mine Production
Silver	MYDI	World Mine Production
Platinum	MYDI	Platinum—Group Metals, World Production
Sugar	USDA Sugar and Sweeteners Yearbook Tables	Table 1 World Production, Supply and Distribution, centrifugal sugar
Cotton	FAOSTAT & USDA	Cotton Lint
Coffee	FAOSTAT	Coffee, Green
Cocoa	FAOSTAT	Cocoa Beans

This table reports the sources used for the production data of commodities. The primary sources are tables on the Food and Agriculture Organization of the UN Statistical Data Service ("FAOSTAT") and the US Geological Survey National Minerals Information Center ("MYDI")

Table 2 Data sources of conversion factors

Commodity	Source	Table	Location
Crude Oil	Basic Petroleum Data Book, Volume XXII, Number 1, February 2006	Gallon, Barrel, Pound and Ton Equivalents for Converting Measures of Crude Petroleum and Refined Petroleum Products	Section XVI Table 3
Wheat, Corn and Soybeans	Agricultural Statistics 2009 United States Department of Agriculture, 2009 ("ASUS")	Weights and Measures	Page VII, VIII
Cattle	ASUS	Tables 7, 8 and 9 Cattle and calves: Production, disposition, cash receipts and gross income, United States, and 7–66 Read Meat: Production, by class of slaughter, United States 2000–2009	VII-7, VII-40
Gold	Statistical Yearbook 49 th Issue, United Nations 2005 ("SYUN")	Annex II A. Equivalents of Metric, British Imperial, and United States Units of Measure	Page 847
Silver	SYUN	Annex II A. Equivalents of Metric, British Imperial, and United States Units of Measure	Page 847
Platinum	SYUN	Annex II A. Equivalents of Metric, British Imperial, and United States Units of Measure	Page 847
Sugar	ASUS	Weights and Measures	Page VII
Cotton	ASUS	Weights and Measures	Page VII
Coffee	ASUS	Weights and Measures	Page VII
Natural Gas	ASUS	Standard Metric Practice Guide (A Guide to the Use of SI—The International System of Units, 1974)	Page 21

This table reports the sources used for commodity conversion factors. The primary sources are the Agriculture Statistics United States (ASUS) and Statistical Yearbook United Nations (SYUN)

4.2 Measurement of value, size, and momentum in different asset classes

Regarding the value of single stocks, the ratio of the company's stock price to its book value per share is used. Since the goal of this work is not to find the best measure to predict future stock returns but rather to apply strategies to a broad sample that includes all asset classes listed on financial markets, it has been decided to maintain a simple approach of value measure applicable to all asset classes. Stocks are consequently classified based on the previous year's price-to-book ratio, and then portfolios are formed. Regarding the size strategy, we used market capitalization (in US dollars) as of June 30 of the year prior to the portfolio formation period. In this regard, it is worth noting that, as many studies show (e.g., Alquist et al. 2018; Asness et al. 2018; Bryan 2014; Crain 2011; Vassalou and Xing 2004), whatever size premium is present, it is concentrated in microcap stocks that are extremely small and difficult to trade. Hence, excluding from the dataset the smallest 10% of companies might help us verify if this bias is confirmed. Regarding the momentum strategy, we follow Asness et al. (2013) procedure.

For global equity indices, we used the value measure of Asness et al. (2013), the previous year's price-to-book ratio of the country's Datastream index. As far as size strategy, we use two measures. Initially, we used the stock market index's market capitalization as Alquist et al. (2018) proposed. However, this classification posed the problem that countries with more developed stock markets (for example, the United States) could risk being overrepresented. For these reasons, a second kind of definition is based on the ratio of market capitalization to GDP[4] (in US dollars, constant prices, and PPPs, reference year 2015) of the country. This definition makes it possible to give all countries an appropriate weight, which considers both an indicator of the degree of development of a given country's financial markets and a measure of the degree of development of its economy. As in Asness et al. (2013), we decided not to skip the most recent months to assess momentum returns of this asset class (MOM 1–12).

As regards the government bond indices, following Asness et al. (2013), we used the 5-year change in the yields of 10-year bonds as a value measure, similar to the past 5-year return with the negative sign. Regarding size and momentum strategies, we used the same measure of equity indices. On one hand, we classified government bond indices by weighing their market capitalization over the country's GDP (in US dollar, constant prices and PPPs, reference year 2015) to avoid overweighing countries with a higher number of issuances (i.e., those with a higher level of absolute debt). On the other hand, we computed MOM 1–12 to assess the momentum strategy of this asset class.

As far as commodity futures' measure of value is concerned, we defined value as the log of the spot price five years ago (actually, the average spot price from 4.5 to 5.5 years ago) divided by the most recent spot price, as proposed by Bessembinder (1992), De Roon et al. (2000), Moskowitz, Ooi, and Pedersen (2012), Koijen et al. (2018), and reiterated by Asness et al. (2013). To measure size, the approach used by Bloomberg in assigning weights to each commodity within the Bloomberg Commodity Index was adopted. To ensure a fair representation, Bloomberg employs a dual approach, incorporating liquidity and US-dollar-weighted production data to determine the proportional quantities of included commodities. Liquidity data represent the relative trading activity of each commodity. Additionally, production data serve as a valuable metric for assessing

4 https://stats.oecd.org/

a commodity's significance in the global economy. However, relying solely on production data might underestimate the economic importance of storable commodities, such as gold, at the expense of relatively non-storable ones, like live cattle. Hence, to determine the size factor for commodities, the estimation procedure involved the following steps: *i)* each commodity's liquidity percentage was derived by multiplying the trading volume by the exchange price and the number of units per contract. The result was then divided by the total sum of products to obtain the weight of each commodity; *ii)* Each commodity's production percentage was calculated by multiplying the production by the conversion factor and the exchange price. The result was then divided by the total sum of products to determine the weight of each commodity. The size factor will be composed in the following manner:

$$\frac{2}{3}\ \textit{liquidity percentage} + \frac{1}{3}\ \textit{production percentage} \tag{1}$$

Finally, we computed MOM 1–12 to measure the momentum strategy.

4.3 Portfolio construction

We employ the abovementioned criteria to create portfolios based on value, size, and momentum within every market and asset class. This involves ranking securities in each asset class according to their value, size, or momentum and sorting them into three equal-weighted groups. Subsequently, we established three portfolios – low, middle, and high – by equally weighing each asset class's total returns of each security in the portfolios. Thus, we generate three portfolios – low, middle, and high – for each of the three characteristics – value, size, and momentum – in each market and for each asset class, producing 90 test portfolios. Considering that this portfolio construction procedure was carried out every year from 1980 to 2021 and for every asset class, it is possible to state that the sample is among the largest ever built, with a total of 43,416 monthly returns. The result of each strategy will then be the difference between the high portfolio and the low portfolio returns. To not underweight the returns of the value companies – quintessentially the ones that mostly distribute dividends – and to homogenize them with those of non-value companies, we decided to measure the returns of each asset class in terms of total returns, including any dividends distributed.

4.4 Value, size, and momentum returns: descriptive statistics

Table 3 reports the monthly mean excess returns (over the global short-term risk-free rate), the *t*-statistic of the mean, the standard deviation, and the downside risk of the returns of the 90 value, size and momentum portfolios. The monthly mean returns on the 30 high-minus-low portfolios in each market and asset class are also shown.[5] Securities are sorted

[5] For the government bond asset class, results were analyzed for completeness by applying the size strategy, based solely on market capitalization, to the asset class of equity and government bond indices. Regarding the equity index asset class, the results do not differ in terms of sign (the strategy's returns improve, going from 0.26% to 0.36% monthly, as well as the standard deviation and downside risk). In contrast, the strategy's performance changes signs and becomes positive regarding the asset class of government bond indices. However, it is worth noting that the positive return is not statistically different from zero.

Table 3 Performance of value, size and momentum portfolios across markets and asset classes

Panel A: Individual Stock Portfolios		Value Portfolios				Size Portfolios			
		V1	V2	V3	V3-V1	S1	S2	S3	S3-S1
Asia Pacific Developed stocks	Mean	−0.52%	−0.28%	0.48%	1.00%	−0.45%	−0.30%	0.42%	0.88%
	(t-stat)	(−1.93)	(−1.07)	(1.62)	(5.99)	(−1.80)	(−1.11)	(1.36)	(4.72)
	Stdev	6.07%	5.85%	6.53%	3.71%	5.59%	5.98%	6.89%	4.12%
	Downside risk	4.24%	4.05%	4.05%	1.86%	3.96%	4.08%	4.29%	1.98%
	Sharpe ratio	−0.09	−0.05	0.07	0.27	−0.08	−0.05	0.06	0.21
	Sortino ratio	−0.12	−0.07	0.12	0.54	−0.11	−0.07	0.10	0.44
Canada stocks	Mean	−0.76%	−0.37%	0.39%	1.15%	−0.55%	−0.36%	0.29%	0.85%
	(t-stat)	(−2.73)	(−1.45)	(1.35)	(7.55)	(−2.47)	(−1.22)	(0.94)	(4.34)
	Stdev	6.21%	5.59%	6.32%	3.37%	4.95%	6.45%	6.98%	4.33%
	Downside risk	4.14%	3.69%	3.74%	1.67%	3.36%	4.11%	4.15%	1.96%
	Sharpe ratio	−0.12	−0.07	0.06	0.34	−0.11	−0.06	0.04	0.20
	Sortino ratio	−0.18	−0.10	0.10	0.69	−0.16	−0.09	0.07	0.43
Continental Europe stocks	Mean	−0.68%	−0.38%	0.07%	0.75%	−0.39%	−0.38%	−0.20%	0.19%
	(t-stat)	(−3.27)	(−1.95)	(0.33)	(6.92)	(−1.84)	(−1.87)	(−1.10)	(1.88)
	Stdev	4.62%	4.29%	4.58%	2.40%	4.59%	4.55%	4.30%	2.19%
	Downside risk	3.21%	3.01%	2.94%	1.29%	3.19%	3.13%	2.77%	1.16%
	Sharpe ratio	−0.15	−0.09	0.01	0.31	−0.08	−0.08	−0.05	0.08
	Sortino ratio	−0.21	−0.13	0.02	0.58	−0.12	−0.12	−0.07	0.16
Emerging Markets stocks	Mean	−0.23%	−0.08%	0.73%	0.96%	−0.11%	0.12%	0.51%	0.61%
	(t-stat)	(−0.70)	(−0.30)	(2.35)	(3.38)	(−0.36)	(0.43)	(1.62)	(2.30)
	Stdev	7.23%	5.91%	6.89%	6.29%	6.58%	6.42%	6.94%	5.93%
	Downside risk	4.41%	3.67%	3.82%	3.18%	4.06%	3.73%	3.93%	3.32%
	Sharpe ratio	−0.03	−0.01	0.11	0.15	−0.02	0.02	0.07	0.10
	Sortino ratio	−0.05	−0.02	0.19	0.30	−0.03	0.03	0.13	0.19

