Essays on Empirical Asset Pricing and Under-investment Puzzle: Evidence From the UK

Dongna Zhang

PhD

University of York

Economics

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Abstract

Chapter 1 provides an overall introduction. In Chapter 2, I construct UK-version Fama-French asset pricing factors and portfolios. The Fama-French five-factor model is augmented with a momentum factor to form the six-factor model. The performance of the Fama-French three-, Carhart four-, Fama-French five- and six-factor models is comprehensively compared. The three- and four-factor models perform poorly comparing with the five-factor and six-factor models. The profitability factor appears to be a promising factor while the investment factor is redundant in the UK market. It is shown that a four-factor model that includes the market, value, momentum and profitability factors perform better than the other models in explaining the cross-sectional variation of stock returns. Chapter 3 estimates a dynamic asset pricing model that jointly prices excess returns on stocks and government bonds in the UK. This model fits the cross section of test assets on average as well as providing time-varying countercyclical risk premiums. The results indicate that the equity market factor, level and slope of the yield curve are priced in both stock and bond returns. Inflations and the output gap are informative in predicting asset returns at business cycle frequencies. Risk premiums are found to be substantially higher and more volatile during economic recessions. Chapter 4 investigates the under-investment puzzle using three categories of variables: innovation, capital structure and uncertainty. The empirical results show that the real sales growth is more important than cash flow in explaining the under-investment issue in the post-2008 period. The evidence shows that R&D expenditures and TFP growth play an important role in explaining the UK under-investment puzzle. Leverage contributes to explain the investment gap since 2002. It is confirmed that uncertainty is one important determinant of UK firms' investment decisions. Chapter 5 outlines the contributions and directions for the future work.

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Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

Chapter 1

Introduction

This thesis comprises three essays investigating topics in empirical asset pricing, macro-finance and the investment gap in the UK. The story in this thesis starts from one key concept: the risk premium, which is the return in excess of the risk-free rate. As the foundation of asset pricing literature, the capital asset pricing model (CAPM) shows that the expected excess return should be proportional to risk beta. Instead of a single factor model specification, multifactor asset pricing models use multiple regressions to analyse the relationship between the risk premium and risk factors. The Fama-French three-factor and Carhart four-factor models have received huge empirical success in explaining the variation of average stock returns since the 1990s. Recent developments in multifactor models have added the investment and profitability factors. In early work, Cochrane (1996) explains average stock returns variation through an investment return factor pricing model. More recently, Hou et al. (2015) propose a Q-factor model based on the neoclassical Tobin's Q theory of investment. In addition to the market and size factors the Q-factor model introduces two new factors: an investment factor, which is the difference between the return on a portfolio of low investment stocks and the return on a portfolio of high investment stocks; and a profitability factor, which is the difference between the return on a portfolio of high profitability stocks and the return on a portfolio of low profitability stocks. Motivated by the dividend discount model, Fama & French (2015) include investment and profitability factors to the Fama-French three-factor model. The intuition is that there exists a discount rate that links stock price to its expected dividends. Both Hou et al. (2015) and Fama & French (2015) show that the new multifactor models outperform the Fama-French three-factor model and provide a better explanation of cross-sectional anomalies. However, the literature regarding the investment and profitability factors is mainly confined to the US market.

The motivation of Chapter 2 is to answer the following questions: Are the investment and profitability factors able to dominate in the variation of average returns in the UK equity market as in the US? Can the new five-factor model explain the momentum anomaly and if not, what will happen when adding a momentum factor to the five-factor model? Is there a more parsimonious model capable of providing equally or even better asset pricing performance? Therefore in Chapter 2, I build a large novel dataset and construct the asset pricing factor and test portfolios. The ability of a range of multifactor asset pricing models is assessed in terms of their ability to explain the time-series as well as cross-sectional variation of average stock returns. In particular, the role of investment and profitability factors is examined. The empirical findings show that profitability is an informative asset pricing factor while the investment factor is consistently insignificant. Furthermore, it is confirmed that the Fama-French five-factor model performs better than the Fama-French three-factor model and the Carhart four-factor model. This finding is in line with the US results (Hou et al. (2015) and Fama & French (2015)). Nevertheless, the momentum factor is still needed to explain the significant momentum premium. In addition, the redundancy of the size and investment factors is broadly consistent among the empirical findings. Moreover, there exists a negative relationship between the value and momentum factors. It is argued that a four-factor model consists of the market, value, momentum and profitability factors is able to summarize the cross-sectional of average stock returns, and outperforms the rest of tested multifactor models.

In contrast to Chapter 2 which employs a static estimation methodology, Chapter 3 focuses on the time-varying feature of risk premiums by applying a dynamic regression-based estimator. Imposed by the arbitrage-free restrictions, the model specification in Chapter 3 allows market prices of risk to vary over time as well as a linear pricing kernel. This model set up is different from the well-fitting but non-structural empirical asset-pricing models in Chapter 2. To be more specific, Chapter 3 is of interest for academics, policy-makers and investors for the following reasons: Firstly, monetary policy affects the risk premium through the influence on consumption and investment spending as well as market participants expectations of future economic activity. Investigating the time-varying feature of the risk premium is of significance in interpreting the impact of economic policy actions. The information contained in financial markets helps the central bank to build up a picture of the outlook facing the economy which in turn helps to inform policy rate decisions. Secondly, risk premiums have an important influence on the borrowing rates faced by governments, households and companies. Risk premiums also provide information about future macroeconomic outcomes that conventional indicators do not typically reveal. Adjusting interest rates in response to the risk premium in financial markets can be an effective way to mitigate financial instability and the resulting macroeconomic instability. For example, an unusually low risk premium may reflect that investors underestimate the riskiness of assets and engage in excessive risk-taking. Consequently, a contractionary monetary policy is needed in this situation.

Chapter 3 has a broader scope than Chapter 2 as the risk premium in both stock and government bond markets are investigated. Stocks and bonds are linked through common shocks to business conditions. Macroeconomic factors capture variation in business conditions. For instance, changes in the expected inflations influence nominal cash flows as well as the nominal rate of interests. Ferson & Harvey (1991) show that risk premiums are higher at business cycle troughs than that at peaks in the US equity market. Cochrane & Piazzesi (2005) find that the term premium is countercyclical in the US. The main motivation of Chapter 3 is to discover the relationship between macroeconomic conditions and the risk premium in UK financial markets. I propose and examine a joint model of stocks and government bonds which prices the cross-section of test assets on average and generates significant time variation in the risk premium. It is shown that inflation expectations and the output gap have a noticeable influence on the dynamics of the risk premiums. Furthermore, it is found that the term structure of interest rates factors are able to price the cross-section of average stock returns, which is consistent with results in Fama & French (1993). Most importantly, it is demonstrated that the risk premium in the UK market contains a remarkable countercyclical component. The intuition is that the risk premium varies over time and is closely related to business cycle conditions. The variation in the risk premium corresponds to the countercyclical changes in risk aversion of investors (Campbell & Cochrane (1999)). It is revealed that time-varying risk premiums are substantially higher and more volatile during recessions. The results confirm that the pronounced countercyclical behaviour of risk premiums is a pattern that holds across UK stock and government bond market.

The findings shed light on the importance of using information beyond that contained in financial factors for uncovering countercyclical, business cycle-frequency variation in the risk premium. Since macroeconomic variables do not contain the level of asset prices, using non-financial factors removes the suspicion that asset return predictability arises from any error in the process of asset pricing (see also **?**). Macroeconomic factors are found to contribute substantially to the understanding of the dynamics of the risk premium in the UK.

As one important driver of economic growth, investment growth in the UK has been sluggish in the past decade. Tobin's Q is the ratio of the market value of capital stock to its replacement cost which incorporates the forward looking nature of firm investment decisions. Theoretically, a firm should invest if Tobin's Q is greater than one, as the profits of committing to the investment is higher than the relevant cost. However, it is a current common phenomenon that firms with high Tobin's Q choose to buy back shares or pay higher dividends rather than invest. There is little evidence on how to explain this under-investment issue in the business investment area, therefore I ask what are the reasons behind this under-investment puzzle in the UK? Did the under-investment issue originate from the 2008 financial crisis? Under a neoclassical investment framework, Chapter 4 explores the answers to the under-investment puzzle from three categories: capital structure, innovation and uncertainty.

More specifically, capital structure reflects the proportion between equity and debt capital that a firm uses to finance new investment projects. Firms prefer to finance new investments initially with retained earnings, then with debt, and finally with equity. The reason is that debt binds the firm to make repayments and reduce agency costs between management and shareholders by reducing the free cash flow. As a proxy for capital structure, the literature has shown that a high leverage causes a decrease in firm's investment (Aivazian et al. (2005)). In theory, highly levered firms are less likely to seize valuable growth opportunities as compared to firms with low levels of leverage. Furthermore, research and development (R&D) expenditures and total factor productivity (TFP) growth are used to summarize the information content of innovation. The role of innovation is of interest in explaining firms' investment decisions; the reason is that technological progress has led to more and more technology-intensive companies. Increases in R&D expenditures generally reduce short-term profits but will significantly boost a firm's long-term valuation. Last but not least, since higher uncertainty increases the option value of waiting before making an investment, the implication of uncertainty on firms' investment decisions is also explored. The option to delay is more valuable at higher levels of volatility and uncertainty suggesting that a firm is less likely to undertake an investment action. Two measures of uncertainty are employed: the first measure targets the stock market volatility, and the second measure is based on the effect of uncertainty on firm-level demands.

Chapter 4 provides new empirical evidence that casts light on the UK under-investment puzzle. Firstly, the time effects in investment illustrate that the investment gap actually started from 2002 in the UK. Secondly, it is confirmed that leverage is significantly negatively related with investment and partially explains the under-investment issue. It is shown that the lack of investment is linked with low TFP growth and high R&D expenditures. Increased level of uncertainty has a profound effect on the lowered level of investment. It is also found that uncertainty and R&D play a key role in explaining the investment behaviour in the post-crisis than pre-crisis period. Thirdly, through the overall model decomposition, it is shown that TFP growth and R&D expenditures explain about 29% of the investment gap in the pre-crisis period, while uncertainty accounts for approximately 35% of the investment changes since the 2008 financial crisis. In addition, firm split subsample estimation results are analysed by controlling for firm size, dividend payout ratio and book leverage to ensure the comparison results are not driven by financial constraints. It is concluded that real sales growth and cash flow have more significant impacts on the investment for small, high leverage and low dividends paying firms.

The rest of this thesis proceeds as follows: Chapter 2 compares the model performance of a variety of multifactor asset pricing models. Chapter 3 evaluates the properties of macroeconomic variables and risk premiums in UK equity and government bond markets. Chapter 4 investigates the causes behind the under-investment puzzle in the UK. Chapter 5 overviews the contributions and outlines the future research directions.

Chapter 2

A Comparison of the Multifactor Asset Pricing Models – Evidence From UK Firms

2.1 Introduction

Asset pricing theory can represent portfolio risk by a factor model that is linear, where returns are a sum of risk factor returns. These sensitivities are described as factor-specific beta coefficients or factor loadings (see also **?**). Though the one-factor Capital Asset Pricing Model (CAPM) provides a theoretically description of average returns, its empirical performance is fairly limited. Fama & French (1992) demonstrate that the CAPM's measure of systematic risk beta cannot account for the variation in cross-sectional returns once firm size and book-to-market are controlled for in their cross-sectional regressions. The Fama-French three-factor model delivers a better description of average stock returns in empirical tests than the CAPM. In the light of this empirical evidence, numerous attempts have been made to extend the CAPM in order to achieve empirical success.

In the dividend discount model, the firm's stock is worth the present value of expected dividends. Under clean surplus accounting, the dividend at time t can be formulated as equity earnings, E_t, minus retained earnings (reinvestments of earnings), RE_t. The present market value, M, of the firm's equity is then derived as

$$M_t = \sum_{t=1}^{\infty} \frac{(E_t - RE_t)}{(1+r)^t} \tag{2.1}$$

where r is the required rate of return on expected dividends. Using fundamental accounting relationships equation (2.1) can be reformulated as

$$M_t = \sum_{t=1}^{\infty} \frac{ROE_t \times B_{t-1} - (B_t - B_{t-1})}{(1+r)^t} \tag{2.2}$$

where ROE_t is the return on equity, and B_t is the book value of common equity. Similar to the investment-based asset pricing framework, equation (2.2) suggests that a higher return on book equity, i.e. profitability, implies a higher expected return of the firm, while an increase in book value of common equity implies lower expected returns.

The Fama-French five-factor model attempts to explain the relationship between these new variables and expected stock returns from the perspective of the dividend discount model and valuation theory. The implications can be summarized as: higher book-to-market ratio implies higher expected returns, higher expected earnings lead to higher expected returns, higher expected growth in book equity implies higher expected returns.

The economic intuition behind the investment and profitability factors can be illustrated by the following expected-return equation:

$$\text{Expected Return} = \frac{\text{Expected Profitability}}{\text{Marginal Cost of Investment}} \tag{2.3}$$

Equation (2.3) shows that profitability and investment are the two fundamental drivers of expected returns in the investment-based asset pricing framework that links returns and firm characteristics. The expected return of a firm is the expected profitability divided by marginal cost of investment (which increases with investment). Thus, given expected profitability, the expected return decreases with increasing investment-to-assets, while, given investment-to-assets, firms with higher expected profitability should earn higher expected returns.

However, Blitz et al. (2018) outline five major concerns about the Fama-French five-factor model; one of which is that momentum effect is ignored in the five-factor model. Hence in this study, the five-factor model is augmented with the momentum factor to provide a picture of the role of momentum in the new baseline asset pricing model.

Given that the empirical investigation of the profitability and investment factors is largely confined to the US market, this chapter focuses on the UK stock market by using test portfolios sorted on size-B/M, size-momentum, size-profitability, size-investment and size-profitability-investment. The performance of the following models are assessed: Fama-French three-factor model, Carhart four-factor model, Fama-French five-factor model and a six-factor model, which is a model augments Fama-French five-factor model with a momentum factor.

The findings can be summarized as follows: Firstly, summary results of portfolio excess returns show that the size and investment effect is rather weak, whereas the momentum and profitability premium is significant in the UK stock market. Secondly, through factor spanning tests, it is found that the size and value factors are spanned by the other factors in the five-factor model. This result is consistent with the findings in the US market (Fama & French (2017)). However, the redundancy of the value factor disappears in the six-factor model. In addition, the market, momentum and profitability factors are significant at the 5% significance level while the investment factor provides little information not captured by the other factors. Thirdly, GRS tests confirm that size and investment are redundant factors in the UK. The null hypothesis that the intercept is jointly zero is rejected for both the Fama-French three-factor and Carhart four-factor models when test portfolios are sorted on size-investment and size-profitability-investment. Fourthly, the results of Fama-MacBeth regressions show that the Fama-French five-factor and six-factor models perform consistently better than the Fama-French three-factor and Carhart four-factor models.

This study fills a gap by illustrating how firm's profitability and investment level influence expected stock returns in the UK equity market. Furthermore, through the comparison of multifactor asset pricing models, new evidence on the importance of the momentum factor is provided. In addition, it is proposed that a four-factor model including the market, value, momentum and profitability factors (VMP), outperforms the other four models tested in this study in explaining the cross-section variation of stock returns in the UK market.

The rest of this chapter is structured as follows: Section 2.2 provides the literature review. Section 2.3 describes the data collection and equity screening procedures. Section 2.4 provides the empirical framework. Section 2.5 presents the methodology. Section 2.6 discusses the empirical findings. Section 2.7 examines the robustness. Conclusions are in section 2.8.

2.2 Literature Review

Building on the work of Markowitz (1959) on portfolio diversification theory, Sharpe (1964), Lintner (1965) and Black (1972) develop the capital assets pricing model (CAPM), respectively. Ross (1976) develops the fundamental framework of multifactor asset pricing models–Arbitrage Pricing Theory, which shows under the condition of no arbitrage opportunities, the expected asset returns are approximately linearly related to the factor loadings. Roll & Ross (1980) empirically prove that expected asset returns are closely related to estimated factor betas.

Fama & MacBeth (1973) point out stock returns are linearly increasing in their exposure to systematic risk. Banz (1981) finds that total market value of the common stock of a firm can explain the cross-section of expected stock returns. He argues that small size firms with low market value tend to have higher average returns, while big size firms have lower average returns. Rosenberg et al. (1985) and Chan et al. (1991) find that book-to-market equity contains significant relationship with the cross-section of average returns on US and Japanese stocks.

Fama & French (1992) show that the size and book-to-market factors can be used to capture the cross-sectional variation in average stock returns. The Fama-French three-factor asset pricing model (Fama & French (1993)) explains 95% of the variation of the average excess return on US stocks. Fama & French (1995) provide insights on the role of profitability in explaining stock returns: a negative relationship exists between book-to-market equity and firm's profitability, and small stocks tend to be less profitable than large stocks.

Jegadeesh & Titman (1993) find the momentum effect, which refers to stocks that performed well in the recent past will continue to perform well in the future. Carhart (1997) proposes a four-factor model by combining the Fama-French three-factor model with a momentum factor, which substantially improves the average pricing errors of the CAPM and the Fama-French three-factor model.

Brennan et al. (1998) examine whether non-risk characteristics have marginal explanatory power relative to the arbitrage pricing theory benchmark. They find a strong momentum effect both before and after risk-adjustment, while the size and book-to-market factors are insignificant in explaining the cross-section of expected stock returns.

Implied by the standard-Q theory, Xing (2007) explains the value premium with an investment factor. Chen & Zhang (2010) show that a three-factor including the market factor, an investment factor, and a return-on-assets factor summarize the cross-sectional variation of expected stock returns. The new three-factor model substantially outperforms traditional asset pricing models in explaining anomalies. Ammann et al. (2012) examine the three-factor model introduced by Chen & Zhang (2010) for European countries. They show that the model is not worse than that of traditional models in explaining five stock market anomalies. Gregory et al. (2013) construct and test alternative versions of the Fama-French and Carhart models for the UK stock market. They show that a four-factor model using decomposed and value-weighted factor components is able to explain the cross-section of returns in large firms without extreme momentum exposures. However, they do not find that risk factors are consistently and reliably priced.

Hou et al. (2015) construct a Q-factor model consisting of the market factor, a size factor, an investment factor and a profitability factor, which largely summarizes the cross section of average stock returns. They argue that the Q-factor model is comparable to the Fama-French three-factor model and the Carhart four-factor model in most cases in capturing the significant anomalies. Fama & French (2015) present a five-factor model aimed at capturing the size, value, profitability and investment patterns in average stock returns, which performs better than the Fama-French three-factor model. With the addition of the profitability and investment factors, the value factor becomes redundant for describing average returns. Fama & French (2017) further investigate the role of investment and profitability in explaining the cross-section of average excess stock returns internationally. They find that the five-factor model has limited explanatory power for small firms with high investment and low profitability.

2.3 Data

2.3.1 Data Collection

The monthly data is collected from two sources: Datastream and Worldscope. The sample consists of all UK active and dead firms on London Stock Exchange main market for the period of January 1990 to December 2015. Dead UK companies that cease to exist (due to mergers, bankruptcy or other reasons at any point in time over the span of the data) are included to avoid the presence of survivorship bias and mitigate any potential problems that are associated with microstructure issues such as bid-ask spreads.

2.3.2 Equity Screenings

In line with the leading studies of this type, financial firms, unit trusts, investment trusts, depositary receipts are excluded from the sample. Stocks with missing or negative book value of equity are also excluded in order to prevent distortion of the results. Specifically, the screening procedure is to keep major listings, stocks located in the domestic market, and firms of the equity type. If the firms are not major listings (e.g. preferred shares), are foreign stocks, or additional listings (e.g. closed-end-funds, REITs, ADRs.) then they are also excluded.

To attenuate the effects of possible data errors from Datastream, several screening procedures for monthly returns are applied as suggested by Ince & Porter (2006) and Griffin et al. (2003). Firstly, whenever the return index of a stock appears with the same value at least four times consecutively, the first value is kept and the rest of the repeated values are defined as missing. If any monthly return is over 990%, it is coded as missing. Secondly, in order to exclude remaining outliers in returns that cannot be identified as stock splits or mergers; the monthly returns that fall outside the 0.1% to 99.9% percentile range are also treated as missing. Thirdly, firms included in the sample are required to have at least 12 monthly returns during the sample period.

2.3.3 Treatment of Data

The firms with dual or multiple classes of quoted shares are manually identified and deleted, i.e. two or more stocks with different Datastream identification code (DSCD) and different market value time series data, while having the same company name and the same accounting data for a particular financial year. These firms with dual or multiple classes of shares will distort the sample since each DSCD is assumed to represent one single firm so that the market value is representing the firm's market capitalization equivalently across all firms within the sample. Therefore, these particular Datastream code are removed from the sample.

For firms that are no longer listed, Datastream leaves the market value for all months after the delisting month the same as the delisting month's market value. These dead firms will appear alive if raw Datastream market data is left untreated. The TIME variable, which provides a date about when the database received the last price update for a listed stock, is used to treat this particular problem. The month information from TIME is used to determine the delisting month. This process gives a reasonable event time when the share stopped trading on the market. The market value of firms after the delisting month are set to nil. All missing variables are set to be zero, where it is assumed that if a firm chooses not to report a particular accounting amount, it is equal to zero. The name of these firms are not delisted from the list to keep the coherence of the dataset.

In addition, in order to eliminate survival bias from the sample, it is ensured that the return of an individual firm which ceases to exist as a separate entity is written down by -100% in the final month of its existence, unless its value is shown to be preserved through merger or acquisition.

2.4 Empirical Framework

2.4.1 Factor and Portfolio Construction

Market returns are proxied by the FTSE All Share Index total returns. The risk-free rate is the three-month UK Treasury Bill rate. The portfolio formation mechanism closely follows Fama & French (2017), with adjustments where necessary to account for characteristics of the UK data. The FTSE UK Index Series present a comprehensive summary of indexes that measure the performance of the UK equity market. In particular, FTSE Small Cap Index is an index of small market capitalisation companies consisting of the 351st to the 619th largest-listed companies on the London Stock Exchange main market. Therefore to limit the influence of microcaps and illiquid stocks, the breakpoints are considered from the largest 619 stocks on the London Stock Exchange main market each year when constructing factors and portfolios.

In addition, value-weight returns instead of equal-weight ones are used to reduce the influence of serial correlation in returns, by giving stocks with serially correlated returns lower weight in the computation of portfolio returns, which is usually more frequent for small stocks. Each year (April t- March t+1[1]) stocks and stock weightings are re-defined to include the currently active securities. The value-weighted portfolios are calculated by the following formula:

$$R_{p,m} = \Sigma_{i=1}^{n} w_{i,t} R_{i,m} \tag{2.4}$$

where $R_{p,m}$ is the portfolio p return in month m, $w_{i,t}$ is the weight of stock i in the portfolio p for year t, $R_{i,m}$ is the stock i return in month m, and n is the number of stocks in portfolio p.

[1]This corresponds with the annual period of the UK tax year.

Factor Construction

The asset pricing factors are constructed from 2x3 portfolios sorted on size and each of B/M, momentum, profitability and investment. From April of year t to March of year t+1, stocks are allocated to two size groups based on the median market value of the largest 619 stocks at the end of March each year. The stocks are also sorted based on the 30th and 70th percentiles breakpoints of book-to-market, momentum, profitability and investment of the largest 619 stocks. In particular, to make sure the accounting data is known before stock returns, the financial statement data book value of equity at March of year t is matched with market value of equity at September of year t.

The intersections of size and the other variable leads to six portfolios, which are used to produce factor returns. By grouping stocks in six portfolios, the factor construction mechanism ensures factors are uncorrelated so that there is no multicollinearity by construction. Every year in March, a realignment of the portfolios takes place taking new information from the sample.

The intersection of the independent 2x3 sorts on size and B/M produces six portfolios, SH, SM, SL, BH, BM, and BL, where S and B indicate small or big and H, M, and L indicate high, medium and low (bottom 30%, middle 40%, and top 30% of B/M), respectively. Monthly value-weight returns are calculated for each portfolio from April of year t to March of t+1.

Size is measured by market value. Market value for a firm of a given calendar year t, is measured six months after the date of its balance sheet. For example, for a firm whose financial year is considered to end on December 31, 1990, its market value will be measured on June 30, 1991, or the nearest trading day. The reason for doing this is that all UK listed firms have six months to prepare and release their annual accounting information. The six-month gap ensures that the accounting-based variables are known before the returns and therefore not suffer from look-ahead bias. The size factor SMB for the three- and four-factor models is the equal-weight average of the returns on the three small stock portfolios minus the average of the returns on the three big stock portfolios:

$$SMB = \frac{(SH + SM + SL)}{3} - \frac{(BH + BM + BL)}{3} \tag{2.5}$$

Book-to-market (B/M) is the ratio of book value of common equity to market equity. The book-to-market factor HML is the difference between the average returns on the two high-B/M portfolios and the average returns on the two low-B/M portfolios. The HML describes the premium of the high book-to-market over the low book-to-market firms:

$$HML = \frac{(SH + BH)}{2} - \frac{(SL + BL)}{2} \tag{2.6}$$

Six value-weighted portfolios formed monthly on size and prior (2-12) return are used to construct the momentum factor MOM. Month t-1 is skipped to mitigate the impact of microstructure biases such as bid-ask bounce or non-synchronous trading. The momentum factor is the average return on the two high (top 30 percent) prior (2-12) return portfolios minus the average return on the two low (bottom 30 percent) prior (2-12) return portfolios.

$$MOM = \frac{(SW + BW)}{2} - \frac{(SL + BL)}{2} \tag{2.7}$$

Profitability is measured as operating income divided by book equity. Investment is defined as the annual change in total assets from the year t-1 to t, divided by total assets in year t-1. The profitability and investment factors are constructed in the same way as HML except the second sort is either on profitability (top profitability minus bottom profitability) or investment (low investment minus high investment). The profitability factor is the difference between the average returns of the two top profitability portfolios minus the average returns of the two bottom profitability portfolios. The investment factor is the difference of the average returns of the two low investment (conservative investment style) portfolios minus the average returns on the two high investment (aggressive investment style) portfolios.

$$PRO = \frac{(ST + BT)}{2} - \frac{(SB + BB)}{2} \tag{2.8}$$

$$INV = \frac{(SC + BC)}{2} - \frac{(SA + BA)}{2} \tag{2.9}$$

The 2x3 sorts portfolios used to construct PRO and INV produce two additional size factors, SMB (PRO) and SMB (INV). Hence the overall size factor SMB* for the five- and six-factor models is the average of SMB, SMB (PRO), and SMB (INV). Equivalently, SMB* is the average returns on the small stock portfolios minus the average returns on the big stock portfolios:

$$SMB(Pro) = \frac{ST + SC + SB}{3} - \frac{BT + BC + BB}{3} \tag{2.10}$$

$$SMB(Inv) = \frac{(SC + SN + SA)}{3} - \frac{(BC + BN + BA)}{3} \tag{2.11}$$

$$SMB^{*} = \frac{(SMB + SMB(PRO) + SMB(INV))}{3} \tag{2.12}$$

Test Portfolio Construction

At the end of March each year, 25 Size-B/M, 25 Size-Mom, 25 Size-Pro, 25 Size-Inv and 27 Size-Pro-Inv portfolios are constructed as test portfolios. The breakpoints are the quintiles of sample firms on London Stock Exchange Main Market. For the three-way sorted portfolios, stocks are allocated to three groups using the 30th and 70th percentiles breakpoints. The intersections of the three sorts produce 27 portfolios in total.

1) 25 (5x5) intersecting size and book-to-market portfolios

2) 25 (5x5) intersecting size and momentum portfolios

3) 25 (5x5) intersecting size and investment portfolios

4) 25 (5x5) intersecting size and profitability portfolios

5) 27 (3x3x3) sorting on size, profitability and investment portfolios

2.4.2 The Multifactor Models

The first model is the Fama & French (1993) three-factor model:

$$R_{it} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + s_i SMB_t + h_i HML_t + \varepsilon_{it} \tag{2.13}$$

where R_{it} is the return on an portfolio i for time t; α_i is the intercept; R_{mt} is the market return; R_{ft} is the risk free rate of return, $R_{mt} - R_{ft}$ is the market factor; SMB and HML are the size and book-to-market factors, respectively. The book-to-market ratio is defined as the ratio of a stocks book value to its market value. SMB is the difference between the returns of small market capitalisation stocks and large market capitalisation stocks, and HML is the difference between the returns of high B/M (value) stocks and low B/M (growth) stocks. SMB is used to explain the size premium, the positive spread in average returns between small and big stocks. HML explains the value premium, that value stocks tend to have larger average returns than growth stocks. The factor loadings are represented by β_i, s_i and h_i. The final term, ε_{it}, represents a stochastic error term.

The second model is the Carhart (1997) four-factor model , which uses a winner-minus-loser factor to capture the momentum effect in addition to Fama & French (1993) three factors. The model is in the form:

$$R_{it} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + s_i SMB_t + h_i HML_t + m_i MOM_t + \varepsilon_{it} \tag{2.14}$$

where MOM is the momentum factor, m_i is the corresponding momentum factor loading and the other terms are the same as in equation (2.4). Momentum is calculated following the strategy in Jegadeesh & Titman (1993), which is the value-weighted average return of buying the winner stocks and selling the loser stocks, rebalanced monthly. In order to minimize the impact of microstructure biases such as bid-ask bounce or non-synchronous trading, one month is skipped between ranking and holding periods when constructing the momentum factor.

The third model is the Fama & French (2017) five-factor model, which adds the profitability and investment factors to the three-factor model:

$$R_{it} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + s_i^* SMB_t^* + h_i HML_t + n_i INV_t$$
$$+ p_i PRO_t + \varepsilon_{it} \tag{2.15}$$

where SMB^* is the average return on small stock portfolios minus the average return on big stock portfolios from sorting on size-B/M, size-pro and size-inv. The profitability factor PRO is the difference between the returns on portfolios of stocks with high and low profitability. The investment factor INV is the difference between the returns on portfolios of stocks of low and high investment firms; p_i and n_i are the corresponding factor loadings.

Finally, the six-factor model adds the momentum factor to the Fama-French five-factor model:

$$R_{it} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + s_i^* SMB_t^* + h_i HML_t$$
$$+ m_i MOM_t + p_i PRO_t + n_i INV_t + \varepsilon_{it} \tag{2.16}$$

This six-factor model represents that average stock return is described by the sensitivities to six factors: the market excess return, the difference between the return of small size stocks and big size stock, the difference between the return of high book-to-market stocks and low book-to-market stocks, the difference between the return of winner stocks and loser stocks, the difference between the return of high profitability and low profitability stocks, and the difference between the return of low investment and high investment stocks.

2.5 Methodology

2.5.1 Factor Spanning Test

Following Fama (1998), factor spanning tests are used to compare the relative informativeness of the asset pricing factors. When a factor is regressed against all the other factors in the model, the factor might be seen redundant if the spanning test intercept is not significantly different from zero. For instance, the following regression is adopted to test whether information provided by the size factor is fully captured by other factors in the model:

$$SMB_t = \alpha + \beta_1 MKT_t + \beta_2 HML_t + ... + \varepsilon_t \tag{2.17}$$

The statistical significance of the regression intercepts indicates whether the size factor provides additional information uncaptured by the right hand side factors. Intuitively, if the other factors are enough to price *SMB*, then they are enough to price anything that *SMB* prices. Thus a zero regression intercept implies the left hand side factor adds nothing to the description of average returns provided by other factors.

2.5.2 Gibbons, Ross and Shanken Test

The asset pricing restriction is that the regression intercept is zero for all assets:

$$H_0 : \alpha_i = 0, i = 1, 2...N. \tag{2.18}$$

which, in the single factor case with the factor equal the excess return on a market index, is the CAPM restriction. A model is able to capture the variation of average returns if the intercepts are all not statistically different from zero. Denoted by $\hat{\alpha}$ the N-vector of the alphas, and by $\hat{\Sigma}$ the N by N matrix of the cross products of the estimated residuals divided by T. If H_0 is true, $\hat{\alpha}$ should be close to zero. Under the assumption that the regression residuals are identically, and independently normally distributed, Gibbons et al. (1989) provide the following test:

$$GRS = (\frac{T}{N})(\frac{T-N-L}{T-L-1})[\frac{\hat{\alpha}'\hat{\Sigma}^{-1}\hat{\alpha}}{1+\bar{\mu}'\hat{\Omega}^{-1}\bar{\mu}}] \sim F(N, T-N-L) \tag{2.19}$$

where $\hat{\alpha}$ is a Nx1 vector of estimated intercepts. $\hat{\Sigma}$ is an unbiased estimate of the residual covariance matrix. $\bar{\mu}$ is a Lx1 vector of the portfolios' sample means. $\hat{\Omega}$ is an unbiased estimate of the portfolios' covariance matrix. The hypothesis is that the intercepts are jointly equal to zero. If $\alpha_i = 0 \ \forall \ i$, then the GRS statistic equals zero; the larger the αs are in absolute value the greater the GRS statistic will be.

The Gibbons et al. (1989) F-test is applied to test the joint significance of intercepts. The purpose of this test is to compute an alpha estimate for each portfolio i and then test the hypothesis that all alphas are jointly equal to zero. No cross-sectional regression is being performed here - the alpha estimates are the intercepts from the time-series regression for each portfolio. If a multifactor model completely captures expected returns, the intercept is indistinguishable from zero in a regression of portfolios' excess returns on the model's factor returns. In this approach, excess returns on test portfolios are regressed on returns of various factor mimicking portfolios.

2.5.3 Fama-MacBeth Regression

The Fama & MacBeth (1973) two-step regression is one way of testing how the factors describe the cross-section of portfolio returns. In the first step, individual risk betas are estimated using time-series regressions:

$$R_{it} - R_{ft} = \alpha_i + \beta_{i1}S_{1t} + ... + \beta_{ij}S_{jt} + \varepsilon_{it} \tag{2.20}$$

where $R_{it} - R_{ft}$ is the excess return of portfolio i at time t, S_{jt} denotes the asset pricing factor j at time t, β_{ij} is the sensitivity of excess returns of portfolio i to factor j and ε_{it} is the idiosyncratic risk. The time-series slopes obtained from the first step estimation have natural interpretations as factor loadings, which judge how well different combinations of the factors can explain average returns across a variety of portfolios.

The Newey & West (1987) estimator produces consistent estimates when there is autocorrelation in addition to possible heteroskedasticity. Therefore Newey-West (HAC) standard errors are applied in the second-stage estimation to help correct the problem of autocorrelation and heteroskedasticity.

In the second step, risk beta estimates $\hat{\beta}$ are used as independent variables to estimate the following cross-sectional regressions month-by-month:

$$R_{it} - R_{ft} = \lambda_{0t} + \lambda_{1t}\hat{\beta}_{1i} + ... + \lambda_{jt}\hat{\beta}_{ji} + \eta_{it} \tag{2.21}$$

where $\hat{\beta}_i$ is estimated factor loadings from the first-pass regression, λ_{jt} are regression coefficients used to calculate the risk premium for each factor. If the η_{it} is assumed to be independent and identically distributed, the estimated risk premium is calculated as the time series average of the estimates at each point in time:

$$\bar{\lambda} = \frac{1}{T}\Sigma_{t=1}^{T}\hat{\lambda}_{jt} \tag{2.22}$$

where T is the number of time periods. If the model is correct, the λ estimate should not be significantly different from the risk premium associated with the corresponding factor and the intercept should not be significantly different from zero. In addition, the risk premium estimates are expected to explain the cross-sectional differences in average returns.

2.6 Estimation Results

2.6.1 Descriptive Statistics

[Table 2.1]

Table 2.1 reports the summary statistics for the monthly asset pricing factors. It can be seen that average MKT return is 0.40% with a standard deviation of 4.72%. The average value of the size and value premiums are 0.11% and 0.39%, respectively. Momentum has the highest mean value which is 0.82% per month. However, the momentum factor also exhibits the largest variance indicated by the 6.12% standard deviation, and also the greatest skewness and kurtosis. The monthly premium for the profitability and investment factors have a mean value of 0.36% and 0.15%, respectively for the full sample period.

[Table 2.2]

Table 2.2 presents the correlations between the monthly asset pricing factors. It can be seen that the correlation is strongly positive between the two different measures of size factors SMB and SMB* with a correlation of 0.92. The size factors are positively correlated with market factor but negatively correlated with the other factors. The value factor has a positive relationship with the market and investment factors. The negative correlation between the value and momentum premium is consistent with the findings of Asness et al. (2013) for the US and Gregory et al. (2013) for the UK. The momentum factor is positively correlated with the profitability factor with a coefficient of 0.28 but negatively correlated with the investment factor. There is a positive correlation of 0.17 between the two new factors: investment and profitability. Except for the profitability factor, the investment factor also has a positive correlation of 0.41 with the value factor.

[Table 2.3]

Table 2.3 illustrates that the newly constructed dataset for this study is largely comparable to Gregory et al.(2013)'s UK dataset. The main difference is that the standard deviation, skewness and kurtosis in this study are all greater. The reason is mainly the different breakpoints used in the factor construction. It appears that the stocks included in this study are more diversified. Therefore this study offers a greater coverage of stocks in the sample.

[Table 2.4]

Table 2.4 provides average excess returns and corresponding standard deviation for the four sets of double-sorted portfolios. Panel A of Table 2.4 shows that the expected size effect only exists for extreme growth (low B/M) stocks, where small stocks have higher average returns than big stocks. However, in the other four columns of the size-B/M matrices, there is a reversed size effect where the small value (high B/M) stock portfolios tend to have lower average returns than the big value stock portfolios. Moreover, there are value premiums in all size groups; average returns increase from left to right in every row of the size-B/M matrices. The value premium ranges from 0.54% per month in the first row to 1.36% per month in the fifth row.

Panel B of Table 2.4 provides average excess returns for the 25 size-momentum portfolios. There are positive momentum effects in all size groups; average returns increase from past losers to past winners in each row of the size-momentum matrices. The largest and smallest average returns are 2.79% and 1.82%, respectively. The size effect is not completely monotonic in the first, second and fourth column of the size-momentum matrices. It is evidenced that average returns for small stocks increase from 2.05% per month to 2.07% per month for big stocks in the second lowest momentum quintile. A typical size effect shows up in the other two columns. The momentum premium is in a range of 0.61% to 0.84%.

