Firm-level Idiosyncratic Volatility – Evidence from the UK Market

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Author's Declaration

I declare that no part of the material contained in this thesis has been previously submitted, either in whole or in part, for a degree in this or in any other university.

Fathima Roshan Rakeeb

Abstract

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This thesis attempts to address a number of issues identified in the asset pricing and corporate finance literature in relation to the role of idiosyncratic volatility. These issues include the need to uncover the determinants of idiosyncratic volatility in the UK equity market, examine its association with financial constraints and corporate investment behaviour. The sample used in this thesis provide a comprehensive evidence on the idiosyncratic volatility dynamics of the UK equity market, including firms listed on both the main and the alternative exchange – the Alternative Investment Market (AIM), which was established with a goal of helping small and growing firms to raise capital with less regulatory cost.

In light with the findings of extant literature, the results presented in this thesis, reinforces the ability of firm-specific in driving the cross-sectional variation in idiosyncratic volatility for UK firms. Specifically, we find that the aggregate idiosyncratic volatility in the UK financial market has been significantly lower after the 2007-08 global financial crisis, which is a similar trend to that of US. Subsequently, we observe that the crisis has led to a shift in the dynamics of firm fundamentals. Firms with high idiosyncratic volatility after the financial crisis are firms operating in a non-regulated industry, firms that do not pay dividend and those with high book-to-market ratio, small firm size, low earnings, and high previous period volatility. In line with the mosaic of evidence, we suggest that the level of financial constraints faced by a firm is associated with its idiosyncratic volatility. We empirically document that small

and young firms have high idiosyncratic volatility, and this relationship is strengthened as the financial constraints faced by a firm increases. In other words, financial constraints act as a moderating factor in the firm size-idiosyncratic volatility, firm age-idiosyncratic volatility relationships.

The results in this thesis also support the implication of idiosyncratic volatility on corporate investment behaviour. We examine this using a sample of firms listed on the AIM. Our results support that increase in firm-specific uncertainty discourages firms to invest in capital assets as ‘real option’ value is created by waiting. However, this is not the case for firms with a higher competitive position in the market. Firms with high market share or market power are able to exploit investment opportunities by investing more amidst uncertainty. The tendency of firms with stronger competitive position to extract monopolistic rents demonstrates a strategic response to increased competition. Therefore, effective competition policies in the alternative exchange may encourage firms with average competitive position to stimulate investment activity and thus economic growth.

Acknowledgement

This thesis would not have been possible without the great support of some incredible people. I would first like to thank my supervisors, Dr Mohamed Nurullah and Dr Emmanouil Noikokyris, for their extensive guidance through my PhD journey. They have been great mentors who would *find* time to hear me out amidst busy schedules and those whom I can rely on for any advice anytime. They have really been patient with me and have always encouraged me to get closer to my goal even when things looked bleakest. I also thank the faculty members, especially the Department of Accounting, Finance and Informatics, for the excellent collegiality and last but not least, to Kingston Business School for giving me an opportunity by awarding me with a PhD scholarship.

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Andy, this is all for you!

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1. CHAPTER 1 – INTRODUCTION

1.1 Introduction

This thesis explores the idiosyncratic volatility dynamics in the UK equity market and its implication for some major corporate finance decisions. In the light of recent developments in the literature, we demonstrate the relevance of idiosyncratic volatility for firms listed on the London Stock Exchange (LSE), including smaller and growing firms that are part of the Alternative Investment Market (AIM). Empirical evidence from the asset pricing literature confirms that idiosyncratic risk is a priced factor, for instance, Cotter, Sullivan and Rossi (2015) finds that idiosyncratic risk is negatively priced in the UK equity market. However, the inferences of this risk factor on corporate decisions is mainly produced using data from the US equity market. Consequently, this thesis is aimed to provide the first comprehensive empirical evidence of idiosyncratic volatility dynamics for the UK market.

Capital asset pricing models are seen as elegant financial-economic solution for the problem of portfolio selection. One of the first models in asset pricing literature is the CAPM, developed by Jan Mossin (1966), William Sharpe (1967), John Linter (1965) and Fischer Black (1972) independently. CAPM implies that expected return of an asset must be linearly related with the covariance of its return with the return of the market portfolio (Campbell, et al., 2006). In theory, any security that is added to the portfolio is based on its beta or systematic risk and is priced by the market, since the theory assumes that unsystematic risk can be diversified and therefore need not be priced (Dowen, 1988). Unfortunately, CAPM holds true only if all of its assumptions are met.

Asset-pricing literature identifies a number of systematic risk factors that affect stock returns. For instance, CAPM, Fama and French three-factor model (1993), Carhart four-factor model (1997), Fama and French five-factor models identify that factors such as market risk, size (SMB – difference in the returns between small versus big stocks), value (HML – difference in the returns between high versus low book to market equity stocks), momentum (UMD – up versus down), investment and profitability are systematically priced in the cross-section of returns. While the list of systematic risk factors has been evolving in the empirical front, all these models assume that idiosyncratic risk can be diversified away. However, Malkiel and Xu (2006) argue that idiosyncratic risk itself is a priced risk factor when investors cannot eliminate idiosyncratic risk through efficient portfolio diversification. Studying the dynamics of this idiosyncratic risk is the focus of this thesis.

The recent literature has pointed out the importance of idiosyncratic volatility and its contribution to the asset pricing literature. A seminal work by Campbell et al., (2001) established the positive deterministic trend of idiosyncratic volatility compared to market volatility. They question the increasing trend of idiosyncratic volatility in their study and highlight the reasons why dynamics of idiosyncratic volatility should be investigated further. Other literature has not only investigated the trend of idiosyncratic volatility for various equity markets but has also examined the determinants of both the time series trend and the cross-sectional variation. Despite an enormous corpus of literature, the findings are by far inconclusive. The main challenge remains with measuring idiosyncratic volatility since it is unobservable and model dependant. Also, the differences in sample selection criteria and other methodological challenges have further contributed to this inconsistency.

The significance of the information content of idiosyncratic volatility has also been highlighted in the corporate finance literature. According to the real options theory, when uncertainty increases, firms lower their corporate investment levels waiting for new information to arrive or until uncertainty is resolved. As opposed to exercising the investment opportunity immediately, delaying creates ‘option value’ and helps managers in avoiding large potential losses ahead of uncertainty (Bernanke, 1983; McDonald and Siegel, 1986; Pindyck, 1993; Dixit and Pindyck, 1994). Extant empirical evidence confirms that firm-specific uncertainty incentivises firms to delay its investment plans (Bulan, 2005; Baum, Caglayan and Talavera, 2008; Panousi and Papanikolaou, 2012). Other studies link idiosyncratic volatility to growth options available to the firm (Cao, Simin and Zhao, 2008a; Guo and Savickas, 2008), profitability and cash flows (Pastor and Veronesi, 2003; Irvine and Pontiff, 2009) and ownership structure (Xu and Malkiel, 2003; Panousi and Papanikolaou, 2012).

Product market structure and competitive environment is another factor that influences universally all corporate decisions and it adds to the complexity of how firms respond to shocks. For instance, while the irreversibility channel suggests that uncertainty incentivises firms to delay investments, fear of pre-emption by rivals might affect the way in which uncertainty feeds through corporate investment decisions (Caballero, 1991; Ghosal and Loungani, 1996; Kulatilaka and Perotti, 1998; Grenadier, 2002). On the empirical front, the evidence is by far inconclusive and points to the importance of unique product market structures and competition proxies in driving the variation in findings.

1.2 Definitions: Systemic, Systematic and Idiosyncratic Risk

In finance, Systematic risk refers to the risk of an entire financial system collapsing. Unlike risk associated with an individual firm, which in most cases can be controlled therein with minimal detriment to the entire financial system, systemic risk affects the financial stability of the market and thus the economy as a whole. The Systemic Risk Centre (SRC) of London School of Economics (LSE) defines systemic risk as the "risk of breakdown of an entire system rather than simply the failure of individual parts. In a Financial context, it captures the risk of a cascading failure in the financial sector, caused by inter-linkages within the financial system, resulting in a severe economic downturn" (Systemic Risk Centre n.d.).