Table 3 (continued)

Japan stocks	Mean	−0.97%	−0.65%	−0.35%	0.63%	−0.80%	−0.70%	−0.46%	0.34%
	(t-stat)	(−3.61)	(−2.64)	(−1.41)	(5.55)	(−3.35)	(−2.67)	(−1.69)	(2.29)
	Stdev	5.98%	5.45%	5.48%	2.50%	5.27%	5.84%	6.02%	3.27%
	Downside risk	4.01%	3.58%	3.46%	1.36%	3.53%	3.82%	3.82%	1.83%
	Sharpe ratio	−0.16	−0.12	−0.06	0.25	−0.15	−0.12	−0.08	0.10
	Sortino ratio	−0.24	−0.18	−0.10	0.46	−0.23	−0.18	−0.12	0.18
U.K. stocks	Mean	−0.63%	−0.27%	0.16%	0.79%	−0.37%	−0.27%	−0.07%	0.30%
	(t-stat)	(−2.59)	(−1.23)	(0.68)	(5.64)	(−1.62)	(−1.14)	(−0.29)	(2.02)
	Stdev	5.37%	4.97%	5.24%	3.10%	5.01%	5.27%	5.40%	3.25%
	Downside risk	3.68%	3.32%	3.24%	1.80%	3.47%	3.52%	3.27%	1.68%
	Sharpe ratio	−0.12	−0.06	0.03	0.25	−0.07	−0.05	−0.01	0.09
	Sortino ratio	−0.17	−0.08	0.05	0.44	−0.11	−0.08	−0.02	0.18
U.S. stocks	Mean	−0.27%	−0.11%	0.35%	0.62%	−0.26%	−0.12%	0.38%	0.64%
	(t-stat)	(−0.97)	(−0.42)	(1.47)	(4.61)	(−1.18)	(−0.46)	(1.30)	(3.90)
	Stdev	6.19%	5.53%	5.35%	3.00%	4.83%	5.81%	6.51%	3.64%
	Downside risk	3.96%	3.63%	3.45%	1.61%	3.22%	3.83%	3.89%	1.63%
	Sharpe ratio	−0.04	−0.02	0.07	0.21	−0.05	−0.02	0.06	0.18
	Sortino ratio	−0.07	−0.03	0.10	0.39	−0.08	−0.03	0.10	0.39
Global stocks	Mean	−0.58%	−0.31%	0.26%	0.84%	−0.42%	−0.29%	0.13%	0.54%
	(t-stat)	(−2.87)	(−1.62)	(1.34)	(9.72)	(−2.26)	(−1.47)	(0.61)	(6.10)
	Stdev	4.50%	4.17%	4.33%	1.92%	4.10%	4.35%	4.55%	1.97%
	Downside risk	3.26%	2.99%	2.86%	0.95%	2.99%	3.09%	3.01%	0.91%
	Sharpe ratio	−0.13	−0.07	0.06	0.44	−0.10	−0.07	0.03	0.28
	Sortino ratio	−0.18	−0.10	0.09	0.88	−0.14	−0.09	0.04	0.59

Table 3 (continued)

Panel B: Other Asset Class Portfolios		Value Portfolios				Size Portfolios			
		V1	V2	V3	V3-V1	S1	S2	S3	S3-S1
Country equity indices	Mean	−0.45%	−0.39%	−0.19%	0.26%	−0.37%	−0.36%	−0.30%	0.07%
	(t-stat)	(−1.92)	(−1.64)	(−0.83)	(1.89)	(−1.61)	(−1.58)	(−1.22)	(0.46)
	Stdev	5.16%	5.32%	5.02%	3.04%	5.06%	5.12%	5.47%	3.20%
	Downside risk	3.51%	3.63%	3.30%	1.73%	3.46%	3.51%	3.60%	1.82%
	Sharpe ratio	−0.09	−0.07	−0.04	0.09	−0.07	−0.07	−0.06	0.02
	Sortino ratio	−0.13	−0.11	−0.06	0.15	−0.11	−0.10	−0.08	0.04
Fixed income	Mean	−0.88%	−0.98%	−1.09%	−0.21%	−1.04%	−1.00%	−0.93%	0.10%
	(t-stat)	(−6.56)	(−7.02)	(−9.09)	(−2.13)	(−7.78)	(−6.98)	(−8.29)	(1.38)
	Stdev	2.63%	2.75%	2.35%	1.94%	2.61%	2.82%	2.21%	1.48%
	Downside risk	1.89%	1.92%	1.70%	1.26%	1.88%	1.94%	1.64%	0.83%
	Sharpe ratio	−0.33	−0.36	−0.46	−0.11	−0.40	−0.36	−0.42	0.07
	Sortino ratio	−0.47	−0.51	−0.64	−0.17	−0.55	−0.52	−0.57	0.13
Commodities	Mean	−1.22%	−0.99%	−0.61%	0.61%	−1.05%	−0.77%	−0.64%	0.41%
	(t-stat)	(−5.32)	(−4.95)	(−2.79)	(2.31)	(−5.33)	(−3.66)	(−2.62)	(1.64)
	Stdev	5.09%	4.44%	4.87%	5.83%	4.36%	4.67%	5.39%	5.54%
	Downside risk	3.39%	2.94%	2.94%	3.18%	2.86%	2.96%	3.31%	2.89%
	Sharpe ratio	−0.24	−0.22	−0.13	0.10	−0.24	−0.16	−0.12	0.07
	Sortino ratio	−0.36	−0.34	−0.21	0.19	−0.37	−0.26	−0.19	0.14
Global other asset classes	Mean	−0.81%	−0.71%	−0.51%	0.30%	−0.78%	−0.66%	−0.55%	0.22%
	(t-stat)	(−5.17)	(−4.84)	(−3.37)	(2.50)	(−5.59)	(−4.38)	(−3.35)	(1.88)
	Stdev	3.47%	3.27%	3.38%	2.63%	3.08%	3.36%	3.66%	2.63%
	Downside risk	2.46%	2.31%	2.22%	1.37%	2.18%	2.33%	2.43%	1.39%
	Sharpe ratio	−0.23	−0.22	−0.15	0.11	−0.25	−0.20	−0.15	0.08
	Sortino ratio	−0.33	−0.31	−0.23	0.22	−0.36	−0.28	−0.23	0.16

Table 3 (continued)

Global all asset classes	Mean	−0.64%	−0.41%	0.04%	0.68%	−0.50%	−0.38%	−0.06%	0.45%
	(t-stat)	(−3.58)	(−2.50)	(0.26)	(9.04)	(−3.12)	(−2.22)	(−0.32)	(6.10)
	Stdev	3.94%	3.67%	3.80%	1.67%	3.59%	3.80%	3.97%	1.63%
	Downside risk	2.87%	2.66%	2.57%	0.85%	2.63%	2.73%	2.69%	0.78%
	Sharpe ratio	−0.16	−0.11	0.01	0.41	−0.14	−0.10	−0.01	0.27
	Sortino ratio	−0.22	−0.16	0.02	0.80	−0.19	−0.14	−0.02	0.57
Panel A: Individual Stock Portfolios									
		Momentum Portfolios					50/50 Combination		
		M1	M2	M3		M3-M1	HML-SMB	SMB-MOM	MOM-HML
Asia Pacific Developed stocks	Mean	−0.21%	0.03%	−0.13%		0.08%	0.94%	0.48%	0.54%
	(t-stat)	(−0.68)	(0.14)	(−0.49)		(0.41)	(6.62)	(4.29)	(6.54)
	Stdev	6.86%	5.60%	6.13%		4.11%	3.15%	2.46%	1.83%
	Downside risk	4.23%	3.80%	4.37%		2.93%	1.41%	1.38%	1.01%
	Sharpe ratio	−0.03	0.01	−0.02		0.02	0.30	0.19	0.30
	Sortino ratio	−0.05	0.01	−0.03		0.03	0.67	0.34	0.53
						Correlation =	0.29	−0.28	−0.57
Canada stocks	Mean	−0.25%	−0.25%	−0.20%		0.05%	0.10%	0.45%	0.60%
	(t-stat)	(−0.75)	(−1.03)	(−0.73)		(0.25)	(7.60)	(3.77)	(6.03)
	Stdev	7.27%	5.29%	5.93%		4.48%	2.91%	2.64%	2.21%
	Downside risk	4.46%	3.38%	3.87%		2.85%	1.12%	1.29%	1.19%
	Sharpe ratio	−0.03	−0.05	−0.03		0.01	0.34	0.17	0.27
	Sortino ratio	−0.06	−0.07	−0.05		0.02	0.89	0.35	0.50
						Correlation =	0.13	−0.28	−0.40

Table 3 (continued)