From panel C of table 2.4, it can be seen that the size effect is found for the lowest profitability portfolios. There is no monotonic relation between size and average returns in the other four columns of the size-profitability matrices. Additionally, average returns increase with profitability in all size quintiles consistently, which implies that more profitable firms have higher average returns than less profitable ones. The small profitable stocks have the largest average return at 2.95% per month. It is noticeable that the smallest standard deviation of returns 5.18% from the four panels lies in Panel C.

Panel D demonstrates that there does not exist a clear size effect in portfolios sorted by size and investment. Firms with aggressive approach of investment tend to have lower average returns than conservative firms, since average returns decline with investment for small stocks in the first row of the size-investment matrices. There is no consistently monotonic pattern of average returns in the other four rows of the size-investment matrices. In addition, the largest average return among the 25 size-investment portfolios is 1.77%, which is even smaller than the smallest average return of 2.29% within the 25 size-profitability portfolios. The investment premium ranges from 0.09% for the fourth size quintile to 0.28% for the smallest size quintile.

In summary, there is a significant value, momentum and profitability premium whereas the size and investment effects are small and inconsistent in the UK equity market.

2.6.2 Model Performance

Factor Spanning Test

Factor spanning tests results for the Fama-French five-factor and the six-factor models are evaluated in this section.

[Table 2.5]

Table 2.5 provides the test results of five regressions with MKT, SMB, HML, INV and PRO as dependent variable in each of the regressions. The explanatory power of the market factor is not spanned by the other factors as the regression intercept is statistically different from zero at the 5% significance level. It is concluded that the market factor is informative in the UK. However, regression intercept estimate of SMB on the other factors are statistically indifferent from zero. This result is consistent with the portfolio summary statistics that size effect does not exist in the UK market. The value factor is spanned by the remaining factors in the five-factor model, although HML is economically and statistically more significant than SMB. The redundancy of the value factor is also found in the US (Fama & French (2017)). In addition, the investment factor is not an important component in the five-factor model with a regression intercept of 0.23% and the corresponding t-statistic of 1.26. By contrast, the profitability factor has a significant explanatory power in describing average equity returns (0.49%, t=2.28).

[Table 2.6]

Table 2.6 shows factor spanning test results for the six-factor model. The intercept in the market factor regression is strongly positive, with a estimate of 0.79% per month and statistically significant at the 1% significance level. The size factor is still redundant in the six-factor model with an intercept of 0.19% per month (t = 0.22). Moreover, it can be seen that the value factor is important for describing average returns in the six-factor model. The possible reason might be that the negative correlation with the momentum factor makes the value factor no longer redundant. The intercept in the regression of HML on the other factors is 0.47% per month with a t-statistic of 3.23. Additionally, it is indicated that the profitability factor contributes substantially to the six-factor model's description of average stock returns. The intercept in the profitability regression is 0.46% per month and significant at the 1% significance level. While the intercept in the investment regression is marginal (0.25%, t = 1.37). The momentum factor has a large positive intercept of 0.46%, which is economically and statistically significant at the 1% significance level.

Overall, MKT, HML, MOM and PRO are important factors to explain average stock returns in the UK. Whereas SMB and INV contribute marginally to the description of average returns since the size and investment premiums are captured by the exposures of SMB and INV to the other factors in both the five- and six-factor models.

GRS Test

In this section, GRS test results including the GRS test statistics, the adjusted R^2, and the Sharpe ratio for the intercept, SR(α), are discussed. The null hypothesis of the GRS test is that whether the regression intercepts are jointly equal to zero. The intercept is indistinguishable from zero if an asset pricing model completely captures expected returns. According to the definition of the Sharpe ratio for the intercept SR(α) in Lewellen et al. (2010):

$$SR(\alpha) = (\alpha\Sigma^{-1}\alpha)^{(1/2)} \tag{2.23}$$

where α is the column vector of the regression intercepts produced by a model when applied to test portfolios, and Σ is the covariance matrix of regression residuals. The smaller SR(α), the less unexplained average returns, and the better the model. The advantage of SR(α) as a summary statistic is that it combines the regression intercepts with the covariance matrix of the regression residuals, which is an important determinant of the precision of the alphas.

[Table 2.7]

Table 2.7 reports the results of GRS tests using four multifactor models to explain the returns on five different sets of test portfolios. The GRS statistic tests whether all intercepts in a set of 25 or 27 regressions are jointly zero. In addition to the GRS test statistic and the corresponding p-values, Table 2.7 reports the average absolute value of the 25/27 intercepts from each set of regressions, the average of the 25/27 regression adjusted R^2, the average of the standard errors of the intercepts, and the Sharpe ratio for the intercepts SR(α).

As can be seen from Panel A, all of the models pass the GRS test. However, the GRS statistic reduces from 1.31 for the Fama-French three-factor model to 0.87 for the six-factor model. The average intercept reduces to 0.13% from 0.16% as the number of factors increases from three to six. The five-factor model has the highest average adjusted R^2 of 0.82 and is similar to that of the six-factor model of 0.81. The limited increase of 0.07 in adjusted R^2 from the three- to five-factor model might be due to the poor performance of the investment factor. Furthermore, the five-factor model has the lowest Sharpe ratio of 0.39, indicating the greatest precision in the estimates of the intercepts. The average adjusted R^2 and GRS test statistic point out the superiority of the Fama-French five-factor model over the Fama-French three-factor model in explaining the returns of portfolios sorted on size and book-to-market.

Panel B illustrates that the four- and six-factor models pass the GRS test while the three- and five-factor models fail the GRS test. Switching from the three-factor model to the six-factor model improves the description of average returns on the size-mom portfolios. As a result, the GRS statistic falls from 2.06 to 1.08 and the average absolute intercept falls from 0.28% to 0.19%. The four- and six-factor models have better overall model performance than the three- and five-factor models. Adding MOM to the Fama-French three- and five-factor models produces an increase of 0.07 and 0.15 in average R^2, respectively. The average absolute intercept decreases from 0.30% for the five-factor model to 0.19% for the six-factor model. It is argued that the improvement relative to the three- and five-factor models are big for size-momentum test portfolios. It might be the case that it is crucial to include a momentum factor when explaining the portfolio returns sorted on momentum.

Panel C shows that the three- and four-factor models fail the GRS test whereas other models pass the test when explaining the returns on 25 size-pro portfolios. The five-factor model produces the smallest GRS statistic of 0.96. The p-value for the six-factor model's GRS statistic is 0.46, and the average absolute intercept is 0.22%. Adding the profitability and investment factors raises the average R^2 from 0.51 for the three-factor model to 0.68 for the five-factor model, and the average standard error of the intercepts falls by almost half, from 0.26% for the three-factor model to 0.16% for the five-factor model. SR(α) declines from 0.71 to 0.49 as the number of factors increases from three to six. These results confirm that the six-factor model provides better explanatory power in explaining average returns on size-pro portfolios than the other three models.

From Panel D, it can be seen that the three- and four-factor models fail the GRS test while the five- and six-factor models pass the test when explaining average returns on 25 size-inv portfolios. The GRS test favours the six-factor model, which lowers the GRS statistic from 1.98 for the four-factor model to 1.36. The average absolute intercepts are similar for the five- and six-factor models, with a difference of 0.02%. The three-factor models produces the largest average return, which is 0.20% higher than that of the six-factor model. The five- and six-factor models have a intercept standard errors of 0.22% and 0.25%, respectively. Similar to the results in Panel A- Panel C, the five- and six-factor models provide a better description of average stock-inv returns than the three- and four-factor models. Despite the focus on one single country UK, these results are in line with the evidence for Europe in Fama & French (2017).

Panel E indicates that all of the models except for the six-factor model fail the GRS test when explaining the returns on 27 size-pro-inv portfolios. In particular, adding momentum to the five-factor model reduces the GRS statistic from 1.55 to 1.24, and shrinks the average absolute intercept from 0.26% to 0.21%. The average Sharpe ratio of intercepts in the six-factor model, 0.32, is the lowest among the four models. The five-factor model does outperform the three-factor model in explaining the average returns on size-pro-inv portfolios. Additionally, adding the momentum factor improves the model performance, as the four- and six-factor models both have lower GRS statistic and intercept, higher average adjusted R^2 and smaller SR(α) when comparing with the three- and five-factor models, respectively.

To sum up, with respect to the information content of new asset pricing factors, the five- and six-factor models consistently outperform the three- and four-factor models across the test portfolios. Therefore it can be concluded that adding the profitability and investment factors improves multifactor model performance in the UK. It is important to explain momentum sorted portfolio returns with a momentum factor.

Fama-MacBeth Regressions

In this section, Fama-MacBeth cross-sectional regression results are analysed. The factor loadings computed in the first stage time-series regression are the independent variables in the cross-sectional regressions, while the average excess returns of the assets are the dependent variables. If the loadings with respect to the factors are important determinants of average returns, then there should be a significant market price of risk associated with the factors. The risk betas are estimated from the time-series regressions and represent generated regressors in the cross-sectional regressions. This is the classical errors-in-variables problem, arising from the two-pass nature of the Fama-MacBeth approach. Hence, in addition to the Newey-West estimator (Newey & West (1987)), the Shanken (1992) procedure which accounts for the errors-in-variables problem is also applied. Shanken (1992) correction is designed to adjust for the overstated precision of the FamaMacBeth standard errors. It assumes that the error terms from the time-series regression are independently and identically distributed over time, conditional on the time series of observations for the risk factors. The adjustment also assumes that the risk factors are generated by a stationary process. If the error terms are heteroscedastic, then the Fama-MacBeth procedure does not necessarily result in smaller standard errors of the cross-sectional coefficients.

[Table 2.8]

Table 2.8 presents the results of Fama-MacBeth cross-sectional regressions testing the average excess returns on 25 portfolios sorted by size and book-to-market. For all of the four models, the null hypothesis that pricing errors are jointly zero is not rejected, with the chi-squared test statistic ranges from 19.34 to 24.89. As can be seen from Panel A, the value factor is significantly priced at the 1% significance level, the intercept term is significantly positive at the 5% significance level and the market premium is economically and statistically significant at the 10% level with a coefficient of 0.51%. In the case of the four-factor model in Panel B, only the market and value factors are significantly priced at the 5% significance level. This result is consistent with Gregory et al. (2013). Panel C shows that the market price of the profitability factor is 0.31%, which is significant the 10% significance level in the five-factor model. The consistent finding from the four models is that the price of the market, value and profitability factors is always significant at at least 10% significance level. The implied market price of value factor is similar among the four models, ranging from 0.53% to 0.59%. However, it can be seen that the size and investment factors are never significantly priced. Momentum and profitability are both priced at the 5% significance level in the six-factor model with a coefficient of 0.68% and 0.35%, respectively. The average adjusted R^2 increases from 0.56 to 0.75 as the number of factors increases from three to six. The higher adjusted R^2 for the five- and six-factor models show that the factor loadings from these two models provide a better explanation of the cross-sectional variation in the average returns of test portfolios, compared with the three- and four-factor models.

[Table 2.9]

Table 2.9 shows the Fama-MacBeth regression results when explaining the returns on 25 size-mom portfolios. It can be seen that through Pane A to Panel D, the four models all pass the chi-squared test and indicates that the pricing errors are jointly insignificant. The average adjusted R^2 rises from 0.33 to 0.82 as the number of factors increases from three to six. The large adjusted R^2 statistic of 0.82 in Panel D demonstrates that the excess returns of the 25 portfolios are explained well by the six-factor model. SMB is never significantly priced and it can be concluded that SMB is not an important factor in the cross-section of returns sorted by size and momentum. Further, the loadings on the value factor represent a significant factor at the 5% significance level in the cross-section of the 25 size-mom portfolios. The size and investment premiums lack explanatory power while the value and momentum effect is consistently reliable. Momentum is significantly priced in both the four- and six-factor models. The market price of risk is priced at the 5% significance level in the five- and six-factor models. Particularly, the profitability factor is priced at the 10% significance level in the six-factor model. The large t-statistics on the value and momentum premiums show that these two factors contribute significantly to the cross-section variation of average equity returns.

[Table 2.10]

In Table 2.10, all of the models pass the chi-squared test when explaining the cross-sectional returns on the 25 size-pro portfolios. The chi-squared test statistic is in the range of 10.23 to 17.24. The six-factor model has the greatest average adjusted R^2, 0.65, which is an improvement comparing with that of 0.59 for the five-factor model. The six-factor model captures a substantial fraction of the cross-sectional variation of average equity returns. The market premium is significantly priced at the 10% significance level in the three-, four- and six-factor models. The size factor is priced at the 10% significance level in the five-factor model with a size premium of 0.35%. Profitability is significantly priced in the five- and six-factor models at at least the 5% significance level. There are large positive profitability premium in the five- and six-factor models, which are 0.77% and 0.93%, respectively. However, the value factor is insignificant in the five-factor model, in which the value effect might be absorbed by the price of profitability and investment risk. The results confirm that MKT, HML, MOM and PRO are priced risk factors.

[Table 2.11]

Table 2.11 exhibits that the chi-squared test is not rejected for all of the candidate models, which indicates that pricing errors are jointly insignificant different from zero across 25 size-inv portfolios for each multifactor model. There is no evidence supports that the market price of the size factor is significant. HML is significantly priced at the 10% level in the five-factor model and presents a more significant price of value risk in the three-, four- and six-factor models. The market factor is priced in the four- and six-factor models. PRO is priced at the 5% significance level in the five-factor model and at the 1% significance level in the six-factor model. Additionally, the momentum premium is significantly priced at the 10% significance level in the six-factor model. There is a remarkable increase of 0.59 in average R^2 from the three- to five-factor model. Furthermore, the improvement relative to the three- and four-factor models are big on size-inv test portfolios.

[Table 2.12]

Table 2.12 demonstrates that the chi-squared test strongly rejects the null of no significant pricing errors for the three-factor and four-factor models. The chi-squared test statistic is significant at the 10% significance level for the five-factor model, whereas the six-factor passes the chi-squared test. The market premiums are significantly positive at the 10% significance level with a parameter of 0.80% and 0.66% in the five- and six-factor models, respectively. In addition, the intercept decreases from 0.75 in Panel A to 0.52 in Panel D. The average adjusted R^2 rises from 0.28 to 0.46 as the number of factors increases from three to six, which shows that the six-factor model is a modest improvement from the three-factor model. Also, the market price of the size and investment factors do not appear to be significant in the cross-section of average returns for the sample period. It is shown that they are not priced factors in size-pro-inv portfolio returns. However, the value factor is significantly priced in all cases, the market price of PRO is priced in the five- and six-factor models. Momentum is also priced at the 10% significance level with a parameter of 0.91 in the six-factor model.

In particular, evidence is provided that there is significant value premium in the UK equity market when tested on the 25 size-B/M portfolios, 25 size-mom portfolios and 27 size-pro-inv portfolios. Nevertheless, the value factor becomes redundant in the five-factor model when explaining the returns on 25 size-pro portfolios and 25 size-inv portfolios. Although the value factor is significantly priced in the six-factor model when tested on the same test portfolios. This reflects that the relative informativeness of HML partially depends on the model specification.

Next, the model performance is examined visually (see also Cochrane (2005)). This is done by plotting the fitted expected return of each portfolio against its realized average return. The fitted expected return is computed using the estimated parameter values from the model specification. The realized average return is the time-series average of the portfolio return. If the fitted expected return and the realized average return for each portfolio are the same, then they should lie on a 45-degree line through the origin.

[Figure 2.1]

Figure 2.1 shows the fitted expected returns on the vertical axis and realized average returns on the horizontal axis returns for 25 size-B/M portfolios for the Fama-French three-factor model. Each two-digit number represents a separate portfolio. The first digit refers to the size breakpoints of the portfolio (1 being the smallest and 5 the biggest), while the second digit refers to the book-to-market quintiles (1 being the lowest and 5 the highest). For example, portfolio 15 has the highest book-to-market value among the portfolios in the smallest size group. Equivalently, portfolio 15 denotes the smallest value portfolio. A 45 degree line that passes through the origin is added to highlight the pricing errors (vertical distances to the 45 degree line). It is found that a few portfolios stand out as problematic for the three-factor model in terms of distance from the 45-degree line. They are the small stock portfolios within the extreme growth and value quintiles (11, 12, and 25).

[Figure 2.2]

As can be seen from Figure 2.2, the anomaly portfolios are mainly small growth stocks, with portfolio numbers as (11,12,31).

[Figure 2.3]

Figure 2.3 plots the Fama-French five-factor model's fitted expected return for each of the 25 size-B/M sorted portfolios against its realised 25 average returns. The model explains the vaerage returns of the extreme growth and value portfolios (11,41,55) poorly.

[Figure 2.4]

Figure 2.4 repeats the same plots for 25 size-B/M portfolios derived using the six-factor model. The points generally lie closer to the 45 degree line than they do in Figure 3. But the problematic portfolios remain the same due to the poor fit of smallest stocks within the extreme growth and value stock groups: (11,15).

The empirical evidence discussed in this chapter so far demonstrates that the market, value, momentum and profitability factors are consistently significantly priced in the UK stock market. Therefore, a four-factor model including the market, value, momentum and profitability factors (VMP) are proposed. The asset pricing power of the VMP model is examined by the Fama-MacBeth regressions.

[Table 2.13]

As shown in Table 2.13, the VMP model does a good job pricing the cross-sectional variation of average returns for the test portfolios. The null hypothesis of pricing errors being jointly zero is not rejected with the chi-squared statistic ranging from 15.33 to 25.42. From Panel A to Panel E, the intercept terms are always insignificant. The market price of risk is economically and statistically significant at the 10% significance level across the five sets of test portfolios. The value factor is consistently priced in Panel A, Panel D and Panel E, although the market price of the value factor rises from 0.14% for size-B/M portfolios to 0.26% for size-pro portfolios. Momentum and profitability factor remains significant throughout. The VMP model produces a higher precision of the estimation for size-inv portfolios, indicated by the lower value of the standard errors. It can be seen that the VMP model significantly improves the description of average returns, especially for the 27 size-pro-inv portfolios, compared with the Fama-French three-, Carhart four-, Fama-French five- and six-factor model. Consequently, dropping the size and investment factors has negligible effect on the description of average equity returns, at least for the sample period of 1990-2015.

2.7 Robustness Checks

Alternative Factor Measures

This section investigates the robustness of the new asset pricing factor: profitability. The aim is to further explore whether the information content in the profitability factor is sensitive to different measures and whether the significance of the factor arises due to measurement error. As a consequence, the profitability factor is measured using two alternative definitions. The first alternative profitability measure is income before extraordinary items/book equity as in Hou et al. (2015). The second measure follows Novy-Marx (2013) using gross profit/book equity to construct the profitability factor.

[Table 2.14]

Table 2.14 shows the Fama-MacBeth cross-sectional regressions on 25 size-B/M portfolios for the five- and six-factor models with alternative profitability definition. Chi-squared test for the pricing errors are jointly zero is not rejected when profitability is measured differently. As can be seen from Pane A and Panel B, the market price of risk is priced at the 10% significance level in both the five- and six-factor models. The value and profitability factors are significantly priced at the 5% significance level in both of the models. The momentum premium is significant at the 5% significance level with a parameter of 0.59% in the six-factor model. The explanatory power indicated by the adjusted R^2 is rather close for the two models, with a difference of 0.02. As can be seen from Panel C and Panel D, the market premium is statistically significant at at least the 10% level. The value factor is priced at the 10% significance level in the five- and six-factor models. There exist substantial value and momentum premiums at the 10% significance level in the six-factor model. However, the profitability premium is not significantly priced in both of the five- and six-factor models.

There is a drop of 0.11 in the average adjusted R^2 from Panel A to Panel C, and a decrease of 0.17 in the average adjusted R^2 from Panel B to Panel D, which implies that the measurement of the profitability factor does matter for the model performance. It is shown that models with profitability measured as income before extraordinary/book equity provide a better description of average equity returns than the ones with the profitability definition as gross profit/book equity.

Parameter Stability

In this section, the robustness of multifactor models is examined through tests of parameter stability in the time-series regressions. The intuition is to check whether potential structural changes in the parameters have an influence on the model performance, especially during the 2008 financial crisis.

[Figure 2.5]

[Figure 2.6]

[Figure 2.7]

[Figure 2.8]

Figure 2.5 to 2.8 illustrate recursive constancy statistics for the Fama-French three-, Carhart four-, Fama-French five- and six-factor models. In each figure, the top panel demonstrates the graphs of 1-step residuals, the middle panel shows the 1-step Chow tests and the break-point Chow tests at the 1% significance level in the bottom panel. It can be seen from the top panel in each figure, the 1-step residuals results show that outliers exist around the 2008 financial crisis, which is a period associated with increases in the standard errors. It is noticeable that the vast majority of the 1-step residuals lie within their anticipated 95% confidence intervals. From the middle panel in each figure, the 1-step Chow tests results present a more profound effect of the 2008 financial crisis on UK stock market with a sharp spark in the beginning of the 2008 financial crisis. As in the bottom panel in each figure, the break-point Chow test concludes there is no significant breakpoint at the 1% significance level, hence the null hypothesis of parameter stability cannot be rejected. However, it is noteworthy that the majority of break-dates identified in the top and middle panel are around from 2008 to 2010. In addition, the Fama-French three-factor model and Carhart four-factor models demonstrate similar pattern of the parameter constancy in the period of 1998-1999.

2.8 Concluding Remarks

In this chapter, the ability of multifactor asset pricing models in explaining the time-series and cross-sectional variation of UK equity returns is empirically compared; especially the role of the profitability and investment factors. The asset pricing factors and test portfolios are constructed for the period of January 1990-December 2015.

Firstly, it is revealed that there is no evident size and investment effect on average monthly stock returns in the UK. Secondly, the GRS and Fama-MacBeth test results both demonstrate the superiority of the Fama-French five-factor and six-factor models over the Fama-French three-factor and Carhart four-factor models. However, the five-factor model fails to capture the time-series variation of average returns on 25 size-mom as well as 27 size-pro-inv portfolios. The six-factor model is capable of explaining return variations when test assets sort including momentum, which points out the importance of using a pricing factor that matches the characteristics of test portfolios. The results also show that there are significant market, value, momentum and profitability premiums in the UK. Thirdly, it is confirmed that the profitability factor is a significantly priced factor while the investment factor is not informative in the UK equity market. It is argued that a four-factor model including the market, value, momentum and profitability factors (VMP), is able to provide better description of cross-sectional average returns than the other models tested in this chapter. The VMP model does address some of the deficiencies of the three-, four- and five-factor models, such as an inadequate explanation of returns for 27 size-pro-inv portfolios. Finally, it is found that the definition of the profitability factor matters for model performance. In light of the evidence for structural shifts in the parameters estimates, there is no significant structural change in the estimated coefficients over the sample period whereas there exist increased pricing errors associated with the 2008 financial crisis period.

Table 2.1: Factor Summary Statistics

	MKT	*SMB*	*HML*	*MOM*	*SMB**	*PRO*	*INV*
Mean(%)	0.40	0.11	0.39	0.82	0.15	0.36	0.15
Std. Dev.(%)	4.72	5.28	5.39	6.12	5.07	2.34	1.97
Max(%)	12.21	16.52	17.88	18.39	12.59	9.76	6.50
Min(%)	-13.61	-19.20	-21.32	-26.55	-15.63	-20.93	-14.62
Skewness	-0.67	0.27	-0.93	-2.44	0.23	0.82	0.65
Kurtosis	4.32	3.22	3.87	10.90	3.09	7.35	4.42

Notes: This table reports the summary statistics of asset pricing factors. MKT is the market risk premium. SMB is the size factor. HML is the value factor. MOM is the momentum factor. SMB* is the size factor in the five-factor and six-factor models. PRO is the profitability factor. INV is the investment factor. Statistics reported are the Mean, Standard Deviation (Std. Dev.), Maximum (Max), Minimum (Min), Skewness, and Kurtosis. The sample period is January 1990 to December 2015.

Table 2.2: Factor Correlations

	MKT	*SMB*	*HML*	*MOM*	*SMB**	*PRO*	*INV*
MKT	1.00						
SMB	0.07	1.00					
HML	0.15	-0.10	1.00				
MOM	-0.23	-0.11	-0.54	1.00			
*SMB**	0.07	0.92	-0.08	-0.09	1.00		
PRO	-0.21	-0.16	-0.38	0.28	-0.42	1.00	
INV	-0.27	-0.20	0.41	-0.01	-0.11	0.17	1.00

Notes: This table reports the correlations between the asset pricing factors. MKT is the market risk premium. SMB is the size factor. HML is the value factor. MOM is the momentum factor. SMB* is the size factor in the 5-factor and 6-factor models. PRO is the profitability factor. INV is the investment factor. The sample period is January 1990 to December 2015.

Table 2.3: Data Comparison

Panel A	*MKT*	*SMB*	*HML*	*MOM*
Mean(%)	0.38	0.12	0.22	1.42
Std Dev(%)	4.18	5.24	5.88	5.16
Max(%)	10.48	14.94	17.88	18.92
Min(%)	-13.61	-18.26	-21.83	-20.67
Skewness	-0.51	0.16	-0.86	-2.20
Kurtosis	3.52	5.68	11.84	9.54
Panel B	*MKT*	*SMB*	*HML*	*MOM*
Mean(%)	0.39	0.16	0.14	0.99
Std Dev(%)	4.14	3.30	3.36	4.72
Max(%)	10.48	15.61	12.29	16.04
Min(%)	-13.60	-11.48	-18.61	-25.03
Skewness	-0.49	0.08	-0.49	-1.01
Kurtosis	3.57	4.93	9.83	7.88

Notes: This table reports the comparison of the summary statistics of the market,size,value and momentum factors between two UK datasets. Panel A reports the dataset constructed in this chapter. Panel B shows the one constructed by Gregory et al.(2013). The sample period is January 1990 to June 2015.

Table 2.4: Portfolio Summary Statistics

	Low	*2*	*3*	*4*	*High*	*Low*	*2*	*3*	*4*	*High*
	Mean(%)					*Standard Deviation(%)*				
Panel A: 25 Size-B/M Portfolios										
Small	2.14	2.26	2.39	2.51	2.68	8.24	8.19	8.14	8.11	8.16
2	2.01	2.31	2.48	2.53	2.62	8.29	5.65	6.32	6.37	6.48
3	1.85	2.39	2.83	2.85	3.07	8.31	7.92	7.88	7.83	7.75
4	1.84	2.36	3.03	3.08	2.99	8.44	8.36	8.16	8.08	8.04
Big	1.79	2.54	2.91	3.02	3.15	7.62	7.72	7.85	7.93	8.01
Panel B: 25 Size-Momentum Portfolios										
Small	1.95	2.05	2.63	2.78	2.79	7.62	7.55	7.38	6.32	6.29
2	1.88	1.94	2.24	2.25	2.71	7.78	7.72	7.68	7.75	7.54
3	1.82	2.08	2.16	2.19	2.67	7.53	6.81	6.83	7.62	7.76
4	1.91	2.03	2.11	2.14	2.58	7.44	7.36	7.43	7.28	7.21
Big	1.83	2.07	2.09	2.16	2.44	7.79	7.28	6.19	6.25	7.29
Panel C: 25 Size-Profitability Portfolios										
Small	2.65	2.79	2.82	2.83	2.95	6.24	7.12	7.23	7.36	7.28
2	2.62	2.73	2.80	2.89	2.89	6.18	6.15	6.19	6.11	6.21
3	2.41	2.56	2.64	2.78	2.82	6.14	6.08	6.05	6.09	6.07
4	2.37	2.58	2.71	2.78	2.91	6.16	6.12	5.23	5.18	6.22
Big	2.29	2.52	2.55	2.69	2.82	6.23	6.14	6.25	6.27	6.33
Panel D: 25 Size-Investment Portfolios										
Small	1.66	1.59	1.56	1.52	1.38	8.75	8.23	7.62	7.31	6.94
2	1.68	1.48	1.54	1.58	1.44	8.69	8.45	7.93	7.22	6.57
3	1.70	1.46	1.52	1.46	1.51	7.51	7.22	6.09	6.54	7.35
4	1.65	1.39	1.42	1.35	1.56	7.02	7.34	7.68	8.18	8.23
Big	1.77	1.40	1.48	1.30	1.63	6.95	7.25	7.28	7.31	7.96

Notes: This table reports the average value and standard deviation of the returns per month for the two-way sorted test portfolios. The sample period is January 1990 to December 2015.

Table 2.5: Factor spanning tests for the Fama-French five-factor model

	α	*MKT*	*SMB*	*HML*	*INV*	*PRO*	R^2
MKT	0.52**		-0.16	0.24	-1.02	-0.45**	0.15
	(2.51)		(-0.09)	(0.07)	(0.08)	(-2.12)	
SMB	0.14	-0.03		0.09	0.28***	0.17*	0.09
	(0.25)	(-0.62)		(0.11)	(2.39)	(1.98)	
HML	0.18	0.06	-0.25*		0.59***	-0.32***	0.31
	(1.09)	(0.09)	(1.98)		(2.97)	(2.86)	
INV	0.23	-0.12	-0.05	0.29**		0.07	0.17
	(1.26)	(-1.33)	(-0.08)	(2.14)		(0.12)	
PRO	0.49**	-0.24***	-0.07	-0.25***	-0.18		0.28
	(2.28)	(-4.62)	(-1.03)	(4.19)	(0.05)		

Notes: This table reports the results of time-series regressions with each of the variables being regressed by the remaining of the four factors. The estimates are presented in terms of percent per month. MKT is the market factor, SMB is the size factor, HML is the value factor, PRO is the profitability factor and INV is the investment factor. The corresponding t-values are reported in the parenthesis. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Table 2.6: Factor spanning tests for the six-factor model

	α	MKT	SMB	HML	INV	PRO	MOM	R^2
MKT	0.79***		-0.07	0.03	0.05	-0.49**	0.31	0.24
	(3.40)		(-0.12)	(0.09)	(0.09)	(-2.27)	(1.05)	
SMB	0.19	-0.01		0.06	0.24**	0.12*	0.28	0.11
	(0.22)	(0.08)		(0.13)	(1.98)	(1.69)	(1.34)	
HML	0.47***	0.04	-0.28**		0.41*	-0.23	-0.36**	0.29
	(3.23)	(0.11)	(2.03)		(1.71)	(1.65)	(2.05)	
INV	0.25	-0.28	-0.08	0.25**		0.04	0.12	0.13
	(1.37)	(-1.09)	(-0.16)	(1.98)		(0.07)	(0.09)	
PRO	0.46***	-0.22*	-0.12	-0.28**	-0.14		0.17**	0.24
	(5.89)	(-1.75)	(-0.89)	(1.99)	(0.06)		(2.15)	
MOM	0.46***	0.22**	0.18	-0.39**	0.15	0.33**		0.26
	(4.39)	(1.99)	(0.31)	(2.16)	(0.11)	(2.02)		

Notes: This table reports the results of time-series regressions with each of the variables being regressed by the remaining of the five factors. The estimates are presented in terms of percent per month. MKT is the market factor, SMB is the size factor, HML is the value factor, PRO is the profitability factor and INV is the investment factor. The corresponding t-values are reported in the parenthesis. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Table 2.7: GRS Tests

	GRS	*P(GRS)*	$\lvert\alpha\rvert$	*Adj.*R^2	*S.E.*(α)	*SR*(α)
Panel A: 25 Size-B/M portfolios						
FF 3-factor	1.31	0.15	0.16%	0.75	0.25%	0.48
Carhart 4-factor	1.24	0.20	0.14%	0.76	0.22%	0.42
FF 5-factor	0.89	0.61	0.15%	0.82	0.19%	0.39
6-factor	0.87	0.64	0.13%	0.81	0.18%	0.40
Panel B: 25 Size-Mom portfolios						
FF 3-factor	2.06	0.00	0.28%	0.54	0.28%	0.66
Carhart 4-factor	1.44	0.08	0.23%	0.61	0.20%	0.54
FF 5-factor	1.95	0.00	0.30%	0.55	0.23%	0.63
6-factor	1.08	0.36	0.19%	0.70	0.18%	0.51
Panel C: 25 Size-Pro portfolios						
FF 3-factor	1.78	0.01	0.33%	0.51	0.26%	0.57
Carhart 4-factor	1.61	0.03	0.34%	0.59	0.25%	0.53
FF 5-factor	0.96	0.52	0.19%	0.68	0.16%	0.49
6-factor	1.23	0.46	0.22%	0.70	0.19%	0.52
Panel D: 25 Size-Inv portfolios						
FF 3-factor	1.95	0.00	0.45%	0.50	0.24%	0.71
Carhart 4-factor	1.98	0.00	0.36%	0.54	0.29%	0.66
FF 5-factor	1.42	0.19	0.23%	0.66	0.22%	0.53
6-factor	1.36	0.21	0.25%	0.73	0.25%	0.49
Panel E: 27 Size-Pro-Inv portfolios						
FF 3-factor	3.28	0.00	0.51%	0.46	0.29%	0.68
Carhart 4-factor	1.96	0.00	0.35%	0.51	0.21%	0.59
FF 5-factor	1.55	0.01	0.26%	0.68	0.18%	0.37
6-factor	1.24	0.08	0.21%	0.70	0.16%	0.32

Notes: This table reports GRS test results for Fama-French three-factor, Carhart four-factor, Fama-French five-factor and the six-factor model.The null hypothesis that all the intercept terms are jointly zero. Test assets are 25 Size-B/M portfolios in Panel A, 25 Size-Mom portfolios in Panel B, 25 Size-Pro portfolios in Panel C, 25 Size-Inv portfolios in Panel D, 27 Size-Pro-Inv portfolios in Panel E. Column one through column six reports the GRS statistic, p value, the average absolute intercept, the average time-series adjusted R-squared, the average standard error of the intercepts and the Sharpe ratio for the intercepts.