Kaufman, (2000) demonstrates that systemic risks could arise from various causes such as 'big shock' (e.g. failure of a major bank), 'spillovers' (e.g. the 2008 financial crisis) and 'common shock' (e.g. the 9/11 attack). It has been of great concern to governments, central bankers, regulators and policymakers due to the potential devastating consequences to the entire economy and therefore the society (Bartram, Brown and Hund, 2007).

Systematic risk also known as the aggregate risk arises from the market structure and therefore common to all agents in the market. It could arise from government policy, international economic forces or natural causes and therefore cannot be eliminated through diversification. Thus, conventional asset pricing models were developed in order capture investors' exposure to systematic risk which can be reduced only by sacrificing expected returns. Systematic risk is generally captured by the 'beta' of an asset pricing model (Lakonishok and Shapiro, 1986).

On the other hand, idiosyncratic or unsystematic risk is specific to an agent. Unlike systematic risk, it is not driven by a systematic factor common to all securities in the market but rather by factors that are specific to the firm or industry (Cotter, Sullivan and Rossi, 2015). Due to the idiosyncratic nature, unsystematic risk can be diversified by holding an efficient portfolio of assets, at least based on theory. However, some early evidence such as Levy (1978) had detected that idiosyncratic risk could be a priced factor in imperfect markets. They empirically document that the residuals of a Capital Asset Pricing Model (CAPM) is able to explain the return behaviour compared to market beta.

Investors are exposed to idiosyncratic risk. One of the main reasons for this is because investors, for various reasons, are constrained to hold a well-diversified portfolio. For example, wealth constraints, lack of financial knowledge, restrictions based on employment contracts or mere personal preferences could lead to investors holding specific stocks (Xu and Malkiel, 2003). This in turn suggests that investors could be exposed to uncertainty that is specific to those stocks. Regardless, even in a well-diversified portfolio, the total risk depends on the idiosyncratic risk of individual stocks that constitute the portfolio. Therefore, idiosyncratic risk is a fundamental component of the total risk of a typical stock (Goyal and Santa-clara, 2003).

1.3 Evolution of Idiosyncratic Volatility

Campbell et al., (2001) suggest that idiosyncratic volatility constitutes the largest proportion of a firms' total volatility and is above 70% of an average US firm. Further, they also document that the idiosyncratic volatility of US stocks has dramatically increased over 1962-1997, with a positive and deterministic trend. This increased volatility observed in the market is attributed to the volatility firm level as opposed to industry or market levels. Lebedinsky and Wilmes (2018) updates the findings of Campbell et al., (2001) using a recent sample incorporating the Dot-com Bubble and the 2007-2008 financial crisis, which are two of the major stock market events. They observe large spikes in idiosyncratic volatility during crisis period. The trend in idiosyncratic volatility is not universal. Bekaert, et al., (2012) show that 22 out of 23 developed equity markets used in their study does not demonstrate a trend. Rather they suggest that the evolution of idiosyncratic volatility can be described as a stationary auto-regressive process that occasionally switches to short-lived high volatile phases. In terms of UK market, Angelidis and Tessaromatis (2008) provides similar evidence of a positive trend over 1979-2003. They show that the idiosyncratic component of the total volatility accounts for 75% to 95% of an average firm.

Goyal and Sant-Clara, (2003) confirms the upward trend in Campbell et al., (2001) and report an interesting observation that the phases of high market volatility being different from the phases of high idiosyncratic volatility. This is turn has led to flurry of research which examine the peculiar behaviour of idiosyncratic volatility over time and across firms. For instance, Xu and Malkiel (2003) used an indirect approach proposed by Campbell et al., (2001) and find similar increasing trend of idiosyncratic volatility between 1980's and 1990's. Their finding is robust to both a direct approach – a return decomposition method which is derived based on theory, and an indirect approach – where idiosyncratic volatility is estimated relative to a market model such as CAPM or Fama-French three factor model. The latter approach is common in the empirical literature since idiosyncratic volatility of a stock is inherently unobservable.

The literature has attributed the trend in idiosyncratic volatility to many factors such as sample period (Bekaert, Hodrick and Zhang, 2012), growth options (Cao, Simin and Zhao, 2008a), new listings by risky companies (Brown and Kapadia, 2007), decline in maturity of a typical firm (Fink *et al.*, 2010), volatile fundamentals (Irvine and Pontiff, 2009), irrational "noise" traders (Brandt *et al.*, 2010) and institutional ownership (Xu and Malkiel, 2003) among others. Despite, recent evidence by Bartram, Gregory and Stulz (2018) suggest that idiosyncratic volatility has been historically low in the recent years especially after the financial crisis. They show that the number and composition of listed firms has changed since the 1990s and a typical firm is now larger and older with lower idiosyncratic volatility. Consistent with Fox, Fox and Gilson (2016), they find that idiosyncratic volatility dramatically increases during crisis periods.

1.4 Idiosyncratic Volatility in the UK

In this section, we provide a summary of the evolution of idiosyncratic volatility in the UK market. Using daily stock returns data from Bloomberg[1] for FTSE all-share index constituents[2] between January 1998 to June 2015 we estimate idiosyncratic volatility of firms as per the Fama-French three factor model (FF3) (1996). This approach is well-established in this stream of literature (see for instance, Ang et al., 2006; Cao et al. 2008; Bekaert et al., 2012; Bharma and Shim, 2017 among others)[3]. The model for excess stock returns of individual firm *i* on day *t* is,

$$R_{i,t} = b_{0,i,m} + b_{1,i,m}.MKT_t + b_{2,i,m}.SMB_t + b_{3,i,m}.HML_t + u_{i,t}^{FF} \quad (1)$$

where day *t* belongs to month m. $R_{i,t}$ is the excess firm return by subtracting the UK T-bill rate, MKT_t is the excess market return of FTSE ALL-Share index over the risk-free rate, SMB_t is the size factor which captures the difference in the returns between small versus big stocks and HML_t is the value factor which captures the difference in the returns between high versus low book to market equity stocks. Daily data on the FF factors and T-bill rates were obtained from the website for the Xfi Centre for Finance and Investment, constructed and well documented by Gregory et al. (2013) for the UK market[4].

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[1] For their studies on developed markets, Fama and French (2012) have used Bloomberg to obtain returns and accounting data. Cotter et al. (2015) reported Bloomberg as a reliable source for stock-level data for the UK.

[2] From the original sample of 629 constituents, firms with missing data were removed and thereby resulting in a final sample of 604 firms.

[3] We also estimate IV using CAPM and Carhart 4-factor model (1997) as part of our robustness tests. Our results largely remain the same irrespective of the market models used to estimate IV. We report the results in the Appendix.

[4] We obtain the Fama-French factors for the UK market from the Xfi Centre for Finance and Investment, University of Exeter described by Gregory et al., (2013).