Continental Europe stocks	Mean	−0.65%	−0.35%	0.14%	0.79%	0.47%	0.49%	0.77%
	(t-stat)	(−2.79)	(−1.98)	(0.67)	(6.31)	(5.83)	(6.51)	(10.94)
	Stdev	5.18%	3.93%	4.53%	2.77%	1.78%	1.66%	1.56%
	Downside risk	3.59%	2.79%	2.87%	1.49%	0.88%	0.89%	0.73%
	Sharpe ratio	−0.13	−0.09	0.03	0.28	0.26	0.29	0.49
	Sortino ratio	−0.18	−0.13	0.05	0.53	0.53	0.55	1.05
					Correlation =	0.20	−0.12	−0.28
Emerging Markets stocks	Mean	0.11%	0.06%	0.35%	0.24%	0.79%	0.43%	0.60%
	(t-stat)	(0.35)	(0.22)	(1.09)	(0.86)	(3.10)	(2.69)	(3.80)
	Stdev	6.90%	5.99%	7.08%	6.22%	5.63%	3.53%	3.49%
	Downside risk	3.94%	3.60%	4.17%	3.69%	2.87%	2.09%	1.89%
	Sharpe ratio	0.02	0.01	0.05	0.04	0.14	0.12	0.17
	Sortino ratio	0.03	0.02	0.08	0.06	0.27	0.20	0.32
					Correlation =	0.70	−0.33	−0.38
Japan stocks	Mean	−0.57%	−0.60%	−0.63%	−0.06%	0.48%	0.14%	0.28%
	(t-stat)	(−1.97)	(−2.49)	(−2.40)	(−0.35)	(4.91)	(1.53)	(3.30)
	Stdev	6.42%	5.36%	5.79%	3.61%	2.18%	2.03%	1.91%
	Downside risk	4.09%	3.52%	3.69%	2.28%	1.06%	1.12%	1.08%
	Sharpe ratio	−0.09	−0.11	−0.11	−0.02	0.22	0.07	0.15
	Sortino ratio	−0.14	−0.17	−0.17	−0.03	0.45	0.13	0.26
					Correlation =	0.12	−0.31	−0.26

Table 3 (continued)

U.K. stocks	Mean	−0.51%	−0.24%	0.02%	0.53%	0.54%	0.41%	0.66%
	(t-stat)	(−1.90)	(−1.15)	(0.10)	(3.69)	(4.97)	(4.73)	(8.55)
	Stdev	5.93%	4.72%	5.02%	3.19%	2.42%	1.94%	1.71%
	Downside risk	3.74%	3.22%	3.35%	2.17%	1.06%	1.04%	0.96%
	Sharpe ratio	−0.09	−0.05	0.00	0.17	0.22	0.21	0.39
	Sortino ratio	−0.14	−0.08	0.01	0.24	0.51	0.40	0.69
					Correlation =	0.16	−0.28	−0.41
U.S. stocks	Mean	0.06%	−0.05%	0.06%	0.00%	0.63%	0.32%	0.31%
	(t-stat)	(0.21)	(−0.24)	(0.24)	(0.02)	(6.09)	(3.43)	(4.15)
	Stdev	6.42%	4.84%	6.00%	3.16%	2.30%	2.08%	1.68%
	Downside risk	4.03%	3.23%	3.84%	2.06%	1.03%	1.07%	0.93%
	Sharpe ratio	0.01	−0.01	0.01	0.00	0.27	0.15	0.19
	Sortino ratio	0.02	−0.02	0.02	0.00	0.62	0.30	0.34
					Correlation =	−0.05	−0.26	−0.41
Global stocks	Mean	−0.29%	−0.20%	−0.06%	0.23%	0.69%	0.39%	0.54%
	(t-stat)	(−1.31)	(−1.14)	(−0.28)	(2.34)	(10.17)	(6.86)	(11.21)
	Stdev	4.86%	3.89%	4.36%	2.21%	1.51%	1.25%	1.06%
	Downside risk	3.31%	2.78%	3.04%	1.34%	0.56%	0.63%	0.46%
	Sharpe ratio	−0.06	−0.05	−0.01	0.11	0.46	0.31	0.51
	Sortino ratio	−0.09	−0.07	−0.02	0.17	1.24	0.61	1.17
					Correlation =	0.20	−0.28	−0.48

Table 3 (continued)

Panel B: Other Asset Class Portfolios								
		Momentum Portfolios				50/50 Combination		
		M1	M2	M3	M3-M1	HML-SMB	SMB-MOM	MOM-HML
Country equity indices	Mean	−0.26%	−0.42%	−0.33%	−0.06%	0.16%	0.00%	0.10%
	(t-stat)	(−1.14)	(−1.84)	(−1.33)	(−0.38)	(1.42)	(0.02)	(1.18)
	Stdev	5.14%	5.10%	5.47%	3.71%	2.54%	2.26%	1.85%
	Downside risk	3.32%	3.48%	3.73%	2.45%	1.42%	1.39%	1.08%
	Sharpe ratio	−0.05	−0.08	−0.06	−0.02	0.06	0.00	0.05
	Sortino ratio	−0.08	−0.12	−0.09	−0.03	0.11	0.00	0.09
					Correlation =	0.33	−0.15	−0.41
Fixed income	Mean	−0.95%	−1.05%	−0.98%	−0.03%	−0.05%	0.04%	−0.12%
	(t-stat)	(−7.50)	(−7.05)	(−7.77)	(−0.30)	(−0.86)	(0.58)	(−1.90)
	Stdev	2.48%	2.91%	2.47%	2.02%	1.22%	1.24%	1.25%
	Downside risk	1.73%	2.03%	1.81%	1.21%	0.79%	0.73%	0.83%
	Sharpe ratio	−0.38	−0.36	−0.40	−0.02	−0.04	0.03	−0.10
	Sortino ratio	−0.55	−0.52	−0.54	−0.03	−0.07	0.05	−0.15
					Correlation =	−0.01	−0.03	−0.20
Commodities	Mean	−1.18%	−1.02%	−0.65%	0.53%	0.51%	0.47%	0.57%
	(t-stat)	(−5.43)	(−5.72)	(−2.86)	(2.17)	(2.62)	(2.60)	(4.10)
	Stdev	4.82%	3.94%	5.07%	5.37%	4.31%	4.00%	3.06%
	Downside risk	3.04%	2.87%	3.26%	3.10%	2.12%	2.20%	1.57%
	Sharpe ratio	−0.24	−0.26	−0.13	0.10	0.12	0.12	0.18
	Sortino ratio	−0.39	−0.35	−0.20	0.17	0.24	0.21	0.36
					Correlation =	0.15	0.07	−0.40

Table 3 (continued)

Global other asset classes	Mean	−0.73%	−0.74%	−0.57%	0.15%	0.26%	0.19%	0.23%
	(t-stat)	(−4.79)	(−5.13)	(−3.53)	(1.23)	(2.82)	(2.24)	(3.35)
	Stdev	3.37%	3.18%	3.60%	2.79%	2.04%	1.87%	1.49%
	Downside risk	2.27%	2.29%	2.51%	1.71%	0.97%	1.06%	0.82%
	Sharpe ratio	−0.22	−0.23	−0.16	0.06	0.13	0.10	0.15
	Sortino ratio	−0.32	−0.32	−0.23	0.09	0.27	0.18	0.28
					Correlation =	0.20	−0.05	−0.40
Global all asset classes	Mean	−0.40%	−0.35%	−0.20%	0.21%	0.56%	0.33%	0.44%
	(t-stat)	(−2.17)	(−2.22)	(−1.11)	(2.33)	(9.62)	(6.38)	(10.80)
	Stdev	4.14%	3.49%	3.91%	1.98%	1.30%	1.14%	0.91%
	Downside risk	2.86%	2.53%	2.75%	1.19%	0.53%	0.57%	0.40%
	Sharpe ratio	−0.10	−0.10	−0.05	0.11	0.43	0.29	0.49
	Sortino ratio	−0.14	−0.14	−0.07	0.18	1.06	0.58	1.12
					Correlation =	0.24	−0.21	−0.51

This table reports the average excess (of the global risk free rate) return, *t*-statistic of the average return (in parentheses), standard deviation and downside risk of returns, and Sharpe and Sortino ratio of each value, momentum and equal-weighted 50/50 value, size and momentum combination strategy in each market and asset class we study: Asia Pacific Developed stocks, Canada stocks, Continental Europe stocks, Emerging Markets stocks, Japan stocks, U.K. stocks, U.S., stocks, country equity indices, government bond indices and commodities. In each market or asset class the universe of securities is first sorted by either value, size or momentum and then broken into three equal groups based on those sorts to form three portfolios – low, middle, and high. Also reported is the high minus low spread in returns. The 50/50 value/size/momentum combination strategies are an equal-weighted average of the value, size and momentum spread strategies for each market/asset class. Results are also reported for an average of all individual stock strategies across all stock markets ("Global stocks"), across all nonstock asset classes ("Global other asset classes"), and across all markets and asset classes ("Global all asset classes") by value (V), size (S), and momentum (M) into three groups, with V1, S1, and M1 indicating the lowest groups, V2, S2, M2 the medium groups, and V3, S3, and M3 the highest groups. There are also shown the above statistics of the following markets: *i*) all stock markets ("Global stocks"), measured as the average of monthly returns of strategies applied in equity markets; *ii*) all nonstock asset classes ("Global other asset classes") measured as the average of monthly returns of strategies applied in nonequity markets, *iii*) all markets and asset classes ("Global all asset classes"), measured as the average of monthly returns of strategies applied to all asset classes in all markets. Cooper et al. (2022) calculated the excess return of all portfolios over the US Treasury bill rate. However, they deal with a global sample (perhaps since they deal with a less global sample than that used in this analysis). To maintain homogeneity in the results and since this is a global sample from the perspective of the portfolios constructed (dependent variable of the model) and the macroeconomic factors (independent variables of the model), we considered it appropriate to calculate excess returns over a global risk-free interest rate. The global short-term risk-free rate is calculated as the market-cap weighted average of individual country short-term rates. For the US, we use the 1-month Treasury bill from Ibbotson Associates. For the other countries, we use short-term rates from Datastream. When the short-term rate of some countries was not available from the starting year (1980), it was included in the average as it became available. The table also measures two risk-adjusted performance indicators: Sharpe and Sortino ratios. The Sharpe ratio is obtained by dividing each portfolio's excess return by its standard deviation, and the Sortino ratio is obtained by dividing each portfolio's excess return by its downside risk (assuming target return $rt = rf$). The last three columns of Table 3 report the above statistics for the 50/50 combination of value, size, and momentum. The last row for each asset class and country reports the correlation of returns between value, size, and momentum.