Table 2.8: Fama-MacBeth Regressions for the 25 Size-B/M Portfolios

	λ(%)	S.E.(%)	FM-t	Shanken-t	Adj.R^2	χ^2
Panel A: Fama-French three-factor model						
α	0.48**	0.23	2.06	1.98		
mkt	0.51*	0.26	1.98	1.96	0.56	24.89
smb	0.09	0.15	0.62	0.59		(0.30)
hml	0.56***	0.20	2.85	2.81		
Panel B: Carhart four-factor model						
α	0.34	0.30	1.12	1.05		
mkt	0.49**	0.22	2.28	2.21		
smb	0.09	0.18	0.51	0.47	0.58	22.07
hml	0.59***	0.19	3.04	2.98		(0.46)
mom	0.71	0.68	1.05	1.03		
Panel C: Fama-French five-factor model						
α	0.12	0.12	0.98	0.96		
mkt	0.36*	0.17	2.11	2.08		
smb	0.10	0.16	0.64	0.62	0.72	18.62
hml	0.58***	0.20	2.96	2.94		(0.67)
pro	0.31*	0.17	1.85	1.86		
inv	0.28	0.37	0.76	0.77		
Panel D: Six-factor model						
α	0.11	0.11	0.98	0.95		
mkt	0.40**	0.18	2.23	2.21		
smb	0.08	0.15	0.53	0.49		
hml	0.53***	0.17	3.08	3.01	0.75	19.34
mom	0.68**	0.32	2.12	1.99		(0.62)
pro	0.35**	0.15	2.33	2.29		
inv	0.25	0.26	0.96	0.95		

Notes: This table reports the results of second step Fama-MacBeth regressions when test assets are 25 Size-B/M portfolios. λ is the average coefficient from the regressions. Column 2 reports heteroskedasticity and autocorrelation corrected (HAC) standard error. FM-t represents the Fama-MacBeth t-statistic calculated with Newey-West (HAC) estimator. Shanken-t is the Shanken errors-in-variables corrected t-statistic. Column five reports the average cross-sectional adjusted R-squared. Column six reports the χ^2 test statistic with the null the pricing errors are jointly zero. The corresponding p-value is reported in the parenthesis. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Table 2.9: Fama-MacBeth Regressions for the 25 Size-Momentum Portfolios

	λ(%)	*S.E.(%)*	*FM-t*	*Shanken-t*	*Adj.*R^2	χ^2
Panel A: Fama-French three-factor model						
α	0.56	0.46	1.23	1.21		
mkt	0.33	0.39	0.85	0.82	0.33	26.63
smb	0.21	0.46	0.46	0.45		(0.21)
hml	0.87**	0.39	2.23	2.19		
Panel B: Carhart four-factor model						
α	0.49	0.73	0.67	0.64		
mkt	0.41	0.23	1.75	1.72		
smb	0.16	0.37	0.43	0.44	0.38	21.87
hml	0.82***	0.29	2.81	2.78		(0.45)
mom	1.24**	0.58	2.15	2.13		
Panel C: Fama-French five-factor model						
α	0.38	0.75	0.51	0.51		
mkt	0.61**	0.30	2.04	2.02		
smb	0.27	0.15	1.82	1.79	0.75	22.42
hml	0.94***	0.34	2.73	2.68		(0.43)
pro	0.58	0.46	1.26	1.22		
inv	0.44	0.42	1.05	0.99		
Panel D: Six-factor model						
α	0.23	0.55	0.42	0.38		
mkt	0.59**	0.25	2.37	2.34		
smb	0.31	0.17	1.78	1.75		
hml	0.82***	0.30	2.69	2.66	0.82	16.51
mom	1.15***	0.40	2.88	2.83		(0.72)
pro	0.61*	0.34	1.79	1.78		
inv	0.40	0.36	1.12	1.09		

Notes: This table reports the results of second step Fama-MacBeth regressions when test assets are 25 Size-Momentum portfolios. λ is the average coefficient from the regressions. Column 2 reports heteroskedasticity and autocorrelation corrected (HAC) standard error. FM-t represents the Fama-MacBeth t-statistic calculated with Newey-West (HAC) estimator. Shanken-t is the Shanken errors-in-variables corrected t-statistic. Column five reports the average cross-sectional adjusted R-squared. Column six reports the χ^2 test statistic with the null the pricing errors are jointly zero. The corresponding p-value is reported in the parenthesis. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Table 2.10: Fama-MacBeth Regressions for the 25 Size-Profitability Portfolios

	$\lambda(\%)$	*S.E.(%)*	*FM-t*	*Shanken-t*	*Adj.*R^2	χ^2
Panel A: Fama-French three-factor model						
α	0.48	0.44	1.09	1.06		
mkt	0.62*	0.28	2.21	2.07	0.26	16.98
smb	0.42	0.31	1.35	1.33		(0.76)
hml	0.75**	0.31	2.41	2.37		
Panel B: Carhart four-factor model						
α	0.46	0.52	0.88	0.85		
mkt	0.63*	0.35	1.82	1.76		
smb	0.25	0.44	0.57	0.54	0.28	17.24
hml	0.94**	0.39	2.38	2.36		(0.75)
mom	0.78	0.59	1.33	1.29		
Panel C: Fama-French five-factor model						
α	0.31	0.34	0.92	0.88		
mkt	0.42	0.34	1.22	1.17		
smb	0.35*	0.20	1.79	1.75		
hml	0.49	0.65	0.75	0.73	0.59	12.51
pro	0.77**	0.31	2.48	2.42		(0.95)
inv	0.54	0.65	0.83	0.81		
Panel D: Six-factor model						
α	0.18	0.23	0.79	0.76		
mkt	0.54*	0.30	1.81	1.78		
smb	0.25	0.41	0.61	0.59		
hml	0.60***	0.20	2.96	2.96	0.65	10.23
mom	0.89*	0.51	1.73	1.71		(0.98)
pro	0.93***	0.35	2.68	2.66		
inv	0.32	0.30	1.05	1.04		

Notes: This table reports the results of second step Fama-MacBeth regressions when test assets are 25 Size-Profitability portfolios. λ is the average coefficient from the regressions. Column 2 reports heteroskedasticity and autocorrelation corrected (HAC) standard error. FM-t represents the Fama-MacBeth t-statistic calculated with Newey-West (HAC) estimator. Shanken-t is the Shanken errors-in-variables corrected t-statistic. Column five reports the average cross-sectional adjusted R-squared. Column six reports the χ^2 test statistic with the null the pricing errors are jointly zero. The corresponding p-value is reported in the parenthesis. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Table 2.11: Fama-MacBeth Regressions for the 25 Size-Investment Portfolios

	λ(%)	*S.E.(%)*	*FM-t*	*Shanken-t*	*Adj.*R^2	χ^2
Panel A: Fama-French three-factor model						
α	0.41	0.31	1.31	1.27		
mkt	0.36	0.40	0.89	0.85	0.21	17.82
smb	0.25	0.44	0.57	0.42		(0.72)
hml	0.70***	0.30	2.33	2.25		
Panel B: Carhart four-factor model						
α	0.39	0.41	0.96	0.92		
mkt	0.53*	0.29	1.83	1.80		
smb	0.34	0.62	0.55	0.50	0.24	17.15
hml	0.88**	0.36	2.44	2.36		(0.76)
mom	0.76	0.55	1.39	1.34		
Panel C: Fama-French five-factor model						
α	0.28	0.29	0.97	0.89		
mkt	0.45*	0.23	1.96	1.92		
smb	0.22	0.13	1.69	1.65	0.79	13.07
hml	0.68*	0.34	2.02	2.00		(0.93)
pro	0.79**	0.33	2.39	2.34		
inv	0.46	0.54	0.85	0.83		
Panel D: Six-factor model						
α	0.25	0.33	0.76	0.77		
mkt	0.60**	0.29	2.07	2.04		
smb	0.29	0.47	0.62	0.58		
hml	0.84***	0.29	2.90	2.86	0.78	14.38
mom	0.63*	0.36	1.75	1.69		(0.89)
pro	0.88***	0.32	2.75	2.73		
inv	0.37	0.34	1.09	1.06		

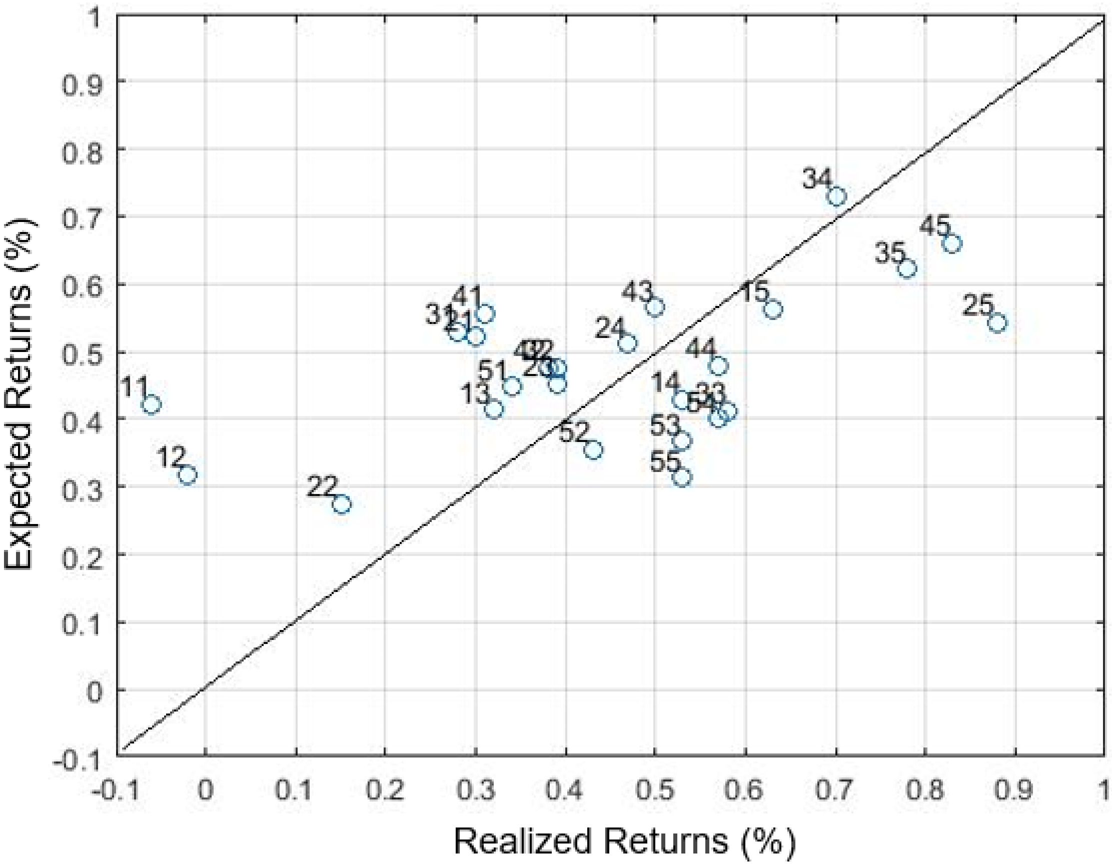
Notes: This table reports the results of second step Fama-MacBeth regressions when test assets are 25 Size-Investment portfolios. λ is the average coefficient from the regressions. Column 2 reports heteroskedasticity and autocorrelation corrected (HAC) standard error. FM-t represents the Fama-MacBeth t-statistic calculated with Newey-West (HAC) estimator. Shanken-t is the Shanken errors-in-variables corrected t-statistic. Column five reports the average cross-sectional adjusted R-squared. Column six reports the χ^2 test statistic with the null the pricing errors are jointly zero. The corresponding p-value is reported in the parenthesis. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Table 2.12: Fama-MacBeth Regressions for the 27 Size-Pro-Inv Portfolios

	λ(%)	*S.E.(%)*	*FM-t*	*Shanken-t*	*Adj.*R^2	χ^2
Panel A: Fama-French three-factor model						
α	0.75	0.35	2.14	2.08		
mkt	0.41*	0.21	1.96	1.96	0.28	48.63
smb	0.09	0.24	0.37	0.33		(0.00)
hml	0.64**	0.28	2.28	2.26		
Panel B: Carhart four-factor model						
α	0.68	0.39	1.75	1.66		
mkt	0.34	0.67	0.51	0.42		
smb	0.21	0.30	0.71	0.69	0.32	42.58
hml	0.45**	0.18	2.48	2.45		(0.00)
mom	0.72	0.35	2.06	2.02		
Panel C: Fama-French five-factor model						
α	0.59	0.45	1.32	1.28		
mkt	0.80**	0.30	2.67	2.65		
smb	0.17	0.25	0.69	0.68	0.35	36.77
hml	0.51***	0.19	2.71	2.67		(0.03)
pro	0.28**	0.20	1.43	1.39		
inv	0.42	0.75	0.56	0.55		
Panel D: Six-factor model						
α	0.52	0.48	1.09	1.05		
mkt	0.66*	0.23	2.06	2.04		
smb	0.23	0.44	0.52	0.48		
hml	0.70***	0.35	2.02	1.99	0.46	28.06
mom	0.91*	0.49	1.86	1.83		(0.09)
pro	0.33**	0.16	2.05	2.04		
inv	0.38	0.47	0.81	0.79		

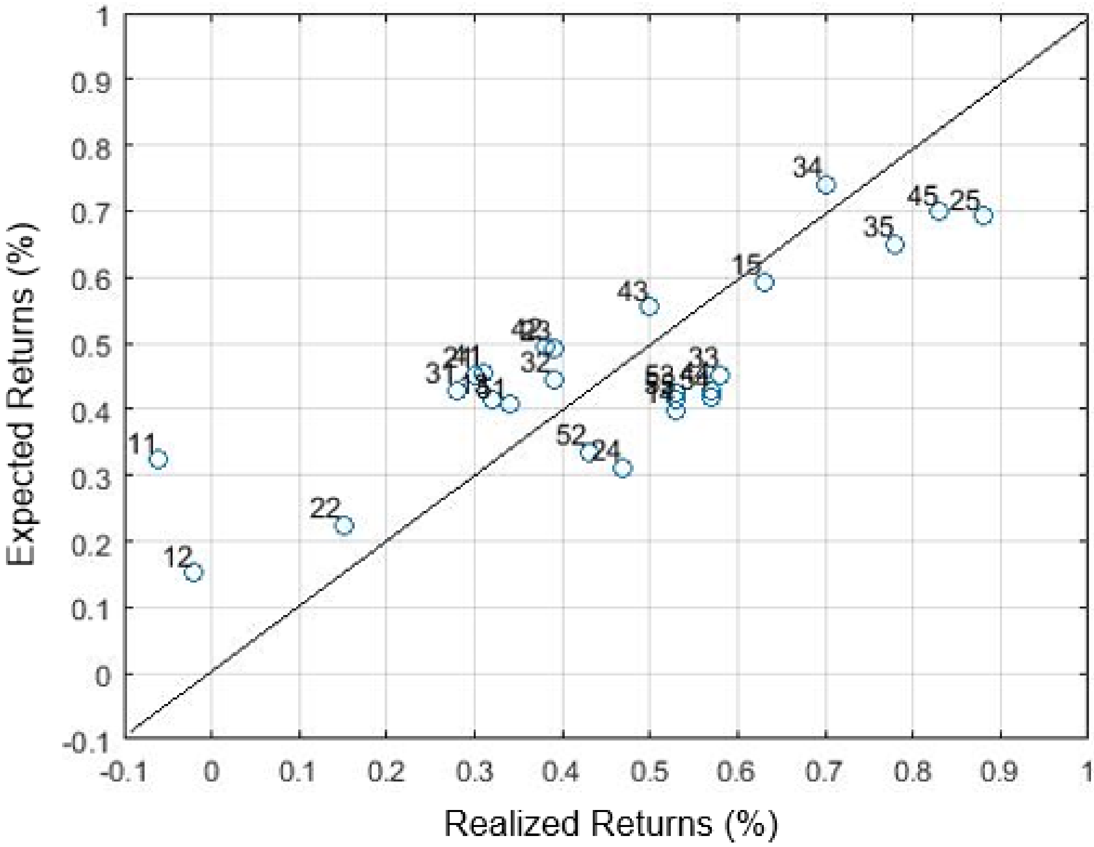
Notes: This table reports the results of second step Fama-MacBeth regressions when test assets are 27 Size-Profitability-Investment portfolios. λ is the average coefficient from the regressions. Column 2 reports heteroskedasticity and autocorrelation corrected (HAC) standard error. FM-t represents the Fama-MacBeth t-statistic calculated with Newey-West (HAC) estimator. Shanken-t is the Shanken errors-in-variables corrected t-statistic. Column five reports the average cross-sectional adjusted R-squared. Column six reports the χ^2 test statistic with the null the pricing errors are jointly zero. The corresponding p-value is reported in the parenthesis. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Figure 2.1: Model Performance: Fama-French three-factor model



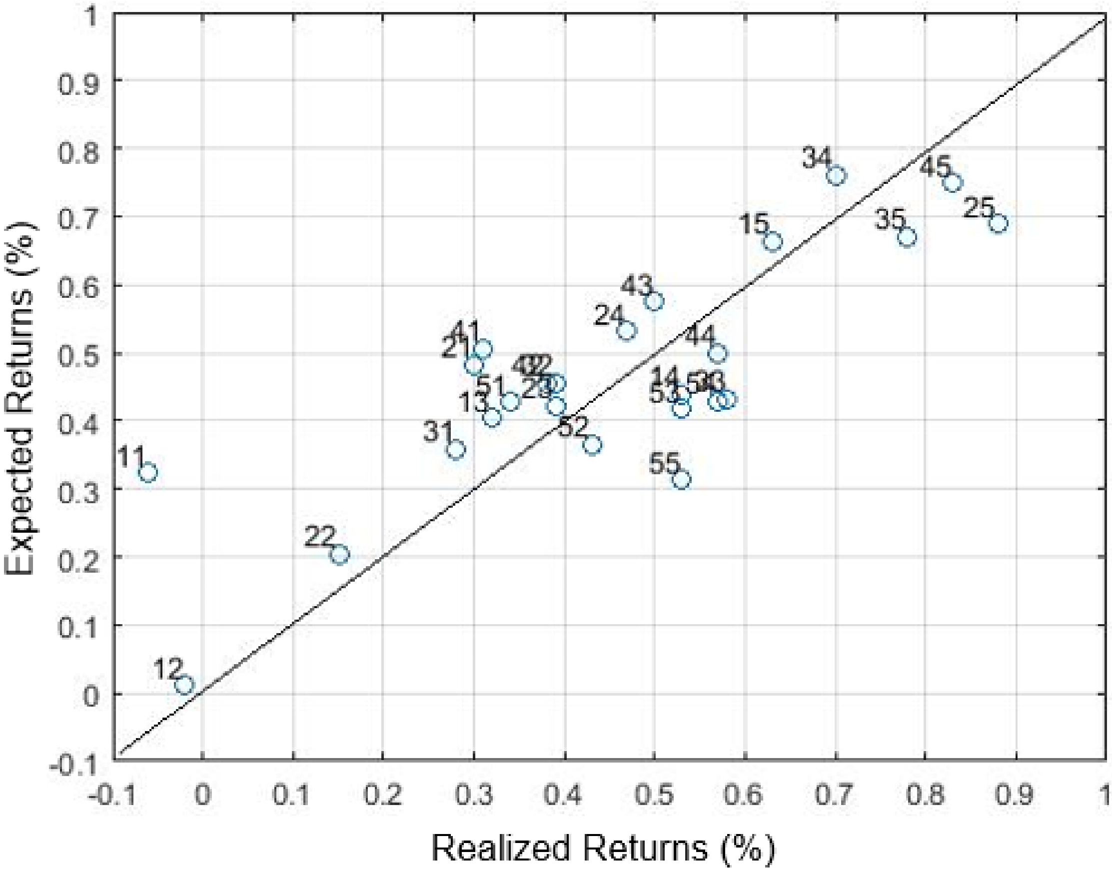
Notes: This figure shows model performance of Fama-French three-factor model based on Fama-MacBeth regressions results. The horizontal axis represents realized average returns(%) on the horizontal axis. The vertical axis demonstrates fitted expected returns(%). Each two-digit number represents a separate portfolio. The first digit refers to the size quantile (1 being the smallest and 5 the largest), while the second digit refers to the book-to-market quantile (1 being the lowest and 5 the highest). For each portfolio, the realized average return is the time-series average of the portfolio return and the fitted expected return is the fitted value for the expected return from the corresponding model. The straight line is the 45-degree line from the origin.

Figure 2.2: Model Performance: Carhart four-factor model



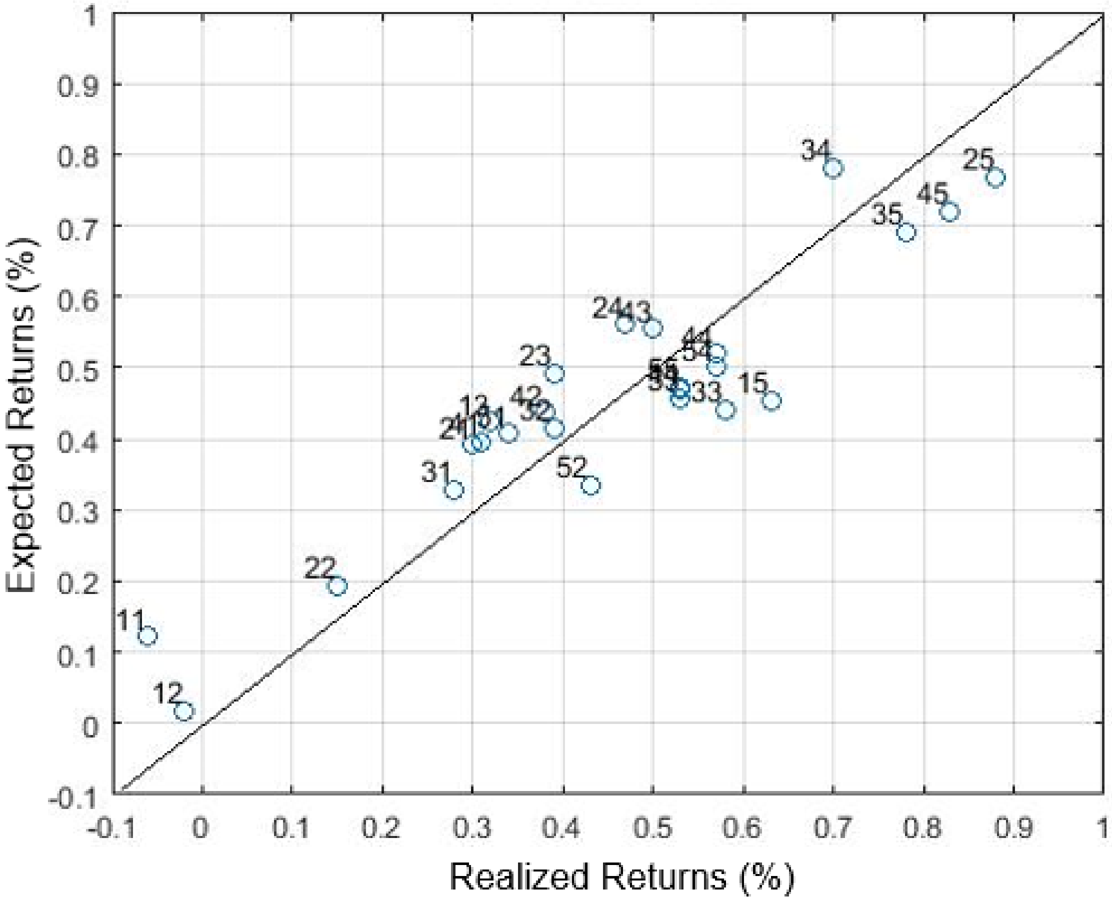
Notes: This figure shows model performance of Carhart four-factor model based on Fama-MacBeth regressions results. The horizontal axis represents realized average returns (%) on the horizontal axis. The vertical axis demonstrates fitted expected returns (%). Each two-digit number represents a separate portfolio. The first digit refers to the size quantile (1 being the smallest and 5 the largest), while the second digit refers to the book-to-market quantile (1 being the lowest and 5 the highest). For each portfolio, the realized average return is the time-series average of the portfolio return and the fitted expected return is the fitted value for the expected return from the corresponding model. The straight line is the 45-degree line from the origin.

Figure 2.3: Model Performance: Fama-French five-factor model



Notes: This figure shows model performance of Fama-French five-factor model based on Fama-MacBeth regressions results. The horizontal axis represents realized average returns (%) on the horizontal axis. The vertical axis demonstrates fitted expected returns (%). Each two-digit number represents a separate portfolio. The first digit refers to the size quantile (1 being the smallest and 5 the largest), while the second digit refers to the book-to-market quantile (1 being the lowest and 5 the highest). For each portfolio, the realized average return is the time-series average of the portfolio return and the fitted expected return is the fitted value for the expected return from the corresponding model. The straight line is the 45-degree line from the origin.

Figure 2.4: Model Performance: Six-factor model



Notes: This figure shows model performance of the six-factor model based on Fama-MacBeth regressions results. The horizontal axis represents realized average returns (%) on the horizontal axis. The vertical axis demonstrates fitted expected returns (%). Each two-digit number represents a separate portfolio. The first digit refers to the size quantile (1 being the smallest and 5 the largest), while the second digit refers to the book-to-market quantile (1 being the lowest and 5 the highest). For each portfolio, the realized average return is the time-series average of the portfolio return and the fitted expected return is the fitted value for the expected return from the corresponding model. The straight line is the 45-degree line from the origin.

Table 2.13: Fama-MacBeth Regressions for the VMP Model

	λ(%)	*S.E.(%)*	*FM-t*	*Shanken-t*	*Adj.*R^2	χ^2
Panel A: 25 Size-B/M portfolios						
α	0.16	0.16	1.02	0.98		
mkt	0.35*	0.18	1.98	1.93		
hml	0.14**	0.07	2.12	2.06	0.64	18.82
mom	0.39 *	0.20	1.95	1.91		(0.77)
pro	0.28**	0.12	2.43	2.38		
Panel B: 25 Size-Mom portfolios						
α	0.12	0.14	0.85	0.81		
mkt	0.39**	0.17	2.24	2.19		
hml	0.31	0.19	1.65	1.62	0.72	16.59
mom	0.52***	0.18	2.97	2.93		(0.63)
pro	0.36**	0.15	2.44	2.37		
Panel C: 25 Size-Inv portfolios						
α	0.17	0.09	1.91	1.85		
mkt	0.28 ***	0.10	2.82	2.76		
hml	0.23	0.12	1.88	1.82	0.68	16.25
mom	0.19 **	0.09	2.05	2.01		(0.58)
pro	0.31 **	0.14	2.16	2.12		
Panel D: 25 Size-Pro portfolios						
α	0.11	0.13	0.86	0.81		
mkt	0.33 **	0.14	2.39	2.36		
hml	0.26 **	0.12	2.11	2.05	0.76	15.33
mom	0.18*	0.09	1.95	1.92		(0.76)
pro	0.45 ***	0.16	2.82	2.77		
Panel E: 27 Size-Pro-Inv portfolios						
α	0.14	0.15	0.94	0.93		
mkt	0.36 *	0.18	1.98	1.98		
hml	0.25**	0.10	2.62	2.56	0.79	25.42
mom	0.34 **	0.14	2.37	2.32		(0.11)
pro	0.22 **	0.11	2.05	2.04		

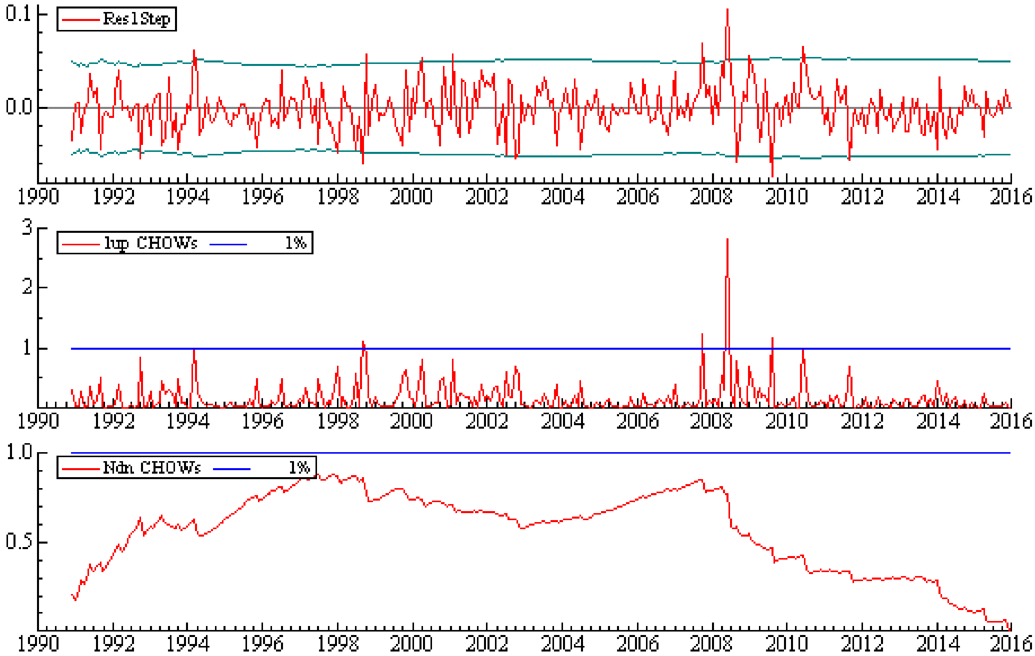
Notes: This table reports the results of second step Fama-MacBeth regressions for the value, momentum and profitability (VMP) model on five sorts of test portfolios. λ is the average coefficient from the regressions. Column 2 reports heteroskedasticity and autocorrelation corrected (HAC) standard error. FM-t represents the Fama-MacBeth t-statistic calculated with Newey-West (HAC) estimator. Shanken-t is the Shanken errors-in-variables corrected t-statistic. Column five reports the average cross-sectional adjusted R-squared. Column six reports the χ^2 test statistic with the null the pricing errors are jointly zero. The corresponding p-value is reported in the parenthesis. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Table 2.14: Fama-MacBeth Regressions with alternative profitability measures

	$\lambda(\%)$	*S.E.(%)*	*FM-t*	*Shanken-t*	*Adj.*R^2	χ^2
Panel A: Fama-French five-factor model						
α	0.16	0.18	0.89	0.86		
mkt	0.28*	0.14	1.95	1.92		
smb	0.15	0.25	0.61	0.58	0.73	19.75
hml	0.72***	0.24	2.99	2.97		(0.61)
pro-roe	0.44**	0.19	2.30	2.26		
inv	0.27	0.32	0.84	0.81		
Panel B: Six-factor model						
α	0.15	0.16	0.94	0.93		
mkt	0.26*	0.13	2.00	1.98		
smb	0.11	0.14	0.79	0.76		
hml	0.61***	0.20	3.07	3.05	0.75	20.87
mom	0.59**	0.28	2.14	2.09		(0.53)
pro-roe	0.40**	0.19	2.08	2.05		
inv	0.25	0.31	0.82	0.79		
Panel C: Fama-French five-factor model						
α	0.13	0.14	0.91	0.88		
mkt	0.36**	0.16	2.25	2.21		
smb	0.09	0.23	0.39	0.35	0.62	23.62
hml	0.54*	0.27	2.01	1.98		(0.37)
pro-gr	0.23	0.18	1.28	1.26		
inv	0.21	0.26	0.81	0.78		
Panel D: Six-factor model						
α	0.14	0.16	0.85	0.84		
mkt	0.32*	0.15	2.11	2.09		
smb	0.14	0.17	0.82	0.78		
hml	0.60*	0.29	2.04	2.03	0.58	24.53
mom	0.62*	0.31	1.97	1.95		(0.32)
pro-gr	0.19	0.11	1.68	1.64		
inv	0.28	0.27	1.05	1.02		

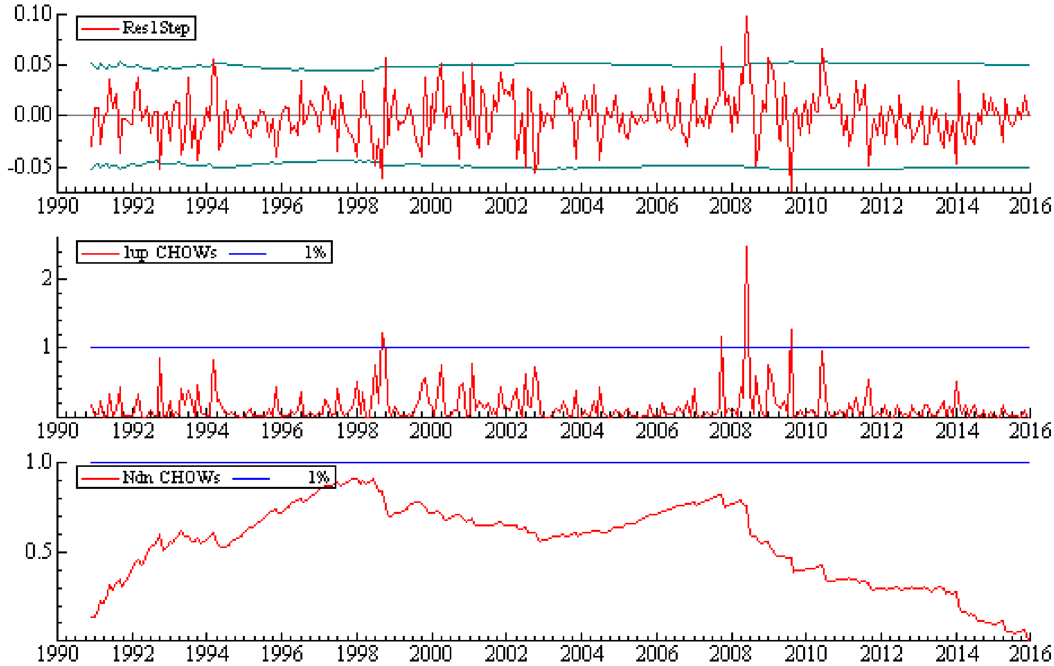
Notes: This table reports the results of second step Fama-MacBeth regressions of 25 Size-B/M portfolios with alternative profitability measures. Panel A and Panel B show the results when profitability is measured as income before extraordinary items/book equity. Panel C and Panel D present the results when profitability factor is constructed as gross profit/book equity. λ is the average coefficient from the regressions. Column 2 reports heteroskedasticity and autocorrelation corrected (HAC) standard error. FM-t represents the Fama-MacBeth t-statistic calculated with Newey-West (HAC) estimator. Shanken-t is the Shanken errors-in-variables corrected t-statistic. Column five reports the average cross-sectional adjusted R-squared. Column six reports the χ^2 test statistic with the null the pricing errors are jointly zero. The corresponding p-value is reported in the parenthesis. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Figure 2.5: Recursive constancy statistics



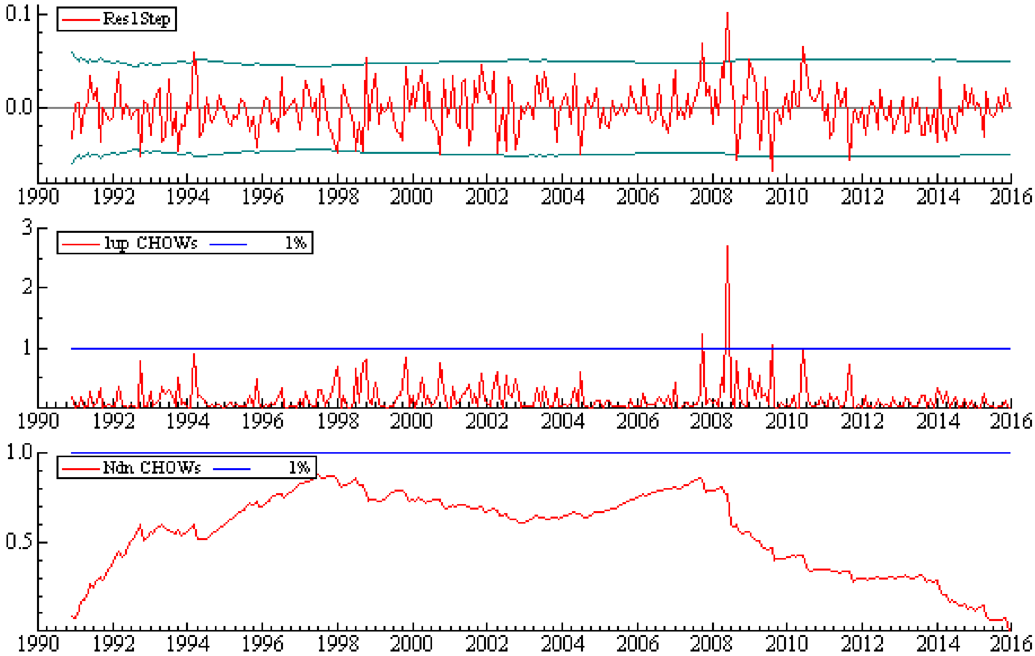
Notes: This figure shows the parameter constancy of the Fama-French three-factor model when test assets are 25 size-B/M portfolios. The top panel graphs the 1-step residuals with with error bands of two residual standard errors around zero. The middle panel graphs the 1-step Chow tests scaled by their critical values at the 1% significance level. The bottom panel graphs the break-point Chow tests, each point is the value of the Chow F-test for that date, scaled by their critical values at the 1% significance level. The 1% significance line locates at unity.

Figure 2.6: Recursive constancy statistics



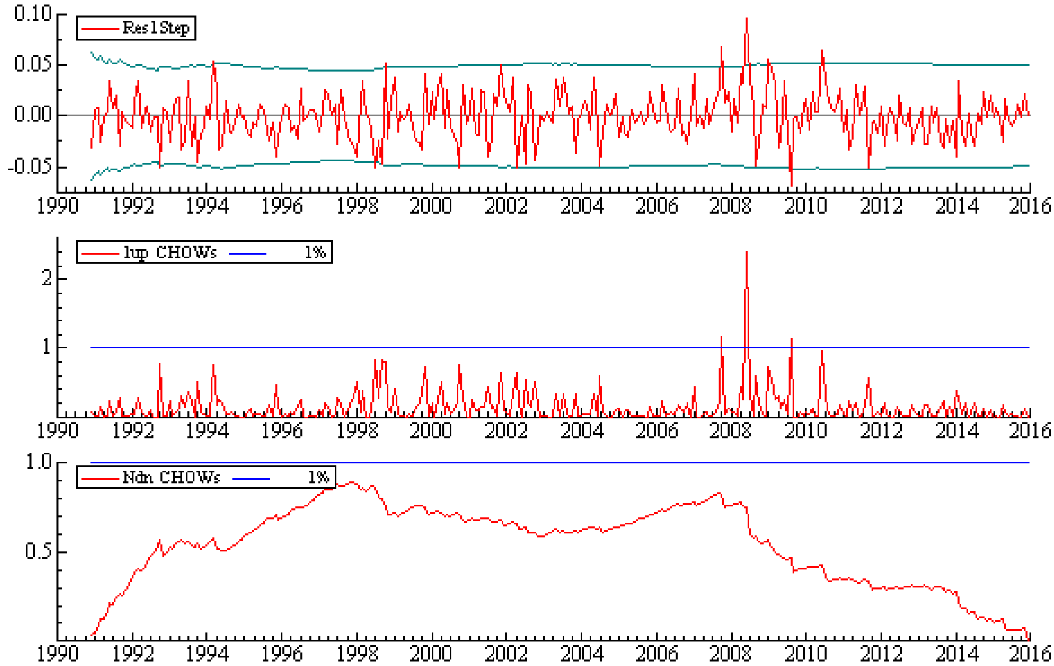
Notes: This figure shows the parameter constancy of the Carhart four-factor model when test assets are 25 size-B/M portfolios. The top panel graphs the 1-step residuals with with error bands of two residual standard errors around zero. The middle panel graphs the 1-step Chow tests scaled by their critical values at the 1% significance level. The bottom panel graphs the break-point Chow tests, each point is the value of the Chow F-test for that date, scaled by their critical values at the 1% significance level. The 1% significance line locates at unity.

Figure 2.7: Recursive constancy statistics



Notes: This figure shows the parameter constancy of the Fama-French five-factor model when test assets are 25 size-B/M portfolios. The top panel graphs the 1-step residuals with with error bands of two residual standard errors around zero. The middle panel graphs the 1-step Chow tests scaled by their critical values at the 1% significance level. The bottom panel graphs the break-point Chow tests, each point is the value of the Chow F-test for that date, scaled by their critical values at the 1% significance level. The 1% significance line locates at unity.

Figure 2.8: Recursive constancy statistics



Notes: This figure shows the parameter constancy of the six-factor model when test assets are 25 size-B/M portfolios. The top panel graphs the 1-step residuals with with error bands of two residual standard errors around zero. The middle panel graphs the 1-step Chow tests scaled by their critical values at the 1% significance level. The bottom panel graphs the break-point Chow tests, each point is the value of the Chow F-test for that date, scaled by their critical values at the 1% significance level. The 1% significance line locates at unity.

Chapter 3

Macro Factors and Time-varying Risk Premia in UK Financial Markets

3.1 Introduction

Understanding the risk premium has become increasingly important for both investors and policy-makers since the financial crisis. As bond market rates are building blocks for pricing all financial assets, the joint pricing of stocks and bonds is fundamental for financial markets. A widely held view held for many years is that monetary policy is normally closely related to current and expected future short-term interest rates. The recession that accompanied the credit crunch in the 2008 delivered a massive blow to demand. As a response, the Bank of England pushed the benchmark policy rates close to the zero lower bound to reduce borrowing costs and stimulate spending. After the short-term interest rate becomes constrained by the zero lower bound, the central bank can most effectively influence the path of the aggregate demand by affecting long-term interest rates, primarily through asset market purchases, which highlights the importance of understanding the unconventional monetary policy. As any long-term interest rate can be decomposed into an investor's expectation component about future short-term interest rates, and a risk premium component, the central bank can aim at either component, or both, to achieve its policy goal. To be more specific, the risk premium has an important impact on the borrowing rates faced by governments, households and companies, as well as containing useful information about investor's attitude towards risk. It is therefore crucial to price the time-series and cross-section of bond and stock returns in order to uncover the relation between the yield curve, equity returns and states of the economy.

[Figure 3.1]

Figure 3.1 plots UK nominal government bond yields for maturities 1- through 10-year from January 1990 to December 2015. During the UK's economic recessions, July 1990- September 1991 and April 2008-September 2009, it can be seen that the yields dropped significantly. The dynamics of nominal government bond yields demonstrate a declining trend during this time period. The 1990s' recession and high inflation caused by the spikes of oil prices resulted in yields dropping significantly. Furthermore, following the introduction of quantitative easing program, the zero lower bound on interest rates is reflected in 1-year government bond yields over the period of 2012-2016.