To allow the betas to vary through time, we estimate the model every month with daily data. The IV of firm *j* is then calculated as within-the-month the variance of the daily residual $u_{i,t}^{FF}$,

$$IV_{i,m} = \sigma^2(u_{i,t}^{FF}) \quad (2)$$

We provide the brief historical summary of aggregate IV in the UK from 1998-2015 in Figure 1. We aggregate IV of our sample firms in two ways; using an equal-weighted and a value-weighted measure as described in detail below. Our first equal-weighted IV measure, we follow Goyal and Santa-clara, (2003) and Bali et al., (2005) to aggregate firm IV every month as follows;

$$IV_{ew,m} = \frac{1}{N}\sum_{i=1}^{N} IV_{i,m} \quad (3)$$

where *N* is the number of stocks traded in month *m*. Bali et al., (2005) empirically show that an equal-weighted average stock variance is not a robust measure mainly due to inflated underlying volatility caused by large bid-ask bounce from small and illiquid stocks. Thus, they recommend using a value-weighted measure that is less affected by microstructure noises. Therefore, we construct our second value-weighted measure following Bali et al., (2005), Cao et al., (2008). The monthly value-weighted idiosyncratic volatility is aggregated as follows;

$$IV_{vw,m} = \sum_{i=1}^{N} w_{i,m} \,.\, IV_{i,m} \quad (4)$$

where the weight $w_{i,m}$ is computed using firm *i*'s market capitalisation in the previous month. We plot the equal-weighted and value-weighted annualized means of monthly IV time series in Figure 1[5]. The figure shows the raw (light line) and the 12-month

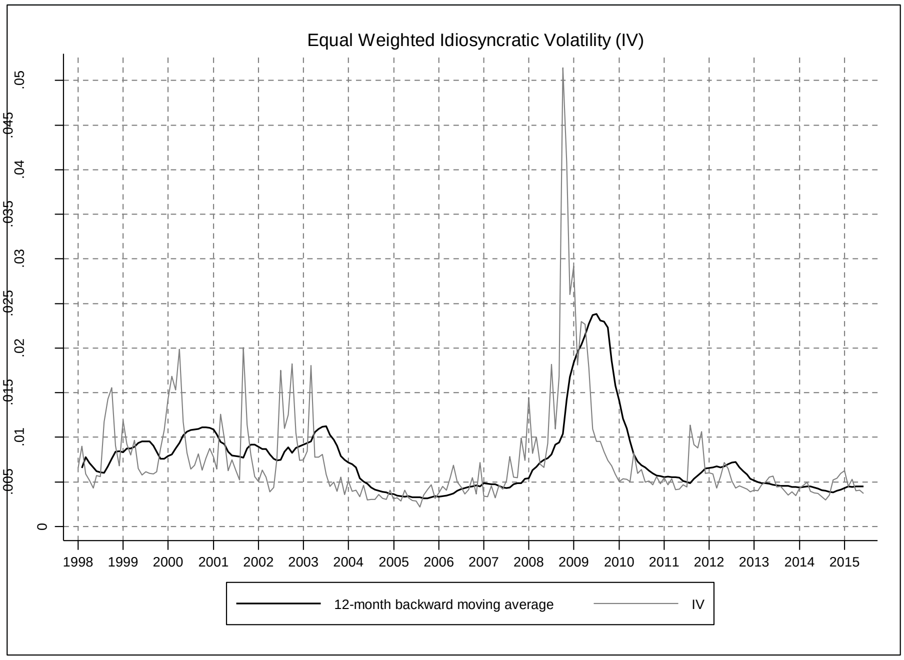
[5] We provide the equal-weighted and value-weighted idiosyncratic volatility for descriptive purposes in order to understand the aggregate volatility levels in the UK. Exploring the time series dynamics of aggregate IV is beyond the scope of this paper.

backward moving average (dark line) of the monthly time series of IV from Jan 1998 through Dec 2015.

Figure 1. 1 – Idiosyncratic Volatility over time

This figure presents the monthly time series of aggregate idiosyncratic volatility (IV) (light line) and the 12-month backward moving average of this measure (dark line) for each month between Jan 1998 - Jun 2015 for FTSE All-Share stocks in our sample. Graph A of figure 1 plots the equal-weighted IV outlined in equation (3) and graph B of figure 1 plots the value-weighted IV outlined in equation (4). Both the volatility time series are annualised. Firm IV is estimated relative to FF-3 model detailed in equations (1) and (2).

Graph A



Graph B

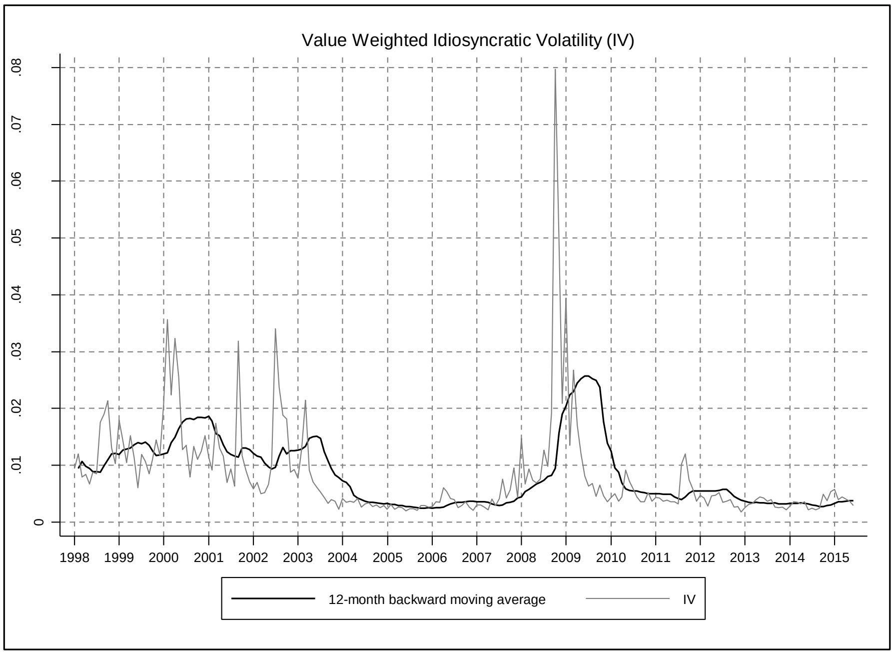


Figure 1.1 present the time series equal-weighted and value-weighted average idiosyncratic volatility. The highest volatility is observed in the recent financial crisis in late 2008 and long-lasting periods of higher volatility are also evident earlier in the sample from 1998 till early 2003 due to the Russian financial crisis in 1998, Dot-com bubble in 2000, economic repercussions of the 9-11 attacks in 2001 and the worldwide stock market downturn in 2002. During crisis periods, it is visible that equal-weighted idiosyncratic volatility is considerably lower than the value-weighted idiosyncratic volatility. During the non-crisis periods, both the measures move closely with one another. Although idiosyncratic volatility and market volatility (as presented in Figure 2.2), share some common periods of excessive volatility especially during early 2000 and around 2008, post-crisis periods exhibit lower idiosyncratic volatility (both equal and value-weighted) and higher market volatility. Investigating the time series dynamics of these volatility series is beyond the scope of this paper.

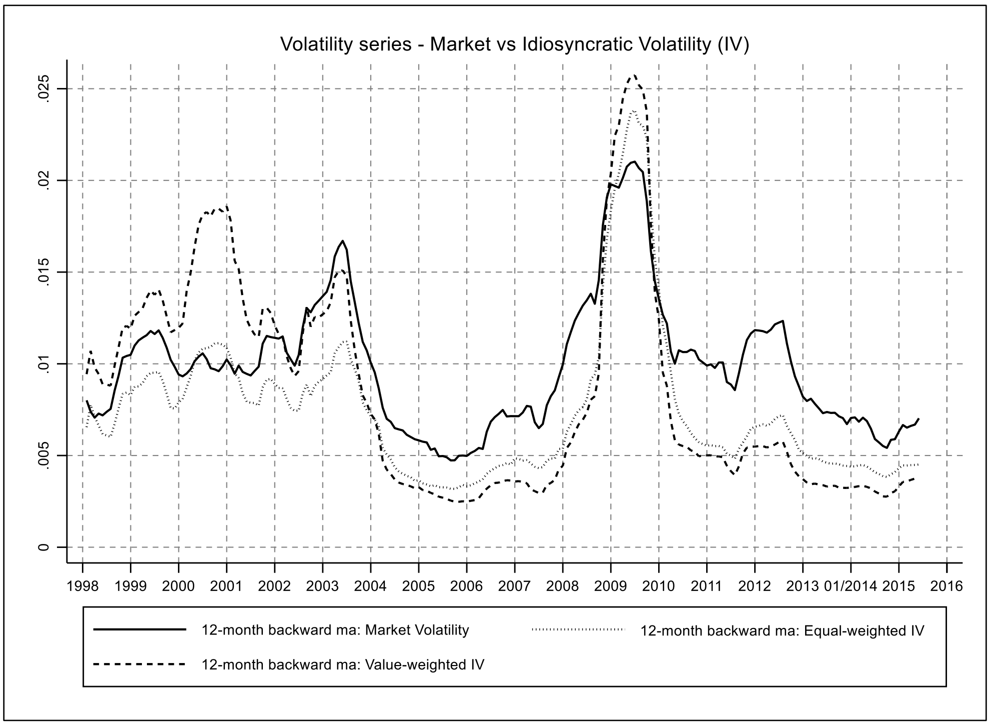
Next, we confirm the negative association between idiosyncratic volatility and stock returns for UK stocks as documented in the literature. We run the following time series regression using simple Ordinary Least Squares (OLS) regressions following Guo and Savickas (2008);