Panel A of Table 3 reports the results for each stock strategy. According to results from international literature, all stock markets have a significant return premium of a value strategy. It ranges from 0.62% to 1.15% monthly. Momentum premia are also positive in all markets (although in the Asia Pacific Developed markets, Canada, Emerging Markets, and the US, they are not significantly different from zero), especially in Continental Europe as observed by Asness et al. (2013), except in Japan, where momentum premium is negative but statistically not different from zero as it also found in the sample of Asness et al. (2013). The size strategy needs some further considerations for two reasons. On the one hand, while Alquist et al. (2018) find that by excluding microcaps from the dataset, the size effect does not exist, in our dataset, we still get positive and statistically significant returns even excluding the 10% of smaller companies. On the other hand, while they show that by applying the strategy to a sample of 24 international countries, only the US provides a positive performance, our dataset provides a positive and statistically significant return in all equity markets worldwide. As the last row of each market indicates, the correlations between momentum and size and between momentum and value are always negative in all countries, averaging respectively about −0.28 and −0.48. In contrast, the correlation between value and size is very low (averaging about 0.20). According to Asness et al. (2013), the correlation between value and momentum strategies remains highly negative, while according to Esakia et al. (2019), the size factor has a particularly low correlation with other traditional factors, making it even more attractive to study its possible different relationship, compared to the value strategy and momentum strategy, with macroeconomic factors. Combining the three strategies (both with such strong negative correlation and low correlation) increases Sharpe ratios in most cases. In the global stocks subsample, the value/momentum, value/size, and momentum/size combinations outperform the value or momentum, or size individually analyzed. In addition, the combination of the strategies is much more stable across markets (with standard deviation and downside risk much lower than the strategies themselves). For instance, as observed by Asness et al. (2013), previous research attempting to explain why momentum does not work very well in Japan needs to compare the fact that value has performed exceptionally well in Japan during the same period, as well as the fact that the correlation between value and momentum in Japan is −0.26 over this period. Hence, before trying to explain why the momentum strategy in Japan does not perform well, it is firstly critical to understand which factors make the value strategy perform well in the same time frame and then to understand whether there is a common risk structure that explains why the two strategies are negatively correlated. One of the objectives of this work is to investigate whether the decorrelated returns of different strategies can be explained by their different sensitivity to the macroeconomic risk factors. Panel B of Table 3 reports the same statistics for the other asset classes. As observed by Alquist et al. (2018), there are no consistent size return premia in country equity index and government bond asset classes (although, overall, when evaluating the performance of all nonequity asset classes, the returns are positive but statistically not different from zero). On the contrary, the same strategy bears a consistent size return premium in the commodity market. Momentum performs well only in the commodity market while bears a negative performance, although not statistically different from zero, in the country equity indices and fixed income markets. In this case, adding countries (such as those in Developed Asia Pacific or Emerging Markets) concerning the sample of Asness et al. (2013) reduces the performance of this strategy. Value performs well in other asset classes except for fixed income, which is different from the sample of Asness et al. (2013), in which the performance is not statistically different from zero. Therefore, in contrast to Alquist et al. (2018), it is not true that only the size strategy presents problems when extended to asset classes other than individual stocks. Instead, each strategy presents peculiarities when applied to different asset classes. The correlations between momentum and value strategy and between momentum and size also remain negative in nonequity asset classes, with the exception of the correlation between size and momentum in the commodity asset class, which is very low (0.07). Although the intuition of Asness et al. (2013) to extend the application of the value and momentum strategy to nonequity asset classes and the consideration in this study of the size strategy too, it is worth noting that the value, size, and momentum premiums are lower for these asset classes than the equity asset class. Combining equity (Panel A) and nonequity (Panel B), value, size, and momentum strategies across the world and all asset classes always produces positive return premiums, from a 0.21% monthly return for the momentum strategy to 0.68% for the value strategy, passing through the 0.45% for the size strategy. The negative correlations between momentum and value strategies and between size and momentum are also present when aggregating across all markets. The 50/50 value-size combination portfolio produces a monthly Sortino ratio of 1.07, while combining the 50/50 value-momentum and momentum-size portfolios produces a monthly Sortino ratio of 1.12 and 0.58, respectively. These results are about more than double those achieved by US equity. As Asness et al. (2013) observed, it presents an even greater challenge for asset pricing models that need help explaining the magnitude of the US equity premium. These summary statistics pose significant challenges for any asset pricing model. The first question is why the returns of the value and size strategies are negatively correlated with those of the momentum strategy. Do they have different sensitivity to a common risk framework? The second issue is why a 50/50 combination of these strategies generates positive performance. Does it represent a premium return on the risk taken?

4.5 Global macroeconomic risk factors

This study aims to establish a common factor structure across multiple asset classes and markets linked to underlying global macroeconomic risk sources. A noteworthy aspect of the presented factor model is to measure risk as exposure to macroeconomic conditions impacting cash flows and discount rates, as discussed in CRR. Considering the macroeconomic conditions, the CRR factors provide a clear description of risk across global markets. Global macroeconomic variables are utilized to form the global CRR factors, aiming to identify sources of macroeconomic risk on a global scale. The factors are given by the market capitalization-weighted averages of the CRR factors of all 26 countries in our sample. Differently from Cooper et al. (2022), we decided to weigh macroeconomic factors by market capitalization, just as major index providers do in constructing stock and bond market indexes around the world.[6] There are two reasons why it was chosen to deal with market capitalization rather than GDP or GDP per capita. The first reason concerns the need to define a measure of macroeconomic factors'relevance consistent with the dependent variable. Since it is the returns on investment portfolios of asset classes listed on financial markets, the weight of macroeconomic factors should reasonably refer to the perceived relevance of each country from the financial market perspective. The second reason concerns measurement issues about GDP/GDP per capita use. Firstly, the macroeconomic data that represent the independent variables in the model have a monthly frequency, while the GDP or GDP per capita data have a yearly frequency. Therefore, to best weigh the data, it is more appropriate to deal with monthly rather than yearly weights. Secondly, the GDP measures the value of all final goods and services produced within a country in a given period. So, if the considered countries differ in terms of how their industries use outsourcing in their production, by weighing through GDP (or GDP per capita) would underweight countries whose firms tend to outsource production to foreign countries (e.g., the US) and overweight countries (e.g., emerging countries), whose production is prevailingly domestic. Table 4 shows the average weights assigned to each geographic area, using respectively the market capitalization, the GDP per capita, and the GDP as the weighting factor (market capitalization data are monthly averages from Datastream and in USD). Relative to market capitalization weights, the US is the country with the highest average weight. This is undoubted because, over time, US firms have become dominant, as their revenues originate from around the globe, as well as the remarkable rate of financial market development in countries such as the US and UK whose financial systems are market-based compared to other countries whose systems are bank-centric. The second-largest country by average market capitalization is Japan. It has been the US's main competitor for many years. However, over time, Japan lost its relevance in favor of emerging market economies (especially China and India), which gained market share, peaking at about 19% in 2010 and an average weight of about 7%.

The average weights are reported based on the market capitalization, GDP per capita, and GDP of the Asia Pacific Developed, Canada, Continental Europe, Emerging Markets, Japan, UK, and US geographical areas.

The factors of the CRR model are the following five: *i)* the industrial production growth rate (MP); *ii)* the unexpected inflation (UI); *iii)* the change in expected inflation (DEI); *iv)*

[6] For instance, see https://www.msci.com/research-and-insights/visualizing-investment-data/acwi-imi-complete-geographic-breakdown

Table 4 Weights based on market capitalization in comparison with other criteria

	Market capitalization	GDP per capita	GDP
Asia Pacific Developed	4.79%	15.31%	2.19%
Canada	2.86%	4.73%	2.64%
Continental Europe	14.44%	57.11%	24.80%
Emerging Markets	7.18%	8.32%	24.14%
Japan	18.62%	4.43%	10.37%
UK	7.75%	4.35%	4.76%
US	44.17%	5.79%	29.41%

the yield curve shifts (UTS); the changes in default risk premium (UPR). They are measured as follows. The growth rate of industrial production, MP, is defined as

$$MP_t = \log(IP)_t - \log(IP)_{t-1} \tag{2}$$

where IP_t is the global index of industrial production in month t. Data on industrial production are derived from the OECD statistics.[7]

The unexpected inflation is defined as

$$UI_t = I_t - E\left[I_t|t-1\right] \tag{3}$$

and the change in expected inflation as

$$DEI_t = E\left[I_{t+1}|t\right] - E\left[I_t|t-1\right] \tag{4}$$

where the inflation rate is measured as

$$I_t = \log(CPI)_t - \log(CPI)_{t-1} \tag{5}$$

where CPI_t is the seasonally adjusted Consumer Price Index at time t, collected for the US from the US Bureau of Labor Statistics and other countries from Datastream.

The expected inflation is given as

$$E\left[I_t|t-1\right] = r_{f,t} - E[RHO_t|t-1] \tag{6}$$

where $r_{f,t}$ is the short-term rate calculated as a market cap-weighted average of individual country short-term rates. For the US, we use the one-month Treasury bill rate from Ibbotson Associates, while for the other countries, we use the shortest-term rates from Datastream, following Cooper et al. (2022).

$$RHO_t = r_{f,t} - I_t \tag{7}$$

is the realized real short-term return.

We use Fama and Gibbons' (1984) method to measure the ex-ante real rate, $E[RHO_t|t-1]$. The difference between RHO_t and RHO_{t-1} is modeled as a first order moving average process:

$$RHO_t - RHO_{t-1} = u_t + \theta u_{t-1} \tag{8}$$

7 https://stats.oecd.org/

and, consequently, the expected real return is derived from the following relationship:

$$E\left[RHO_t|t-1\right] = \left(r_{f,t-1} - I_{t-1}\right) - \hat{u}_t - \theta\hat{u}_{t-1} \tag{9}$$

where θ is the moving average parameter [MA (1)] estimated following the nonlinear least squares procedure of Box and Jenkins (1976), and $\hat{u}_t$ is the moving average error. The Box-Jenkins methodology allows the selection of an ARIMA (0,0,1) model.