The motivation of this chapter is twofold: Firstly, characteristics of the macroeconomy and the risk premium on financial assets are both related to business cycle conditions. Macro changes have a significant effect on risk-adjusted discount rate. However, there is relatively little evidence on the link between UK macroeconomic activity and the risk premium. This chapter investigates the dynamics of the time-varying risk premium in UK financial markets as well as providing an economic interpretation. Secondly, instead of pricing stock and government bond returns separately, this study evaluates the cross-section of stock and bond returns simultaneously. The intuition behind a joint pricing model is that different asset prices, e.g. stock prices and bond prices, are driven by the same underlying factors causing a co-movement of these prices that can only be captured when the different asset prices are modelled jointly.

This study firstly explores the feature of UK government bond yields, and whether excess bond returns are forecastable by forward spreads as Cochrane & Piazzesi (2005) find for the US. The results show that the combination of forward rates forecast excess bond returns poorly in the UK. Secondly, I present a joint dynamic asset pricing model that can be used to explain differences between average excess returns on the size-sorted stock portfolios, book-to-market-sorted stock portfolios, and government bond portfolios sorted by maturity. This dynamic asset pricing model provides estimates of the time-varying risk premium on stocks and bonds, and allows a linear pricing kernel to be driven by forecasting factors and shocks to pricing variables. This model fits the cross section of test assets on average and demonstrates strongly significant time variation in the risk premium. The equity market return factor, the level of the yield curve, and the term spread are included as pricing factors. Two macro factors: inflation expectations and the output gap along with the term spread are considered as unspanned forecasting factors. Variables which predict excess returns but are not contemporaneously correlated with excess returns are referred to as unspanned factors. The results demonstrate significant time variation of the risk premium, and confirm that macro factors indeed have significant influence on the dynamics of the equity and bond risk premiums in the UK. It is also indicated that the stock market factor play a role in pricing the cross-section of average bond returns. Furthermore, the predictive power of macro factors is not just statistically significant but also economically important. Inflation expectations and the output gap contain information about future stock and bond returns. The results suggest that investors must be compensated for risks associated with recessions. In contrast to financial market variables, macro factors are not related to the level of asset prices, which removes the suspicion that the return predictability arises due to asset mispricing. As classical business cycle variables, the predictive power of the output gap and inflation expectations constitute independent evidence regarding the variation of the risk premium over the business cycle.

Thirdly, the cyclical behaviour of the estimated risk premium is examined. Univariate regressions are estimated using two cyclical indicators: the composite leading indicator (CLI) for the UK, and unemployment rate. I choose these business cycle variables based on the following reasons: First, they indicate the business cycle in a consistent manner, while different trend growth rates make business cycle measurement using growth rates problematic. Second, they provide early signals of turning points in business cycles showing fluctuation of the economic activity around its long term potential level, and lead the business cycle. This is desirable for assessing the cyclical behaviour of the risk premium, since these rise ahead of early parts of recessions, and vice versa fall around the business cycle trough and early parts of expansions. It is found that time-varying risk premiums are substantially higher and more volatile during recessions. The results confirm that pronounced countercyclical behaviour is a pattern that holds across UK financial markets. Finally, parameter stability tests demonstrate robust results that are consistent with the economic interpretation. In the absence of structural breaks, higher standard deviation of time-varying beta estimates are associated with the period of economic recessions.

The findings shed light on the importance of using information beyond that contained in financial factors to reveal countercyclical, business cycle-frequency variation in the risk premium. It is demonstrated that macroeconomic factors contribute substantially to the understanding of the dynamics of risk premiums in the UK. This study contributes to the literature on the stock and bond returns predictability by showing that term spread and macroeconomic factors have important predictive power for excess returns on the UK stocks and government bonds. Two aspects of the findings is emphasized. First, there exists strong predictable variation in excess stock and bond returns that is associated with macroeconomic activity. Second, it is revealed that the equity market factor contains significant cross-sectional pricing power, which is in line with the Capital Asset Pricing Model. The level of the term structure of interest rates and term spread are priced not only in government bond excess returns but also in equity returns.

The remainder of the chapter is organized as follows: Section 3.2 provides the literature review. Section 3.3 presents the dynamic asset pricing framework. The details of the dataset is explained in section 3.4. In Section 3.5, results are discussed. Section 3.6 reports robustness checks. Section 3.7 concludes.

3.2 Literature Review

Using the term spread, the default spread, and the dividend yield, Fama & French (1989) find common predictable components in corporate bond and stock indices. They show that expected returns on common stocks and long-term bonds contain a term premium that has a clear business-cycle pattern and a risk premium that is related to longer-term aspects of business conditions. It is reported that the variation through time in the risk premium is stronger for low-grade corporate bonds than for high-grade bonds and is stronger for stocks than for bonds.

Ferson & Harvey (1991) study stock and bond return sensitivity to aggregate state variables. They conclude that time variation in the equity risk premium is important for understanding the cross-sectional variation in size and industry equity portfolios, and that time variation in the interest rate risk premium is important for understanding the cross-sectional variation in bond return portfolios.

Cochrane (1992) uses a production-based asset pricing model to show that asset returns are associated with economic fluctuations and the covariances of returns with macroeconomic variables. Campbell & Shiller (1991) and Cochrane & Piazzesi (2005) present evidence suggests that term premia vary countercyclically over time in the US. Ang & Piazzesi (2003) investigate the possible empirical linkages between macroeconomic variables and bond prices in a no-arbitrage factor model of the term structure of interest rates. Ludvigson & Ng (2009) apply a factor analysis approach to a broad set of economic variables and show a close relation of the real economy, inflation and financial variables to one-year ahead bond excess returns. Baker & Wurgler (2012) show that government bond returns co-move with bond-like stocks, which are stocks of large, mature, low-volatility, profitable, dividend-paying firms that are neither high growth nor distressed. They propose a common sentiment indicator that drives stock and bond returns. Joslin et al. (2014) indicate that macroeconomic variables contain information about future excess returns on bonds and can be used to explain the time series dynamics of yield curve.

Koijen et al. (2010) show that bond factors which predict future US economics activity are priced in the cross-section of US stock returns. The business cycle itself is a priced state variable in stock and bond markets in their work. Lettau &

Wachter (2011) propose a dynamic risk-based model capable of jointly explaining the term structure of interest rates, returns on the aggregate market, and the risk and return characteristics of value and growth stocks. They argue that the term structure of interest rates and returns on value and growth stocks convey information about how the representative investor values cash flows of different maturities. They model how the representative investor perceives the risks of these cash flows by specifying a parsimonious stochastic discount factor for the economy. They show that shocks to dividend growth, the real interest rate, and expected inflation are priced, but shocks to the price of risk are not. Given reasonable assumptions for dividends and inflation, they prove that the model can simultaneously account for the behavior of aggregate stock returns, an upward-sloping yield curve, the failure of the expectations hypothesis, and the poor performance of the capital asset pricing model. Adrian et al. (2015) illustrate the usefulness of the regression-based dynamic asset pricing approach. They show that allowing for time variation in factor risk exposures substantially improves the precision of price of risk parameters.

3.3 Dynamic Asset Pricing Framework

Section 3.3.1 introduces the affine term structure model (Adrian et al. (2013)) which is used to estimate the yield curve. Section 3.3.2 derives the affine model implied term premium. Section 3.3.3 presents the regression-based estimator (Adrian et al. (2015)) with beta representations and an affine pricing kernel specification across different asset classes.

3.3.1 Exponentially Affine Term Structure Model

Assume that the price of a bond is driven by the innovations to the set of state variables H in the following vector autoregression (VAR) (1):

$$H_{t+1} = \mu + \Phi H_t + h_{t+1} \tag{3.1}$$

where the innovations h_{t+1} are assumed to be conditionally Gaussian, homoscedastic and independent across time. The assumption of no-arbitrage implies the existence of a pricing kernel M_{t+1} such that:

$$P_t^{(n)} = E_t[M_{t+1}P_{t+1}^{(n-1)}] \tag{3.2}$$

where $P_t^{(n)}$ is the price of a bond with maturity n at time t, M_{t+1} is a stochastic discount factor, E_t represents the conditional expectation at time t. The pricing kernel is assumed to be exponentially affine in the factors:

$$M_{t+1} = exp(-r_t - \frac{1}{2}\lambda_t'\lambda_t - \lambda'\Sigma^{-\frac{1}{2}}h_{t+1}) \tag{3.3}$$

The market prices of risk λ_t are assumed to be an affine function of the state variables H_t:

$$\lambda_t = \Sigma^{-\frac{1}{2}}(\lambda_0 + \lambda_1 H_t) \tag{3.4}$$

where λ_0 and λ_1 are prices of risk.

The log excess return of a bond maturing in n periods can be decomposed as:

$$rx_{t+1}^{(n-1)} = lnP_{t+1}^{(n-1)} - lnP_t^{(n)} - r_t \tag{3.5}$$

where $r_t = lnP_t^{(1)}$ denotes the risk-free rate.

Equation (3.2)- equation(3.5) imply that:

$$E_t[exp(rx_{t+1}^{(n-1)} - \frac{1}{2}\lambda_t'\lambda_t - \lambda'\Sigma^{-\frac{1}{2}}h_{t+1})] = 1 \tag{3.6}$$

Applying the properties of the lognormal distribution, equation (3.6) becomes:

$$E_t[rx_{t+1}^{(n-1)}] = cov_t(rx_{t+1}^{(n-1)}, \lambda'\Sigma^{-\frac{1}{2}}h_{t+1}) - \frac{1}{2}var_t(rx_{t+1}^{(n-1)}) \tag{3.7}$$

Denoting $\beta_t^{(n-1)} = cov_t(rx_{t+1}^{(n-1)}, h_{t+1}')\Sigma^{-1}$:

$$E_t[rx_{t+1}^{(n-1)}] = \beta_t^{(n-1)'}(\lambda_0 + \lambda_1 X_t) - \frac{1}{2}var_t(rx_{t+1}^{(n-1)}) \tag{3.8}$$

Unexpected excess bond returns can be decomposed into a term correlates with the factor innovations, h_{t+1}, and one conditionally orthogonal to it:

$$rx_{t+1}^{(n-1)} - E_t[rx_{t+1}^{(n-1)}] = \beta_t^{(n-1)} h_{t+1} + \epsilon_{t+1}^{n-1} \tag{3.9}$$

assuming that ϵ_{t+1}^{n-1} is distributed i.i.d with zero mean and variance σ^2. Following from equations (3.8) and (3.9), the return generating process for log excess bond returns can be expressed as:

$$rx_{t+1}^{(n-1)} = \beta_t^{(n-1)\prime}(\lambda_0 + \lambda_1 H_t) - \frac{1}{2}(\beta_t^{(n-1)\prime}\Sigma\beta_t^{(n-1)} + \sigma^2) + \beta_t^{(n-1)\prime} h_{t+1} + \epsilon_{t+1}^{n-1} \tag{3.10}$$

Stacking the excess bond returns across t and n, equation (3.10) can be written as:

$$rx = \beta'(\lambda_0 i_T' + \lambda_1 H_-) - \frac{1}{2}(B * VEC(\Sigma) + \sigma^2 i_N) + \beta' V + E \tag{3.11}$$

where rx is N x T matrix of excess returns, $\beta = [\beta^1\beta^2...\beta^N]$ is a K x N matrix of factor loadings, i_T and i_N are a T x 1 and N x 1 vectors of ones, $H_- = [H_0 H_1 ... H_{T-1}]$ is a K x T matrix of lagged pricing factors, $B* = [vec(\beta^{(1)}\beta^{(1)\prime})...vec(\beta^{(N)}\beta^{(N)\prime})]$ is an N x K^2 matrix, V is a K x T matrix and E is an N x T matrix.

3.3.2 Term Premium Implied by the Affine Model

The bond prices are exponentially affine functions of state variables:

$$lnP_t^{(n)} = A_n + B_n' H_t + u_t^{(n)} \tag{3.12}$$

where $u_t^{(n)}$is unobservable error.

Equivalently, zero-coupon bond yields are affine functions of state variables:

$$y_t^{(n)} = -\frac{1}{n}[A_n + B_n' H_t] \tag{3.13}$$

where the coefficients A_n and B_n follow the recursive linear restrictions:

$$A_n = A_{(n-1)} + B_{(n-1)}'(\mu - \lambda_0) + \frac{1}{2}(B_{(n-1)}'\Sigma B_{(n-1)} + \sigma^2) + A_1 \tag{3.14}$$

$$B_n' = B_{(n-1)}'(\Phi - \lambda_1) + B_1' \tag{3.15}$$

$$A_0 = 0, B_0' = 0 \tag{3.16}$$

As in Dai & Singleton (2002), an n-period bond yield can be decomposed as:

$$y_t^{(n)} = \frac{1}{n}\Sigma_{i=0}^{n} E_t r_{t+i} + TP_t^{(n)} \tag{3.17}$$

where the term premium $TP_t^{(n)}$ is the compensation investors require for investing in a long-term bond rather than rolling over a series of short-term investments. The expectations term $\frac{1}{n}\Sigma_{i=0}^{n} E_t r_{t+i}$ can be obtained as:

$$\frac{1}{n}\Sigma_{i=0}^{n} E_t r_{t+i} = -\frac{1}{n}[\tilde{A}_n + \tilde{B}_n' H_t] \tag{3.18}$$

where the coefficients $\tilde{A}_n$ and $\tilde{B}_n$ follow the recursive equations:

$$\tilde{A}_n = \tilde{A}_{n-1} + B_{(n-1)}'\mu + A_1 \tag{3.19}$$

$$\tilde{B}_n' = \tilde{B}'_{n-1}\Phi + B_1' \tag{3.20}$$

$$\tilde{A}_0 = 0, \tilde{B}_0' = 0 \tag{3.21}$$

3.3.3 Regression-based Estimation Approach

In this section, a regression-based estimator proposed by Adrian et al. (2015) that allows for price of risk to vary with observable state variables is introduced. The dynamics of these state variables can be assumed to be generated by a general equilibrium model of the macroeconomy. Systematic risk is assumed to be captured by a Kx1 vector of state variables X_t that evolves according to a stationary vector autoregression:

$$X_{t+1} = \mu + \Phi X_t + v_{t+1} \tag{3.22}$$

with initial condition X_0. State variables X_t can be risk factors $X_{1,t}$, price of risk factors $X_{2,t}$, or both $X_{3,t}$. Risk factors or pricing factors C_t refer to variables that are significant factors for the cross-section of asset returns, but do not predict excess returns in the time series. Price of risk factors or forecasting factors F_t stand for variables that significantly predict excess returns in the time series, but do not co-move with returns contemporaneously. In particular, $C_t = [X_{1,t}, X_{3,t}]'$, $F_t = [X_{2,t}, X_{3,t}]'$, $u_t = [v_{1,t}, v_{3,t}]'$, $K = K_1 + K_2 + K_3$, $K_C = K_1 + K_3$, and $K_F = K_2 + K_3$.

Assuming a linear pricing kernel such that:

$$E[M_{t+1} R_{i,t+1} \mid \Gamma_t] = 0 \tag{3.23}$$

$$M_{t+1} = exp(-r_t - \frac{1}{2}\Lambda_t'\Lambda_t - \Lambda_t'\Sigma_{u,t}^{-\frac{1}{2}} u_{t+1}) \tag{3.24}$$

where M_{t+1} is a stochastic discount factor, $R_{i,t+1}$ denote excess returns of asset i, Γ_t denotes the information set at time t, r_t denotes the risk-free rate at time t. Λ_t represent the prices of risk in period t. $\Sigma_{u,t}$ is the unconditional variance of u_{t+1}.

The prices of risk are assumed to be affine functions of price of risk factors F_t:

$$\Lambda_t = \Sigma_{u,t}^{-\frac{1}{2}} (\Lambda_0 + \Lambda_1 F_t) \tag{3.25}$$

where Λ_0 is a K_Cx1 vector, Λ_1 is a K_CxK_F matrix, $\Lambda = [\Lambda_0 \vdots \Lambda_1]$ has full row rank. This affine price of risk specification resembles the affine term structure model.

The beta representation of the dynamic asset pricing model is given by:

$$R_{i,t+1} = \beta_i'(\Lambda_0 + \Lambda_1 F_t) + \beta_i' u_{t+1} + e_{i,t+1} \tag{3.26}$$

In this representation, the realized excess return $R_{i,t+1}$ can be decomposed into, the expected excess return $\beta_i'(\Lambda_0 + \Lambda_1 F_t)$, the component that is conditionally correlated with the innovations to the risk factors $\beta_i' u_{t+1}$, and a return pricing error $e_{i,t+1}$ that conditionally orthogonal to the risk factor innovations. The expected excess return, i.e. the risk premium, hence depends on the asset's exposures with respect to the pricing factors, as well as the associated prices of risk.

The system of equation (3.26) for $i = 1, 2...N$ embeds the no-arbitrage restrictions that are derived from the linear pricing kernel in equation (3.24). To the extent that the model is well specified, the parameter restrictions imposed by no-arbitrage help increase the predictive accuracy for the cross-section of excess returns. The reason is that the kernel estimator imposes less structure than assuming a specific functional form for the parameters and is more robust to misspecification.

Stack equations (3.22) and (3.26) to obtain:

$$X = \mu + \Phi X_{-} + V \tag{3.27}$$

$$R = B\Lambda_0 i_T' + B\Lambda_1 F_{-} + BU + E \tag{3.28}$$

where $X = [X_1...X_T]$ is KxT, $V = [v_1...v_T]$ is KxT, $R = [R_1...R_T]$ is a NxT matrix with $R_t = (R_{1,t}, ..., R_{N,t})'$, $F_{-} = [F_0...F_{T-1}]$ is K_FxT, $U = [u_1...u_T]$ is K_CxT, $E = [e_1...e_T]$ is a NxT matrix with $e_t = (e_{1,t}, ..., e_{N,t})'$. The parameters in this model are stacked risk exposures B and the prices of risk Λ. Nest Equation (3.28) in the form of a seemingly-unrelated regression model:

$$R = A_0 i_T' + A_1 F_{-} + BU + E = AY + E \tag{3.29}$$

$$A_0 = B\Lambda_0, A_1 = B\Lambda_1, A = [A_0 \vdots A_1 \vdots B] \tag{3.30}$$

where A is a N x $(K_C + K_F + 1)$ matrix, $Y = [i_T \vdots F'_{-} \vdots U']$ is $(K_C + K_F + 1)$ x T.

The estimation approach can be summarized in three steps: In the first step, estimate the VAR in equation (3.27), innovations to the state variables are obtained as estimation residuals:

$$\hat{V} = X - \hat{\Psi} Z_{-} \tag{3.31}$$

where $\hat{\Psi} = XZ'_{-}(Z_{-}Z'_{-})^{-1}$, $Z_{-} = [i_T \vdots X'_{-}]'$. $\hat{U}$ is formed as a K_CxT matrix extracted from the first K_C rows of $\hat{V}$. The estimator is constructed as:

$$\hat{\Sigma}_u = \frac{\hat{U}\hat{U}'}{T} \tag{3.32}$$

In the second step, asset returns are regressed in the time series on lagged price of risk factors F_{-} and the contemporaneous innovations to the cross sectional pricing factors $\hat{U}$, generating predictive slopes and risk betas for each test asset:

$$\hat{Y} = [i_T \vdots F'_{-} \vdots \hat{U}'] \tag{3.33}$$

$$\hat{A} = R\hat{Y}'(\hat{Y}\hat{Y}')^{-1} \tag{3.34}$$

$$\hat{E} = T((\hat{Y}\hat{Y}')^{-1} \otimes I_N)(\sum_{t=1}^{T}(\hat{y}_t\hat{y}_t' \otimes \hat{e}_t\hat{e}_t'))((\hat{Y}\hat{Y}')^{-1} \otimes I_N) \tag{3.35}$$

where $\hat{E}$ denote heteroskedasticity robust standard errors, $\otimes$ represents the Kronecker product, $\hat{z}_t = (1, F_{t-1}', \hat{u}_t')'$, $\hat{e}_t = R_t - \hat{A}\hat{z}_t$.

In the third step, price of risk parameters are obtained by regressing the predictive slopes from the time series regressions on the betas cross-sectionally:

$$\hat{\Lambda}_0 = (\hat{B}'\hat{B})^{-1}\hat{B}'\hat{A}_0 \tag{3.36}$$

$$\hat{\Lambda}_1 = (\hat{B}'\hat{B})^{-1}\hat{B}'\hat{A}_1 \tag{3.37}$$

In this dynamic asset pricing model specification, the parameters governing the predictive and the cross-sectional relationships between state variables and asset returns are intimately linked. Adrian et al. (2015) show that this estimation approach is computationally efficient and robust.

3.4 Data

Test assets are 10 value-weighted portfolios univariate sorted on market value, 10 value-weighted portfolios sorted on book-to-market ratio and 7 zero-coupon nominal government bond portfolios with maturities of 1, 2, 3, 4, 5, 7 and 10 years. Excess returns are computed over the three-month UK Treasury Bill rate. The equity data is obtained from Datastream and the yield data from the Bank of England website. The sample period ranges from January 1990 - December 2015 for a total of 312 monthly observations. The portfolio formation mechanism closely follows Fama & French (2017), with adjustments where necessary to account for characteristics of the UK data[1].

Three pricing factors are proposed to price the joint cross section of equities and government bonds. The first one is the stock market factor (MKT), which is the excess return on the value-weighted equity market portfolio. The other two factors are classic term structure of interest rate factors, which have been shown

[1] Test portfolios and stock market factors are constructed from a large dataset of firm characteristics, as in the discussion in Chapter 2.

to dominate the cross-section variation of bond returns (Litterman & Scheinkman (1991)). The second factor describes the level of term structure of interest rates (PC), which is constructed as the first principal component of the one through five year zero-coupon yield data. The third factor is the term spread (TERM) between the yield on a ten-year government bond and the three-month Treasury bill rate, which can be considered as the slope of the zero-coupon yield curve. The data used to construct bond factors is obtained from the Bank of England website. The term spread also serves a role as a forecasting factor, since it has been proved to predict stock returns as well as bond returns (see e.g., Fama & French (1989), Fama & French (1993), and Keim & Stambaugh (1986)). Particularly, Campbell (1987) argues that variables have been used to predict excess returns in the term structure also predict excess stock returns in U.S. monthly data. Chen (1991) shows that the term spread and macroeconomic factors are important determinants of future stock market returns. Moreover, two macroeconomic factors are also considered as forecasting factors. The output gap (GAP) is measured by the deviations of the log of real GDP from a trend that incorporates both a linear and a quadratic component. The monthly GDP estimates is collected from the National Institute of Economic and Social Research. One-year ahead CPI inflation expectations (INF) are computed as the mean of the point forecasts across respondents, and the data are collected from the Consensus forecast survey. There is a sizeable literature on the ability of the output gap and inflation expectations in predicting stock and government bond returns (see e.g., Flannery & Protopapadakis (2002), Diebold et al. (2006), and Campbell & Thompson (2008)). A range of candidate pricing and forecasting factors motivated by the literature are also evaluated through cross-sectional pricing tests and predictive return regressions[2]. The results confirm that MKT, PC and TERM exhibit the highest statistical significance among candidate pricing factors, while TERM, GAP and INF demonstrate the strongest predictive performance for stock and government bond returns.

[2]Further details and test results are reported in Appendix B

3.5 Estimation Results

In section 3.5.1, I estimate the term structure of interest rates and discuss the main feature of the model-implied term premiums. The effectiveness of the Cochrane & Piazzesi (2005) return forecasting factor in the UK is examined in section 3.5.2. In section 3.5.3, estimation results for the joint dynamic asset pricing models are presented. The cyclicality of UK risk premia is explored in section 3.5.4.

3.5.1 The pattern of UK government bond term premium

Litterman & Scheinkman (1991) show that the variation of nominal Treasury yields is almost fully captured by three principal components which are commonly referred to as level, slope, and curvature. To estimate the term structure of interest rates, pricing factors are constructed as the first three principal components extracting from zero-coupon Treasury yields with maturities of 3,4,...120 months.

[Figure 3.2]

Using the monthly observations for the time period of January 1990-December 2015, Figure 3.2 presents historical and fitted yields for 1, 2, 3, 4, 5, 7 and 10-year government bonds. It can be seen that the affine term structure model provides a good fit of the time-series variation in yields with negligible pricing error.

[Figure 3.3]

Figure 3.3 shows the decomposition results of 10-year government bond yields for the UK. It can be seen that there exists substantial uncertainty around term premium estimates. The determination of the UK term premiums can be reflected from the dynamics of term premium over time. The adoption of an inflation targeting framework in 1992 led to a reduction in inflation uncertainty, which contributed to lower bond risk premiums in UK Treasury yields. This may also reflect an increased demand for the safety of government bonds following the Asian financial crisis in 1997. Guimarães (2012) also shows that the term premium significant dropped during the 1990s, which compensated investors for future inflation uncertainty. The term premium was relatively low and stable through the period of 1997-2007, which is a period often called the Great Moderation. During the 2008 financial crisis, since investors require additional compensation for bearing interest rate risk, term premiums increased sharply. However, bond risk premiums fell in 2009 following the lowered interests rates and quantitative easing through purchases of government bonds. Furthermore, it can be seen that the term premium declined significantly as the expectations component increased when the economy rebounded from recessions.

3.5.2 Can forward rates predict bond returns in the UK?

Cochrane & Piazzesi (2005) show that for US data, a single linear combination of forward rates predicts bond excess returns across maturities, but has a low correlation with the principal components of yields. This single-factor can be written as:

$$\hat{cp}_t = \gamma_0 + \gamma_1 {y_t}^{(1)} + \gamma_2 {f_t}^{(1\to 2)} + ... + \gamma_5 {f_t}^{(4\to 5)} \tag{3.38}$$

where γ is a vector of parameter estimates, ${y_t}^{(1)}$ is the log yield on a one-year bond, and ${f_t}^{(n-1\to n)}$ is the log forward rate between time t+n-1 and time t+n.

In this section, whether forward rates can predict excess bond returns in the UK government bond market is examined. The unrestricted regressions of the 1-year excess bond returns takes the form as below:

$$r_{t+1}^{(n)} - y_t^{(1)} = b_0^{(n)} + b_1^{(n)} y_t^{(1)} + b_2^{(n)} f_t^{(1\to 2)} + ... + b_5^{(n)} f_t^{(4\to 5)} + \varepsilon_{t+1}^{(n)} \tag{3.39}$$

where the excess bond returns are forecast by a linear combination of the forward rates.

The restricted regressions project the excess bond returns on a single factor as follow:

$$r_{t+1}^{(n)} - y_t^{(1)} = \rho^{(n)}(\gamma_0 + \gamma_1 {y_t}^{(1)} + \Sigma_{k=2}^{K} \gamma_k f_t^{(k-1\to k)}) + \varepsilon_{t+1}^{(n)} \tag{3.40}$$

where K is the number of forward rates included and $\rho^{(n)}$ is restricted as:

$$\frac{1}{K-1}\Sigma_{n=2}^{K}\rho^{(n)} = 1 \tag{3.41}$$

The single factor is the fitted value of a regression from projecting the average excess bond returns on all forward rates. The average excess bond return regression takes the form:

$$\frac{1}{K-1}\Sigma_{n=2}^{K}(r_{t+1}^{(n)} - y_t^{(1)}) = \gamma_0 + \gamma_1 y_t{}^{(1)} + \Sigma_{k=2}^{K}\gamma_k f_t^{(k-1\to k)} + \varepsilon_{t+1} \tag{3.42}$$

[Figure 3.4]

Figure 3.4 plots the coefficients in a regression of holding period excess returns on the one-year yield and four forward rates. The top panel presents unrestricted estimates. The bottom panel presents restricted estimates from a single-factor model. The legend (2, 3, 4, 5) refers to the maturity of the bond whose excess return is forecast. The x axis gives the maturity of the forward rate on the right hand side. There are resemblances between restricted coefficients and unrestricted coefficients. However, the shape of those coefficients in the UK market do not show the usual tent shape found in the US market.

[Table 3.1]

The predictability of the combination of all forward rates, which is measured by adjusted R-squared are shown in Table 3.1. The single factor can forecast up to 17.1% of the variation in the average excess bond returns in the UK. The χ^2 statistic indicates the joint insignificance of the forward rates for the UK market. Therefore, the results of Cochrane & Piazzesi (2005) are not transferable to the UK market. One possible explanation for the missing pattern of the estimated coefficients, as mentioned in Kessler & Scherer (2009), is due to the high correlations among the forward rates with various maturities.

[Figure 3.5]

It can be seen from Figure (3.5) that there is a low variation of the single CP factor in the UK market, which is consistent with the finding of insignificant coefficients in Table 3.1. Under the expectations hypothesis, the n-year forward rate should be the optimal forecast of the spot rate n-1 years in the future. While the ability of the linear combination of all forward rates to predict excess bond returns in the US suggests the failure of the expectations hypothesis and shows impressive predictability. However, this predictability is extremely weak in the UK government bond market.

3.5.3 A joint model of stocks and government bonds

In this section, a parsimonious dynamic asset pricing model that jointly prices stock and government bond returns is explicitly evaluated. The dynamics of the risk premium in UK financial markets implied by the joint model of stocks and government bonds are investigated as well.

[Table 3.2]

[Table 3.3]

Table 3.2 and Table 3.3 report factor risk exposure estimates from the joint dynamic asset pricing model of the UK equity and government bond markets.

As can be seen from Panel A, all size portfolios significantly load on MKT. Factor loadings of PC on size portfolios are statistically significant except for the 9th and 10th size decile portfolio. The risk exposure to TERM is significant at the 1% significance level for two portfolios with the smallest market capitalization, and the excess returns on stock portfolios with the biggest market capitalization do not contemporaneously co-move with shocks to the term structure of the yield curve. The exposure to MKT does explain the spread between average excess returns on small and large market capitalization stocks, the reason is that the risk exposure to MKT decreases from the smallest stocks portfolio S1 (0.862) to the biggest stocks portfolio S10 (0.530). Similarly, the risk exposures to TERM demonstrates a differential of 0.014 between the smallest and the largest size deciles. Also, factor risk exposure estimates of MKT show that investors require a higher return when investing in small firms, which confirms that larger firms tend to be less risky while investing in smaller companies entail greater risk. Investors are expected to be rewarded for taking the additional risk inherent in small stocks. The market factor MKT and the term-structure factors PC and TERM play a role in explaining the cross-sectional variation in average equity returns. In addition, root mean squared pricing errors for small market capitalization stocks are greater than those for big market capitalization stocks.

Panel B shows that book-to-market portfolios load significantly on MKT at the 1% significance level. The market betas of the book-to-market portfolios have magnitudes around 0.85 with relatively little dispersion. Excess returns on equity portfolios are positively correlated with shocks to MKT. The factor risk exposure to TERM and PC are both statistically significant for growth stock portfolios BM1-BM3 and value stock portfolios BM8-BM10. The results reveal that growth stocks have a negative relationship with the risk exposure to TERM and PC, whereas excess returns on the other six book-to-market portfolios are positively correlated with TERM and PC. The risk exposure to PC shocks varies from -0.152 to 0.208. There is approximately 0.360 difference in risk exposure to PC shocks across ten book-to-market portfolios. Value stocks have a large and positive exposure to MKT shocks while the factor loadings of stocks with the lowest book-to-market ratio is 0.763. Value stocks have higher MKT betas than growth stocks, but the difference is relatively small comparing with size portfolios. The risk compensation for exposure to TERM and PC is negative for growth stocks but positive for value stocks. The term-structure factors capture variation in stock returns. The root mean squared pricing error ranges from 0.021 for the sixth book-to-market decile portfolio to 0.036 for the fifth book-to-market decile portfolio, indicating the existence of a difference of 0.015.

Panel C demonstrates that the cross-section of average bond returns is well described by differences in exposure to MKT, TERM and PC. There is a monotonically increasing pattern in exposures of the government bond portfolio returns to TERM, and a monotonically decreasing pattern to PC as the bond maturity increases. For example, the TERM betas of the Treasury portfolios increase significantly as the maturity increases. TERM and PC are significant at the 1% significance level. All Treasury portfolios significantly load on MKT and PC with a negative sign. Short-term government bond returns contemporaneously co-move with shocks to MKT, suggesting there are common business conditions driving the returns on stocks and bonds. Furthermore, excess returns on government bonds contemporaneously co-move with shocks to TERM and PC, which can be considered as the slope and level of term structure of the yield curve. As can be seen in the first column, the risk exposure to MKT is negative, an unexpected rise of equity market returns is associated with lower excess returns on UK government bond portfolios. In the second column, the factor risk exposures of bond returns to TERM are positive. Moreover, the excess returns on government bond portfolios are negatively correlated with shocks to PC, which implies an unexpected rise of long-term bond yields is associated with lower excess returns on government bonds. In addition, long-horizon bonds have returns that are more sensitive to TERM and PC shocks than short-horizon bonds. The root mean squared pricing error is 0.146 for one-year government bonds and increases to 0.397 for the ten-year government bonds. Long-term government bonds tend to contain higher risk betas as long-term government bonds bear interest rate risk and higher uncertainty. In consequence, investors require higher return for buying long-term government bonds instead of short-term government bonds. By comparing the root mean squared pricing error results in Panel A and Panel B, it can be seen that the pricing factors perform better at pricing the cross-section of equity returns than government bond returns.

[Table 3.4]

Table 3.4 provides market price of risk estimates from the joint model. Forecasting factors TERM, INF and GAP determine the time variation in factor risk premia. The constant coefficients Λ_0 in the market prices of risk are individually significant at the 1% significance level. TERM affects the prices of risk of MKT and TERM with a positive sign. Whereas TERM drives down the price of risk of PC. The price of MKT risk is significant at the 1% significance level across TERM and GAP but at the 5% significance level for the factor INF. The price of TERM and PC risk is statistically different from zero across three forecasting factors, which exhibits substantial time variation. As for macro factors, INF and GAP significantly add to the variation in the price of MKT, TERM and PC risk with a negative effect, which is consistent with that high expected inflations predict low stock returns. TERM has a positive impact on the prices of risk of MKT and TERM but a negative influence on the prices of PC risk. A high term spread raises the price of MKT risk, which implies that a greater term spread predicts higher expected excess stock returns. The results confirm that there exists a positive relationship between the slope of term structure of the yield curve and expected excess returns on equity market. Furthermore, the predictive relationship between macro factors and excess returns on equity and bond portfolios is statistically and economically significant.

The results in Table 3.4 also reveal that TERM, INF and GAP are strong predictors of excess equity and bond returns, while TERM also carries a highly significant risk premium in the cross-section of stock and bond returns. The market price of MKT, TERM and PC risk are all positive. A positive shock to the market factor increases stock returns and lowers the stochastic discount factor, and thus carries a positive risk price. The positive price of TERM and PC risk arises because positive shocks to the yield curve influences lone-term interest rates, which implies a negative innovation to the stochastic discount factor. The standard errors are 0.007 for the MKT price, 0.095 for the TERM price, and 0.053 for the PC price. The risk prices of the three pricing factors are all statistically different from zero at the 1% significance level. The last column reports the Wald statistic for a test whether the coefficients in a particular row of Λ_1 are jointly equal to zero. The results indicate that there is considerably significant time variation in each of the factor risk prices.

In summary, the variation of excess equity and bond returns are determined by risk exposures to MKT, TERM and PC, where the market prices of risk of the pricing factors are vary over time as affine functions of TERM, INF and GAP. The ability of the variables to forecast future asset returns is associated with changes in the macroeconomic environment. The model performance confirms that TERM is an variable that both predicts excess returns on stocks and bonds and acts as well as a significant cross-sectional pricing factor. Additionally, market prices of risk of the MKT, TERM and PC are significantly negatively related to inflation expectations and the output gap, which is in line with theories that suggest that time variation in risk premiums arises from fluctuation in the business cycle. These results also indicate that macroeconomic factors are useful for forecasting UK stocks and bonds returns. Consequently, macroeconomic factors contain important information to uncover the countercyclical nature of the risk premium in UK financial markets.

[Figure 3.6]

Figure 3.6 illustrates the time series of estimated price of risk for the MKT, TERM and PC factors. It can be seen that the three series all exhibit substantial time variation in the prices of risk. Moreover, Figure 3.6 demonstrates that the market price of equity and government bond risk experienced a spike in 2009. The price of TERM risk largely mimics the dynamics of the price of PC risk, but has a greater average level. The price of MKT risk is positive for the sample period. While the price of PC risk was mostly negative in the early part of the 1990s, it flipped sign in the mid 1990s and became negative again in the aftermath of the 2008 financial crisis. These results indicate that exposure to long-term Treasury risk generated strongly fluctuating risk prices for stock portfolios over the last 25 years in the UK. It also can be seen that the prices of risk are generally higher during economic recessions than expansions.

[Figure 3.7]

Figure 3.7 reports the dynamics of the estimated risk premium for the fifth size portfolio, the fifth book-to-market portfolio as well as the five-year constant maturity Treasury portfolio. The first and second chart document that the equity risk premium is strongly time-varying. While it has on average amounted to about 3.7 percent over the past 25 years, there have been a few episodes where the estimated risk premium has been markedly high. In particular, during the first two years of the recent financial crisis the estimated risk premium rose above 5 percent, implying that equity investors anticipated extra high risk compensation when investing in equities during this period. For the fifth size portfolio, the risk premium varies in a range from 1.71 percent to 7.62 percent. The risk premium ranges from 1.78 percent to 7.53 percent for the fifth book-to-market portfolios.

The third plot shows that there is substantial time variation in the estimated risk premium for five-year government bond portfolios. The time variation of the risk premium is in a narrower range of around minus 0.44 percent to slightly over 1.45 percent. The fall in the risk premium on five-year government bonds since the onset of the 2008 financial crisis reflects lower expectations of real interest rates at shorter horizons, consistent with an expectation that policy rates will remain low during the economic recovery. As a consequence, the joint model predicts meaningful variation in the risk premium, consistent with the persistence of actual excess returns over long horizons. Additionally, it can be seen that both the equity risk premium and government bond risk premium increased following the 2008 financial crisis but dropped significantly since Quantitative Easing takes effect. The interpretation is that the asset purchases increases asset prices and thus lower risk premiums on longer-term debt securities. Finally, the equity and government bond risk premiums in the UK are informative about the state of the economy and hence are meaningful for the policy-maker.