$$MKT_m = \alpha_m + \gamma_1 MV_{m-1} + \gamma_2 IV_{m-1} + \gamma_3 Crisis_m + u_m \quad (5)$$

where MKT_m is the market returns on month m is, MV_{m-1} is 1 month lagged market volatility measures as the volatility of the FTSE all share index and for IV_{m-1}, we use both the equal-weighted and value-weighted idiosyncratic volatility in equation (3) and (4) respectively. We also add to the equation, a dummy variable to capture the volatility spikes during the recent financial crisis periods. We define the crisis period as the period between July 2007 and December 2008 similar to Huang et al (2015). The results are provided in Table 1.1.

Figure 1. 2 – Market Volatility and Idiosyncratic Volatility

This figure presents the monthly time series of the 12-month backward moving average of market volatility and aggregate idiosyncratic volatility (IV) between Jan 1998 - Jun 2015. All volatility time series are annualised. Firm IV is estimated relative to FF-3 model detailed in equations (1) and (2).



Consistent with the literature, we find negative and significant albeit weak relationship between value-weighted idiosyncratic volatility and one-month-ahead market returns. However, the equal-weighted idiosyncratic volatility is not significant but has a negative relationship with one-month-ahead market returns. Table 1.2 reports the average excess returns of portfolios sorted idiosyncratic volatility. The first column shows the pooled sample average excess returns across idiosyncratic volatility portfolios while second and third columns show the average excess returns during non-financial crisis period and financial crisis period respectively. The difference in average excess returns between portfolio 3 and portfolio 1 is roughly -0.1% per month statistically significant at 1%. The difference in average excess returns between highest and the lowest idiosyncratic volatility portfolios remain significant at 1% during financial crisis period and non-financial crisis period.

Table 1. 1 – The relationship between market returns and idiosyncratic volatility

This table presents the estimation results of the regression in equation (5) of one period ahead market volatility on two alternative measures of idiosyncratic volatility; the equal-weighted measure and the value-weighted measure. We calculated idiosyncratic volatility of FTSE all share index-constituents using equations (1) and (2) for the period between January 1998 and June 2015. MV is market volatility of FTSE all share index, IV is idiosyncratic volatility, Crisis is the dummy variable capturing the volatility spikes.

	Equal-weighted portfolio	Value-weighted portfolio
MV_{m-1}	0.00298	0.00564^{**}
	(0.89)	(2.27)
$IV_{ew,\ m-1}$	-0.00447	
	(-0.10)	
$IV_{vw,\ m-1}$		-0.0343^{*}
		(-1.86)
Crisis	-0.00150^{***}	-0.00161^{***}
	(-3.39)	(-3.85)
Constant	-0.000155	-0.000315
	(-0.62)	(-1.18)
N	209	209
R^2	0.0416	0.0499

Table 1. 2 – Average excess returns sorted by idiosyncratic volatility portfolio

This table provides the average excess returns of FTSE all share index constituents sorted by idiosyncratic volatility portfolios for the period between January 1998 and June 2015. We calculate two alternative measures of idiosyncratic volatility; the equal-weighted measure and the value-weighted measure. Column (1) provides the average excess returns for the pooled sample and column (2) and (3) provides the excess returns for the non-crisis period and crisis period respectively.

Idiosyncratic volatility portfolio	Pooled sample	Non-financial crisis period	Financial crisis period
1 (Low)	0.0003917	.0004144	-.0008769
2	0.0003261	.0004065	-.0012848
3 (High)	-0.0003381	.0002159	-.0039016
3-1 (High-Low)	-0.0007298***	-.0001985***	-.0030247***

Next, we provide descriptive statistics of idiosyncratic volatility across 10 industries considered in our study. We follow the Industry Classification Benchmark

(ICB) [6] to identify the industry a firm operates in. ICB classifies the industry into 10 categories and the industries are further divided into 41 subsectors which contain 114 subsectors. The first digit of the 4-digit code is used to identify the industry. For our analysis between financial and non-financial firms we divide the sample as follows; we classify firms with an ICB code starting at 8000 as financial firms with the remaining classified as non-financial firms [7].

The mean idiosyncratic volatility and market beta as shown in Figure 1.2 and 1.3 reveals some interesting facts about the dynamics of idiosyncratic volatility across the 10 industries. Mean idiosyncratic volatility is the lowest in financial industry but as expected, their market beta is one of the highest among the industries. Industries such as technology, basic materials, telecommunication and oil and gas, have higher idiosyncratic volatility and at the same time higher market beta. Health care industry shows higher idiosyncratic volatility but lower market betas at the same time. This is not surprising given high research and development intensity of health care firms leading to higher firm specific uncertainty.

[6] For UK firms, studies such as Cotter et al. (2015) have used Industry Classification Benchmark (ICB) to classify industries. ICB is a globally classified standard managed by FTSE Russell.

[7] As per ICB, financial industry includes sectors such as banks, equity investment instruments, financial services, life insurance, non-life insurance, real estate investment and services, real estate investment trusts.

Figure 1. 3 – Mean breakdown of Idiosyncratic Volatility over industries

This figure shows the mean annualised idiosyncratic volatility of firms belonging to 10 industry categories. Industry categories are based on Industry Classification Benchmark (ICB). Idiosyncratic volatility is computed using the Fama-French (1986) model as per equation (1). The percentage of the firms in each industry in our sample is as follows: Financials=46.36%, Utilities=1.16%, Consumer Goods=5.96%, Consumer Services=14.40%, Industrials=18.21%, Oil and Gas=2.81%, Health Care=2.98%, Telecommunications=0.99%, Basic Materials=4.64% and Technology=2.48%.

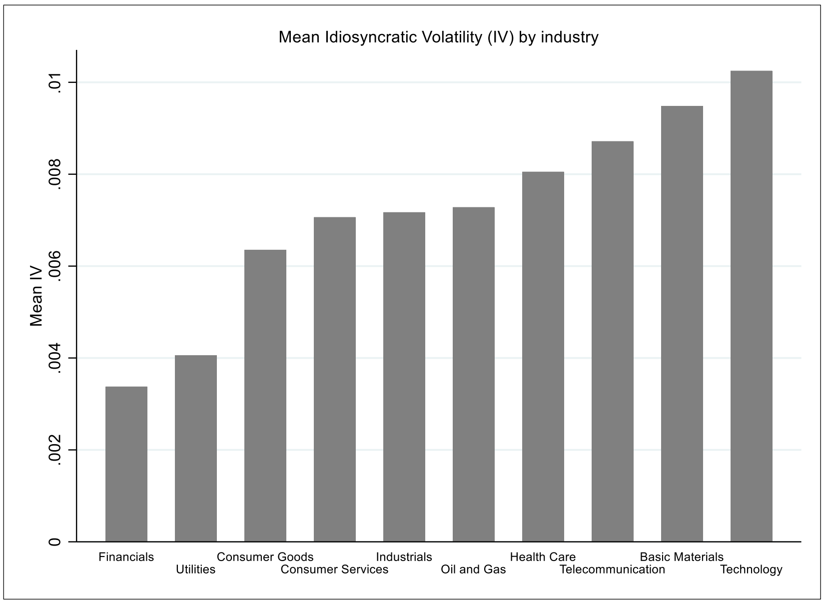
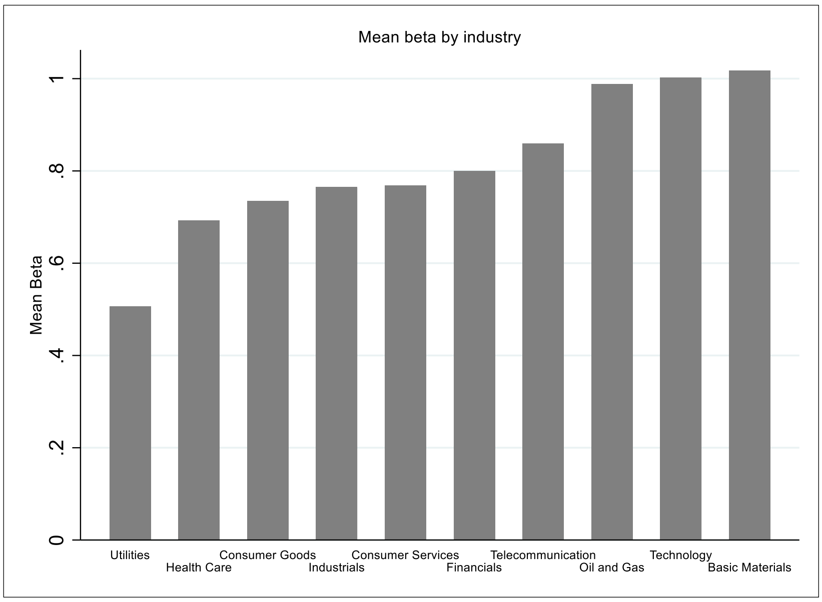