The global term premium, UTS, is the market cap-weighted long-term government bond yield minus the market cap-weighted short-term government bond yield. The long-term interest rate data for the US are from the Federal Reserve Bank of St. Louis, while the data for the remaining countries are derived from Datastream.

Due to the limited availability of data on corporate bond yields, the default factor is represented by the US default spread, UPR. The default spread is the difference between Moody's Baa and Aaa corporate bond yields. Data are from the Federal Reserve Bank of St. Louis.

Table 5 shows the correlation matrix between the five macroeconomic factors (the independent variables). As can be seen, all macroeconomic factors are uncorrelated or little related except for the UI and DEI factors, which exhibit high correlation (this will be discussed in Sect. 4). Finally, regarding the macroeconomic data of different countries, it is worth noting that not all data have been available since 1980. As each country's macroeconomic data becomes available, it is included in the market-cap-weighted average.

5 The empirical test: design and results

This section's objective is to test whether global macroeconomic factors affect the returns of these investment strategies. The objective is first to test whether there is a statistically significant macroeconomic effect and then to try to understand whether the results are economically meaningful. Once the relationships with macroeconomic factors have been found, the section will try to answer the possible causes behind the low (or even negative) correlations between the returns of the three strategies analyzed. In this regard, it is crucial in this context to deal not only with the value and momentum strategies (as done by Cooper et al. 2022) but also with the third strategy – size – that can help us integrate and possibly confirm/confute the results obtained. We ask whether the different correlation between the strategies'returns can be explained through a different (or opposite) sensitivity of the strategies to global macroeconomic factors. In addition, Table 3 shows another

Table 5 Correlations among macroeconomic factors

	MP	UI	DEI	UTS	UPR
MP	1	0.03	0.05	−0.01	−0.22
UI	0.03	1	0.83	0.04	0.01
DEI	0.05	0.83	1	0.03	0.01
UTS	−0.01	0.04	0.03	1	−0.07
UPR	−0.22	0.01	0.01	−0.07	1

This table reports the correlation matrix between the five macroeconomic factors (that is, the independent variables of the model): industrial production index (MP), unexpected inflation (UI), change in expected inflation (DEI), term spread (UTS), and default spread (UPR) important element: the combination between low (or negative) correlated strategies always produces a positive return. A further objective is therefore to understand if such positive returns could be explained in terms of their exposition to macroeconomic risks.

5.1 The tested model

The goal of the model is to investigate whether a price of risk of the global macroeconomic risk factors exists, in the three portfolio strategies and to examinate whether these factors can explain the cross section of returns. Hence, the first step consists in estimating the risk premia of the five CRR global macroeconomic risk factors and examine whether these factors can explain the cross-sectional differences in returns. To this end, we specify a multi-factor linear model that can explain the expected returns:

$$E(r_{i,t}) = \lambda_0 + \beta' \lambda \tag{10}$$

where: $r_{i,t}$ is the excess return on asset i; λ_0 is a constant; β' is a vector of regression coefficients obtained from a multiple regression of excess returns on the global CRR 5 factors; λ is a vector of prices of risk. The model is estimated using the cross-sectional regression methodology à la Black et al. (1972), which follows two steps. The first step involves a time-series regression over the period June 1980 – June 2021 of the 90 obtained portfolios'excess returns on the five macroeconomic factors using the entire sample period:

$$r_{i,t} = \alpha_i + \beta_{i,MP} MP_t + \beta_{i,UI} UI_t + \beta_{i,DEI} DEI_t + \beta_{i,UTS} UTS_t + \beta_{i,UPR} UPR_t + \varepsilon_{i,t} \tag{11}$$

The second step involves the estimation of the risk premium associated with each macroeconomic variable through a single cross-sectional regression of the average excess returns of each 90 portfolios on the factor loadings estimated in the time series regressions.

$$\overline{r}_i = \lambda_0 + \widehat{\beta}_{i,MP} \lambda_{MP} + \widehat{\beta}_{i,UI} \lambda_{UI} + \widehat{\beta}_{i,DEI} \lambda_{DEI} + \widehat{\beta}_{i,UTS} \lambda_{UTS} + \widehat{\beta}_{i,UPR} \lambda_{UPR} + \eta_i \tag{12}$$

where:

- $\overline{r}_i$ is the average excess return on each 90 portfolios i.
- λ_{MP}, λ_{UI}, λ_{DEI}, λ_{UTS}, λ_{UPR} are the estimated risk premium associated with the global industrial production growth, unexpected inflation, changes in the expected inflation, yield curve changes, and default spread factors.
- $\widehat{\beta}_{i,MP}$, $\widehat{\beta}_{i,UI}$, $\widehat{\beta}_{i,DEI}$, $\widehat{\beta}_{i,UTS}$, $\widehat{\beta}_{i,UPR}$ are the coefficients estimated in the time-series regression for the regressors mentioned above.
- η_i is the residual component.

Each factor is given by the market capitalization-weighted averages of the CRR factors of all 26 countries in the sample. It may seem counterintuitive to examine the average returns to value, momentum, and size across a broad set of markets and asset classes simultaneously. However, as Asness et al. (2013) demonstrate, the power of looking at the universal average return to value, momentum, and size strategies greatly improves the ability to identify their common factor exposure. In fact, averaging across all markets and asset classes helps to reduce the impact of noise unrelated to value, size, or momentum. This noise includes idiosyncratic regional or asset-specific factors. By doing so, it becomes easier to identify common factors. When attention is limited to a single asset class or a specific strategy within an asset class, detecting these patterns becomes challenging.

The comprehensive and uniform study of value, momentum, and size across all markets simultaneously could enable the identification of these patterns.

5.2 The empirical results

Table 6 reports the estimates of the prices of risk for 5 CRR global macroeconomic factors from the second step of Black et al. (1972) procedure, where we use the average excess returns on the 90 long-only value, size, and momentum returns as the testing assets. In particular, the first step estimates the factor loadings for each of the 90 portfolios with a time-series regression of the portfolio excess returns on the five global CRR factors, using the entire sample period (June 1980 – June 2021). The second step is a cross-sectional regression of average excess portfolio returns on the estimated loadings. Despite the high correlation between UI and DEI factors, we chose to run the model as proposed by Chen et al. (1986). In fact, in empirical analysis, a correlation coefficient of 0.83 does not necessarily indicate severe multicollinearity or significantly impact regression results. The condition number proposed by Belsley et al. (1980) is a more reliable measure. In particular, we observed that the VIFs (variance inflation factors) of the regression are all below 10 (the threshold value for the absence of multicollinearity) and the highest Besley, Kuh, and Welsch condition index is 7.76 (with a value above 30 indicating moderate to strong

Table 6 Estimates of prices of risk from the cross-sectional asset pricing test

	Coefficient	std. error	t-stat	*p*-value	
const	−0.666	0.001	−6.602	3.5E-09	***
$\hat{\lambda}$ MP	−0.358	0.002	−1.695	9.4E-02	*
$\hat{\lambda}$ UI	−0.066	0.001	−0.918	3.6E-01	
$\hat{\lambda}$ DEI	0.118	0.001	2.166	3.3E-02	**
$\hat{\lambda}$ UTS	0.265	0.001	3.985	1.4E-04	***
$\hat{\lambda}$ UPR	0.559	0.001	6.002	4.8E-08	***
R-squared	0.365	Adjusted R-squared	0.327		

HAC standard errors, bandwidth 5, Kernel of Bartlett

White test for heteroscedasticity -

Null hypothesis: absence of heteroscedasticity

Test statistics: LM = 26.89

with p-value = P (Chi-square (20) > 26.89) = 0.138

Test for normality of residuals -

Null hypotesis: error is normally distributed

Test statistics: Chi-square (2) = 3.152

with *p*-value = 0.207

*Indicates statistical significance at the 10% level

**Indicates statistical significance at the 5% level

***Indicates statistical significance at the 1% level

This table reports the estimates of prices of risk for the industrial production growth (MP), unexpected inflation (UI), change in expected inflation (DEI), term spread (UTS), and default spread (UPR), using the Black et al. (1972) 2-step methodology. The test assets are the 90 value, size, and momentum portfolios. The intercept and the prices of risk are in percentage. The sample period is June 1980 – June 2021. Test results for heteroscedasticity and normality of residuals are also reported.

collinearity), confirming that the condition of no multicollinearity is met. However, in the robustness tests we have also run the regression without UI factor. Moreover, to test the robustness of the estimation of linear regression parameters, we tested whether the residuals'normality and homoscedasticity (the latter is often violated in cross-sectional regressions) were met. In this regard, we ran: *i)* White's test for heteroscedasticity tests the null hypothesis of the absence of heteroscedasticity. The value of the test statistic is 26.89 with a p-value (Chi-square distribution) of 0.138. Therefore, the null hypothesis was accepted; *ii)* Chi-square test for normality of residuals tests the null hypothesis that the error is normally distributed. In this case, the value of the test statistic (Chi-square distribution) is 3.152 with a p-value of 0.207, leading us to accept the null hypothesis.