3.5.4 Cyclicality of UK risk premia

I further examine the cyclical behaviour of the risk premium, by running univariate regressions of the median size equity risk premium and ten-year term premium on two macro factors: Composite Leading Indicator (CLI) and the unemployment rate, as in the form:

$$RP_t^{(S5)} = \beta_0 + \beta_1 CLI_t + \beta_2 U_t + \varepsilon_t \tag{3.43}$$

$$TP_t^{(10)} = \beta_0 + \beta_1 CLI_t + \beta_2 U_t + \varepsilon_t \tag{3.44}$$

where $RP_t^{(S5)}$ is the equity risk premium on the fifth size portfolios, $TP_t^{(10)}$ is the ten-year term premium, CLI_t is Composite Leading Indicator (CLI) of the UK, collected from the OECD data website. The CLI is designed to provide early signals of turning points, and leads the business cycle. This is desirable for estimating the cyclical behaviour of the risk premium, since these rise ahead of and early in recessions, and vice versa fall around the business cycle trough and early in expansions. U_t denotes the unemployment rate.

[Table 3.5]

[Table 3.6]

Results in Table 3.5 and Table 3.6 confirm that the risk premium in UK financial markets is a countercyclical variable: the coefficient on the business cycle indicator CLI is negative and statistically significant. Furthermore, the relationship between the risk premium and unemployment is positive and statistically significant, which indicates that the term premium tends to rise when unemployment rises during recessions and fall when unemployment decreases during expansions. The results are evidence of a pronounced countercyclical pattern for UK equity and bond risk premiums. These are broadly consistent with theories that investors must be compensated for bearing risks associated with economic environment and business conditions. Additionally, during the financial crisis, increases in risk aversion helps to create a higher demand for safe assets government bonds and leads to a decline in the yields. These findings confirm the importance of using information beyond asset prices to uncover business-cycle variation in the risk premium associated with macroeconomic conditions.

3.6 Robustness Checks

The robustness of the estimation results is investigated through parameter stability tests in this section. To assess the constancy of the parameters, robustness checks are performed by rolling window estimations and recursive estimations.

[Figure 3.8]

Figure 3.8 provides plots of five-year rolling window beta estimates for different pairs of test assets and pricing factors. In the top panel, test asset is the fifth size decile portfolio. In the middle panel, test asset is the fifth book-to-market decile portfolio. In the bottom panel, test asset is the government bond portfolios for the five-year maturity. The graphs in the first column represent results for MKT, the graphs in the second column show results for TERM, and the ones in the third column report results for PC. It can be clearly seen that there are considerable variations in the rolling estimates. A sharp drop in the beta estimates from the onset of the 2008 financial crisis can be found in each graph, indicating the instability of stock and bond market during that period. Furthermore,the five-year Treasury portfolio's beta on the stock factor MKT and bond factor PC switches from a positive to a negative sign in the mid 1990s and demonstrate a big fluctuation during the period of 2008-2013 recession. The size fifth portfolio's beta on the factor TERM switches from a negative to a positive sign in late 1990s. These results are consistent with that the correlation between stock and bond returns have flipped signs in the 1990s. In addition, the beta of the fifth book-to-market portfolio onto the MKT factor and the beta of the five-year Treasury portfolio onto the TERM factor fluctuate quite substantially over time.

[Figure 3.9]

Figure 3.9 illustrates the recursive estimation results and the corresponding structural break test results. Firstly, the 1-step residuals lie within their approximate 95% confidence bands except the 2008 financial crisis period, it can be seen that the major outlier is around the Great Recessions occurred in the beginning of the 2008 financial crisis. Secondly, the standardized innovations highlight residuals in the period of 1990-1992 and the 2008 financial crisis, which is in correspondence to the two economic recessions in the UK. Lastly, the 1-step Chow structural break test demonstrates the parameter instability from 2008 to 2009. The break point Chow test does not indicate parameter instability in the sample period. Overall, parameter constancy is not rejected, suggesting the joint model provides a reasonable explanation of time-series variation of stock and bond returns.

3.7 Concluding Remarks

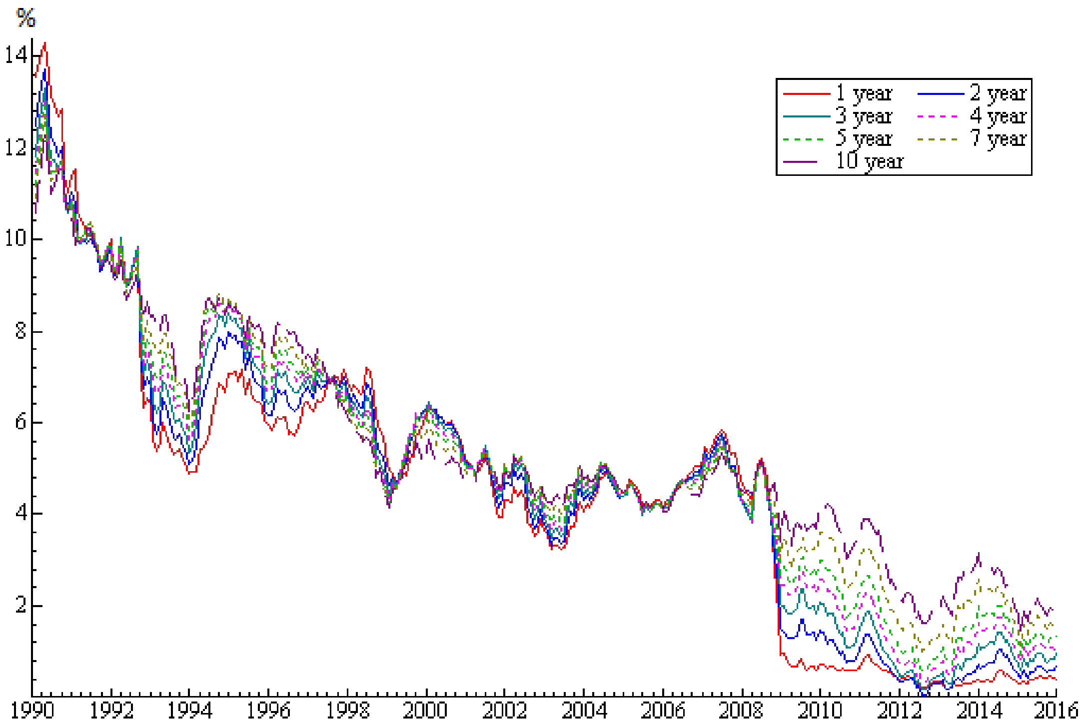
In this chapter, I estimate a joint dynamic asset pricing model that can be used to explain average returns for size-sorted stock portfolios, book-to-market-sorted stock portfolios and government bond portfolios sorted by maturity. The equity market return factor, the level of the yield curve, and the term spread factor are used as the cross-sectional pricing factors. Two macro factors: inflation expectations and the output gap along with the term spread are considered as unspanned forecasting factors. The results demonstrate significant time variation in risk premiums, and confirm that macro factors indeed have significant influence on the dynamics of the equity and bond risk premiums in the UK. In addition, it has been shown that the equity and bond risk premiums are countercyclical while the Cochrane-Piazzesi forward factor performs poorly in the UK.

The predictive power of unspanned macro factors is not just statistically significant but also economically important. Macro variables based on the output gap and inflation expectations contain useful information about future equity and bond returns. Despite the crucial role of macroeconomic factors, economic theories suggest that investors should be compensated for exposures associated with economic fluctuations (Campbell & Shiller (1988), Cochrane (2011)). Risk premiums are found to be substantially higher and more volatile during economic recessions.

The empirical results also demonstrate two important implications: firstly, a single factor, either constructed along the lines of the Cochrane & Piazzesi (2005) factor or as a principal component of the term structure of interest rates, is unlikely to be capable of summarising all the necessary information for a correct pricing of risks. Secondly, despite the financial origin of the 2008 crisis, the market turbulence was quickly spreading to the real economy in the UK and worldwide, and it is important that modelling risk premia in financial markets takes into account direct macroeconomic information to identify the risks associated with a given financial investment.

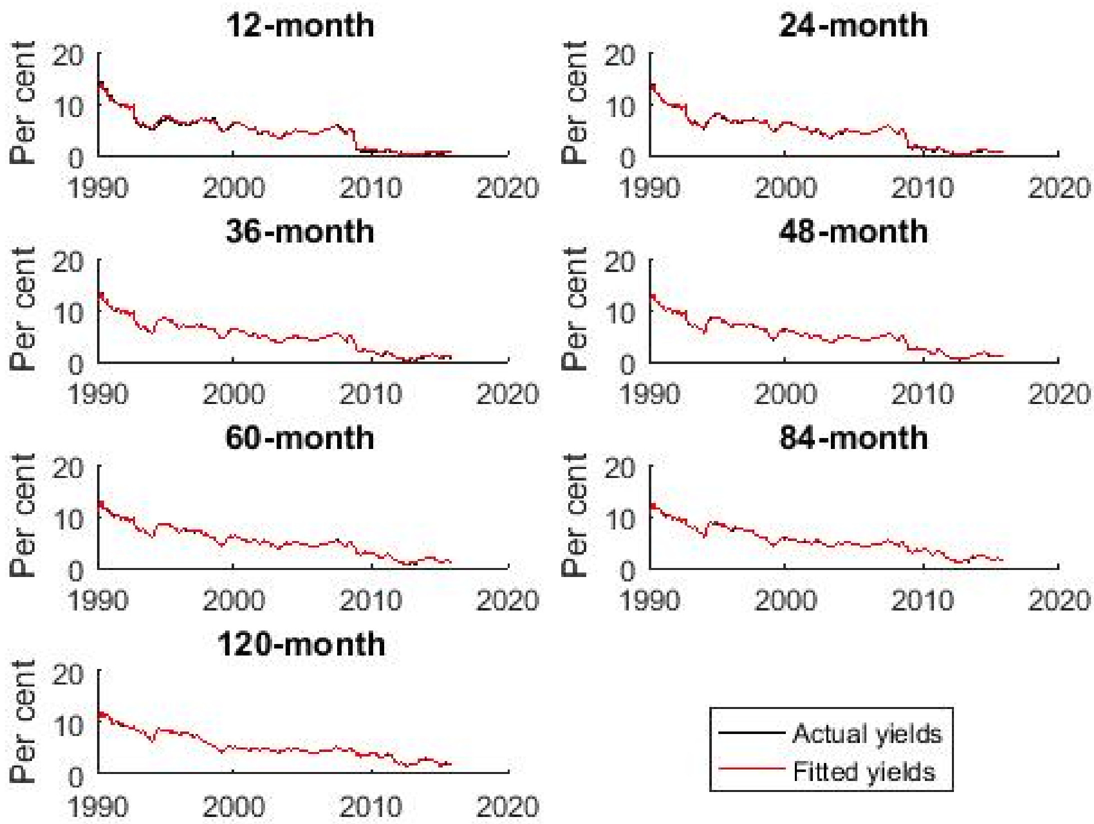
This chapter contributes to the literature on stock and bond returns predictability by showing that macroeconomic fundamentals have important predictive power for excess returns on UK stocks and government bonds. Three aspects of the findings is stressed. First, in contrast to the existing empirical literature, this study provides evidence on the strong predictable variation in excess stock and bond returns that is associated with macroeconomic activity. Second, it has been demonstrated that the term spread contains significant cross-sectional pricing power and forecasting ability, which is in line with the literature. The level and slope of the yield curve is priced not only in the government bond excess returns but also in part of equity portfolios. Finally, this study adds to the growing empirical research on the cyclicality of risk premia. The results show that the equity and bond risk premiums obtained from the joint model contain a significant countercyclical feature as well as providing an economic interpretation.

Figure 3.1: UK nominal government bond yields



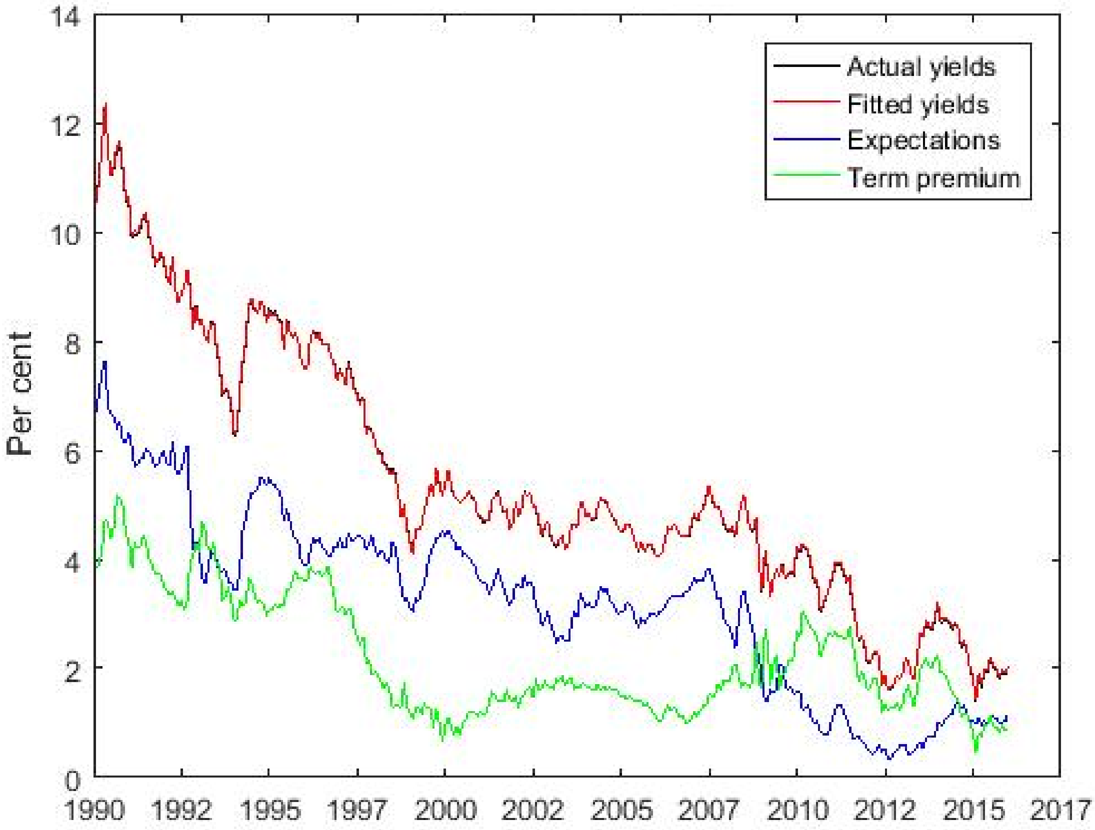
Notes: This figure provides plots of monthly UK nominal government bond yields for the maturities of 1, 2, 3, 4, 5, 7 and 10-year. 1-year government bond yields are plotted by a solid red line. 2-year government bond yields are plotted by a solid blue line. 3-year government bond yields are plotted by a solid green line. 4-year government bond yields are plotted by a dashed pink line. 5-year government bond yields are plotted by a dashed green line. 7-year government bond yields are plotted by a dashed yellow line. 10-year government bond yields are plotted by a solid purple line. The sample period is January 1990 to December 2015. The data source is the Bank of England.

Figure 3.2: Actual and fitted government bond yields



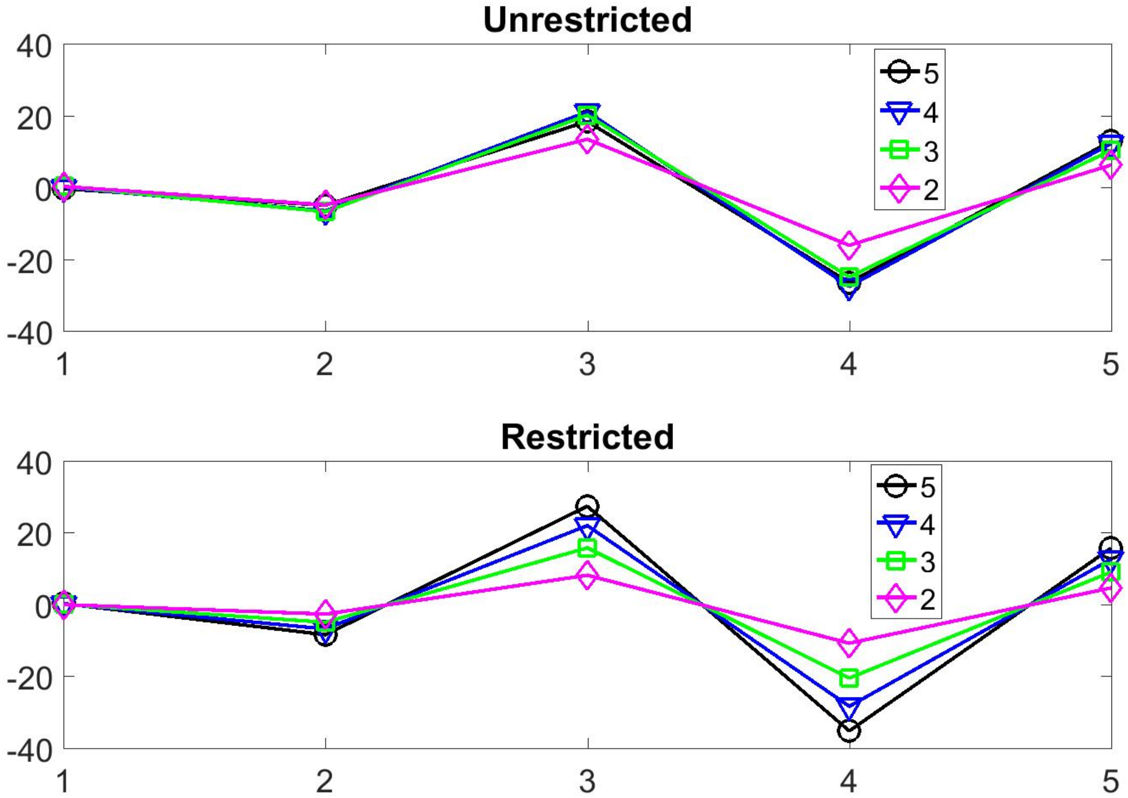
Notes: This figure provides plots of yields $y_t^{(n)}$ for the maturities of 1, 2, 3, 4, 5, 7 and 10-year as observed and estimated in the equation $y_t^{(n)} = -\frac{1}{n}[A_n + B_n' H_t]$. The sample period is January 1990 to December 2015.

Figure 3.3: Decomposition of 10-year government bond yields



Notes: This figure illustrates the decomposition of 10-year government bond yields. Black line and red line report plots of the yields for the 10-year maturity as observed and estimated in the form $y_t^{(n)} = -\frac{1}{n}[A_n + B_n' H_t]$, respectively. Using estimation equation $y_t^{(n)} = \frac{1}{n}\Sigma_{i=0}^{n} E_t r_{t+i} + TP_t^{(n)}$, the term premium is computed as the difference between bond yields and the model forecast of the average expected policy rate. Blue line corresponds to expectations and green line shows model-implied term premiums. The sample period is January 1990 to December 2015.

Figure 3.4: Unrestricted and restricted coefficients



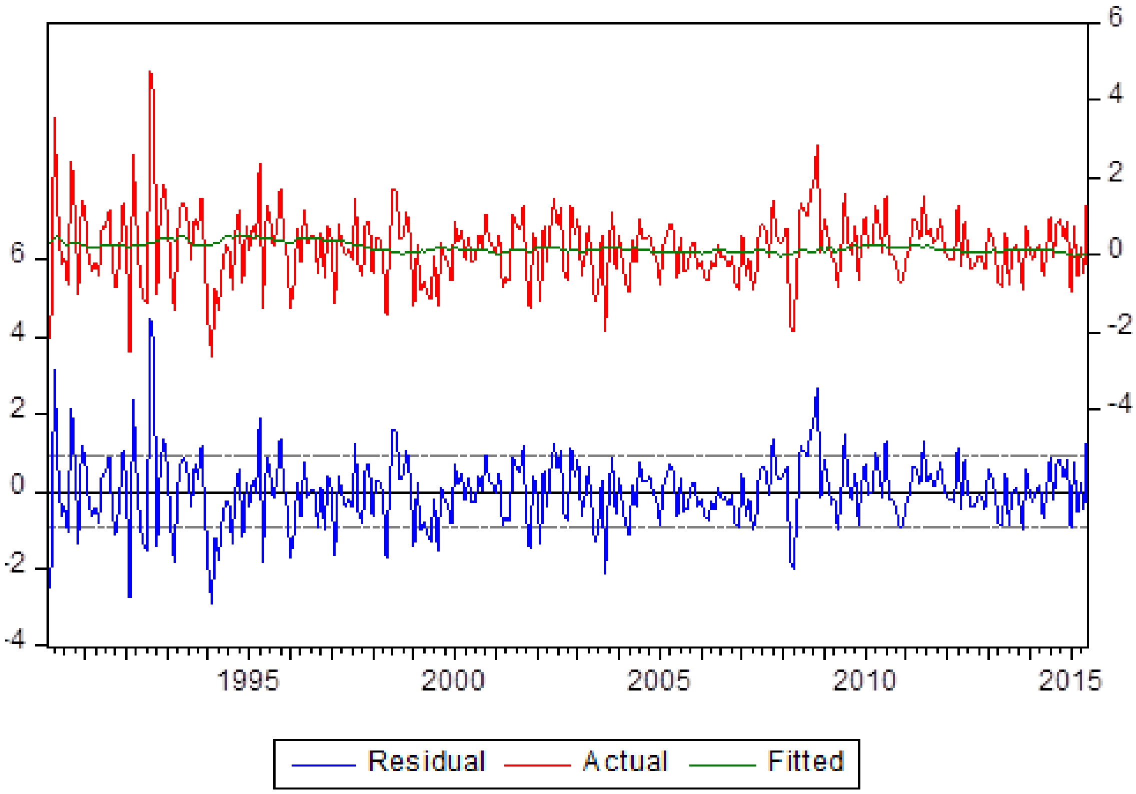
Notes: This figure plots regression coefficients of one-year excess returns on forward rates. The top panel presents estimates b from the unrestricted regressions of bond excess returns on all forward rates as in the form $r_{t+1}^{(n)} - y_t^{(1)} = b_0^{(n)} + b_1^{(n)} y_t^{(1)} + b_2^{(n)} f_t^{(1\rightarrow 2)} + ... + b_5^{(n)} f_t^{(4\rightarrow 5)} + \varepsilon_{t+1}^{(n)}$. The bottom panel presents restricted estimates $\rho\gamma$ from the single-factor model $r_{t+1}^{(n)} - y_t^{(1)} = \rho^{(n)}(\gamma_0 + \gamma_1 y_t{}^{(1)} + \Sigma_{k=2}^{K} \gamma_k f_t^{(k-1\rightarrow k)}) + \varepsilon_{t+1}^{(n)}$. The legend (5, 4, 3, 2) gives the maturity of the bond whose excess return is forecast. The x axis shows the maturity of the forward rate on the right-hand side of estimation equation. The sample period is January 1990 to December 2015.

Table 3.1: Regressions of excess bond returns on forward rates

Maturity	γ_0	*y1*	γ_1	γ_3	γ_4	γ_5	$Adj.R^2$	$\chi^2(5)$
2	-37.861	0.513	-4.625	13.671	-15.852	6.492	0.171	12.891
	(-0.562)	-0.686	-0.354	(0.937)	(1.124)	(0.475)		[0.244]
3	-70.82	0.553	-6.504	20.362	-24.670	10.623	0.142	9.95
	(0.918)	-1.265	(0.685)	(0.185)	(0.223)	(0.933)		[0.767]
4	-112.89	0.285	-6.264	21.291	-27.308	12.509	0.138	10.75
	(1.312)	(1.691)	(1.938)	(1.862)	(1.256)	(1.129)		[0.566]
5	-166.562	-0.141	-4.722	18.622	-26.235	13.14	0.131	13.67
	(1.653)	(0.992)	(1.121)	(1.315)	(1.379)	(1.159)		[0.178]

Notes: This table reports restricted regression coefficients γ in $r_{t+1}^{(n)} - y_t^{(1)} = \rho^{(n)}(\gamma_0 + \gamma_1 {y_t}^{(1)} + \Sigma_{k=2}^{K}\gamma_k f_t^{(k-1\rightarrow k)}) + \varepsilon_{t+1}^{(n)}$. Column 7 reports adjusted R^2. Standard errors use the Hansen-Hodrick GMM correction for overlap are reported in parentheses. χ^2 is the Wald statistic that tests whether the slope coefficient is zero. All χ^2 statistics are computed with 15 Newey-West lags to ensure a positive definite covariance matrix. Square brackets report asymptotic p-values. The sample period is January 1990 to December 2015.

Figure 3.5: Forecast and realized 10-year government bond average excess returns



Notes: This figure plots the realized 10-year government bond excess returns with red line. Forecast of 10-year government bond returns by CP factor and corresponding residuals are plotted by green and blue line, respectively. The sample period is January 1990 to December 2015.

Table 3.2: Factor risk exposure estimates

	MKT	*TERM*	*PC*	*Adj.R^2*	*RMSE*
Panel A Size Portfolios					
S1	0.862***	0.026***	0.208***	0.329	0.033
	[0.075]	[0.009]	[0.065]		
S2	0.833***	0.023***	0.212***	0.387	0.036
	[0.079]	[0.014]	[0.062]		
S3	0.796***	0.015	-0.344***	0.492	0.031
	[0.092]	[0.011]	[0.098]		
S4	0.835***	0.016	- 0.306***	0.496	0.029
	[0.059]	[0.013]	[0.092]		
S5	0.712***	0.036*	-0.323***	0.559	0.033
	[0.049]	[0.021]	[0.089]		
S6	0.728***	0.028*	-0.256***	0.572	0.034
	[0.042]	[0.015]	[0.087]		
S7	0.652***	-0.021*	0.209**	0.588	0.028
	[0.051]	[0.011]	[0.083]		
S8	0.673***	-0.018*	0.227**	0.643	0.022
	[0.058]	[0.009]	[0.099]		
S9	0.582***	-0.016*	0.190*	0.690	0.021
	[0.038]	[0.008]	[0.093]		
S10	0.530***	0.012	0.188*	0.687	0.023
	[0.032]	[0.010]	[0.095]		
Panel B Book-to-market Portfolios					
BM1	0.763***	-0.027***	-0.144***	0.583	0.025
	[0.039]	[0.006]	[0.051]		
BM2	0.712***	-0.032***	-0.152***	0.579	0.028
	[0.033]	[0.007]	[0.061]		
BM3	0.702***	-0.026***	-0.136***	0.611	0.031
	[0.036]	[0.005]	[0.045]		
BM4	0.868***	-0.012	-0.139*	0.625	0.024
	[0.035]	[0.008]	[0.078]		
BM5	0.906***	0.023	0.136	0.582	0.036
	[0.042]	[0.014]	[0.085]		
BM6	0.961***	0.014	0.175*	0.596	0.021
	[0.042]	[0.011]	[0.091]		
BM7	1.038***	0.016	0.183**	0.520	0.027
	[0.051]	[0.010]	[0.070]		
BM8	0.925***	0.015*	0.198***	0.558	0.030
	[0.054]	[0.008]	[0.049]		
BM9	1.182***	0.016*	0.205***	0.487	0.033
	[0.059]	[0.009]	[0.068]		
BM10	1.195***	0.021**	0.208***	0.466	0.028
	[0.071]	[0.009]	[0.060]		

Notes: See Notes in Table 3.3.

Table 3.3: Factor risk exposure estimates

Panel C Maturity Portfolios					
	MKT	*TERM*	*PC*	*Adj.* R^2	*RMSE*
Y1	-0.163***	1.482***	-1.597***	0.112	0.146
	[0.028]	[0.005]	[0.006]		
Y2	-0.252***	1.762***	-3.632***	0.095	0.183
	[0.046]	[0.008]	[0.014]		
Y3	-0.281***	1.701***	-4.737***	0.084	0.205
	[0.055]	[0.012]	[0.022]		
Y4	-0.212**	1.673***	-5.487***	0.076	0.224
	[0.085]	[0.018]	[0.029]		
Y5	-0.267*	1.686***	-6.075***	0.073	0.319
	[0.145]	[0.027]	[0.036]		
Y7	-0.240	2.229***	-7.698***	0.054	0.358
	[0.144]	[0.035]	[0.051]		
Y10	-0.235	4.328***	-9.587***	0.044	0.397
	[0.158]	[0.046]	[0.069]		

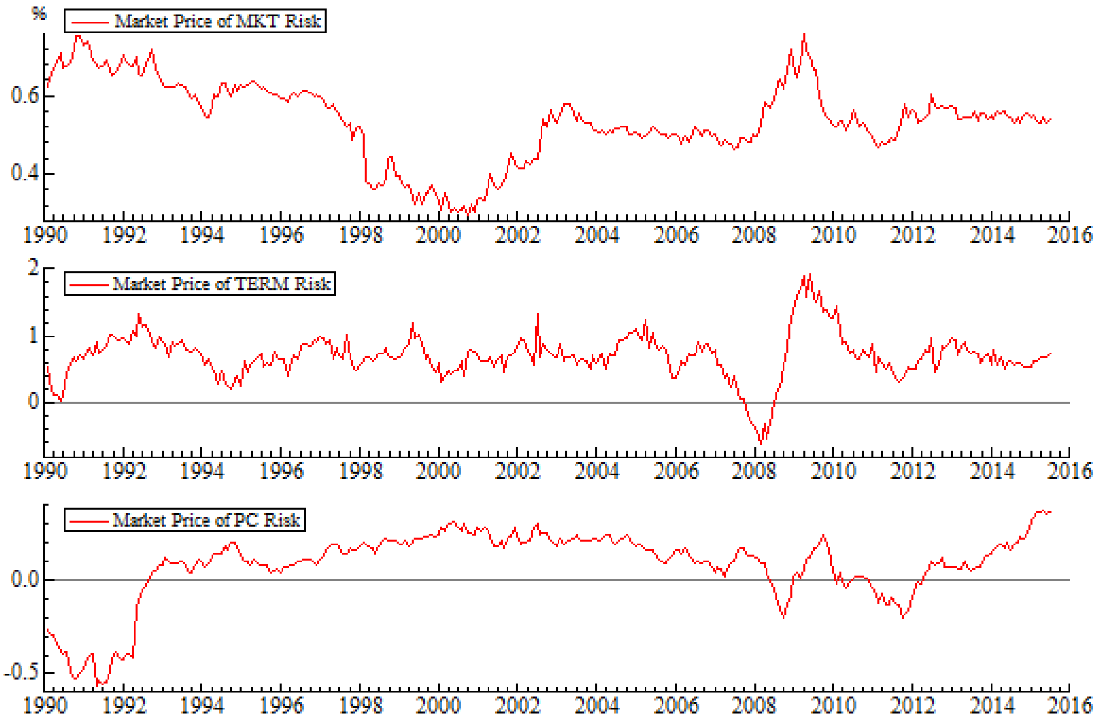
Notes: Table 3.2 and Table 3.3 provide estimates of factor risk exposures as in equation $\hat{A} = R\hat{Y}'(\hat{Y}\hat{Y}')^{-1}$ for the joint UK equity and bond model. Panel A reports estimates for ten size sorted stock decile portfolios. Panel B presents results for ten book-to-market sorted decile portfolios. Panel C reports estimates for seven constant maturity Treasury returns for maturities ranging from 1, 2, 3, 4, 5, 7 and 10 years. Heteroskedasticity robust standard errors are reported in square brackets. The pricing factors are MKT, the excess return on the value-weighted equity market portfolio, TERM, the term spread between the yield on a ten-year government bond and the three-month Treasury bill rates TERM, which can be considered as the slope of the zero-coupon yield curve, and the level of the term structure of interest rates PC, which is constructed as the first principal component of the one through five year zero-coupon yield data. The fifth and sixth columns provide adjusted R^2 and root mean squared pricing error for each test asset, respectively. The sample period is January 1990 to December 2015. ***, **, and * denotes statistical significance at the 1%, 5%, and 10% level, respectively.

Table 3.4: Price of risk estimates

	Λ_0	*TERM*	*INF*	*GAP*	$W_{\Lambda 1}$
MKT	0.098***	0.625***	-0.205**	-0.125***	12.652***
	[0.007]	[0.021]	[0.086]	[0.036]	[0.004]
TERM	0.706***	0.867***	-0.924***	-0.216***	31.396***
	[0.095]	[0.044]	[0.220]	[0.072]	[0.002]
PC	0.364***	-0.580***	-0.476***	-0.125***	28.410***
	[0.053]	[0.029]	[0.095]	[0.041]	[0.005]

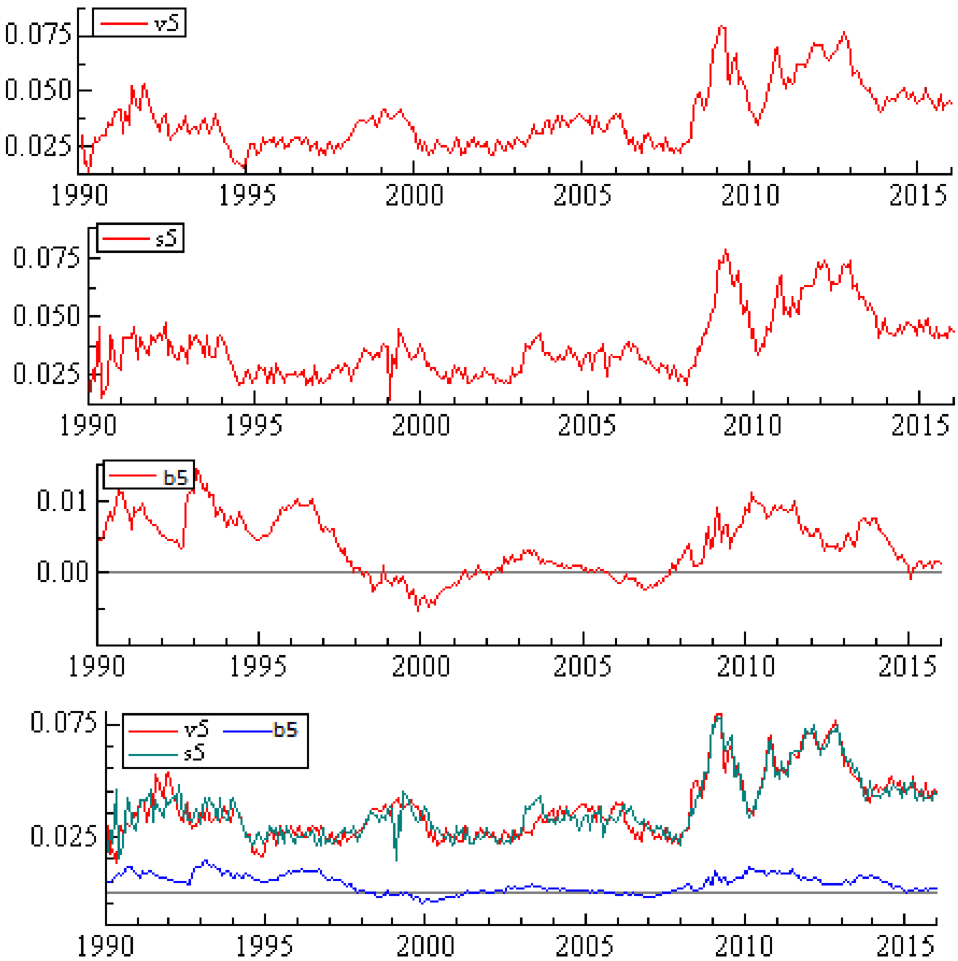
Notes: This table provides estimates of market price of risk parameters as in the form $\hat{\Lambda}_0 = (\hat{B}'\hat{B})^{-1}\hat{B}'\hat{A}_0, \hat{\Lambda}_1 = (\hat{B}'\hat{B})^{-1}\hat{B}'\hat{A}_1$ for the joint UK equity and bond model. The pricing factors are MKT, the excess return on the value-weighted equity market portfolio. TERM, the term spread between the yield on a ten-year government bond and the three-month Treasury bill rates TERM, which can be considered as the slope of the zero-coupon yield curve. The level of the term structure of interest rates PC, which is constructed as the first principal component of the one through five year zero-coupon yield data. The test assets are the ten size sorted stock decile portfolios, ten book-to-market ratio sorted stock decile portfolios, as well as seven maturity-sorted the UK government bond portfolios from 1-year through 10-year. The forecasting factors are TERM, inflation expectations INF, and output gap GAP. The first column, Λ_0, gives the estimated constant in the affine price of risk specification for each pricing factor. The second through forth column provide the estimated coefficients in the matrix Λ_1 which determine loadings of prices of risk on the price of risk factors. The last column provides the Wald test statistic of the null hypothesis that the associated row of the matrix Λ_1 is all zeros. Asymptotic standard errors are provided in square brackets. The estimates of the risk premium are reported in terms of percent per month. The sample period is January 1990 to December 2015. ***, **, and * denotes statistical significance at the 1%, 5%, and 10% level, respectively.

Figure 3.6: Time variation in the market price of risk



Notes: This figure provides plots of the estimated time series of the price of MKT, TERM and PC risk implied by the joint dynamic asset pricing model. The upper panel plots the price of MKT risk, the middle panel reports the price of TERM risk, and the bottom panel illustrates the price of PC risk. All quantities are stated in annualized percentage terms. The sample period is January 1990 to December 2015.

Figure 3.7: Estimated risk premium dynamics



Notes: This figure provides plots of the estimated expected excess returns for three test assets implied by the joint model. In the first panel, v5 denotes the fifth decile portfolio from the set of book-to-market-sorted stock portfolios. In the second panel, s5 denotes the fifth decile portfolio from the set of size-sorted stock portfolios. In the third panel, b5 denotes the constant maturity Treasury returns for the 5-year maturity. The sample period is January 1990 to December 2015.