Figure 1. 4 – Mean breakdown of beta based on industry

This graph shows the mean market beta of firms belonging to 10 industry categories. Industry categories are based on Industry Classification Benchmark (ICB). Beta is the factor loading of excess market return (MKT) in the Fama-French (1986) model as per equation (1). The percentage of the firms in each industry in our sample is as follows: Financials=46.36%, Utilities=1.16%, Consumer Goods=5.96%, Consumer Services=14.40%, Industrials=18.21%, Oil and Gas=2.81%, Health Care=2.98%, Telecommunications=0.99%, Basic Materials=4.64% and Technology=2.48%.



1.5 Alternative Investment Market (AIM)

London Stock Exchange's (LSE) Alternative Investment Market (AIM) was established in 1995 to allow smaller growing companies to float their shares in order to raise capital to fund their growth. According to the latest monthly statistics published by the AIM for December 2019, the total number of firms listed in this junior exchange equals to 863 with a market capitalisation of £104,228 million. It consists of 740 UK firms and 123 international firms. To date, the total number of new issues in the AIM totals 3,869 with over £115,683 million being raised so far.

The AIM model rests on two pillars; low admission requirements and low disclosure requirements (Revest and Sapio, 2013). It consists of firms from high growth industries such as technology, clean technology and bio technology and it is also referred as the 'European NASDAQ'. Mendoza (2008, p. 261) criticises the "one-size-fits-all approach that prevails in the U.S. securities regulation" and appraises AIM as the alternative solution to this problem.

Despite high level of investor protection provided by primary exchanges, countries are considering alternative regulatory structures to lower the cost of raising capital and their effective monitoring (Gerakos, Lang and Maffett, 2012). Increasingly, companies seek to raise capital in alternative exchanges especially due to the light regulatory structure (Campbell and Tabner, 2014). In fact, Piotroski and Srinivasan, (2008) predict that smaller foreign firms are likely to choose AIM-listing over a regulated exchanges in the US in favour of less stringent governance. AIM's investor base is largely comprised of institutional investors and wealthy individuals (Mendoza, 2008). Since AIM provides less regulatory burden, it could be possible that the volatility of the market and individual firms are subjected to manipulation by institutional investors.

While AIM listed firms are known to grow faster than comparable private companies, they struggle in terms of productivity (Revest and Sapio, 2013). Underperformance of AIM firms compared to firms listed in the traditionally regulated primary exchange has been also highlighted in studies by Piotroski, (2012) and Gerakos, et al., (2013). Although there is substantial discussion about the regulatory environment in business press and legal literature, there is very little empirical evidence on the performance of AIM listed firms and to the best of our knowledge, no empirical evidence on idiosyncratic volatility dynamics and the investment behaviour of these firms.

1.6 Contribution of the thesis

Motivated by the evidence that idiosyncratic volatility is a priced factor in the cross-section of returns and that investors are exposed to it, this thesis is intended to study the behaviour of idiosyncratic volatility of UK firms listed on both the primary and the alternative exchange and provide important implications to corporate decisions. The contribution of the chapters of this thesis are outlined below.

Chapter 2 explores the determinants of idiosyncratic volatility using a large cross-section of UK stocks. While extant literature has derived most of its findings based on a sample before the financial crisis, we use an extended sample period between 1998 and 2015 to understand the cross-sectional dynamics of idiosyncratic volatility. We identify a number of firm characteristics that are associated with firm-specific uncertainty, and examine their predictive power in estimating the cross-sectional variation in idiosyncratic volatility.

The general observation is that idiosyncratic volatility has increased over the years especially in the late 1990's. A number of studies attribute this to various factors. Brown and Kapadia (2007) argue that the number of riskier firms in the economy is significantly increasing. In favour of this argument, Fink et al., (2010) shows that the age of a typical firm at IPO has declined in the recent years. However, Bartram, Gregory and Stulz (2018) show that idiosyncratic volatility levels has been historically lower during 2013-2017 in the US equity market. They argue that this is attributable to significantly lower number of listed firms since the late 1990's with public firms becoming larger and older. Another observation in idiosyncratic volatility levels has been around financial crises. It is very high during the crisis and then followed by a period of significantly lower level of volatility (Fox, Fox and Gilson, 2016; Bartram, Gregory and Stulz, 2018). Motivated by these findings, this chapter focuses on the determinants of idiosyncratic volatility in the UK equity market and whether this relationship is affected by the recent 2007-08 global financial crisis.

The results show that idiosyncratic volatility in the UK has been significantly low following the 2007-08 financial crisis. Our cross-sectional analysis suggests that firm characteristics can explain over 37% of the variation in idiosyncratic volatility. A given equity is likely to have high idiosyncratic volatility if associated with high book-to-market ratio, small firm size, high share turnover, low earnings, has paid dividend and operates in a non-regulated industry (where regulated industries are classified as financials and utility industries). While the aggregate idiosyncratic volatility has dropped significantly after the financial crisis and has returned to pre-crisis levels, average firm-level idiosyncratic volatility has remained relatively the same. Around 42% of the variation in post-crisis volatility levels can be explained through changes in firm characteristics, a 7% higher than pre-crisis levels. Our results are robust to alterative measures of idiosyncratic volatility. Our findings imply that the role of firm-specific factors that drive cross-sectional variation in idiosyncratic volatility has shifted significantly after the financial crisis. The sign of the coefficient estimates are in line with the theoretical priori and empirical evidence reported in relevant literature.

Chapter 3 examines the role of financial constraints in the fundamental relationship between firm size, firm age and idiosyncratic volatility. Li and Zhang (2010) show that theories of investment frictions and limits-to-arbitrage are likely to overlap since different frictions focused by these theories may coexist in firms. For instance, according to the asset pricing literature, it is a stylized fact that small and young firms have high idiosyncratic volatility due to risky and volatile fundamentals. On the other hand, corporate finance literature suggests that small and young firms tend to be more financially constrained. Since financial constraints are unobservable and generally measured by observable proxies, it is likely that some of the variables used as traditional proxies for financial constraints may be driving firm-specific volatility. For example, Li and Luo (2016) provides convincing evidence that firms with a high level of cash holding typically have high idiosyncratic volatility. However, level of cash holding is one of the most commonly used proxy for financial constraints in the corporate finance literature. Therefore, the mosaic of evidence in the literature points to the importance of segregating the effect of financial constraints from firm characteristics that are known to predict idiosyncratic volatility. Motivated by this, we formally test the role of financial constraints and whether it affects the predictive power of well-known determinants of idiosyncratic volatility.