The prices of risk associated with MP, DEI, UTS and UPR are statistically significant. Analyzing the results, we can state that for each unit of portfolio beta associated with the MP, DEI, UTS, and UPR factors, that unit contributes −0.358, 0.118, 0.265, and 0.559 monthly, respectively, to the portfolio average excess return. Therefore, in phases of rising industrial production, for example, we expect that on average, for each unit of beta in our portfolio associated with the MP factor, the portfolio will lose 0.358 monthly, while in phases of rising inflation expectations we expect that for each unit of beta in our portfolio associated with the DEI factor, the portfolio will gain on average 0.118 monthly. The use of the new dataset, in comparison with that of Cooper et al. (2022), changes the sign of the estimated risk premiums for the MP, DEI, and UPR factors, but without impacting their statistical significance. In addition, compared with the analysis conducted by Cooper et al. (2022), the risk premium associated with the UTS factor results to be statistically significant, while the risk premium associated with the UI factor is not statistically significant like in Cooper et al. (2022). The negative sign on MP and the positive sign on DEI are not consistent with the findings of Cooper et al. (2022). The positive and statistically significant signs of UTS and UPR are consistent with the findings of Fama and French (1993) and Asness et al. (2013). To test the effect on the expected returns of the strategies, one should compare the sign of the estimated risk premium for each macroeconomic factor with the coefficients obtained for each strategy (and not portfolio) in the time-series regressions. What we can say with certainty, however, is that the five macroeconomic factors explain more than 30% of the cross-sectional variation among the returns of the 90 portfolios constructed according to the value, momentum, and size strategies. This explanatory power indicates that markets are integrated across countries and asset classes and that the returns produced by these strategies price the global macroeconomic risk.

The cross-sectional analysis has been useful in investigating whether macroeconomic risk factors are priced into the returns of the 90 portfolios constructed by ranking them according to value, size, and momentum factors. However, this analysis is not useful in determining the effect the macroeconomic factors have on the returns of the value, size, and momentum strategies. The second step is to analyze the betas obtained by regressing the time-series returns of the strategies on the five macroeconomic factors. Figure 1 graphically shows the obtained results.

This figure plots the loadings concerning the five macroeconomic global factors for the value, size and momentum. Graph A presents the loadings with respect to industrial production growth (MP). Graph B plots the loadings on unexpected inflation (UI). Change in expected inflation (DEI), Term spread (UTS), and default spread (UPR) loadings are respectively plotted in Graphs C, D, and E. Everywhere represents the macroeconomic factor loadings for the entire sample. Equity represents the macroeconomic factor loadings for the equity asset class of all countries analyzed. Non-equity represents the macroeconomic factor loadings for the bond asset class and commodities.

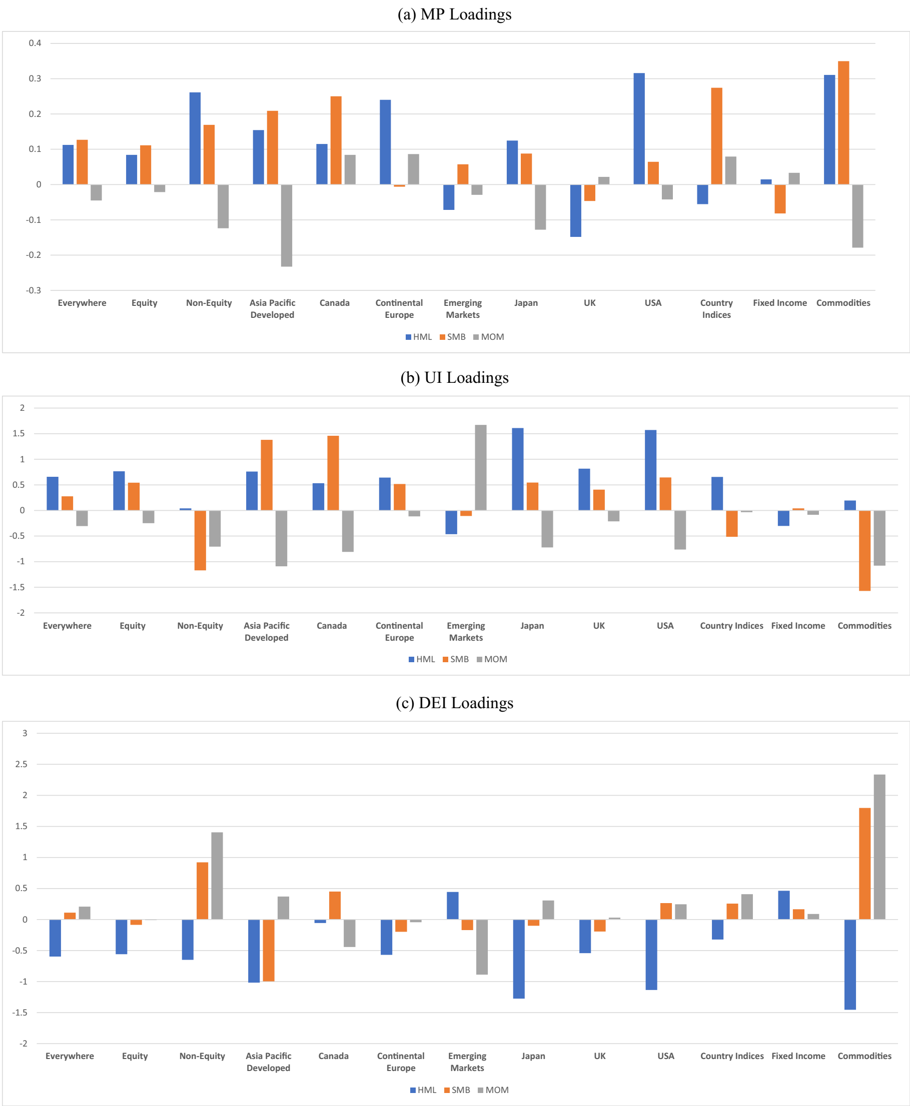

Fig. 1 Factor loadings of Value, Size and Momentum strategies

Relative to the relationship with the industrial production index growth rate (MP), whose risk premium obtained from the cross-sectional regression is negative, it emerges that for the value strategy the sign of the beta coefficient estimated in the time-series regressions is positive everywhere, for the equity asset class and the nonequity asset classes (bond and commodities). In most cases, there is a negative expected return contribution from exposure to the MP factor. This is consistent with the definition of value companies as those undervalued by the market. The results are consistent with Baltussen et al. (2021) and Hu et al. (2024) findings: value strategy in the equity market has significantly higher returns during recession periods. As far as the SMB strategy, the sign

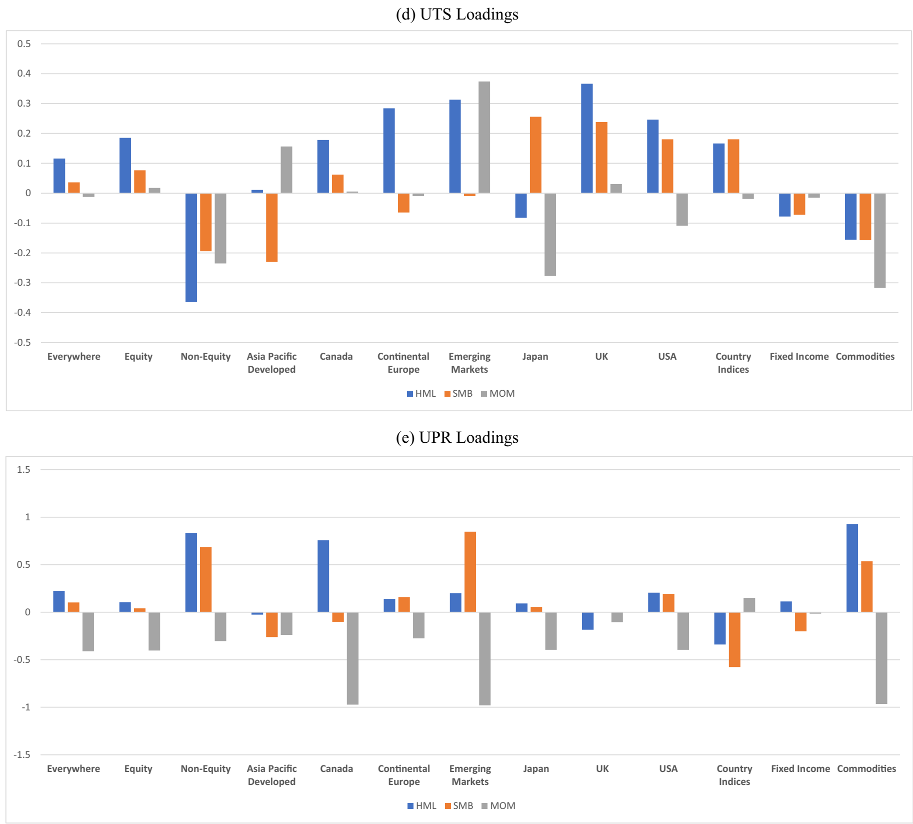

Fig. 1 (continued)

of the estimated beta coefficient in the time-series regressions is positive everywhere, especially for the equity and nonequity asset classes. In most cases, there is a negative expected return contribution from exposure to the MP factor. This result is not consistent with what might be expected since, in expansionary phases of the economy, the performance of small-cap stocks is expected to be higher than that achieved by large-cap stocks. However, it should be noted that this result may depend on the financial market environment of the past 20 years. In fact, we observed the emergence of companies that have captured a huge market share at the expense of small caps. It should be considered, for example, Amazon, Apple, Alphabet, and Microsoft, which have seen their earnings, and thus their stock price, increase enormously, leaving little room for small caps to outperform. About the momentum strategy, the sign of the estimated beta coefficients in the time-series regressions is mainly negative everywhere. In most cases, there is a positive expected return contribution from exposure to the MP factor, according to Chordia and Shivakumar (2002) and Goyal et al. (2025). In an expected growth context, a greater appetite for risk by investors and a greater enthusiasm in the financial markets (perhaps also due to behavioral errors) could be expected, which may lead to more trading of securities as well as more liquidity in the markets, thus favoring the returns of this strategy.