Table 3.5: Regressions of equity risk premium on macroeconomic factors

	Coefficient	*S.E.*	*t-Statistic*
Constant	6.728***	2.165	3.108
CLI	-0.392***	0.099	-3.944
U	0.255***	0.022	11.536

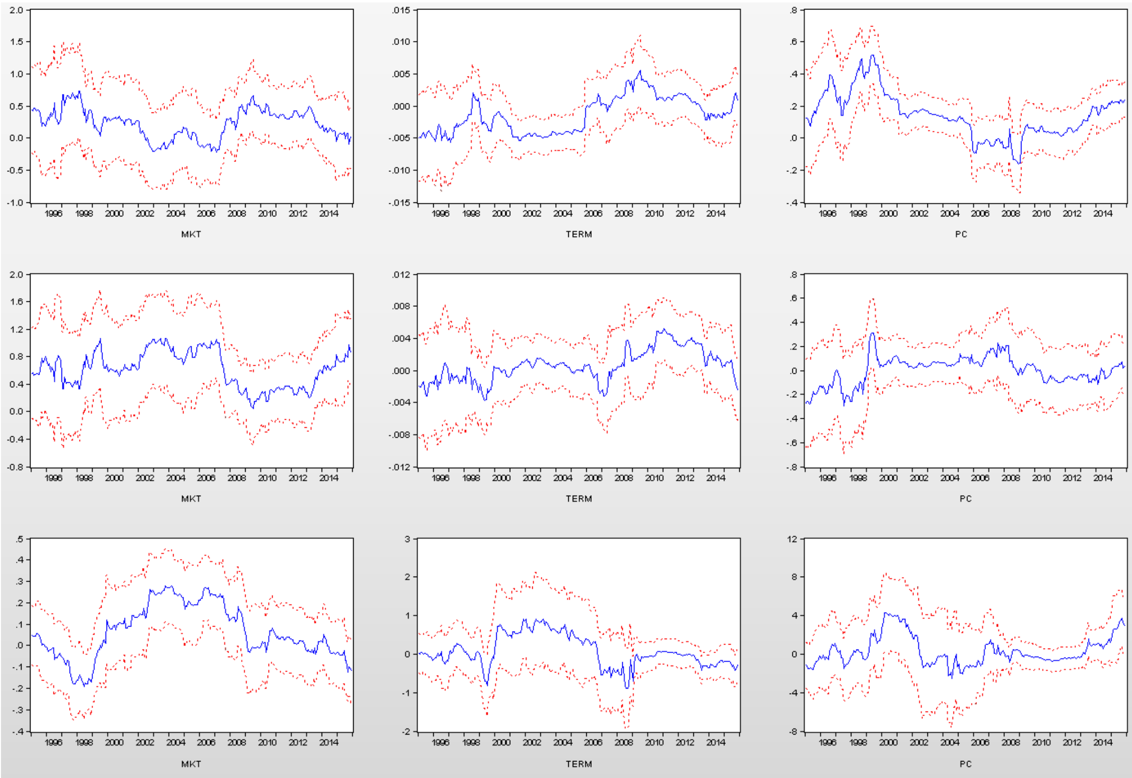
Notes: This table reports regressions results of median size equity risk premium on two macroeconomic factors: Composite Leading Indicator (CLI) and the unemployment rate (U). The data source is the Organisation for Economic Co-operation and Development and Bank of England website. The sample period is January 1990 to December 2015.

Table 3.6: Regressions of bond risk premium on macroeconomic factors

	Coefficient	*S.E.*	*t-Statistic*
Constant	9.354***	3.220	2.905
CLI	-0.105***	0.032	-3.271
U	0.481***	0.024	19.955

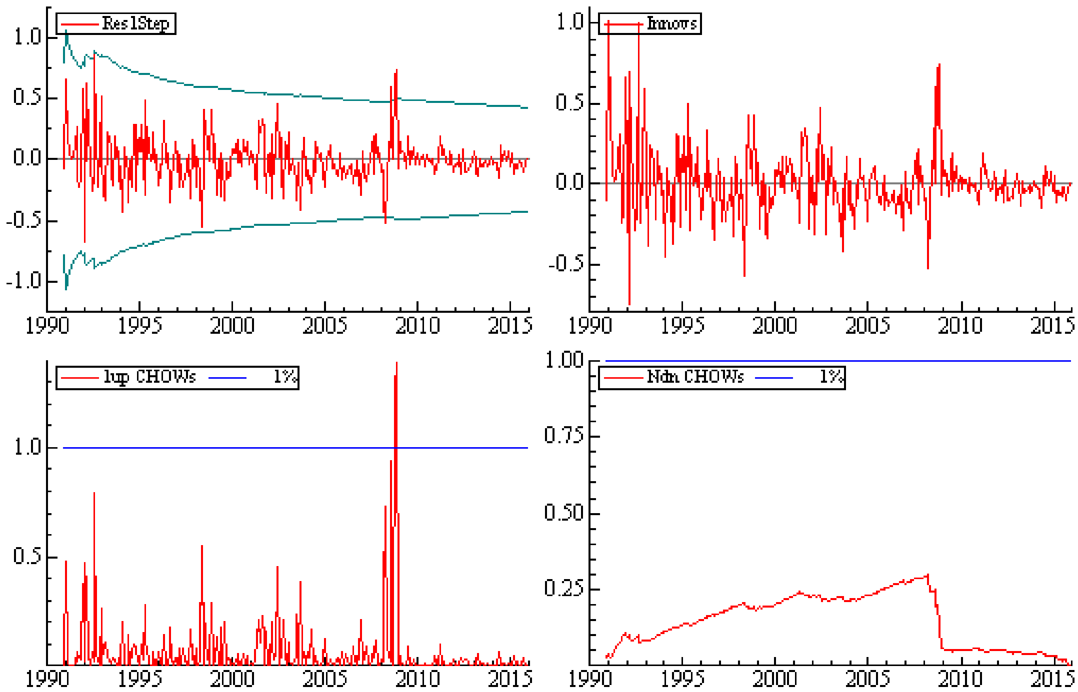
Notes: This table reports regressions results of median size bond risk premium on two macroeconomic factors: Composite Leading Indicator (CLI) and the unemployment rate (U). The data source is the Organisation for Economic Co-operation and Development and Bank of England website. The sample period is January 1990 to December 2015.

Figure 3.8: Five-year rolling window regressions with 95% confidence bands



Notes: This figure provides plots of time-varying beta estimates using a rolling regression procedure with a five-year window. In the top panel, test asset is the fifth size decile portfolio. In the middle panel, test asset is the fifth book-to-market decile portfolio. In the bottom panel, test asset is the government bond portfolios for the 5-year maturity. The graphs in the first column represent results for MKT, the graphs in the second column show results for TERM, and the ones in the third column report results for PC. The sample period is January 1990 to December 2015.

Figure 3.9: Testing the stability of regression parameters



Notes: This figure demonstrates the parameter stability of the joint model. The top left panel graphs the 1-step residuals with with error bands of two residual standard errors around zero. The top right panel plots the standardized innovations. The bottom left panel graphs the 1-step Chow tests scaled by their critical values at 1% significance level. The bottom right panel graphs the break-point Chow tests, each point is the value of the Chow F-test for that date, scaled by their critical values at 1% significance level. The 1% significance line locates at unity.

Chapter 4

What Explains Under-Investment Puzzle in the UK? Evidence From Firm-Level Panel Data

4.1 Introduction

When an economy shows declining investment, it also experiences declining productivity growth. Investment growth is thus seen as a key to improving the weak productivity that has been evident in the UK since the global financial crisis, which will be especially important for the post-Brexit environment. In theory, firms have an ideal capital stock which is determined based on the marginal product of capital, and firms have to invest to reach such a level and maintain this capital stock which naturally depreciates over time.

[Figure 4.1]

[Figure 4.2]

Figure 4.1 shows that UK business investment rate has declined considerably since 1990. From the comparison of net rate of return and cost of capital of UK non-financial firms in Figure 4.2[1], it can be seen that they are becoming more profitable with a lower cost of capital since the onset of the 2008 financial crisis, which is contradictory with the weakness of investment.

[1]The ratios shown in Figure 4.1 and Figure 4.2 are both nominal quantities.

In theory, the relevant measure of investment opportunities is the present value of expected future profits from additional capital investment, which is commonly called marginal Q. The well-known Tobin's Q model of investment relates investment to the firms' stock market valuation, which is meant to reflect the present discounted value of expected future profits. For the special case of perfectly competitive markets and constant returns to scale technology, Hayashi (1982) shows that average Q - the ratio of the maximised value of the firm to the replacement cost of its existing capital stock - would be a sufficient statistic for investment rates. The usual empirical measure–Tobin's Q, further assumes that the maximised value of the firm can be measured by its stock market valuation. Under these assumptions, stock market valuation would capture all relevant information about expected future profitability. However if the Hayashi conditions are not satisfied, or if stock market valuations are influenced by bubbles or any factors other than the present discounted value of expected future profits; then Tobin's Q would not capture all relevant information about the expected future profitability of current investment. In this case additional explanatory variables are needed to proxy for the missing information about expected future conditions.

The empirical investment-Q literature is extensive and dates back at least to Ciccolo & Fromm (1980). Tobin's Q is based on the idea that investment opportunities, which are forward looking, can be captured by equity market participants, who are also forward looking. In particular, securities' prices and therefore financial markets' evaluations of investment prospects are keystones in the literature of Tobin's Q theory . However, in the presence of information asymmetries in capital markets, a tension is introduced by the use of Tobin's Q. In such circumstances suppliers of external funds are unable to accurately assess firms investment opportunities, and it is almost certain that there will be gaps in the information sets of the firms insiders and outsiders. Tobin's Q will thus only capture outsiders evaluation of opportunities. It is possible that cash flow and real sales growth significantly affect investment simply because it is correlated with the insiders evaluation of opportunities, which are not captured by Tobin's Q.

In this study, a variety of possible reasons for the under-investment puzzle in the UK is explored. Potential explanations in three categories are considered: capital structure, innovation and uncertainty. The relationship between the investment puzzle and the 2008 financial crisis is further analysed by estimating models in the pre-crisis and post-crisis period in addition to the full sample period.

In the baseline empirical model, Tobin's Q, cash flow and real sales growth are used to capture the information effects on investment decisions. Cash flow is widely used to measure the availability of internal funds and internal financial constraints. Cooper & Ejarque (2001) provide an illustration of this mechanism, using simulated data from a model in which firms have market power and average Q is not a sufficient statistic for investment rates. In addition, a business firms decision to make new investment depends on the demand for its product and hence sales income. Theoretically, if real sales is growing, investment spending will increase; if real sales are stable, investment will be constant; if real sales decline, investment will fall.

Capital structure represents the ratio of debt to equity that a company uses to finance future investment opportunities. In other words, capital structure serves as a combination of debt and equity capital which a firm uses to finance its long term operations. Debt capital refers to a firms long term borrowings and equity capital is the long term funds provided by shareholders. Firms would prefer to finance new investments initially with retained earnings, then with debt and finally with equity. The reason is that debt binds the firm to make repayments, reduce agency costs between management and shareholders by reducing the free cash flow. The corporate finance literature has shown that increases in leverage cause decreases in firm investment. For instance, Aivazian et al. (2005) investigate the effect of leverage on investment decisions and find a significantly negative relationship between leverage and investment. In theory, high leverage reduces the incentives of shareholders of the firm to invest in investment opportunities with positive net present value, since the benefits accrue to the bondholders rather than the shareholders thus highly levered firm are less likely to exploit valuable investment opportunities as compared to firm with low levels of leverage. As a consequence, leverage creates potential underinvestment incentives.

According to the neoclassical growth model, technical progress causes an upward shift of the aggregate production function and the economy subsequently adjusts to a new steady state. If total factor productivity (TFP) growth correctly measures the technological change then a positive change in TFP would raise the investment level. Moreover, consider a firm who has reduced production but maintained investment in research and development (R&D), the firm's labour skill level will go up, since R&D investment typically requires high qualified workers. On the other hand, the firm's measured output and income will decline, since the output of R&D expenditures might not manifest itself for a few years, which further leads to lower investment growth at firm-level. Therefore, TFP growth and R&D expenditures are employed to represent innovation and evaluated for impacts on the investment.

Given the large financial and economic shocks that have hit the UK in recent years, the relationship between uncertainty and investment has received extensive attention. In the presence of partial irreversibility of capital stock choices, increased uncertainty leads firms to delay investment until the benefit to investment is sufficiently large to outweigh the cost. Moreover, uncertainty increases the range of inaction, as the firm prefers to wait and see rather than undertaking a costly action with consequences that are uncertain. The option value to delay the investment is more valuable at higher levels of volatility and uncertainty, suggesting that a firm facing great uncertainty is less likely to undertake an investment action. It is noticeable that the definition and measurement of uncertainty is not straightforward since it is ultimately an unobservable variable. In this chapter, two measures of uncertainty are adopted: the first measure reflects stock market volatility. The second measure is based on the effect of uncertainty on firm-level demand.

This chapter provides new evidence that sheds light on the UK under-investment puzzle. To be specific, the current literature is extended in the following four ways: firstly, the effect of Tobin's Q, cash flow and real sales growth on UK business fixed investment over different sample periods is revisited, i.e. full sample period, pre-crisis period and post-crisis period. Robustness checks through firm split subsample estimation are also conducted. Secondly, it is discovered that weak investment in the UK started from around 2002, which is before the onset of the 2008 financial crisis. Through subsample estimation, it is found that uncertainty and R&D play a more important role in explaining the investment behaviour in the post-crisis period than pre-crisis period. Secondly, I separately, and then simultaneously, investigate the effect of capital structure, innovation and uncertainty on investment decisions to provide a picture of interpreting firm's investment behaviour. Prior studies have looked at specific components in isolation, this study is the first to provide a full accounting of the use of these three types of variables for the UK. Thirdly, it is revealed that leverage is negatively related with investment and partially explains the under-investment issue, and it does diminish the explanatory power of cash flow. The lack of investment represents a reluctance to invest with low TFP growth and high R&D expenditures. The investment gap also appears to be linked to increased level of uncertainty. The investment behaviour of UK firms can be explained by a model in which uncertainty slows down the process of capital stock adjustment. This is consistent with the idea that the option to wait is valuable.

By examining the time effects in investment, it is found that the investment gap actually started from 2002 in the UK. Moreover, through the overall model decomposition, it is shown that TFP growth and R&D expenditures explain about 29% of the investment gap in the pre-crisis period, while uncertainty accounts for approximately 35% of the investment changes since the 2008 financial crisis. In addition, firm split subsample estimation results is conducted by controlling for firm size, dividend payout ratio and book leverage to ensure the comparison results are not driven by financial constraints. It is confirmed that larger firms with low leverage and high dividends are less financially constrained.

The remainder of this chapter is structured as follows: Section 4.2 provides the literature review. Section 4.3 outlines the firm-level panel data. In Section 4.4, the empirical model is described. Results are analysed in Section 4.5- Section 4.8. Section 4.9 presents concluding remarks.

4.2 Literature Review

Blundell et al. (1992) argue that Q is a significant factor in the explanation of company investment in the UK, although its effect is small and a careful treatment of the dynamic structure of Q models appears critical. In addition to Q, both cash flow and output variables are found to play an independent and significant role.

Kopcke et al. (1994) compare the investment spending for 39 firms in the US during the late 1980s and early 1990s to projections of their spending derived from several basic models of investment. According to these models, capital spending, on average, adheres closely to output, profits, and the cost of capital. The pattern of average forecast errors derived from the statistical models does not correspond very closely to measures of indebtedness, liquidity, size, or type of business. They show that these variables influence capital spending so little, once the general business climate, which is represented by sales or cash flow, has been taken into account. Gilchrist & Himmelberg (1995) find Tobin's Q overstates the excess sensitivity of investment to cash flow, particularly for financially unconstrained firms and demonstrate the inadequacy of Tobin's Q as a proxy for investment opportunities. Guariglia (2008) studies the extent to which the sensitivity of investment to cash flow differs in firms in the UK facing different degrees of internal and external financial constraints. The results suggest that the sensitivity of investment to cash flow tends to increase monotonically with the degree of external financial constraints faced by firms. Combining the internal with the external financial constraints, it is found that the dependence of investment on cash flow is strongest for those externally financially constrained firms that have a relatively high level of internal funds. However, Chen & Chen (2012) argue that investment-cash flow sensitivity in the US has declined and disappeared, even during the 2007-2009 credit crunch. The decline and disappearance are robust to considerations of R&D and cash reserves, and across groups of firms. The information content in cash flow regarding investment opportunities has declined, but measurement error in Tobin's Q does not completely explain the patterns in investment-cash flow sensitivity.

Lang et al. (1996) show that there is a negative relation between leverage and future growth at the firm level. This negative relation between leverage and growth holds for firms with low Tobin's Q ratio, but not for high-Q firms. Therefore, leverage does not reduce growth for firms known to have good investment opportunities, but is negatively related to growth for firms whose growth opportunities are either not recognized by the capital markets or are not sufficiently valuable to overcome the effects of their debt overhang.

Bloom et al. (2007) argue that uncertainty increases real option values making firms more cautious when investing or disinvesting. This implies the responsiveness of firms to any given policy stimulus may be much weaker in periods of high uncertainty, such as after the 1973 oil crisis and September 11, 2001. Alfaro et al. (2018) show that uncertainty shocks reduce both tangible and intangible firm investment, and employment on the real side, and increase cash holdings, while reducing equity payouts and debt on the financial side.

Gutiérrez & Philippon (2016) analyse private fixed investment in the U.S. over the past 30 years. They show that investment is weak relative to measures of profitability and valuation, particularly Tobins Q. They find weak support for regulatory constraints as one possible driver of under-investment relative to Q. Globalization and intangibles explain some of the trends at the industry level, but their explanatory power is quantitatively limited. Furthermore, they show that decreased product market competition, increased short-termism and tightened corporate governance provide strong support for the under-investment issue.

Dottling et al. (2017) find that intangible investment accounts for some but not all of the weakness in measured investment gap. They show that EU firms have been catching up with their US counterparts in intangible capital investment. The process of intangible deepening happens mostly within firms in Europe, as opposed to between firms in the US.

4.3 Data

Annually firm-level panel data is used for the sample period of 1992-2016. The dataset consists of 650 non-financial UK firms with an unbalanced panel structure. By allowing for both entry and exit, the use of an unbalanced panel partially mitigates potential selection and survivor bias. All non-financial UK firms with no fewer than four consecutive years of data on any variables within the sample period are selected. Then, firm-year observations with negative book or market value, or with missing year, assets, Q, or book liabilities are excluded. Firms with sales growth exceeding 100% are also excluded to avoid potential business discontinuities caused by mergers and acquisitions. The data are winsorized at the 1 and 99 percentile levels to reduce the influence of outliers.

Firm's balance sheet and stock returns data are collected from Datastream and Worldscope. Investment is measured as capital expenditures in year t divided by total assets in year t-1. This measure of the replacement value of capital stock is derived from the book value of the firms stock of net fixed assets, using the investment data in a standard perpetual inventory formula. Q is calculated as the ratio of the sum of the market value of equity plus book value of pref stock and debt to book value of total assets. Cash flow is measured as funds from operations, which represents the sum of net income, depreciation, amortization of intangibles, deferred taxes and all non-cash charges or credits. Real sales growth is the growth rate of real sales, where real sales is constructed as net sales or revenues deflated by the GDP deflator. R&D is the firm's research and development expenditures scaled by total assets. Book leverage is calculated as the ratio of total debt to total assets. Leverage is proxy for firm's capital structure. Total factor productivity growth (TFPG) is measured at the aggregate level, and the annual data is extracted from the Bank of England website. Stock market uncertainty (SV) is measured as the FTSE 100 Volatility Index (VIX). The FTSE 100 Volatility Index data is not available before 2000. Prior to this date, historical volatility (rolling 60-day standard deviation) of the FTSE 100 Index is used to measure stock market volatility. The volatility of FTSE 100 index provides a forward looking indicator of the volatility of the firm's funding environment, which is weighted in accordance with the impact of different sources of uncertainty on the firm's value. As for the second measure of uncertainty, the uncertainty about demand score is extracted from the question: What factors are likely to limit your capital expenditure authorisations over the next twelve months? in the Confederation of British Industry's (CBI) Quarterly Industrial Trends and Service Sector surveys.

[Figure 4.3]

Figure 4.3 plots the two measures of uncertainty which demonstrate that there was significant uncertainty in the stock market and the UK firm investment environment during the global financial crisis.

4.4 The Empirical Model

A panel regression framework that is theoretically grounded in the neoclassical investment literature is employed. In a perfect capital market where financial frictions are absent, as assumed by Modigliani & Miller (1958), internal and external funds are perfect substitutes and a firms investment decisions are made independently of its financing choices. Capital markets in reality tend to be less than perfect and firms face higher cost for external financing due to asymmetric information and agency problems. Therefore, firms are considered financially constrained when their investment is sensitive to internal funds.

Under the following restrictions: no financial constraints, maximized shareholder value, perfect competition and constant returns to scale; the standard Q-theory of investment (Hayashi 1982) shows that investment should depend on a trade-off between cost of capital and expected returns on capital expenditures. To incorporate the forward-looking nature of firm investment behaviour in the presence of adjustment costs, the firm's investment rate in each period can be described as a function of Tobin's average Q, which equals to the marginal Q obtained from an additional unit of investment divided by the price of this unit of investment. Using the firm's stock market valuation, Tobins Q, is the ratio of the market value of the firm to the replacement cost of capital stock. If Q is greater than one then firms invest, because the benefit of owning capital exceeds the cost of installing it and vice versa if Q is less than one. Current and expected future firm demand are reflected in the equity price of a firm, and the neoclassical theory assumes that equity prices reflect fundamentals, ignoring bubbles or irrational exuberance which may be important in application.

However, capital markets are imperfect and firms face higher cost for external financing due to asymmetric information and agency problems. Therefore, firms are considered financially constrained when their investment is sensitive to internal funds. Firms may hold more cash in anticipation of greater capital investment if expected future profit is high. In this case, the cash flow coefficient may not fully reflect financing constraints. As a consequence, an accelerator term, defined as real sales growth, is incorporated into our model to account for the effects of future opportunities on investment. Therefore, following Fazzari et al. (1988) and Kopcke et al. (1994), the empirical model is specified as follows:

$$INV_{it} = \alpha_i + \alpha_t + \beta_1 INV_{it-1} + \beta_2 Q_{it-1} + \beta_3 CF_{it} + \beta_4 RSG_{it} + \beta_5 A_{it} + \varepsilon_{it} \quad (4.1)$$

where INV_{it} denotes a firm's fixed investment, which is measured as the ratio of the firm's capital expenditures in year t to total assets in year t-1. The model allows for the firm-specific and time-specific year fixed effects through α_i and α_t, respectively. α_t is controlled for by including time dummies in all the specifications. A lagged dependent variable INV_{it-1} is added to allow for persistence in capital expenditures that could arise through adjustment costs. Q_{it-1} is Tobin's Q in year t-1, which is a proxy for investment opportunities. CF_{it} is the firm's cash flow in year t to total assets in year t-1. RSG_{it} denotes real sales growth in year t divided by total assets in year t-1. A_{it} represents the alternative explanatory control variable: book leverage, TFP growth, R&D, and uncertainty. The control variables are included individually and then simultaneously. In particular, R&D and book leverage are scaled by one-year lagged total assets in the model. R&D is not included in the measure of fixed investment INV_{it}.

4.5 Estimation Results

[Table 4.1]

Table 4.1 presents the summary statistics for the firm-level balance sheet variables in this study. Book leverage has the highest standard deviation among all the variables. The standard deviation of Q is 1.787 and ranks the second. INV and CF have similar means which are both near 0.060. The median values of CF and R&D are in the range of 0.090 to 0.100. Q has the largest median at 1.122 while investment has the smallest which is 0.035. Book leverage has the greatest mean which is 4.204 while investment has the lowest mean value of 0.057.

As OLS estimates disregard the space and time dimensions and suffer from biases due to unobserved heterogeneity, fixed effects panel regression results are also reported. In presence of endogeneity of the regressors, both OLS and fixed effects estimates are inconsistent. Therefore, the preferred estimaition method dynamic system GMM estimator (Bond (2002)) is used to control for the heterogeneity and endogeneity simultaneously. In addition, the impact of the 2008 financial crisis on the investment is examined by estimating the model in both the pre- and post- financial crisis period. This analysis starts with a baseline investment regression which only includes lagged investment, Q and cash flow as regressors as a representation of the basic Tobin's Q model (Hayashi (1982)).

[Table 4.2]

[Table 4.3]

As can be seen from Table 4.2 and Table 4.3, Q influences investment positively. Investment is sensitive to cash flow in the pooled OLS and fixed effects regressions. Because firms have to change their investment plans due to adjustment costs, investment does fluctuate with contemporaneous cash flows. The reported results are similar to Bond et al. (2005) and Bond et al. (2003) who find a large and significant cash flow effect on UK firm's investment. The results obtained from the system GMM estimator are similar to the pooled OLS and fixed effects regressions, although Q is rather less significant during the pre-crisis and full-sample period.

Cash flow has a smaller impact on investment decisions in the post-crisis than pre-crisis period as indicated by the OLS and GMM estimation coefficients.

[Table 4.4]

[Table 4.5]

Table 4.4 shows that real sales growth demonstrates consistent significance at the 1% level among the three estimation methods. From Table 4.5, it can be seen that real sales growth is significant at the 5% significance level in GMM estimation in the pre-crisis period. Real sales growth has a bigger effect on investment in the pre-crisis period than the post-crisis period, as indicated by a difference of 0.127 in the GMM estimation coefficient. Furthermore, Q is not a significant variable explaining the investment changes in the GMM estimation results in both Table 4.4 and 4.5, which reflects that the basic Tobin's Q model is inadequate to explain the investment behaviour.

The positive impact of cash flow on the investment is in line with the theory that the level of internal funds affects investment decisions. Intuitively, it is preferred to invest with internal cash flows when firms make intertemporal investment decisions, which allows firms to avoid potential investment adjustment costs that could be incurred when investing with external funds. Similarly, a firm might invest more when cash flow is high for three reasons: (1) internal funds may be less costly than external funds; (2) managers may tend to overspend internally available funds; (3) cash flow may simply be correlated with investment opportunities.

As can be seen from Table 4.5, during a financial crisis the ability of firms to raise external finance is significantly lower due to a growing wedge between the cost of internal and external funds. Accordingly, the investment growth of firms with insufficient cash flow should be more sensitive to the availability of internal funds during a financial crisis. Moreover, the fixed effects regression results show that real sales growth influences the investment more significantly after 2008 while according to the OLS and GMM estimations, the effect of real sales growth on the investment is larger in magnitude for firms in the pre-crisis period than for the post-crisis period, suggesting that the investment decision relies more on the realized demands in the period before the 2008 financial crisis than after the financial crisis.

[Table 4.6]

[Table 4.7]

In Table 4.6 and Table 4.7, it can be seen that real sales growth plays a more important role than cash flow in explaining the investment decisions. Pooled OLS estimation results show that, in the full sample and pre-crisis period, cash flow is insignificant while real sales growth is significant at the 1% significance level. However, cash flow and real sales growth are both significant at the 1% significance level in the OLS estimation for the post-crisis period. The estimated coefficients on cash flow and real sales growth have both increased from the pre-crisis to post-crisis period. The coefficient on Q is small and insignificant under the system GMM specification, while the coefficient on cash flow is economically significant. Additionally, real sales growth is significant at the 1% significance level while cash flow is significant at the 10% significance level using the system GMM estimator for the post-crisis period. Comparing the subsample results, real sales growth and cash flow play a more statistically and economically significant role in explaining investment behaviour in the post-crisis period. The information content in cash flow regarding investment decisions has increased over time, as evidenced by the increased coefficient significance of cash flow. The findings are also consistent with the fact that firms with greater cash flow or sales growth tend to invest more.

[Table 4.8]

[Table 4.9]

As can be seen in Table 4.8 and Table 4.9, TFP growth remains an important determinant of investment because it measures technical change as well as economic fluctuations. Higher TFP growth indicates a better level of technology, higher capital per worker, and larger returns. This enhances an economy's ability to produce more output from a given stock of inputs. As can be seen from the full sample and subsample results, the effect of TFP growth on the investment is the most significant during the post-crisis period, with a parameter of 0.078 using the GMM estimation. Table 9 also shows that TFP growth is capable of explaining the investment changes in both of the subsample time periods. Romer (1990) argues that the link between TFP growth and the investment can also be explained by technological change that stems from investment decisions made by profit-maximizing agents.

[Table 4.10]

[Table 4.11]

As shown in Table 4.10 and Table 4.11, R&D expenditures have a significant negative effect on investment in both full sample period and subsample periods. However, the impact of R&D on investment is stronger in the post-crisis period than in the pre-crisis period, as evidence by a difference of 0.562 in the system GMM estimation coefficients. The reason might be that R&D expenditures increased in advance of the recession. In addition, the parameters on real sales growth are smaller than that of cash flow. Since R&D involves spending on highly skilled technology workers who are costly to hire, train, and replace, one implication is that firms adjust slowly to shocks to their investment decisions as the economy shifts toward intangible capital. It is noteworthy to mention that the explanatory power of R&D is much greater than that of Q both statistically and economically. Although Q has a small but robust and significant effect on the investment in the OLS and fixed effects estimation results. Finally, the cash-flow effect is not robust across different estimation methods, becoming insignificant in the system GMM estimation specification.

[Table 4.12]

[Table 4.13]

In Table 4.12, it can be seen that book leverage provides partial explanatory power in explaining the investment decisions of UK firms. The results indicate that there is a negative relationship between leverage and investment. The reason is that high leverage creates potential underinvestment incentives. Specifically, debt overhang leads to the investment profits accruing to bondholders instead of fully accruing to shareholders, and in turn decreases shareholders' incentives to invest in positive net present value projects. The coefficient of book leverage on investment is approximately -0.004. This effect is robust across different estimation methodologies. In addition, the goodness-of-fit is 0.579 and 0.538 in the pooled OLS and fixed effects regressions, respectively. The coefficients on real sales growth and cash flow remain statistically significant, while the coefficients on Q are marginal in magnitude. It is noticeable that the investment is not sensitive to Q during the full sample period under this model specification.

As can be seen from Table 4.13, book leverage is significant at the 1% significance level in the system GMM estimation during the pre-crisis period. However, the system GMM estimated parameter on book leverage reduces in size and also in statistical significance in the post-crisis period. Briefly, increased leverage reduces both current funds available for investment as well as the firm's ability to raise additional funds to invest. Furthermore, as expected in the presence of firm-specific effects, the pooled OLS estimation appears to give an upward-biased estimate of the coefficient on the lagged dependent variable (see also Bond (2002)).

[Table 4.14]

In Table 4.14, the estimation coefficients under three different methodologies agree with each other in signs, and they agree with predictions from theory. The full sample system GMM estimation results suggest that a 1 percentage point increase in the stock price volatility could reduce a firm's investment by 0.045 percent on average, and a 1 percentage point increase in the demand uncertainty could reduce a firm's investment by 0.035 percent. The findings are in line with Bloom et al. (2007) who suggest that uncertainty has quantitatively significant effects on the behaviour of firm investment. Apart from the negative impact of uncertainty on the investment, the results imply that firms substantially reduce investment as higher uncertainty causes firms to take a more cautious financial position.

[Table 4.15]

[Table 4.16]

As demonstrated from Table 4.15 to Table 4.16, stock price volatility and CBI's 'demand uncertainty limiting investment' score both have a significant negative impact on investment decisions. Uncertainty is more important in explaining the investment decisions especially in the post-crisis period. To be specific, as can be seen in the system GMM estimation results, the absolute value of estimated coefficient rises from 0.054 to 0.110 on stock price volatility and from 0.036 to 0.039 on demand uncertainty. The reason can be that firms postpone obtaining costly financing for investments during times of greater uncertainty. In addition, during the post-crisis period, the relationship between stock price volatility and investment is more likely to be caused by information asymmetries in the capital markets.

The persistence in firm-level explanatory variables Z including cash flow, real sales growth, book leverage and R&D is examined by performing a rolling regression with a 1-year time window. The aim is to uncover the pattern of the information content contained in the current Z regarding the future Z.

[Figure 4.4]

From Figure 4.4, it can be seen that book leverage and R&D exhibit increasing parameter persistence over time, while the persistence in cash flow and real sales growth has declined over the sample period. These findings help to explain that book leverage and R&D better describe the investment behaviour than cash flow and real sales growth in the post-crisis period.

4.6 Time Effects In Investment

In this section, the trend of time fixed effects in investment is investigated.

[Figure 4.5]

In Figure 4.5, it can be seen that the time effects in the regression were above average in the 1990s, but have been trending down since 1998. The time effects were below the average value since 2002 and further lower from 2009.

To account for possible bias due to measurement error in Q, the model is re-estimated using the Erickson & Whited (2000) cumulant estimator. This estimator produces measurement-error-free estimates of investment-Q sensitivity.

[Figure 4.6]

Figure 4.6 illustrates the time fixed effects from errors-in-variables panel regressions of de-meaned investment on Q. The time effects were near the average in the early 2000s but well below-average since 2009. The similar pattern of time effects in Figure 4.5 and Figure 4.6 demonstrate that the low investment relative to high Q since 2002 is not caused by the error in measuring Q. It is evidenced that the estimation results of Tobin's Q models are robust to the correction of measurement error in Q.

Next, the time fixed effects in investment estimated by the system GMM in Tables 4.8, 4.10, 4.12 and 4.14 are reported.

[Figure 4.7]

[Figure 4.8]

As can be seen from Figure 4.7, the time effects demonstrate substantial fluctuation in the period of 2000-2010. They were approximately near the average value between the time of 2011 and 2013 then started to drop since 2014. In Figure 4.8, the time effects were above average in the 1990s and 2004-2007, on average between the year of 2008 and 2014, and below-average in the period of 2002-2003 and 2015-2016.

[Figure 4.9]

[Figure 4.10]

In Figure 4.9 and Figure 4.10, the time effects were consistently above average in 1990s and approximately on average since 2005. To be more specific, the time-effects were substantially lower from 2002. The time effects were below the average in 2002 and 2003 and above the average in 2004 and 2005. The time effects reached the lowest level in 2002 in both 4.9 and Figure 4.10.

As in Figure 4.5 to Figure 4.10, it is concluded that the time effects were high in the 1990s, then they substantially decreased from approximately 2002. The time effects were near the average value since 2005 in the models with alternative explanatory variables, which confirms that innovation, leverage and uncertainty contribute to the explanation of the under-investment puzzle.

4.7 Subperiod Analysis of Investment Gap

In this section, the changes and relative contributions of explanatory variables in explaining the variation of investment is analysed in three separate periods: 1992-2001 (period 1), 2002-2008 (period 2) and 2009-2016 (period 3).

[Table 4.17]

As can be seen in Table 4.17, the average value of Q dropped from 1.9060 in the period of 1992-2001 to 1.7506 in the period of 2002-2008, whereas it then rose to 1.8794 in the period of 2009-2016. Between the period of 1992-2001 and 2002-2008, changes in Q contribute roughly 23.14% to the investment decline. However, the basic Tobin's Q model fails to explain the investment puzzle since the 2008 financial crisis as the increase of 0.0039 in Q is contradictory with 0.0168 decrease in investment levels.

[Table 4.18]

Table 4.18 sets out TFP growth and R&D combined as the innovation model. As the table shows, the average value of TFP growth fell from 1.1520 in period 1 to

0.8414 in period 2, and further slow down to -0.1425 in period 3. However, movement in R&D demonstrates a contrasting pattern, with an increase from 0.0587 in period 1 to 0.1980 in period 2 and a further increase of 0.0611 in the period of 2009-2016. It is indicated that a significant proportion of investment decline was due to the poor TFP growth performance since 1990s. The impact from changes in TFP growth account for 22.57% in period 2 and 23.31% in period 3 of the investment slow down. Since the research interest in this chapter is not related to the effect of lagged investment, R&D is considered as the most important factor in explaining the reduction in investment, as it contributes 23.37% and 24.19% in period 2 and 3, respectively, to explain the changes in investment.

[Table 4.19]

In Panel D of Table 4.19, it can be seen that Tobin's Q, contributes 3.35% to the drop of investment in period 2; Cash flow, which can be used to proxy for internal financial constraint, accounts for 9.53% of investment decline in period 2; Real sales growth, which reflects one side of growth in demand and firm income , account for 9.24% of investment fall in period 3. The combined contribution of Q, cash flow and real sales growth is less than that of leverage, which is 19.48% in period 2 and 11.19% in period 3. There is a approximately 8.29% drop in the explanatory power of leverage on investment changes from period 2 to period 3.

In addition, the average value of book leverage rose remarkably from period 1 to period 3. As can be seen in Panel B, there is a significant negative relationship between leverage and investment at the firm level. This finding agrees with the corporate finance theory suggests that leverage should have a negative impact on investment decisions. The intuition is that the cost of capital of these firms increases with their leverage, and thus it is uncertain whether external funds can be used profitably for new investment projects.

[Table 4.20]

In Panel A of Table 4.20, it can be seen that demand uncertainty increased from 3.8621 to 3.9220 and then 3.9938 over the full sample period of 1992-2016. Stock price volatility presents a similar trend, which rose from 2.5775 in period 1 to 3.0670 in period 3. As shown in Panel D, the contribution of Tobin's Q and cash flow is 1.85% and 6.74% in period 2, respectively. The effect of real sales growth on investment during the period of 2009-2016 is 7.66%. Moreover, the rise of demand uncertainty contributes 12.17% in period 2 and a proportion of 19.42% in period 3 to the slowdown in investment. Stock price volatility accounts for around 25.09% between period 1 and period 2, and 18.95% between period 2 and period 3 of investment changes. The results imply that stock price volatility is a dominant uncertainty determinant of investment slowdown in the period of 2002-2008 while demand uncertainty plays a more important role in explaining the investment gap in the period of 2009-2016.

[Table 4.21]

As shown in Panel B of Table 4.21, it can be seen that book leverage, R&D, and uncertainty affects investment negatively while lagged investment, Tobin's Q, cash flow, real sales growth and TFP growth have a positive impact on investment. Parameter on Q, real sales growth and TFP growth reduced from 0.0060, 0.0193 and 0.0180 in period 1 to 0.0032, 0.0069 and 0.0025 in period 3, respectively. Additionally, the estimated coefficient on cash flow increased from 0.0441 in period 1 to 0.0835 in period 3.