The results show that the relationship between firm size, firm age and idiosyncratic volatility remains robust and negative even in the presence of financial constraints. Using data from UK listed firms for the period 1996 to 2017, we capture the moderating role of financial constraints using interaction terms between firm size and financial constraints, and firm age and financial constraints. While small and young firms have high IV but this relationship gets stronger when the firm faces a high level of financial constraints. Similarly, we find that this negative relationship gets weaker and even reverses for firms with very low levels of financial constraints. Our findings are robust to alternative measures of financial constraints. As such, we provide important implications to the literature that the presence of greater financial constraints reinforces and strengthens the well-known negative firm size-idiosyncratic volatility or firm age- idiosyncratic volatility relationship.

Chapter 4 explores the investment behaviour of firms listed on London Stock Exchange's (LSE) Alternative Investment Market (AIM). AIM was established for the purpose of helping smaller and growing companies to raise capital under a less stringent regulatory environment. Despite the light regulatory structure and subsequent lower cost of compliance, AIM firms are known for their low productivity and underperformance when compared to similar private firms or firms listed on the primary exchange (Gerakos, Lang and Maffett, 2012; Piotroski, 2012; Revest and Sapio, 2013). Given that AIM firms are young and generally small compared to listed firms in the main exchange, and our previous studies suggest that such firms generally have high idiosyncratic volatility, we formally test the investment behaviour of AIM firms when they are faced with firm-specific uncertainty. Following the importance of product market competition highlighted in the literature in shaping corporate investment decisions, we further test the role of firms' competitive position on the relationship between corporate investments and firm-specific uncertainty.

The results show that AIM firms reduce capital investments when firm-specific uncertainty is high. This behaviour is in line with the real options theory which suggests that firms delay investments under uncertainty as 'option' value is created by waiting and is consistent with the behaviour of firms listed on the primary exchange. Introducing competition provides an interesting perspective to our findings. While there are incentives to delay investments according to the irreversibility channel, when firms expect its rivals to invest, it may act faster as a strategic response to face competition (Ghosal and Loungani, 1996). In line with this prediction, we show that when firms' competitive position increases, the negative investment-uncertainty relationship gets weaker. In other words, while an average firm delays its investment plans when uncertainty is high, firms with a substantial competitive position are able to raise their investment levels. These findings are robust to alternative measures of competitive position. We contribute to the literature by providing first empirical evidence on the investment behaviour of small and growing firms listed on a junior exchange such as the AIM. Our study points to the importance of effective competition policies for stimulating investment behaviour of AIM firms under uncertainty.

2. CHAPTER 2 – DETERMINANTS OF IDIOSYNCRATIC VOLATILITY DYNAMICS: EVIDENCE FROM THE UK EQUITY MARKET

2.1 Abstract

Following the 2007-08 global financial crisis, the aggregate idiosyncratic volatility in the UK financial market has been significantly low; a similar trend to that of US. We examine in this paper whether the crisis has led to a shift in the dynamics of firm fundamentals. We estimate firm-level idiosyncratic volatility for a large cross-section of UK stocks and investigate the role of firm-specific characteristics in driving the variation in idiosyncratic volatility. Our cross-sectional analysis suggests that the role of these characteristics has changed significantly over the course of the recent financial crisis. Around 42% of the variation in post-crisis idiosyncratic volatility can be explained through changes in firm characteristics; 7% higher than pre-crisis levels. Stocks with high post-crisis idiosyncratic volatility are those with high book-to-market ratio, small firm size, low earnings, high previous period volatility and those operate in a non-regulated industry and do not pay dividends. These characteristics serve as useful tools in predicting relative idiosyncratic risk of UK securities for portfolio selection needs. Our conclusions are robust to alternative specifications of idiosyncratic volatility.

2.2 Introduction

We estimate firm-level Idiosyncratic Volatility (IV) of UK stocks and examine the role of firm-specific characteristics in explaining cross-sectional variation in IV. We find that an average security is likely to have high IV if it is associated with high book-to-market ratio, small firm size, high share turnover, low earnings and high previous period IV. We observe that aggregate IV has significantly dropped after the 2007-2008 global financial crisis. Motivated by this, we further test whether the role of firm characteristics has changed as a result of the crisis. We find strong evidence for a dramatic shift in the explanatory power of firm characteristics that drive variation in IV. Our study provides first empirical evidence on the determinants of IV for the UK equity market covering a sufficient period throughout the course of the recent financial crisis. Our findings therefore have important implications for investors and researchers in understanding volatility dynamics of UK securities.

IV is the component of a firm's total volatility driven by risk factors specific to a firm as opposed to common risk factors in the market (Becchetti et al., 2015; Cotter et al., 2015). Since IV is firm-specific and is not directly observable, extant literature has explained the variation in IV using firm fundamentals. Recently Bartram, Gregory and Stulz (2018) argue that the historically low IV in US in the recent years is due to dramatic changes in the number and composition of listed stocks and can be explained through firm characteristics. Using panel estimations, they show that characteristics of listed securities can explain around 28% of the variation in firm-level IV. Similarly, Kumari, Mahakud and Hiremath, (2017) provides an emerging market's evidence from the Indian stock exchange that firm fundamentals account for around 34% of the variation in IV. On the other hand, using aggregate IV of US stocks in a pooled OLS estimation, Bekaert, Hodrick and Zhang, 2012 show a predictive power of firm characteristics of up to a 55%-60%. All of the above evidence suggest that IV is not constant through time; it varies across countries; and sensitive to the estimation method used (Ang *et al.*, 2006; Irvine and Pontiff, 2009; Bali *et al.*, 2005; Bekaert, Hodrick and Zhang, 2012). In this light, we contribute to the IV literature in the following ways.

First: We estimate IV for a large cross-section of UK stocks and examine their cross-sectional determinants. Despite the high correlation in IV between UK and US, studies have reported different behaviour of aggregate IV among these countries (Guo and Savickas, 2008; Bekaert, Hodrick and Zhang, 2012). For instance, Bekaert, Hodrick and Zhang, (2012) show that IV levels in the UK is much lower than US and it does not display a deterministic trend similar to the US market as reported by Campbell *et al.*, (2001). Given the differences in aggregate IV, we argue that the determinants of firm-level factors might as well vary. While the empirical evidence on the determinants of IV is predominantly based on US data (see for instance Rubin and Smith, 2011; Bekaert, Hodrick and Zhang, 2012; Vozlyublennaina, 2013; Bartram, Gregory and Stulz, 2018 among others), our study focuses on the UK market. Following the literature, we choose a number of well-researched firm characteristics; book-to-market ratio, firm size, share turnover, earnings-per-share, leverage and firm age in order to explain the variation in IV for UK stocks. We also include two indicator variables; First indicator to identify firms that operate in non-regulated industries and the other to identify firms that pay dividends. Our cross-sectional analysis suggests that all of the considered firm characteristics except for leverage and firm age are significant drivers of cross-sectional variation in IV of UK stocks. Our findings are robust for alternative estimations of IV.

Second: We examine whether the role of firm characteristics in explaining the cross-sectional variation in IV has changed over the course of the recent global financial crisis. After the dramatic increase in aggregate IV during the financial crisis, Bartram, Gregory and Stulz (2018) show that aggregate IV in the US has returned to historically low levels in the recent years. We observe a similar trend in the UK. By using a sample period that is sufficient to capture the financial crisis, we examine whether the role of these firm characteristics have changed throughout the crisis. While none of the firm characteristics are significant during the crisis period, we find that the explanatory power of these characteristics have increased significantly after the crisis compared to pre-crisis levels. This increase corresponds with a combination of certain firm characteristics gaining/losing explanatory power. For instance, the explanatory power has significantly increased after the crisis for book-to-market ratio and firm size while it has decreased for turnover.

The remainder of this paper is organised as follows. Section 2 provides a brief literature review. Section 3 presents the data, construction of idiosyncratic volatility and descriptive statistics. Section 4 provides the empirical methodology along with the discussion of results while section 5 concludes.