Regarding the relationship with the change in inflation expectations (DEI), whose risk premium obtained from the cross-sectional regression is positive, it appears that for the value strategy, the sign is negative everywhere, as are the equity and nonequity asset classes. In most cases, there is a negative expected return contribution from exposure to the DEI factor. The results in the equity asset class are consistent with Neville et al. (2021) findings: the value performance is weak during inflationary periods. On the other hand, the results on nonequity asset classes are consistent with Baltussen et al. (2021) findings. As far as the SMB strategy, the sign is negative for the equity asset class and positive for the nonequity asset class, especially commodities. As for the equity asset class, there is a negative expected return contribution from exposure to the DEI factor, consistent with the hypotheses. An increase in inflation expectations penalizes smaller firms more than larger ones. The results are consistent with Neville et al. (2021) and Blitz (2022) findings: smaller companies perform poorly in inflationary regimes. About commodities asset class, commodities that are"larger"by construction are also those more traded. In periods of upward inflation expectations, the most heavily traded commodities relate to shelter goods and the energy market (so-called anti-inflation commodities). Therefore, in such a macroeconomic environment, we expect the size strategy to be constructed by going short on"anti-inflationary"commodities such as gold, oil, and gas and going long on other commodities (e.g., live cattle, soybeans, wheat, etc.). Since the beta obtained from the time-series regression is negative and the risk premium associated with the DEI factor positive, there is a negative expected return contribution from exposure to the DEI factor for the commodities asset class. Therefore, with increasing changes in inflation expectations, the size strategy applied to commodities is expected to generate negative performance. About the momentum strategy, the sign is slightly negative for the equity asset class and positive for the nonequity asset class, especially commodities. Regarding the equity asset class, the expected returns of the momentum strategy is slightly negative. It is economically meaningful and consistent with the hypotheses: in an increasing inflation expectations scenario, investors may be inclined to sell stocks that produced positive performance during recent periods to take refuge in safer assets (*flight-to-safety*). At the same time, higher inflation especially penalizes the prices of companies that have made many investments, which often coincide with those stocks that have received greater inflows from the capital market. In addition, a rise in inflation expectations generates fears of implementing tight monetary policies that often mean less liquidity in the financial markets and, thus, lower efficiency of the momentum strategy. As for the bond asset class, the expected average return of the momentum strategy is slightly positive. This could be counterintuitive with the hypotheses. However, it should be emphasized that this result does not assume such high importance since the performance of the momentum strategy applied to this asset class turns out to be statistically not different from zero (Table 3, panel B).

About the relationship with the yield curve (UTS), whose risk premium obtained from the cross-sectional regression is positive, it appears that for all three strategies analyzed, the sign of the betas obtained from the time-series regressions is positive for equity and negative for the nonequity asset class. Therefore, for the equity asset class, the effect of the macroeconomic factor related to the yield curve on the average expected returns of the three strategies applied to the equity market is positive. It is economically meaningful and consistent with the hypotheses: an increase in the yield curve is synonymous with entering an expansive phase of the economy and the stock markets welcome the expansionary phase. In particular: *i)* the value strategy will generate positive performance since value stocks are considered riskier by the market (for instance, see Fama and French 1996; Campbell et al. 2011; Maloney and Moskowitz 2021 and Beccalli et al. 2023); *ii)* the size strategy will generate positive performance because, in expansive phases of the business cycle, small companies tend to perform better than large companies; *iii)* the momentum strategy will generate positive performance because more investor appetite for risk and greater enthusiasm in financial markets is expected (perhaps also due to behavioral errors), which may lead to greater trading of securities and thus greater market liquidity, thus favoring the returns of this strategy.

Regarding the relationship with the credit spread (UPR), whose risk premium obtained from the cross-sectional regression is positive, it appears that for the value strategy, the sign is positive over the whole sample. Therefore, the effect of the macroeconomic factor related to the credit spread on the expected returns of the value strategy is positive. A widening of the credit spread positively affects the expected returns of the strategy. A widening credit spread between low and high-rated issuers is synonymous with increased volatility in financial markets. Increased volatility generates positive returns in the value strategy applied to both the stock and bond markets. As far as the size strategy, the sign is slightly positive in the stock market and negative in the bond market. Therefore, a widening of the credit spread generates a positive effect on the expected returns of the strategy in the equity market and a negative effect on the expected returns in the bond market. This is counterintuitive for the equity asset class since the increase of the default risk of less healthy issuers is expected to underperform small caps relative to large caps. However, it should be considered that the beta of the overall equity market tends to be low (almost zero) and that what largely affects the result is the beta associated with the strategy as applied to the Emerging Country equity markets. About the momentum strategy, the sign is negative in all the asset classes. Therefore, the effect of the macroeconomic factor related to the credit spread on the expected returns of the momentum strategy is negative. Widening the credit spread generates volatility in the financial markets that leads investors to sell the best-performing stocks, generating a negative performance of the momentum strategy across all asset classes.

Some preliminary conclusions could be derived. Firstly, there is a statistically significant link between macroeconomic factors and the returns of the three strategies. Hence, it has been possible to demonstrate that a global macroeconomic source of risk does exist and explain the variation in returns across countries and asset classes. Secondly, the results of the empirical analysis are economically meaningful and consistent with the hypotheses. The only exceptions are the findings related to the returns of the size strategy applied to equity, industrial production growth rate, and credit spread. However, the former relationship would seem to be explained by the disproportionate growth of highly capitalized companies relative to small-cap companies that were left with very small portions of the market; the latter relationship, on the other hand, might be attributed to the presence of Emerging Markets into the sample.

5.3 Results of the combo strategies

Table 7 shows how the returns obtained from the portfolios constructed by equally weighting the strategies produce positive returns in all asset classes and across the world.

The first objective is to verify whether it is possible to explain the low (or negative) correlation between strategies by means of the different signs of their relationship with macroeconomic factors. The second is to verify whether the positive performance produced by the combo strategies could be explained in terms of a reward for residual macroeconomic risks. To answer the first question, Fig. 1 shows that: *i)* size and value – the two strategies

Table 7 Combo strategies performances and correlation between strategies

	HML-SMB	SMB-MOM	MOM-HML
Average Performance	0.56%	0.33%	0.44%
Correlation	0.24	−0.21	−0.51

This table shows returns obtained from the portfolios constructed by equally weighting the strategies and their relative correlations

with the highest correlation of returns – have concordant signs of factor loadings. Their loadings always have the same sign with macroeconomic variables, with the only exception of discordant loadings with DEI (moreover, heavily influenced by the commodity loadings); *ii)* size and momentum show discordant signs of factor loadings in the relationships with the MP and UPR factors, while they show concordant signs of factor loadings in the relationships with the DEI and UTS factors; *iii)* value and momentum – the two strategies with the lowest correlation of returns – show discordant signs of factor loadings (except in the relationship with UTS). Therefore, the positive correlation between value and size strategies could be explainable through a similar relationship of these strategies have with the macroeconomic factors analyzed. In the same vein, the negative correlations that the value and size strategy have with the momentum strategy could be explained by the opposite relationships (more pronounced in the case of momentum and value strategies) of these strategies with the macroeconomic factors. For the second objective of the analysis, it is necessary to analyze the factor loadings of the combo strategies with the macroeconomic factors (Fig. 2). Despite the differences in exposure to global macroeconomic risks of individual strategies, the combination between strategies is not neutral to global macroeconomic risk factors. As can be seen, the macroeconomic risk sensitivity of the combination of strategies is neutral only in the combo of momentum and size strategies in a few cases. They are neutral *i)* in the case of DEI loadings in the equity asset class and *ii)* in the relationship everywhere with the UTS factor. Moreover, if we look at the combos between value and size strategies (everywhere), we can see that the combination between these strategies always has a higher sensitivity to macroeconomic factors than the combos they have with the momentum strategy.

This figure plots the loadings concerning the five macroeconomic global factors for the value, size and momentum. Graph A presents the loadings with respect to industrial production growth (MP). Graph B plots the loadings on unexpected inflation (UI). Change in expected inflation (DEI), Term spread (UTS), and default spread (UPR) loadings are respectively plotted in Graphs C, D, and E. Everywhere represents the macroeconomic factor loadings for the entire sample. Equity represents the macroeconomic factor loadings for the equity asset class of all countries analyzed. Non-equity represents the macroeconomic factor loadings for the bond asset class and commodities.

Therefore, we might expect that the combo between value and size strategies should result in higher compensation for the higher macroeconomic risk incurred. In contrast, we might expect this compensation to be lower for the combination of size and momentum strategies, being the only combination that sometimes has null factor loadings. The results of Table 7 show that the combination of size and value strategy produced a higher performance over the period considered. Combining the results in Table 7 and the sensitivities of the combinations between strategies shown in Fig. 2, this higher average return could represent a reward for the higher sensitivity to macroeconomic risk factors than the other two combinations. It can also be seen that the lowest average return is obtained by the