As can be seen in Panel D, in period 2, combined effects of R&D and TFP growth represents approximately 29% of the investment changes, which provides the greatest explanatory power. This effect is empirically more important than Tobin's Q, cash flow and real sales growth effects combined. Furthermore, uncertainty accounts for about 28% of the investment slow down in period 2. The contribution of leverage on investment fell from 10.34% in period 2 to 6.93% in period 3. In period 3, uncertainty became the most important determinant of investment decline, which accounts for approximately 35% of investment slowdown. Innovation is the second most important factor that influences investment changes in period 3, which contributes about 31% of investment changes by adding up the weights of TFP growth and R&D. Moreover, the results show that the decrease of TFP growth led to the drop of investment by 14.42% in period 3, while the increased R&D explains 16.72% of the investment drop in the same time period.

In summary, the results confirm the robustness of the significant impact of TFP growth, R&D, book leverage and uncertainty on the investment, as discussed in section 4.5.

4.8 Firm Split

In this section, the effect of Tobin's Q, cash flow and real sales growth on investment decisions of firms facing different degrees of financial constraints is investigated. For this purpose, firms are partitioned on the basis of their size, book leverage and dividends payout ratio. Firms whose size lies below (above) the median size value in the sample are assigned to the financially constrained (unconstrained) group. Smaller firms are more likely to be financially constrained as they are subject to greater asymmetric information and agency problems and have more difficulties in accessing external finance. The dividend payout ratio is also used as a segmenting variable to classify firms into financially constrained and unconstrained groups. It is argued that dividend paying, as opposed to non-dividend paying firms, are less likely to be financially constrained since they are able to cut dividends whenever their ability to obtain external financing is impaired. However, cutting dividends for the sake of liquidity may also have adverse signalling effects for the firm's stock price. The empirical importance of this breakdown is a natural subject of investigation as well as minimizes the problems of endogenous selection.

[Table 4.22]

From Table 4.22, it is found that the estimation results are robust across subsamples of financial constrained firms. The results show that real sales growth has a more significant impact on the investment for small firms and firms with high leverage. Specifically, real sales growth is significant at the 5% significance level in the investment regressions for small firm with a coefficient of 0.281. The parameter on real sales growth is 0.144 and 0.208 for firms with low and high leverage, respectively. Whereas the effect of real sales growth appears to be broadly similar with a difference in regression coefficients of 0.029 among firms with different levels of dividend payout ratios.

Furthermore, it is revealed that cash flow does not have a significant effect on investment decisions for large firms or firms with low leverage. The results indicate that the effects of cash flow on the investment are much larger on small firms than large firms, with a difference of 0.466 in regression coefficients. This is consistent with the fact that cash flow is more important for financially constrained firms. The reason is that larger firms tend to be less financing constrained and hence have less reason to retain cash flow for financing projects later. The economic size of cash flow is tripled when comparing the coefficient for firms with high leverage (1.081) with that for firms with low leverage (0.359). It can also be found that dividend payout ratios are positively correlated with cash flow and real sales growth. Cash flow has a more significant effect on firms paying low dividends both statistically and economically.

4.9 Concluding Remarks

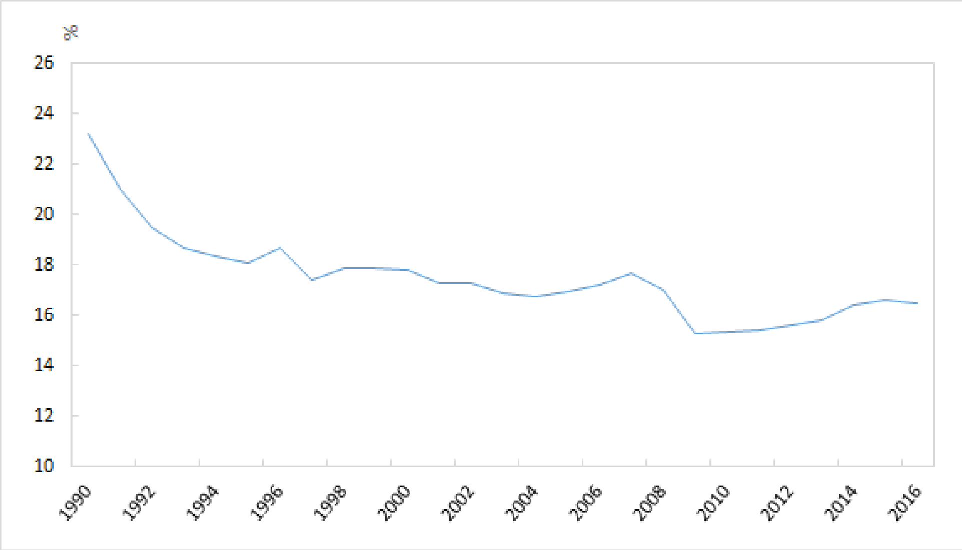
It has been widely reported that business investment in the UK has been lower than expected since the 2008 financial crisis. However, it is found in this study that the UK business investment has been low despite high levels of Tobin's Q and low cost of capital since 2002, and the financial crisis deteriorated the situation. This chapter investigates the alternative explanation of the under-investment puzzle for the period of 1992-2016. Reasons that behind the investment gap from three categories are explored: capital structure, innovation and uncertainty. It is shown that book leverage, R&D, and uncertainty affects investment negatively while Tobin's Q, cash flow, real sales growth and TFP growth have a positive impact on investment. The change of firm's capital structure explains some of the investment gap, and it does diminish the explanatory power of real sales growth and cash flow. Consistent support in the firm-level estimation results show that increased book leverage, R&D expenditures, uncertainty together with lowered TFP growth are important determinants in explaining the under-investment puzzle in the UK.

The contribution of this chapter is fourfold: First, firm-level regressions are conducted for a panel of UK firms by means of the pooled OLS, fixed effects and system GMM estimation methodology, to find the drivers of under-investment puzzle. The reason of applying three different estimators is to control for endogeneity, cross-section dependence and heterogeneous problem. The effect of Tobin's Q, cash flow and real sales growth on UK business fixed investment is investigated over different sample period. Secondly, this chapter examines the impact of financial crises on investment by studying firm investment behaviour in the pre-crisis and post-crisis period separately in addition to the full-sample estimation. During the 2008 financial crisis, the ability of firms to raise external finance is significantly lowered due to a growing wedge between the cost of internal and external funds. Accordingly, the investment expenditures of firms with insufficient cash balances became more sensitive to the availability of internal funds during the economic downturn. It is demonstrated that weak investment in the UK started from around 2002, which is before the onset of the 2008 financial crisis. Thirdly, stylized facts are presented concerning the causes of under-investment puzzle in the UK. It is confirmed that leverage is negatively related with investment and partially explains the under-investment issue. Lowered TFP growth and increased R&D expenditures contribute significantly to the investment gap. Greater stock price volatility and demand uncertainty explains a substantial portion of the investment drop. Lastly, it is argued that the sensitivity of explanatory variables to investment varies over different subsample. Through subsample estimation, it is found that uncertainty and R&D play a more important role in explaining the investment behaviour in the post-crisis period than pre-crisis period.

The results discussed in this chapter shed light on traditional investment literature in the following ways: It is demonstrated that the performance of Tobin's Q is mixed. In particular, the explanatory power of Tobin's Q in the pooled OLS and fixed effects estimation is significant in the pre-crisis period, it does not have a significant effect on investment in the post-crisis period. The significance of real sales growth in both the pre-crisis and post-crisis period demonstrates that real sales growth is a better measure of balance sheet fundamentals than cash flow. Furthermore, both cash flow and real sales growth provide a greater explanatory power in the post-crisis period than in the pre-crisis period. Firm split subsample estimation results indicate that the significance of real sales growth and cash flow differ across firms with different levels of financial constraint. In particular, real sales growth and cash flow play a more important role for small firms paying low dividends than for large firms paying high dividends, which implies that large firms tend to be less financial constrained. When firms are classified according to leverage, real sales growth and cash flow matters more for low leverage firms, as would be expected since financial constraints are likely to be larger for such firms.

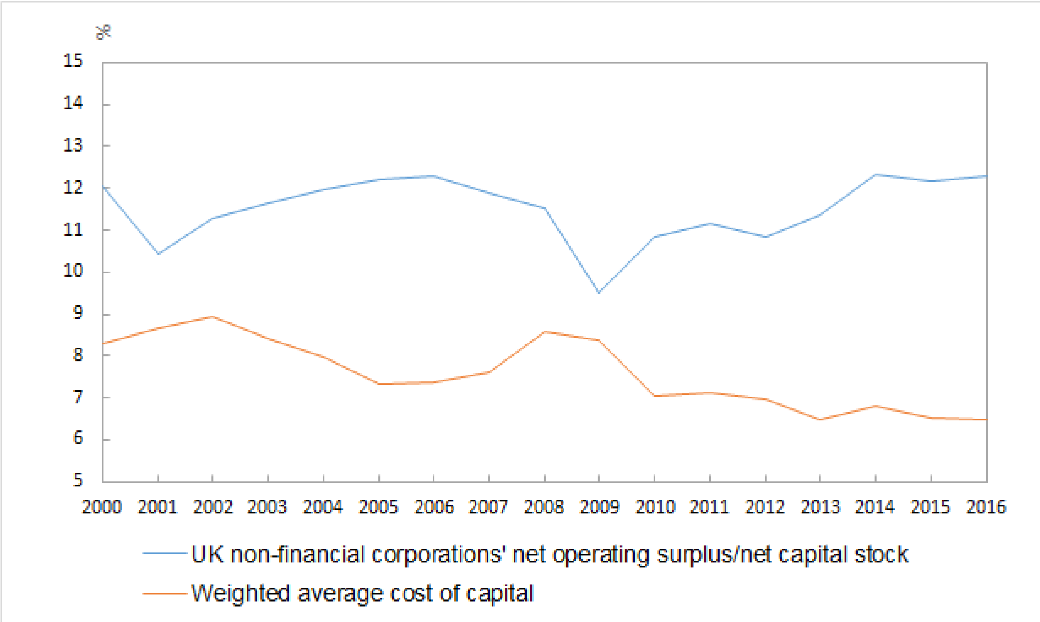
To conclude, this chapter provides empirical evidence that R&D and TFP growth are significantly associated with investment changes. Book leverage also appears to have an important negative impact on investment. Stock price volatility and demand uncertainty do play an important empirical role in explaining the under-investment puzzle.

Figure 4.1: UK Business Investment/Gross Domestic Product



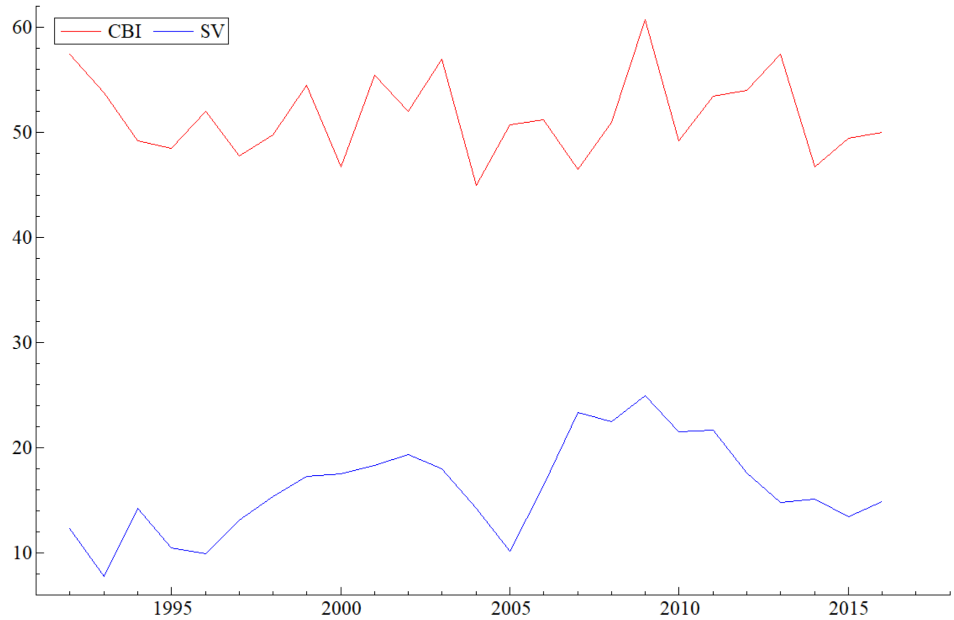
Source: Office for National Statistics.

Figure 4.2: Net Rate of Return Vs. Cost of Capital of UK Non-Financial Firms



Source: Bank of England, Office for National Statistics.

Figure 4.3: Uncertainty Plots



Notes: The figure plots the two measures of uncertainty. CBI and SV represent the firm demand uncertainty and stock market volatility, respectively. The sample consists of annual data for the period of 1992-2016. Data source is Datastream.

Table 4.1: Summary statistics

	Mean	25th percentile	Median	75th percentile	Standard deviation
INV	0.057	0.014	0.035	0.073	0.069
Q	1.655	0.753	1.122	1.816	1.787
CF	0.063	0.032	0.090	0.148	0.203
RSG	0.167	-0.041	0.049	0.183	0.649
R&D	0.246	0.000	0.099	0.342	0.692
BL	4.204	0.144	0.548	1.469	3.981

Notes: The table reports the sample characteristics. INV represents capital expenditures in year t divided by total assets in year t-1. Q, Tobin's Q. CF is cash flow in year t divided by total assets in year t-1. RSG is the growth rate of real sales, where real sales is constructed as nominal sales deflated by the GDP deflator. R&D is the research and development expenditures in year t divided by total assets in year t-1. BL is book leverage, which is calculated as the ratio of total debt to total assets. The balance sheet financial variables data all obtained from Datastream. The sample period consists of annual observations in the range of 1992-2016.

Table 4.2: The effects of cash flow on investment

	Pooled OLS	Fixed Effects	System GMM
INVt-1	0.705***	0.376***	0.564***
	[0.013]	[0.017]	[0.063]
Qt-1	0.047***	0.098***	0.022
	[0.007]	[0.009]	[0.024]
CFt	0.726***	0.117***	0.667*
	[0.087]	[0.022]	[0.326]
R2	0.573	0.456	
AR(2) test (p-value)			0.620
Hansen test (p-value)			0.354
Difference-in-Hansen tests (p-value)			0.116

Notes: Asymptotically robust and firm clustered standard errors are reported in brackets for pooled OLS and fixed effects regressions. Standard errors robust to autocorrelation and heteroscedasticity are reported in brackets for one-step system GMM estimator. Year dummies are included in all specifications. The R-squared is the squared correlation coefficient between actual and predicted levels of the dependent variable. AR(2) using a Lagrange multiplier tests for second-order serial correlation in the first-differenced residuals under the null of no serial correlation. Instrument validity is tested by the Hansen test of the over-identifying restrictions. The difference-in-Hansen test of exogeneity is under the null that instruments used for the equations in levels are exogenous. The full sample period is 1992-2016. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.3: Subsample results: The effects of cash flow on investment

	Pooled OLS	Fixed Effects	System GMM
Panel A: Pre-Crisis			
INVt-1	0.685***	0.297***	0.425***
	[0.018]	[0.024]	[0.086]
Qt-1	0.047***	0.124***	0.011
	[0.009]	[0.014]	[0.029]
CFt	0.815***	0.601***	0.833
	[0.107]	[0.159]	[0.442]
R2	0.546	0.456	
AR(2) test (p-value)			0.655
Hansen test (p-value)			0.347
Difference-in-Hansen tests (p-value)			0.179
Panel B: Post-Crisis			
INVt-1	0.721***	0.213***	0.382***
	[0.015]	[0.024]	[0.032]
Qt-1	0.046***	0.085***	0.061**
	[0.010]	[0.016]	[0.025]
CFt	0.629***	0.748**	0.799**
	[0.115]	[0.238]	[0.379]
R2	0.556	0.481	
AR(2) test (p-value)			0.673
Hansen test (p-value)			0.076
Difference-in-Hansen tests (p-value)			0.296

Notes: Asymptotically robust and firm clustered standard errors are reported in brackets for pooled OLS and fixed effects regressions. Standard errors robust to autocorrelation and heteroscedasticity are reported in brackets for one-step system GMM estimator. Year dummies are included in all specifications. The R-squared is the squared correlation coefficient between actual and predicted levels of the dependent variable. AR(2) using a Lagrange multiplier tests for second-order serial correlation in the first-differenced residuals under the null of no serial correlation. Instrument validity is tested by the Hansen test of the over-identifying restrictions. The difference-in-Hansen test of exogeneity is under the null that instruments used for the equations in levels are exogenous. The pre-crisis period is 1992-2007 and the post-crisis period is 2008-2016. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.4: The effects of real sales growth on investment

	Pooled OLS	Fixed Effects	System GMM
INVt-1	0.712***	0.376***	0.516***
	[0.014]	[0.017]	[0.073]
Qt-1	0.039***	0.098***	0.052
	[0.006]	[0.009]	[0.056]
RSGt	0.038***	0.117***	0.163***
	[0.005]	[0.022]	[0.046]
R2	0.571	0.486	
AR(2) test (p-value)			0.983
Hansen test (p-value)			0.405
Difference-in-Hansen tests (p-value)			0.205

Notes: Asymptotically robust and firm clustered standard errors are reported in brackets for pooled OLS and fixed effects regressions. Standard errors robust to autocorrelation and heteroscedasticity are reported in brackets for one-step system GMM estimator. Year dummies are included in all specifications. The R-squared is the squared correlation coefficient between actual and predicted levels of the dependent variable. AR(2) using a Lagrange multiplier tests for second-order serial correlation in the first-differenced residuals under the null of no serial correlation. Instrument validity is tested by the Hansen test of the over-identifying restrictions. The difference-in-Hansen test of exogeneity is under the null that instruments used for the equations in levels are exogenous. The full sample period is 1992-2016. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.5: Subsample results: The effects of real sales growth on investment

	Pooled OLS	Fixed Effects	System GMM
Panel A: Pre-Crisis			
INVt-1	0.698***	0.292***	0.359***
	[0.019]	[0.024]	[0.099]
Qt-1	0.039***	0.122***	0.010
	[0.008]	[0.013]	[0.063]
RSGt	0.044***	0.120***	0.153**
	[0.006]	[0.037]	[0.059]
R2	0.544	0.409	
AR(2) test (p-value)			0.315
Hansen test (p-value)			0.340
Difference-in-Hansen tests (p-value)			0.481
Panel B: Post-Crisis			
INVt-1	0.723***	0.194***	0.382***
	[0.015]	[0.024]	[0.034]
Qt-1	0.039***	0.079***	0.003
	[0.009]	[0.017]	[0.019]
RSGt	0.032***	0.223***	0.056
	[0.006]	[0.046]	[0.040]
R2	0.552	0.220	
AR(2) test (p-value)			0.849
Hansen test (p-value)			0.063
Difference-in-Hansen tests (p-value)			0.423

Notes: Asymptotically robust and firm clustered standard errors are reported in brackets for pooled OLS and fixed effects regressions. Standard errors robust to autocorrelation and heteroscedasticity are reported in brackets for one-step system GMM estimator. Year dummies are included in all specifications. The R-squared is the squared correlation coefficient between actual and predicted levels of the dependent variable. AR(2) using a Lagrange multiplier tests for second-order serial correlation in the first-differenced residuals under the null of no serial correlation. Instrument validity is tested by the Hansen test of the over-identifying restrictions. The difference-in-Hansen test of exogeneity is under the null that instruments used for the equations in levels are exogenous. The pre-crisis period is 1992-2007 and the post-crisis period is 2008-2016.. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.6: The effects of cash flow and real sales growth on investment

	Pooled OLS	Fixed Effects	System GMM
INVt-1	0.711***	0.375***	0.557***
	[0.014]	[0.017]	[0.060]
Qt-1	0.039***	0.098***	0.023
	[0.006]	[0.009]	[0.023]
CFt	0.036	0.201	0.488
	[0.151]	[0.375]	[0.465]
RSGt	0.038***	0.115***	0.047**
	[0.006]	[0.022]	[0.021]
R2	0.571	0.485	
AR(2) test (p-value)			0.724
Hansen test (p-value)			0.240
Difference-in-Hansen tests (p-value)			0.149

Notes: Asymptotically robust and firm clustered standard errors are reported in brackets for pooled OLS and fixed effects regressions. Standard errors robust to autocorrelation and heteroscedasticity are reported in brackets for one-step system GMM estimator. Year dummies are included in all specifications. The R-squared is the squared correlation coefficient between actual and predicted levels of the dependent variable. AR(2) using a Lagrange multiplier tests for second-order serial correlation in the first-differenced residuals under the null of no serial correlation. Instrument validity is tested by the Hansen test of the over-identifying restrictions. The difference-in-Hansen test of exogeneity is under the null that instruments used for the equations in levels are exogenous. The full sample period is 1992-2016. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.7: Subsample results: The effects of cash flow and real sales growth on investment

	Pooled OLS	Fixed Effects	System GMM
Panel A: Pre-Crisis			
INVt-1	0.696***	0.284***	0.410***
	[0.021]	[0.026]	[0.090]
Qt-1	0.039***	0.115***	0.001
	[0.008]	[0.013]	[0.026]
CFt	0.181	0.221	0.670
	[0.200]	[0.768]	[0.645]
RSGt	0.047***	0.144***	0.045
	[0.007]	[0.041]	[0.031]
R2	0.545	0.488	
AR(2) test (p-value)			0.956
Hansen test (p-value)			0.408
Difference-in-Hansen tests (p-value)			0.385
Panel B: Post-Crisis			
INVt-1	0.717***	0.379***	0.383***
	[0.015]	[0.017]	[0.029]
Qt-1	0.047***	0.101***	0.055*
	[0.010]	[0.010]	[0.021]
CFt	0.620***	0.774***	0.835*
	[0.115]	[0.127]	[0.302]
RSGt	0.089***	0.123**	0.235***
	[0.016]	[0.044]	[0.068]
R2	0.557	0.532	
AR(2) test (p-value)			0.689
Hansen test (p-value)			0.247
Difference-in-Hansen tests (p-value)			0.895

Notes: See Notes in Table 1 and Table 3. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.8: The effects of TFPG on investment

	Pooled OLS	Fixed Effects	System GMM
INVt-1	0.701***	0.379***	0.548***
	[0.014]	[0.017]	[0.057]
Qt-1	0.048***	0.101***	0.029
	[0.007]	[0.010]	[0.021]
RSGt	0.089***	0.123**	0.148**
	[0.016]	[0.044]	[0.051]
CFt	0.714***	0.774***	0.687*
	[0.087]	[0.127]	[0.297]
TFPGt	0.064***	0.805**	0.067***
	[0.011]	[0.326]	[0.010]
R2	0.574	0.532	
AR(2) test (p-value)			0.696
Hansen test (p-value)			0.461
Difference-in-Hansen tests (p-value)			0.160

Notes: Asymptotically robust and firm clustered standard errors are reported in brackets for pooled OLS and fixed effects regressions. Standard errors robust to autocorrelation and heteroscedasticity are reported in brackets for one-step system GMM estimator. Year dummies are included in all specifications. The R-squared is the squared correlation coefficient between actual and predicted levels of the dependent variable. AR(2) using a Lagrange multiplier tests for second-order serial correlation in the first-differenced residuals under the null of no serial correlation. Instrument validity is tested by the Hansen test of the over-identifying restrictions. The difference-in-Hansen test of exogeneity is under the null that instruments used for the equations in levels are exogenous. The full sample period is 1992-2016. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.9: Subsample results: The effects of TFPG on investment

	Pooled OLS	Fixed Effects	System GMM
Panel A: Pre-Crisis			
INVt-1	0.680***	0.288***	0.440***
	[0.020]	[0.026]	[0.075]
Qt-1	0.049**	0.120***	0.037
	[0.010]	[0.015]	[0.024]
RSGt	0.078***	0.136	0.160**
	[0.023]	[0.123]	[0.072]
CFt	0.800***	0.635***	0.823
	[0.109]	[0.169]	[0.433]
TFPGt	0.069**	0.146	0.061**
	[0.022]	[0.198]	[0.022]
R2	0.547	0.459	
AR(2) test (p-value)			0.816
Hansen test (p-value)			0.259
Difference-in-Hansen tests (p-value)			0.719
Panel B: Post-Crisis			
INVt-1	0.717***	0.212***	0.384***
	[0.015]	[0.024]	[0.029]
Qt-1	0.047***	0.085***	0.055*
	[0.010]	[0.016]	[0.021]
RSGt	0.089***	0.274	0.240***
	[0.016]	[0.208]	[0.069]
CFt	0.620***	0.736**	0.865**
	[0.116]	[0.237]	[0.300]
TFPGt	0.117***	0.833**	0.078***
	[0.015]	[0.315]	[0.014]
R2	0.557	0.455	
AR(2) test (p-value)			0.696
Hansen test (p-value)			0.322
Difference-in-Hansen tests (p-value)			0.987

Notes: See Notes in Table 1 and Table 3. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.10: The effects of R&D on investment

	Pooled OLS	Fixed Effects	System GMM
INVt-1	0.680***	0.374***	0.480***
	[0.016]	[0.017]	[0.060]
Qt-1	0.049***	0.097***	0.051*
	[0.007]	[0.010]	[0.023]
RSGt	0.095***	0.132**	0.199***
	[0.013]	[0.041]	[0.044]
CFt	0.756***	0.785***	0.747*
	[0.088]	[0.125]	[0.287]
R&Dt	-0.527***	-0.535***	-0.873***
	[0.057]	[0.101]	[0.224]
R2	0.581	0.544	
AR(2) test (p-value)			0.958
Hansen test (p-value)			0.528
Difference-in-Hansen tests (p-value)			0.287

Notes: Asymptotically robust and firm clustered standard errors are reported in brackets for pooled OLS and fixed effects regressions. Standard errors robust to autocorrelation and heteroscedasticity are reported in brackets for one-step system GMM estimator. Year dummies are included in all specifications. The R-squared is the squared correlation coefficient between actual and predicted levels of the dependent variable. AR(2) using a Lagrange multiplier tests for second-order serial correlation in the first-differenced residuals under the null of no serial correlation. Instrument validity is tested by the Hansen test of the over-identifying restrictions. The difference-in-Hansen test of exogeneity is under the null that instruments used for the equations in levels are exogenous. The full sample period is 1992-2016. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.11: Subsample results: The effects of R&D on investment

	Pooled OLS	Fixed Effects	System GMM
Panel A: Pre-Crisis			
INVt-1	0.665***	0.283***	0.288***
	[0.022]	[0.026]	[0.086]
Qt-1	0.053***	0.117***	0.063**
	[0.010]	[0.015]	[0.028]
RSGt	0.090***	0.167	0.322***
	[0.019]	[0.110]	[0.068]
CFt	0.819***	0.623***	0.822*
	[0.108]	[0.167]	[0.425]
R&Dt	-0.548***	-0.517***	-0.137***
	[0.071]	[0.152]	[0.033]
R2	0.554	0.473	
AR(2) test (p-value)			0.451
Hansen test (p-value)			0.324
Difference-in-Hansen tests (p-value)			0.649
Panel B: Post-Crisis			
INVt-1	0.693***	0.210***	0.363***
	[0.017]	[0.024]	[0.040]
Qt-1	0.047***	0.078***	0.048
	[0.010]	[0.016]	[0.025]
RSGt	0.090***	0.303	0.246***
	[0.015]	[0.207]	[0.059]
CFt	0.680***	0.747**	0.793**
	[0.122]	[0.239]	[0.318]
R&Dt	-0.495***	-0.600**	-0.699**
	[0.069]	[0.223]	[0.261]
R2	0.564	0.463	
AR(2) test (p-value)			0.696
Hansen test (p-value)			0.322
Difference-in-Hansen tests (p-value)			0.987

Notes: See Notes in Table 1 and Table 3. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.12: The effects of leverage on investment

	Pooled OLS	Fixed Effects	System GMM
INVt-1	0.690***	0.375***	0.659***
	[0.014]	[0.017]	[0.051]
Qt-1	0.005	0.010	0.003
	[0.006]	[0.008]	[0.002]
RSGt	0.087***	0.052***	0.031***
	[0.017]	[0.012]	[0.007]
CFt	0.071***	0.078***	0.063*
	[0.009]	[0.013]	[0.027]
BLt	-0.004**	-0.003**	-0.004*
	[0.001]	[0.001]	[0.002]
R2	0.579	0.538	
AR(2) test (p-value)			0.498
Hansen test (p-value)			0.161
Difference-in-Hansen tests (p-value)			0.111

Notes: Asymptotically robust and firm clustered standard errors are reported in brackets for pooled OLS and fixed effects regressions. Standard errors robust to autocorrelation and heteroscedasticity are reported in brackets for one-step system GMM estimator. Year dummies are included in all specifications. The R-squared is the squared correlation coefficient between actual and predicted levels of the dependent variable. AR(2) using a Lagrange multiplier tests for second-order serial correlation in the first-differenced residuals under the null of no serial correlation. Instrument validity is tested by the Hansen test of the over-identifying restrictions. The difference-in-Hansen test of exogeneity is under the null that instruments used for the equations in levels are exogenous. The full sample period is 1992-2016. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.13: Subsample results: The effects of leverage on investment

	Pooled OLS	Fixed Effects	System GMM
Panel A: Pre-Crisis			
INVt-1	0.663***	0.286***	0.558***
	[0.021]	[0.026]	[0.082]
Qt-1	0.005**	0.012***	0.003
	[0.002]	[0.002]	[0.003]
RSGt	0.076***	0.063**	0.035**
	[0.023]	[0.018]	[0.014]
CFt	0.079***	0.061***	0.073
	[0.011]	[0.017]	[0.041]
BLt	-0.009**	-0.005	-0.026***
	[0.004]	[0.003]	[0.007]
R2	0.556	0.473	
AR(2) test (p-value)			0.556
Hansen test (p-value)			0.136
Difference-in-Hansen tests (p-value)			0.235
Panel B: Post-Crisis			
INVt-1	0.689***	0.204***	0.420***
	[0.014]	[0.026]	[0.045]
Qt-1	0.005	0.006	0.003
	[0.004]	[0.008]	[0.002]
RSGt	0.087***	0.026	0.013*
	[0.018]	[0.021]	[0.006]
CFt	0.065***	0.070***	0.072*
	[0.016]	[0.022]	[0.030]
BLt	-0.004***	-0.002**	-0.004**
	[0.001]	[0.001]	[0.002]
R2	0.580	0.458	
AR(2) test (p-value)			0.731
Hansen test (p-value)			0.755
Difference-in-Hansen tests (p-value)			0.642

Notes: See Notes in Table 1 and Table 3. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.14: The effects of uncertainty on investment

	Pooled OLS	Fixed Effects	System GMM	Pooled OLS	Fixed Effects	System GMM
		(1)			(2)	
INVt-1	0.701***	0.380***	0.528***	0.701***	0.380***	0.431***
	[0.014]	[0.017]	[0.061]	[0.013]	[0.016]	[0.037]
Qt-1	0.044***	0.096***	0.035	0.044***	0.095***	0.040
	[0.007]	[0.010]	[0.022]	[0.007]	[0.009]	[0.018]
RSGt	0.089***	0.135**	0.159***	0.089***	0.135***	0.201***
	[0.015]	[0.040]	[0.042]	[0.015]	[0.040]	[0.041]
CFt	0.825***	0.956***	0.844*	0.825***	0.956***	0.824**
	[0.085]	[0.129]	[0.324]	[0.085]	[0.129]	[0.268]
SVt	-0.009***	-0.027	-0.045***			
	[0.002]	[0.029]	[0.005]			
DUt				-0.038***	-0.076	-0.035***
				[0.004]	[0.082]	[0.003]
R2	0.578	0.536		0.578	0.536	
AR(2) test (p-value)			0.821			0.670
Hansen test (p-value)			0.336			0.433
Difference-in-Hansen tests (p-value)			0.794			0.824

Notes: Asymptotically robust and firm clustered standard errors are reported in brackets for pooled OLS regressions. Standard errors robust to autocorrelation and heteroscedasticity are reported for one-step system GMM estimator. Year dummies are included in all specifications. SV represents the stock price volatility. DU is demand uncertainty limiting investment score from CBI survey. AR(2) using a Lagrange multiplier tests for second-order serial correlation in the first-differenced residuals under the null of no serial correlation. Instrument validity is tested by the Hansen test of the over-identifying restrictions. The difference-in-Hansen test of exogeneity is under the null that instruments used for the equations in levels are exogenous. The full sample period is 1992-2016. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.15: The effects of uncertainty on investment in the pre-crisis period

	Pooled OLS	Fixed Effects	System GMM	Pooled OLS	Fixed Effects	System GMM
		(1)			(2)	
INVt-1	0.680***	0.291***	0.400***	0.680***	0.291***	0.402***
	[0.020]	[0.026]	[0.081]	[0.020]	[0.026]	[0.057]
Qt-1	0.047***	0.113***	0.027	0.047***	0.113***	0.043
	[0.010]	[0.015]	[0.027]	[0.010]	[0.015]	[0.022]
RSGt	0.075***	0.203*	0.239***	0.075***	0.203*	0.229***
	[0.021]	[0.087]	[0.066]	[0.021]	[0.087]	[0.056]
CFt	0.914***	0.808***	0.791	0.914***	0.808***	0.670
	[0.108]	[0.172]	[0.475]	[0.108]	[0.173]	[0.321]
SVt	-0.009***	-0.003	-0.054***			
	[0.002]	[0.006]	[0.007]			
DUt				-0.015**	-0.004	-0.036***
				[0.005]	[0.008]	[0.003]
R2	0.554	0.468		0.554	0.468	
AR(2) test (p-value)			0.965			0.960
Hansen test (p-value)			0.265			0.318
Difference-in-Hansen tests (p-value)			0.752			0.438

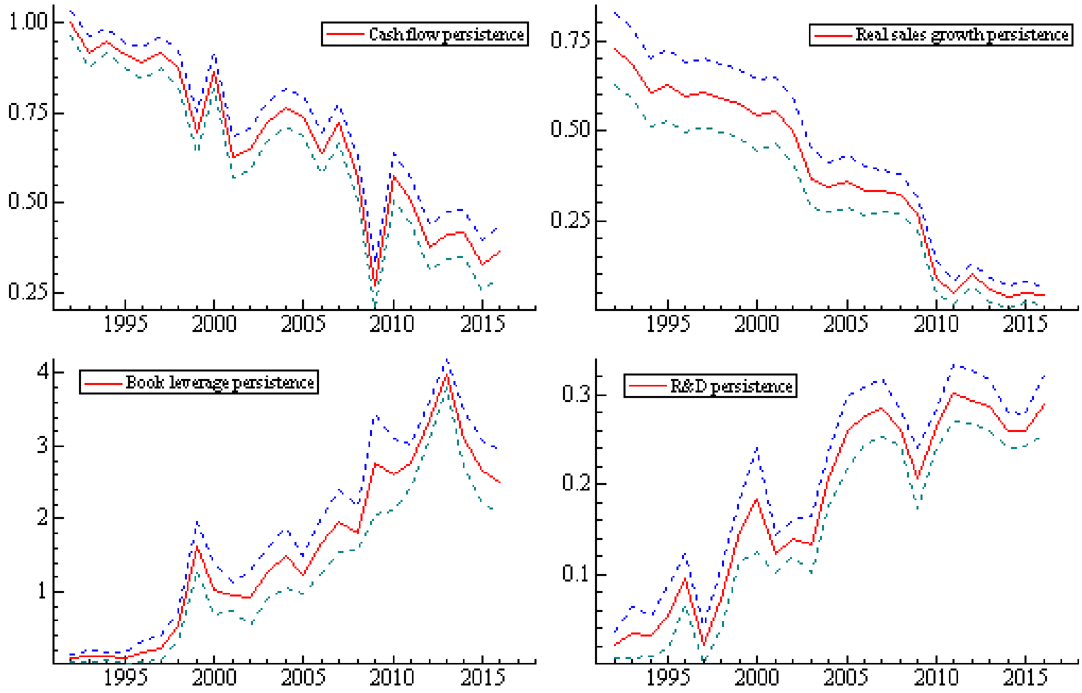
Notes: See Notes in Table 4.14. The pre-crisis period is 1992-2007. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Table 4.16: The effects of uncertainty on investment in the post-crisis period

	Pooled OLS	Fixed Effects	System GMM	Pooled OLS	Fixed Effects	System GMM
		(1)			(2)	
INVt-1	0.717***	0.212***	0.379***	0.717***	0.212***	0.477***
	[0.015]	[0.024]	[0.042]	[0.015]	[0.024]	[0.057]
Qt-1	0.043***	0.078***	0.041	0.043***	0.078***	0.034
	[0.010]	[0.016]	[0.024]	[0.010]	[0.016]	[0.029]
RSGt	0.096***	0.297	0.206**	0.096***	0.297	0.142**
	[0.015]	[0.167]	[0.065]	[0.015]	[0.167]	[0.065]
CFt	0.703***	0.902***	1.054*	0.703***	0.902***	0.845
	[0.117]	[0.252]	[0.394]	[0.117]	[0.252]	[0.477]
SVt	-0.028***	-0.033	-0.110***			
	[0.004]	[0.027]	[0.006]			
DUt				-0.027***	-0.094	-0.039***
				[0.003]	[0.075]	[0.004]
R2	0.558	0.449		0.558	0.449	
AR(2) test (p-value)			0.689			0.885
Hansen test (p-value)			0.286			0.131
Difference-in-Hansen tests (p-value)			0.247			0.185

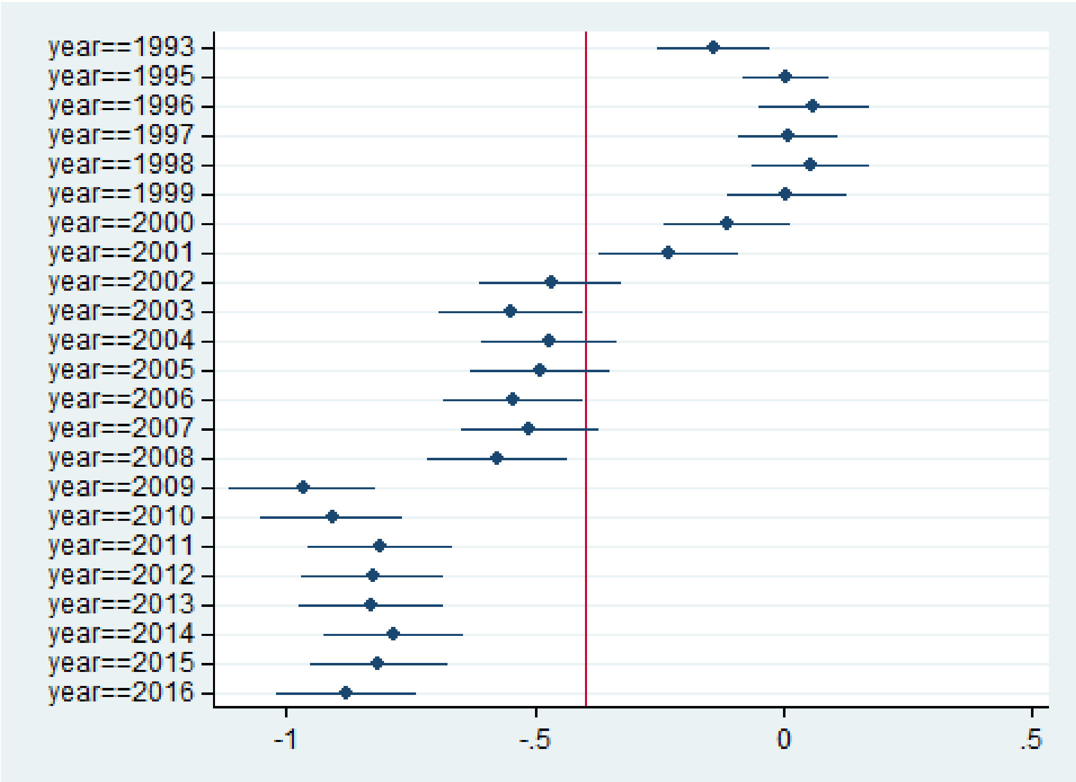
Notes: See Notes in Table 4.14. The post-crisis period is 2008-2016. ***, **, * represent significance at the 1%, 5% and 10% level, respectively..