2.3 Literature Review

Conventional asset-pricing theories suggest that idiosyncratic risk can eliminated through portfolio diversification and only systematic risk factors are priced in equilibrium. However, extant literature has provided convincing evidence that Idiosyncratic Volatility (IV) is a priced factor (Bali et al., 2005; Ang et al., 2006; Angelidis and Tessaromatis, 2008; Cotter, Sullivan and Rossi, 2015; Bhamra and Shim, 2017). Investors are exposed to IV since they are generally constrained from holding an optimal portfolio which eliminates idiosyncratic risks. Some of the reasons include wealth constraints, obligations to hold or restrictions from holding certain stocks or stocks from certain industries, or choice of holding specific stocks[8].

In their seminal work, Campbell et al., (2001) suggest that IV constitutes the largest proportion of a firm’s total volatility and its above 70% of an average US firm. They also documented a positive deterministic trend in IV as opposed to market and industry volatilities for the period 1962-1997. Lebedinsky and Wilmes (2018) updates the findings of Campbell et al., (2001) using a recent sample which incorporates the two major stock market events; the Dot-com Bubble and the 2007-2008 financial crisis. They show that both those crises led to larges spikes in idiosyncratic component of the total volatility of a stock. In terms of UK market, Angelidis and Tessaromatis (2008) provides similar evidence of a positive trend in IV over 1979-2003 and suggests that this component accounts for 75% to 95% of the total volatility of an average UK listed firm.

[8] See Campbell *et al.*, 2001 and Xu and Malkiel, 2003 for a comprehensive discussion

The largest strand of the IV literature focuses on the asset-pricing implications; largely whether it is positively or negatively priced in the cross-section of expected stock returns and the possible explanations. The previous evidence on the price of IV in the cross-section of stock returns is mixed. While some studies document a positive return-IV relationship (see for instance, Malkiel and Xu, 2002; Goyal and Sant-Clara, 2003; Fu, 2009), some document a negative relationship (Ang et al., 2006; Bharma and Shim, 2017). On the other hand, Bali et al., (2005) argue that there is no significant relationship between IV and returns and the previous findings were completely driven by small stocks traded on NASDAQ. Although limited, existing literature concludes that IV is negatively priced in the UK. For instance, in a cross-section of G7 countries, Guo and Savickas, (2007) show that aggregate IV levels in the UK are much lower than that of US and returns relate inversely to IV. Similarly, Cotter et al., (2015) provides convincing evidence that IV is negatively priced in a large cross-section of UK stocks.

The other strand of the literature explores the determinants of IV. While the existing evidence on the determinants is based on US data (Bekaert et al, 2012; Vozlyublennaia, 2013; Rubin and Smith, 2011), we contribute to this strand of the literature by focusing on a different developed equity market. In our study, we are interested in finding whether well researched firm-specific characteristics are significant drivers of the cross-sectional variation in IV of UK stocks. We follow the literature in identifying the following characteristics as explanatory variables in our study; Book-to-market ratio, firm size, share turnover, earnings-per-share, leverage, firm age and indicator variables; whether the firm operates in a non-regulated industry and pays dividend. We discuss in detail below each of the firm characteristics considered in our study and their association with IV.

Book-to-market – Evidence from the literature provides mixed results on the sign of the association between book-to-market ratio and IV. If book-to-market is considered as a proxy for growth opportunities, it is expected to be negatively related to IV (Pastor and Veronesi, 2002; Wei and Zhang, 2005; Brown and Kapadia, 2007; Cao et al., 2008). On the other hand, high book-to-market stocks can be a result of low prices. Since low-priced stocks are attractive for speculative trading, it is expected to be positively related to IV (Brandt et al., 2010; Vozlyublennaia, 2013).

Firm size –Since small firms are generally young, opaque, financially constrained and have increasingly begun to issue equity earlier in their business life cycles, they are more vulnerable to market imperfections and therefore have high IV compared to large, matured firms with fewer financial constraints (Campbell et al., 2001; Brown and Kapadia, 2006; Denis and Sibilkov, 2010;Panousi and Papanikolaou, 2012).

Turnover – Share turnover is a proxy for stock liquidity. Although a noisy proxy, literature has predominantly used share turnover as a measure of stock liquidity (Dennis and Strickland, 2004; Ang et al., 2006; Brown and Kapadia, 2007; Brandt et al., 2010). Some investors use price movements as information to make trading decisions (Schwert, 1989). Therefore, higher price movements lead to higher share turnover and thus result in high IV (Rubin and Smith, 2011; Vozlyublennaia, 2013). On the other hand, Bekaert et al., (2012) also suggest that increased turnover might be associated with higher IV in a more developed and efficient market structure.

Earnings per share – The growth in firm IV observed in the past decades is well accounted by deteriorating firm-level earnings (Wei and Zhang, 2006; Brown and Kapadia, 2007). Since earnings reflect information on future profitability of firms, high earnings signal good times ahead and therefore resulting in low firm IV. This negative association between earnings and IV is well established in the literature (Wei and Zhang, 2006; Irvine and Pontiff, 2009; Brandt et al., 2010; Rubin and Smith, 2011).

Leverage – Literature has provided mixed evidence on the association between financial leverage and firm IV. Since high levels of debt indicate a highly risky capital structure, leverage is expected to have a positive association with volatility (Dennis and Strickland, 2004; Brown and Kapadia, 2007; Bartram, Gregory and Stulz, 2018). However, Brandt *et al.*, (2010) finds that high levels of debt reduces IV. This is a plausible explanation if obtaining additional debt indicates that the security should have lower idiosyncratic risk.

Age – The extant empirical evidence documents a negative association between firm age and idiosyncratic volatility. Since investors learn about profitability over time, IV of firms tend to decrease as the firms mature (Fink *et al.*, 2010; Rubin and Smith, 2011; Pastor and Veronesi, 2003; Brown and Kapadia, 2007).

Not Regulated – We control for regulated industries in our regressions since firms from regulated industries are considered to be less volatile than firms from non-regulated industries (Rubin and Smith, 2011). Thus, we introduce an indicator variable that captures whether the firm operates in a non-regulated industry.

Dividend Paying – We also control for whether the firm is a dividend payer since firms that do not pay dividend has more volatile returns than firms that pay dividends (Pastor and Veronesi, 2003; Rubin and Smith, 2011). Therefore, we introduce an indicator variable that captures whether the firms pays dividend in a given period.

This study contributes to the literature by re-examining the determinants of firm-level idiosyncratic volatility. While, existing literature suggests that idiosyncratic volatility varies across countries and is contingent on factors such as the estimation method used and sample period employed, bulk of the empirical evidence is based on US data (Ang *et al.*, 2006; Irvine and Pontiff, 2009; Bali *et al.*, 2005; Bekaert, Hodrick and Zhang, 2012). Therefore, we provide first empirical evidence on the determinants of idiosyncratic volatility for the UK equity market covering a sufficient period throughout the course of the recent financial crisis.

2.4 Data

2.4.1 Construction of firm Idiosyncratic Volatility (IV)

We obtain daily stock prices data of FTSE All-Share index constituents[9] in the UK from Bloomberg[10]. Daily Fama-French (FF) factors and risk-free rates for the period Jan 1998 to Jun 2015 are from the website for the Xfi Centre for Finance and Investment, constructed and well documented by Gregory et al. (2013) for the UK market[11]. The sample period was chosen in order to allow for sufficient years of observations before and after the 2007-08 Global Financial crisis. For each stock, we first calculate the daily excess stock returns by subtracting the risk-free rate. We then use these daily excess stock returns to estimate monthly Idiosyncratic Volatility (IV) of a firm using Fama-French three-factor (FF-3) (1996) model, an approach adopted by this stream of literature (see e.g., Ang et al., 2006; Cao et al. 2008; Bekaert et al., 2012; Bharma and Shim, 2017 among others)[12]. The model for excess stock returns of individual firm *j* on day *t* is,

[9] From the original sample of 629 constituents, firms with missing data were removed and thereby resulting in a final sample of 604 firms.