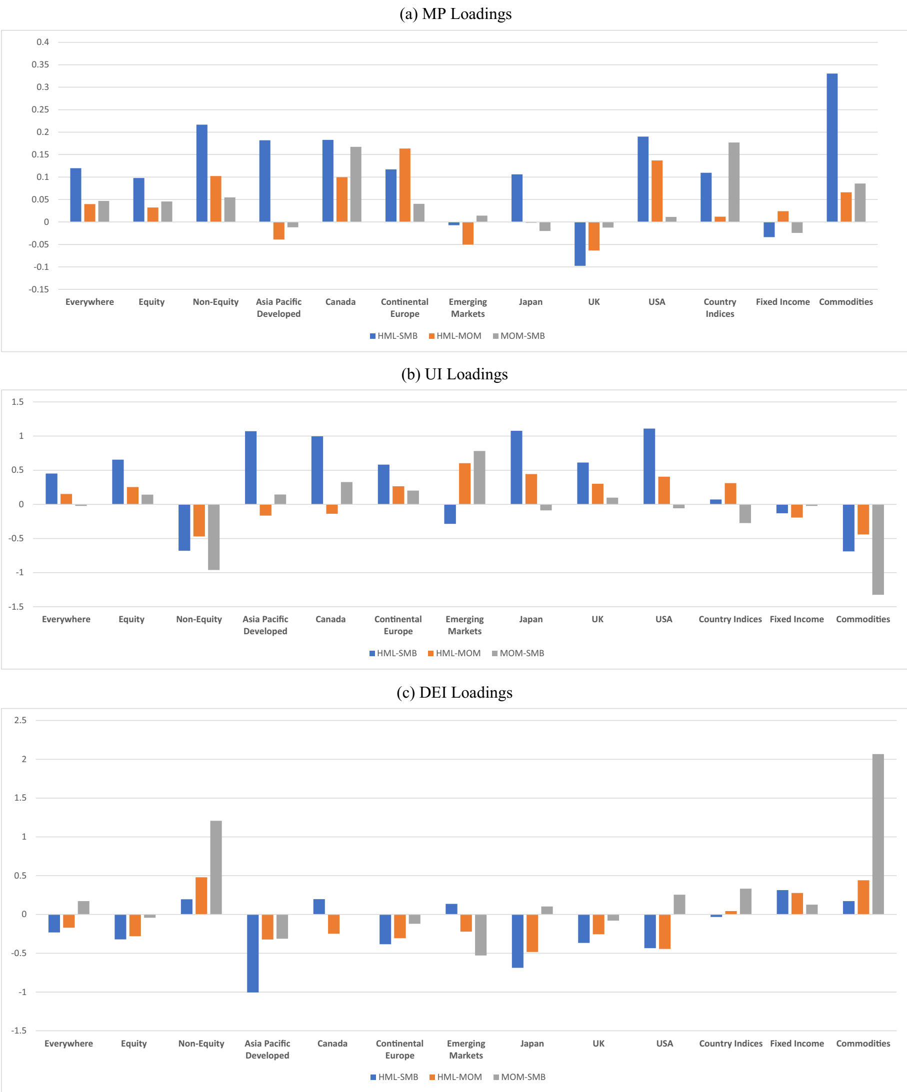

Fig. 2 Factor loadings of Value, Size and Momentum combo strategies

combination of size and momentum strategies, which, on the contrary, is the only combination that has zero sensitivity to some macroeconomic risk factors in some asset classes. Finally, it is possible to conclude that: *i)* the combination of strategies (individually analyzed) whose factor loadings exhibit a non-univocal relationship with macroeconomic risk factors do not exhibit factor loadings that are neutral to overall macroeconomic factors; *ii)* given the risk premia estimated in Table 6, the combination of strategies exhibits positive returns that could be interpreted as a compensation for the residual macroeconomic risks.

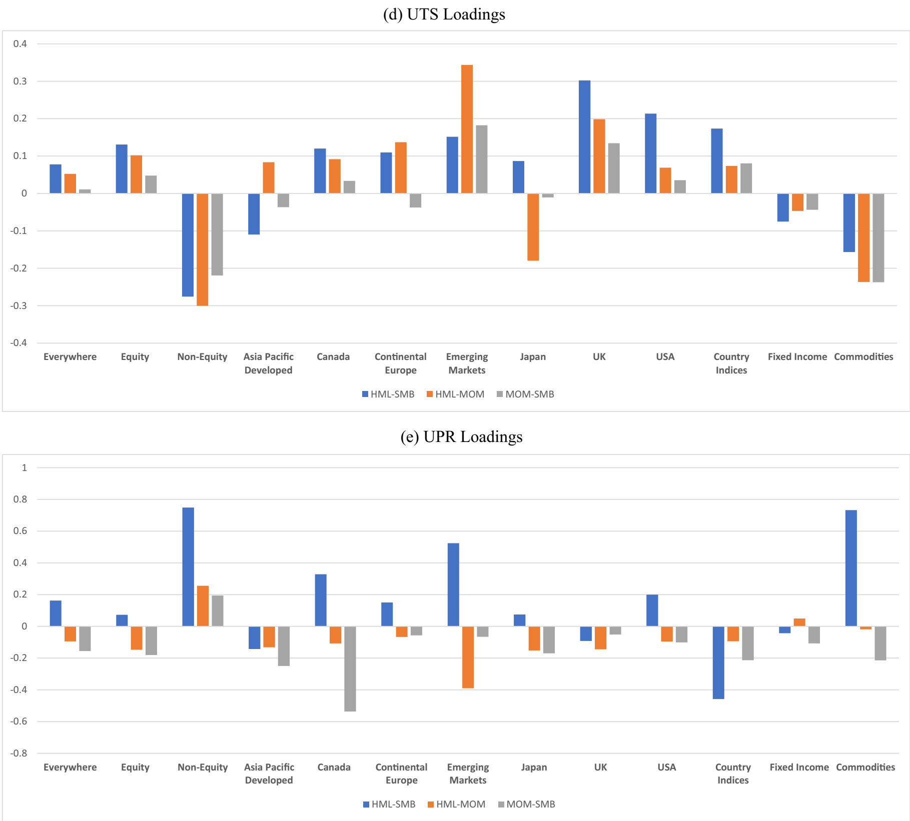

Fig. 2 (continued)

6 Robustness tests

To give more robustness to the obtained results, a set of robustness tests were carried out.[8]

Since the high correlation between UI and DEI factors, as shown in Table 5, we chose to run a cross-sectional regression without UI factor, to avoid any sort of multicollinearity problem. The results indicate no significant differences compared to the main model presented in Table 6 neither in terms of the signs of the coefficients, nor the model's R-squared (which decreases slightly from 0.365 to 0.355), nor the statistical significance of the coefficients. The only exception is DEI, whose significance level shifts from 5 to 1%.

The second robustness test involves the macroeconomic factors weights. It was therefore decided to conduct the same tests, using GDP per capita as weight for the macroeconomic variables. This analysis shows how the results do not differ in terms of sign with macroeconomic variables but in terms of statistical significance of some macroeconomic variables.

The third robustness test was conducted by changing the risk-free rate. In this regard, we note that in our case we are dealing with a global risk-free rate. It means dealing with

[8] Data are available upon request.

an interest rate that is too high, reflecting the interest rate of emerging countries where inflation is sometimes much higher than in developed countries. Therefore, a robustness test was conducted to address this possible objection by regressing the excess US risk-free rate returns of the 90 portfolios on global macroeconomic variables. Results show that the relationships with the macroeconomic variables do not change either in sign or statistical significance (the variable MP is more statistically significant than in the original model, while the variables DEI and UTS are less significant, but remain statistically significant).

Another type of robustness test was developed by regressing excess returns on the macroeconomic variables of the two main geographical areas related to developed countries: the US and Continental Europe. The results show that the use of global macroeconomic factors rather than those of more developed geographic areas affects only the statistical significance of certain variables while it does not affect the sign of the estimated risk premia. Hence, it is possible to state that the worldwide model is also valid for the most developed markets.

Finally, the results were analyzed for completeness by applying the size strategy, based solely on market capitalization/issued debt, to the asset class of equity and government bond indices. Again, there is no difference in both the sign and statistical significance of the estimated risk premia for all four macroeconomic variables, thus confirming the robustness of the main empirical test.

7 Conclusions and practical implications

This study provides comprehensive evidence on the return premia of value, size, and momentum strategies analyzed globally and across many asset classes and reveals a common risk factor structure that affects their performance. By jointly examining the strategy returns across seven macro geographic areas (i.e., Asia Pacific Developed, Canada, Continental Europe, the Emerging Markets, Japan, United Kingdom, and United States) and four different asset classes (i.e., single stocks, equity indexes, government bond indexes, and commodities), we found that the size strategy is negatively correlated with the momentum strategy and has a low correlation with the value strategy. On the other hand, the findings of Asness et al. (2013) are confirmed: the value and the momentum strategies are negatively correlated. Moreover, an equal combination of negatively or poorly correlated strategies produces a positive return over time. In this regard, we further find that exposure to global macroeconomic risk factors, in the form of exposure to the global CRR macroeconomic factors, explains this correlation structure. The empirical evidence indicates that global macroeconomic factors explain more than one-third of the cross-sectional differences in returns of value, momentum, and size applied to all asset classes listed on markets around the world, and, in most cases, they are economically meaningful. These findings indicate that markets are integrated across countries and asset classes and that the returns produced by these strategies price the global macroeconomic risk. The results show that the impacts of global macroeconomic factors on pricing value, size, and momentum portfolios are not limited to equities, but are also observable in nonequity asset classes. Moreover, global macroeconomic factors play an important role in summarizing the average returns on value, size, momentum portfolios, and combinations of strategies across international markets and asset classes. They account for the negative correlations between size and momentum strategies, the negative correlation between value and momentum strategies, and the positive correlation between value and size strategies. We showed how: *i*) size and value – the two strategies with the highest correlation of returns – have concordant signs of macroeconomic factor loadings; *ii*) value and momentum – the two strategies with the lowest correlation of returns – show discordant signs of macroeconomic factor loadings. The power of the macroeconomic risk factors lies in their ability to explain why the combinations between strategies negatively (or scarcely) correlated produce positive returns. In this regard, we showed that the returns of the combination portfolios are not neutral to the macroeconomic risk factors. Hence, the combination of strategies exhibits positive returns that could be interpreted in terms of remuneration of their macroeconomic risks. The work conducted can assume practical importance for operators in the asset management industry. In fact, not only the negative correlations of returns obtained from different investment strategies (e.g., between momentum and size and between momentum and value) were confirmed, but also the causes of these correlations were identified. This implies that asset managers could either mix the three strategies to achieve better risk-adjusted performance or over/underweight one of the strategies based on expectations about macroeconomic factors to generate extra-performance. For example, if it was found that the size strategy produces negative performance during expansive phases of the cycle (i.e., in the presence of growth in the industrial production index), while the momentum strategy produces positive returns during the same phase, then asset managers might decide to underweight the size strategy (without removing it from the portfolio because of its decorrelating effect) and, at the same time, overweight the momentum strategy. Thus, producing an extra-performance in a phase of growing industrial production index. There is ample room for further research on portfolio theory. It is possible to boost the literature by analyzing the relationships between asset classes/portfolio strategies and macroeconomic factors and, therefore, to try to shift the current paradigm.

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This research has been conducted in full compliance with ethical standards and relevant approval protocols. All data and materials used in this study have been independently sourced by the authors and are appropriately cited within the manuscript. The data supporting the findings of this study are available from the corresponding author upon reasonable request.
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