Figure 4.4: Persistence in firm-level explanatory variables over time



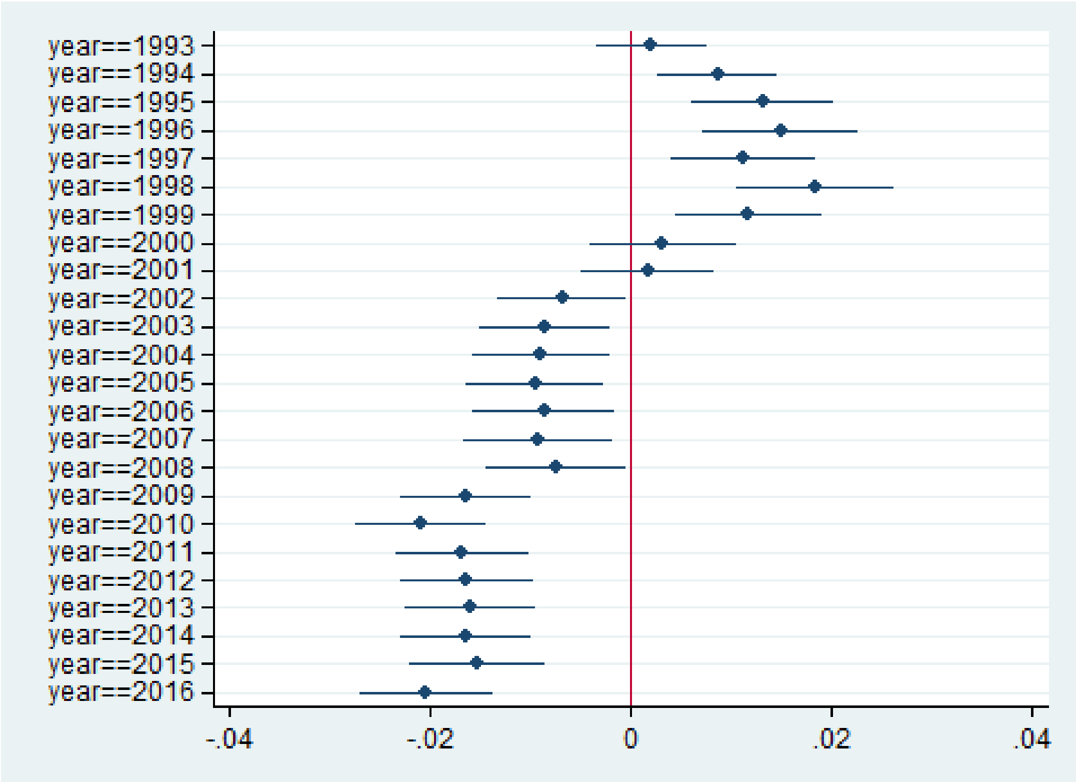
Notes: This figure provides plots of the persistence estimates of firm-level explanatory variables from 1-year rolling window regressions. The upper left panel plots the persistence in cash flow. The upper right panel plots the persistence in real sales growth. The lower left panel plots the persistence in book leverage. The lower right panel plots the persistence in R&D expenditures. The dashed lines indicate the 95% confidence interval. The sample period is 1992-2016.

Figure 4.5: Time fixed effects in Tobin's Q model of investment



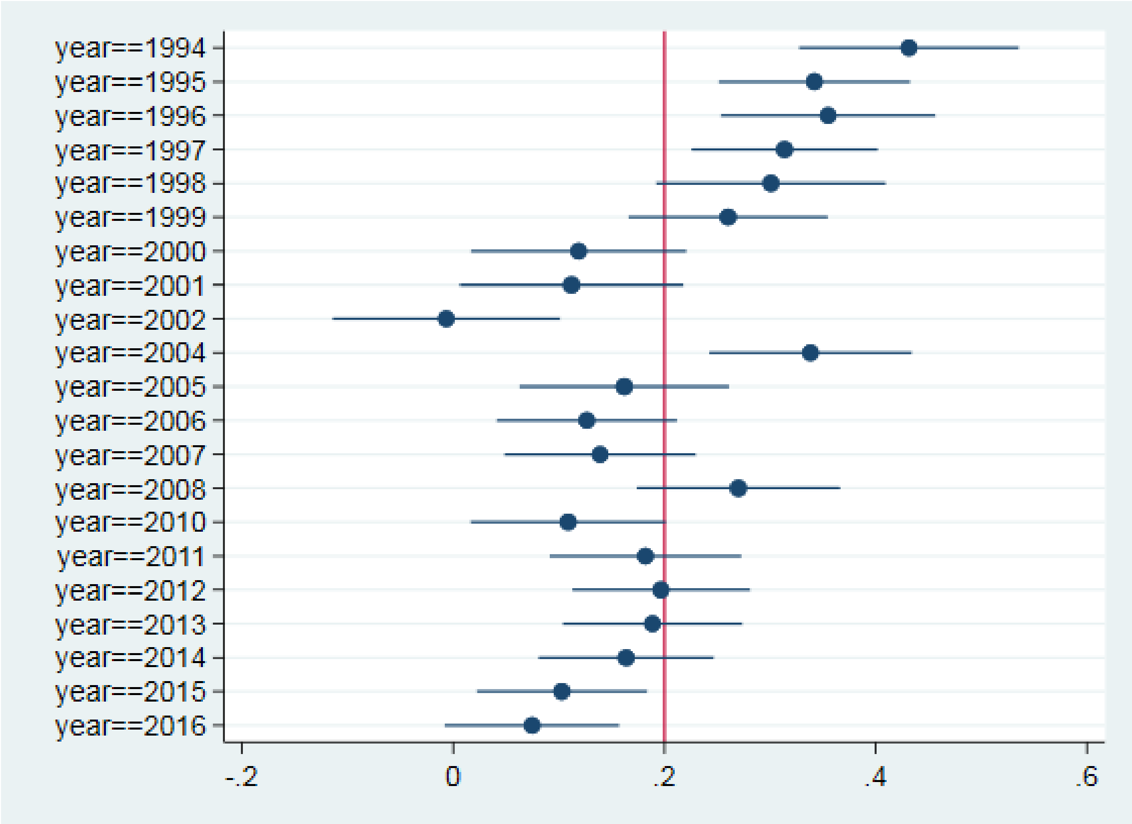
Notes: The dependent variable is investment, which is capital expenditures in year t divided by total assets in year t-1. Regressor is Q_{t-1}, which is the year beginning Tobins Q. The vertical line represents the average time effect across all years for each regression. The sample period is 1992-2016.

Figure 4.6: Time fixed effects in Tobin's Q model of investment (measurement error corrected)



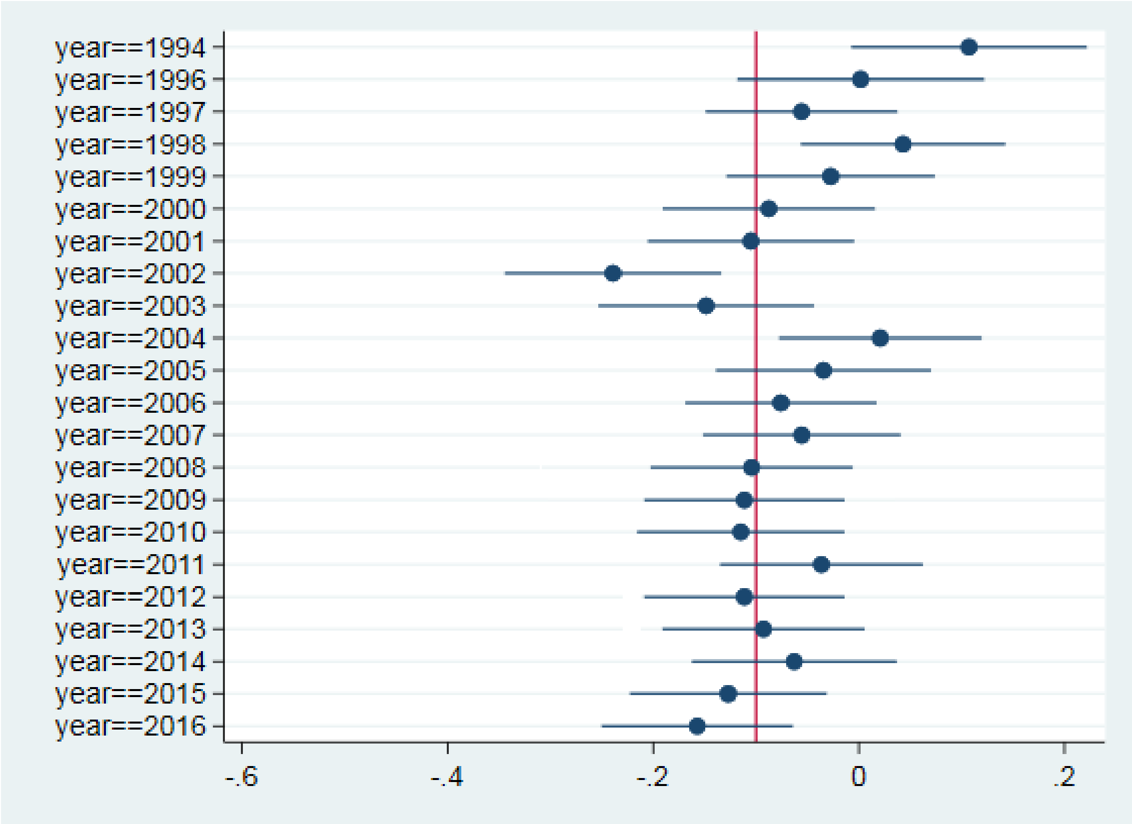
Notes: The dependent variable is investment, which is capital expenditures in year t divided by total assets in year t-1. Regressor is Q_{t-1}, which is the year beginning Tobins Q. The vertical line represents the average time effect across all years for each regression. Measurement error is corrected by Erickson & Whited (2000) cumulant estimator. The sample period is 1992-2016.

Figure 4.7: Time fixed effects in investment in the TFP growth model



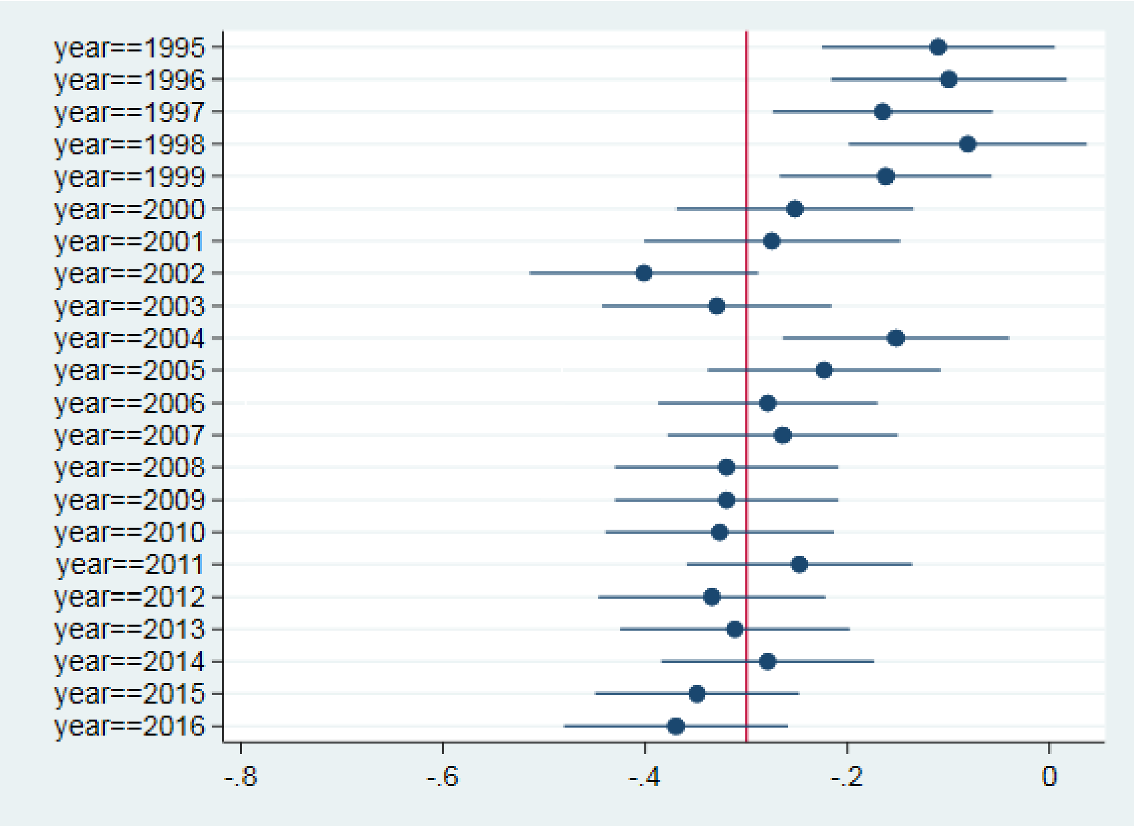
Notes: This figure plots time fixed effects in the system GMM estimation as reported in Table 4.8. The vertical line represents the average time effect across all years for each regression. The sample period is 1992-2016.

Figure 4.8: Time fixed effects in investment in the R&D model



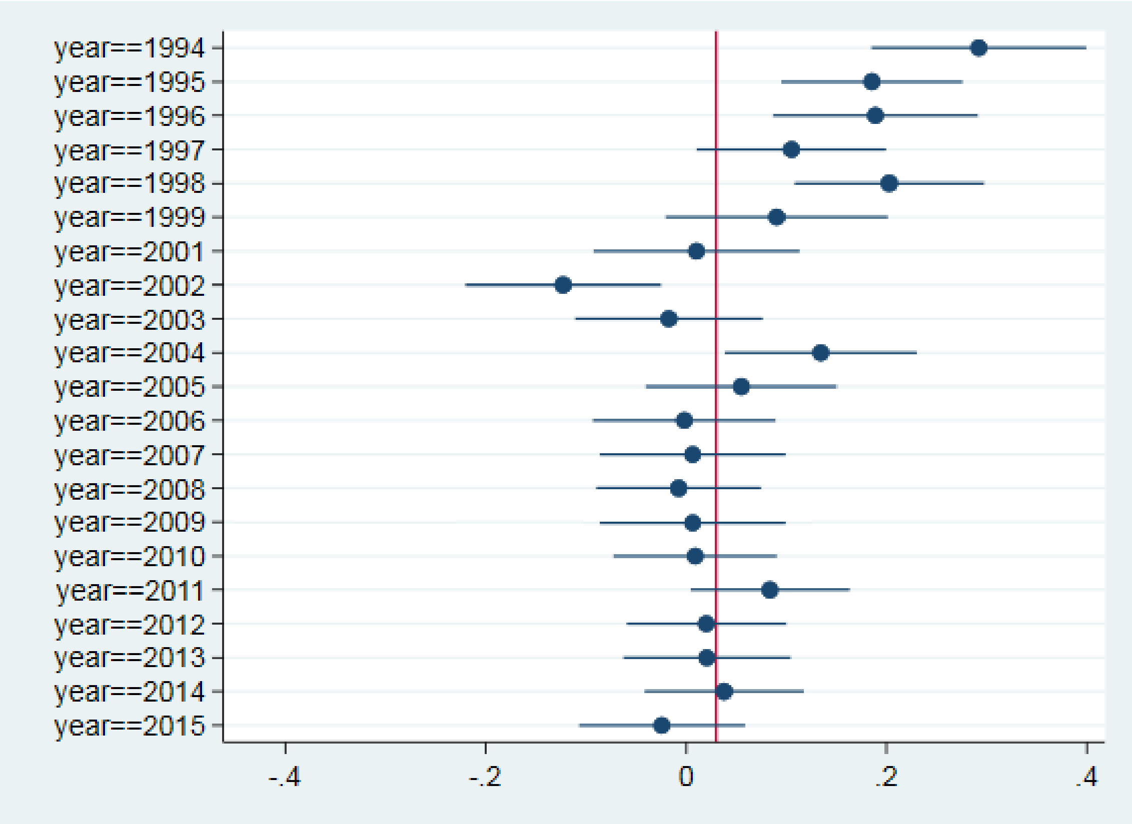
Notes: his figure plots time fixed effects in the system GMM estimation as reported in Table 4.10. The vertical line represents the average time effect across all years for each regression. The sample period is 1992-2016.

Figure 4.9: Time fixed effects in investment in the leverage model



Notes: his figure plots time fixed effects in the system GMM estimation as reported in Table 4.12. The vertical line represents the average time effect across all years for each regression. The sample period is 1992-2016.

Figure 4.10: Time fixed effects in investment in the uncertainty model



Notes: his figure plots time fixed effects in the system GMM estimation as reported in Table 4.14. The vertical line represents the average time effect across all years for each regression. The sample period is 1992-2016.

Table 4.17: Decomposition of Tobin's Q model

Year	*Investment*	*l.INV*	*Qt-1*
Panel A: Average value			
1992-2001	0.0784	0.0798	1.9060
2002-2008	0.0601	0.0612	1.7506
2009-2016	0.0432	0.0456	1.8794
Panel B: Estimated coefficient			
1992-2001		0.6119	0.0329
2002-2008		0.5952	0.0267
2009-2016		0.5540	0.0302
Panel C: Changes			
1992-2001			
2002-2008	-0.0183	-0.0111	-0.0042
2009-2016	-0.0168	-0.0086	0.0039
Panel D: Weights			
1992-2001			
2002-2008	100.00%	60.54%	22.69%
2009-2016	100.00%	51.03%	-23.14%

Notes: Panel A reports the average value of each variable over the three separate time periods. Panel B presents the estimated coefficient using system GMM estimator. Panel C shows the changes in each variable. Changes in the dependent variable, investment, are calculated as the differences between the average values for the sequential time periods. Changes in the independent variable, are calculated as the estimated coefficient in the corresponding period times differences between the average values for the sequential time periods. For example, the results for period 2 are calculated as estimated coefficient in period 2 times the differences of average values between period 1 and 2. -0.0111= 0.5952x(0.0612-0.0798). Panel D reports the ratios of changes in independent variables to changes in dependent variable.

Table 4.18: Decomposition of the innovation model

Year	*Investment*	*l.INV*	*Qt-1*	*CF*	*RSG*	*TFPG*	*R&D*
Panel A: Average value							
1992-2001	0.0784	0.0798	1.9060	0.0939	0.1695	1.1520	0.0587
2002-2008	0.0601	0.0612	1.7506	0.0520	0.2334	0.8414	0.1980
2009-2016	0.0432	0.0456	1.8794	0.0546	0.1040	-0.1425	0.2591
Panel B: Estimated coefficient							
1992-2001		0.3623	0.0056	0.0458	0.0420	0.0178	-0.0502
2002-2008		0.2853	0.0028	0.0322	0.0253	0.0133	-0.0307
2009-2016		0.3489	0.0022	0.0284	0.0146	0.0040	-0.0666
Panel C: Changes							
1992-2001							
2002-2008	-0.0183	-0.0053	-0.0004	-0.0013	0.0016	-0.41%	-0.43%
2009-2016	-0.0168	-0.0054	0.0003	0.0001	-0.0019	-0.39%	-0.41%
Panel D: Weights							
1992-2001							
2002-2008	100.00%	29.02%	2.37%	7.37%	-8.84%	22.57%	23.37%
2009-2016	100.00%	32.14%	-1.68%	-0.44%	11.23%	23.31%	24.19%

Notes: See Notes in Table 4.17.

Table 4.19: Decomposition of the leverage model

Year	*Investment*	*l.INV*	*Qt-1*	*CF*	*RSG*	*Leverage*
Panel A: Average value						
1992-2001	0.0784	0.0798	1.9060	0.0939	0.1695	0.4895
2002-2008	0.0601	0.0612	1.7506	0.0520	0.2334	1.3431
2009-2016	0.0432	0.0456	1.8794	0.0546	0.1040	1.8285
Panel B: Estimated coefficient						
1992-2001		0.4759	0.0036	0.0251	0.0530	-0.0065
2002-2008		0.3694	0.0039	0.0416	0.0329	-0.0042
2009-2016		0.4128	0.0026	0.0739	0.0120	-0.0039
Panel C: Changes						
1992-2001						
2002-2008	-0.0183	-0.0069	-0.0006	-0.0017	0.0021	-0.0036
2009-2016	-0.0168	-0.0064	0.0003	0.0002	-0.0016	-0.0019
Panel D: Weights						
1992-2001						
2002-2008	100%	37.58%	3.35%	9.53%	-11.49%	19.48%
2009-2016	100%	38.03%	-2.01%	-1.14%	9.24%	11.19%

Notes: Panel A reports the average value of each variable over the three separate time periods. Panel B presents the estimated coefficient using system GMM estimator. Panel C shows the changes in each variable. Changes in the dependent variable, investment, are calculated as the differences between the average values for the sequential time periods. Changes in the independent variable, are calculated as the estimated coefficient in the corresponding period times differences between the average values for the sequential time periods. For example, -0.0069= 0.3694x(0.0612-0.0798). Panel D reports the ratios of changes in independent variables to changes in investment.

Table 4.20: Decomposition of the uncertainty model

Year	*Investment*	*l.INV*	*Qt-1*	*CF*	*RSG*	*SV*	*DU*
Panel A: Average value							
1992-2001	0.0784	0.0798	1.9060	0.0939	0.1695	2.5775	3.8621
2002-2008	0.0601	0.0612	1.7506	0.0520	0.2334	2.9527	3.9220
2009-2016	0.0432	0.0456	1.8794	0.0546	0.1040	3.0670	3.9938
Panel B: Estimated coefficient							
1992-2001		0.4244	0.0045	0.0386	0.0133	-0.0354	-0.0168
2002-2008		0.3284	0.0022	0.0295	0.0202	-0.0122	-0.0372
2009-2016		0.3562	0.0037	0.0819	0.0100	-0.0279	-0.0455
Panel C: Changes							
1992-2001							
2002-2008	-0.0183	-0.0061	-0.0003	-0.0012	0.0013	-0.0046	-0.0022
2009-2016	-0.0168	-0.0055	0.0005	0.0002	-0.0013	-0.0032	-0.0033
Panel D: Weights							
1992-2001							
2002-2008	100%	33.40%	1.85%	6.74%	-7.05%	25.09%	12.17%
2009-2016	100%	32.81%	-2.79%	-1.27%	7.66%	18.95%	19.42%

Notes: See Notes in Table 4.19.

Table 4.21: Decomposition of the overall model

Year	*Investment*	*l.INV*	*Qt-1*	*CF*	*RSG*	*Leverage*	*TFPG*	*R&D*	*SV*	*DU*
Panel A: Average value										
1992-2001	0.0784	0.0798	1.9060	0.0939	0.1695	0.4895	1.1520	0.0587	2.5775	3.8621
2002-2008	0.0601	0.0612	1.7506	0.0520	0.2334	1.3431	0.8414	0.1980	2.9527	3.9220
2009-2016	0.0432	0.0456	1.8794	0.0546	0.1040	1.8285	-0.1425	0.2591	3.0670	3.9938
Panel B: Estimated coefficient										
1992-2001		0.3252	0.0060	0.0441	0.0193	-0.0031	0.0180	-0.0504	-0.0311	-0.0236
2002-2008		0.2658	0.0018	0.0235	0.0144	-0.0022	0.0085	-0.0196	-0.0089	-0.0285
2009-2016		0.2719	0.0032	0.0835	0.0069	-0.0024	0.0025	-0.0461	-0.0268	-0.0400
Panel C: Changes										
1992-2001										
2002-2008	-0.0183	-0.0049	-0.0003	-0.0010	0.0009	-0.0019	-0.0026	-0.0027	-0.0034	-0.0017
2009-2016	-0.0168	-0.0042	0.0004	0.0002	-0.0009	-0.0012	-0.0024	-0.0028	-0.0031	-0.0029
Panel D: Weights										
1992-2001										
2002-2008	100%	27.03%	1.56%	5.38%	-5.03%	10.34%	14.45%	14.93%	18.31%	9.34%
2009-2016	100%	25.04%	-2.41%	-1.29%	5.31%	6.93%	14.42%	16.72%	18.23%	17.05%

Notes: See Notes in Table 4.19.

Table 4.22: Subsample results sorted by firm size, book leverage and dividends payout ratio

	Small	Large	Low leverage	High leverage	Low dividends	High dividends
	(1)		(2)		(3)	
INVt-1	0.532***	0.446***	0.438***	0.405***	0.465***	0.483***
	[0.069]	[0.080]	[0.085]	[0.076]	[0.073]	[0.094]
Qt-1	0.062	0.056	0.076	0.081	0.038	0.041
	[0.046]	[0.038]	[0.046]	[0.054]	[0.049]	[0.037]
RSGt	0.281**	0.119*	0.144**	0.208***	0.175***	0.146*
	[0.102]	[0.059]	[0.061]	[0.068]	[0.061]	[0.077]
CFt	0.945*	0.499	0.359	1.081**	1.329**	0.682*
	[0.442]	[0.496]	[0.406]	[0.423]	[0.605]	[0.410]
AR(2) test (p-value)	0.961	0.278	0.754	0.935	0.813	0.948
Hansen test (p-value)	0.328	0.192	0.548	0.258	0.466	0.281
Difference-in-Hansen tests (p-value)	0.492	0.143	0.511	0.293	0.489	0.115

Notes: One-step coefficients and standard errors robust to autocorrelation and heteroscedasticity are reported in brackets for system GMM estimator. Year dummies are included in all specifications. AR(2) using a Lagrange multiplier tests for second-order serial correlation in the first-differenced residuals under the null of no serial correlation. Instrument validity is tested by the Hansen test of the over-identifying restrictions. The difference-in-Hansen test of exogeneity is under the null that instruments used for the equations in levels are exogenous. The sample period is 1992-2016. ***, **, * represent significance at the 1%, 5% and 10% level, respectively.

Chapter 5

Conclusion

This thesis explores the ability of the profitability and investment factors to describe the variation of average stock returns, provides an explanation of the empirical relationship between the risk premium and macroeconomic conditions, and new evidence on the impacts of leverage, uncertainty and R&D on UK business investment and finance decisions.

Chapter 2 empirically evaluates the performance of multifactor asset pricing models in the UK equity market. A novel dataset of firm-level financial characteristics and UK-version Fama-French asset pricing factors are constructed. The Fama-French five-factor model is augmented with a momentum factor to become the six-factor model. The ability of the Fama-French three-factor, Carhart four-factor, Fama-French five-factor and six-factor models in explaining the UK equity returns is comprehensively compared. Particularly, the profitability factor appears to be a promising factor while the investment factor is redundant in explaining the variation of average stock returns the UK market. Based on the results of the GRS test and Fama-Macbeth regressions, the Fama-French three-factor and Carhart four-factor models perform poorly comparing with the Fama-French five-factor and six-factor models. However, the Carhart four-factor and six-factor models outperform the Fama-French three-factor and five-factor models when describing average returns for 25 size-momentum portfolios. It is shown that a four-factor model VMP that includes the market, value, momentum and profitability factors demonstrates a better performance than the other models explaining the cross-sectional variation of UK stock returns.

In Chapter 3, a dynamic asset pricing model that jointly prices excess returns on stocks and government bonds in the UK is examined. This model fits the cross section of test assets on average and provides time-varying countercyclical risk premiums, and allows for a linear pricing kernel to be driven by shocks to contemporaneous pricing variables and unspanned forecasting variables. The results indicate that the equity market factor, level and slope of the term structure of interest rates are priced in both stock and bond returns. Equity and bond returns are predictable by the term spread, inflation expectations and the output gap at business cycle frequencies. Despite the role of macroeconomic factors, the risk premium is found to be substantially higher and more volatile during economic downturns, which suggests that investors must be compensated for risks associated with economic troughs.

The main objective of Chapter 4 is to find the explanation that contributes to the below average business investment level in the UK. Through the application of dynamic panel regressions from the neoclassical investment literature, the explanation for the investment gap in the UK is investigated. The under-investment problem is explored with three categories of variables: capital structure (book leverage), innovation (R&D expenditures and TFP growth) and uncertainty (stock price volatility and CBI demand uncertainty). The empirical results show that the real sales growth is more important than cash flow in explaining the under-investment issue in the post-2008 period. Evidence in Chapter 4 supports that R&D expenditures and TFP growth play an important role in explaining the UK investment puzzle. Leverage also helps to explain the under-investment since 2002. In addition, it is shown that uncertainty is one important determinant of UK firms' investment decisions. Through the overall model decomposition, it is shown that TFP growth and R&D expenditures explain about 29% of the investment gap in the pre-crisis period, while uncertainty accounts for approximately 35% of the investment changes since the 2008 financial crisis.

Future research agenda entails performing out-of-sample estimation of the VMP four-factor model in Chapter 2 and the joint model of stocks and government bonds in Chapter 3. To be specific, it is of interest whether the VMP model is able to describe the variation of average returns in stock markets other than the UK, and whether the joint model is capable of providing satisfactory pricing and predictive results internationally.

Originating from Jensen (1969), evaluating equity mutual fund performance based on asset pricing models offers practical insights. Therefore one future research direction is to assess the mutual fund performance using the VMP model. To provide an enhanced theoretical interpretation, one topic for future work is to develop a production-based structural framework and analyse the economic relation between asset returns, firm-level characteristics and business cycle conditions.

Following the work in Chapter 4, extensions could be done to examine whether the explanation of the investment gap contributes to the productivity puzzle in the UK. In addition, one potential topic is to assess the influence of Brexit on the link between asset prices and macroeconomy in the set up of a dynamic general equilibrium model.

Appendix A

Datastream Variable Definition

Varaible	Datatype	Definition
Total Return Index	RI	Total return index shows a theoretical growth in value of a share holding over a specified period, assuming that dividends are re-invested to purchase additional units of an equity or unit trust at the closing price applicable on the ex-dividend date.
Market Value	MV	Market value is calculated as the share price multiplied by the number of ordinary shares in issue. The amount in issue is updated whenever new tranches of stock are issued or after a capital change.
Common Equity	WC03501	Common equity represents common shareholders' investment in a company.
Total Assets	WC02999	Total assets represent the sum of total current assets, long term receivables, investment in unconsolidated subsidiaries, other investments, net property plant and equipment and other assets.
Gross Income	WC01100	Gross income represents the difference between sales or revenues and cost of goods sold and depreciation/depletion, and amortization.
Operating Income	WC01250	OPERATING Operating income represents the difference between sales and total operating expenses.
Net Income Before Extra Items/Preferred Dividends	WC01551	Net income before extra items/preferred dividends represents income before extraordinary items and preferred and common dividends, but after operating and non-operating income and expense, reserves, income taxes, minority interest and equity in earnings.

Appendix B

Cross-Sectional Pricing Tests and Predictive Return Regressions

This Appendix reports the results of cross-sectional pricing tests and univariate predictive return regressions for candidate factors motivated by the literature (see e.g., Fama & French (2017), Fama & French (2017), Fama & French (1993), Litterman & Scheinkman (1991), Ludvigson & Ng (2009), Diebold et al. (2006)).

Candidate cross-sectional pricing factors include: the market factor (MKT), which is the excess return on the value-weighted equity market portfolio. The size factor (SMB), which is the difference between average returns on the small market capitalization portfolios and big market capitalization portfolios. The book-to-market factor (HML), which is the difference between average returns on the high-B/M portfolios and low-B/M portfolios. The momentum (MOM), which is the average return on the two high (top 30 percent) prior (2-12) return portfolios minus the average return on the two low (bottom 30 percent) prior (2-12) return portfolios. The profitability factor (PRO), which is the robust operating profitability portfolios minus the average return on the weak operating profitability portfolios (PRO). The investment factor (INV), which is the average return on the conservative investment portfolios minus the two aggressive investment portfolios (INV). The level of term structure of interest rates (PC), which is constructed as the first principal component of the one through five year zero-coupon yield data. And the term spread (TERM) between the yield on a ten-year government bond and the three-month Treasury bill rate, which can be considered as the slope of the zero-coupon yield curve. The data used to construct bond factors is obtained from the Bank of England website.

Candidate forecasting factors include: Dividend yield (DY), which represents the log dividend yield of the FTSE100 index. The data is collected from Datastream. Term spread (TERM) between the yield on a ten-year government bond and the three-month Treasury bill rate, which can be considered as the slope of the zero-coupon yield curve. The output gap (GAP), which is measured by the deviations of the log of real GDP from a trend that incorporates both a linear and a quadratic component. The monthly GDP estimates is collected from National Institute of Economic and Social Research. One-year ahead CPI inflation expectations (INF), which are computed as the mean of the point forecasts across respondents, and the data are collected from the Consensus forecast survey. Unemployment rate (U) and industrial production growth (IPG). The data source for unemployment rate and industrial production is the Bank of England website.

Specifically, one month ahead predictive return regressions is estimated in the form of:

$$R_{i,t+1} = \alpha_i + \beta_i X_t + e_{i,t+1} \tag{B.1}$$

where the X_t variables are candidate forecasting factors. Dependent variables are excess stock and bond returns. These regressions assess the return predictive power of explanatory variables. The ability of the candidate pricing factors in explaining the cross-section of excess returns is evaluated by the Fama-MacBeth regressions[1].

Factors are compared based on a general-to-specific model selection strategy (see Campos et al. (2005)). This method focuses on the explanatory power of independent variables for the stock and bond excess returns, which provides higher transparency and interpretability. This method is preferred to principal components or other statistical techniques that instead summarise the information content of the explanatory variables. These pretests provide evidence that the factors used in the joint model are statistically and economically significant.

[1]Esmitation methodology can be found in section 2.5 of Chapter 1.

Table B.1: Cross-Sectional Pricing Test

	$\bar{\lambda}$	*S.E.*	*NW-t*
MKT	-4.769***	1.220	-3.909
SMB	-0.009	0.009	-0.989
HML	-0.067**	0.027	-2.448
MOM	0.118**	0.054	2.191
INV	-0.002	0.009	-0.216
PRO	1.747**	0.746	2.344
PC	6.507***	0.253	25.753
TERM	-3.076***	1.049	-2.931

Notes: This table provides results comparing cross-sectional pricing power of candidate factors. The test assets are ten size sorted stock decile portfolios, ten book-to-market sorted decile portfolios, and seven constant maturity Treasury returns for maturities ranging from 1 through 10 years. $\bar{\lambda}$ denotes average estimates of the cross-sectional prices of risk associated with each of the factor. *S.E.* stands for Newey-West adjusted standard errors. *NW-t* represents the Fama-MacBeth t-statistic calculated with the Newey-West estimator. ***, **, * represent significance at the 1%, 5% and 10% levels, respectively. The sample period is January 1990 to December 2015.

Table B.2: Predictive Return Regressions

	S5			*BM5*			*Y5*		
	β	*Stambaugh-t*	R^2	β	*Stambaugh-t*	R^2	β	*Stambaugh-t*	R^2
DY	-0.068**	-2.335	0.017	-0.062**	-2.073	0.014	0.013	1.366	0.006
TERM	0.005***	2.687	0.023	0.003*	1.697	0.009	1.782**	2.341	0.018
U	0.002	1.399	0.006	0.002	0.633	0.001	0.079*	1.725	0.010
IPG	-0.099	-0.430	0.001	0.149	0.679	0.001	-1.645	-1.470	0.007
GAP	-2.664***	-3.017	0.029	-3.335***	-2.669	0.020	-8.111*	-1.867	0.011
INF	-0.008**	-2.291	0.017	-0.005	-1.007	0.008	-0.307*	-1.793	0.012

Notes: This table provides results for one month ahead predictive return regressions. The dependent variables are the excess return on the fifth size sorted stock decile portfolio (S5), the excess return on the fifth book-to-market sorted stock decile portfolio (BM5), as well as the excess return on the constant maturity five-year Treasury portfolio (Y5). β represents estimation coefficient. Stambaugh-t provides t-statistics for Stambaugh-bias adjusted regression coefficients with Newey-West standard errors that are robust to heteroskedasticity and serial correlation in the pricing errors. R^2 denotes predictive R-squared. ***, **, * represent significance at the 1%, 5% and 10% levels, respectively. The sample period is January 1990 to December 2015.

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