[10] For their studies on developed markets, Fama and French (2012) have used Bloomberg to obtain returns and accounting data. Cotter et al. (2015) reported Bloomberg as a reliable source for stock-level data for the UK.

[11] We obtain the Fama-French factors for the UK market from the Xfi Centre for Finance and Investment, University of Exeter described by Gregory et al., (2013).

[12] We also estimate IV using CAPM and Carhart 4-factor model (1997) as part of our robustness tests. Our results largely remain the same irrespective of the market models used to estimate IV. We report the results in the Appendix.

$$\mathrm{R}_{j,t} = b_{0,j,m} + b_{1,j,m}\mathrm{MKT}_t + b_{2,j,m}\mathrm{SMB}_t + b_{3,j,m}\mathrm{HML}_t + u_{j,t}^{FF}, \quad (1)$$

where day *t* belongs to month *m*. MKT_t is the excess market return of FTSE ALL-Share index over the risk-free rate, SMB_t is the size factor which captures the difference in the returns between small versus big stocks and HML_t is the value factor which captures the difference in the returns between high versus low book to market equity stocks. The IV of firm *j* is then calculated as within-the-month the variance of the daily residual $u_{j,t}^{FF}$,

$$\mathrm{IV}_{j,m} = \sigma^2\left(u_{j,t}^{FF}\right) \quad (2)$$

We provide the brief historical summary of aggregate IV in the UK from 1998-2015 in in this section. We aggregate IV of our sample firms in two ways; using an equal-weighted and a value-weighted measure as described in detail below. Our first equal-weighted IV measure, we follow Goyal and Santa-clara, (2003) and Bali et al., (2005) to aggregate firm IV every month as follows;

$$\mathrm{IV}_{ew,m} = \frac{1}{N}\Sigma_{j=1}^{N}\mathrm{IV}_{j,m} \quad (3)$$

where *N* is the number of stocks traded in month *m*. Bali et al., (2005) empirically show that an equal-weighted average stock variance is not a robust measure mainly due to inflated underlying volatility caused by large bid-ask bounce from small and illiquid stocks. Thus, they recommend using a value-weighted measure that is less affected by microstructure noises. Therefore, we construct our second value-weighted measure following Bali et al., (2005), Cao et al., (2008). The monthly value-weighted IV is aggregated as follows;

$$\mathrm{IV}_{vw,m} = \Sigma_{j=1}^{N} w_{j,m}\,\mathrm{IV}_{j,m}\ , \quad (4)$$

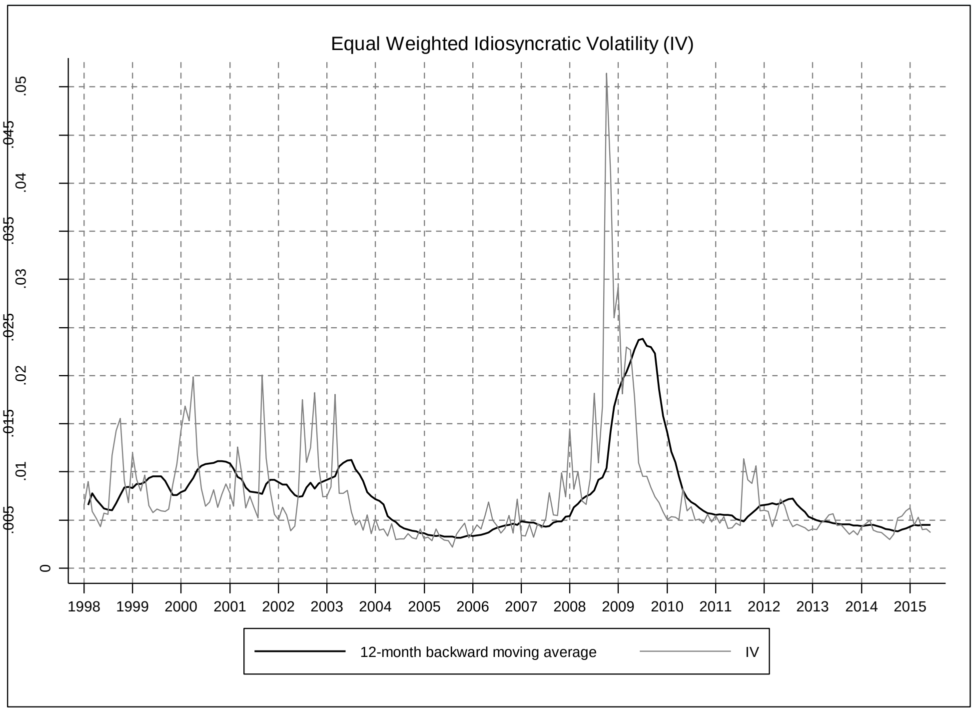
where the weight $w_{j,m}$ is computed using firm j's previous month market capitalization. We plot the equal-weighted and value-weighted annualized means of monthly IV time series in Figure 2.1[13]. The figure shows the raw (light line) and the 12 month backward moving average (dark line) of the monthly time series of IV from Jan 1998 through Dec 2015.

[13] We provide the equal-weighted and value- weighted IV for descriptive purposes in order to understanding the aggregate IV levels in the UK. Exploring the time series dynamics of aggregate IV is beyond the scope of this paper.

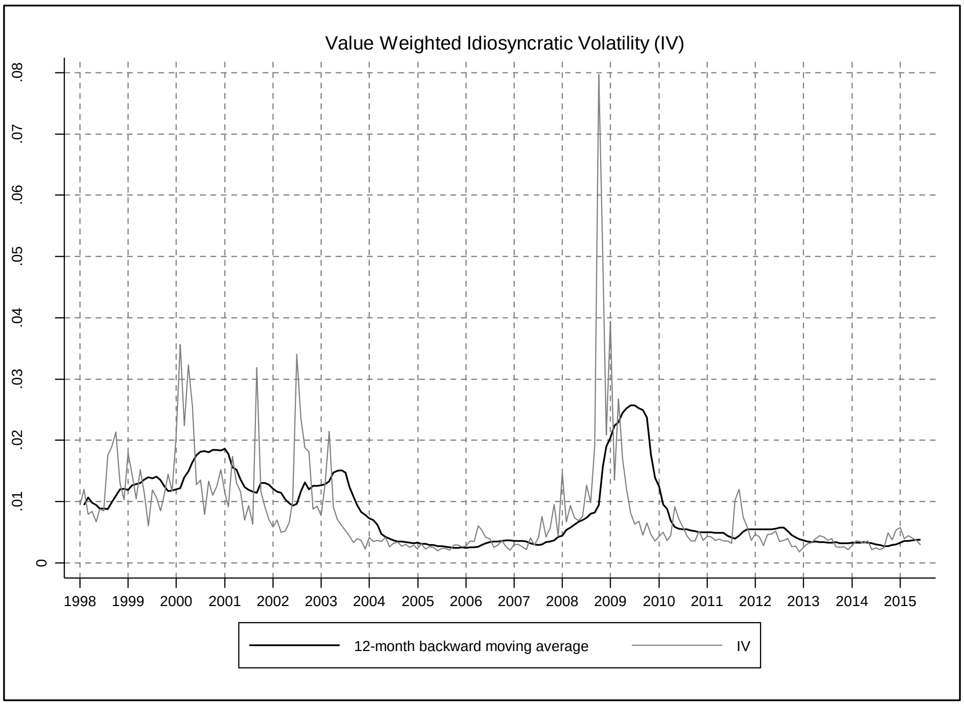
Figure 2. 1 – Idiosyncratic Volatility (IV) over time

This figure presents the monthly time series of aggregate idiosyncratic volatility (IV) (light line) and the 12-month backward moving average of this measure (dark line) for each month between Jan 1998 and Jun 2015 for FTSE All-Share stocks in our sample. Graph A of figure 1 plots the equal-weighted IV outlined in equation (3) and graph B of figure 1 plots the value-weighted IV outlined in equation (4). Both the volatility time series are annualised. Firm IV is estimated relative to FF-3 model detailed in equations (1) and (2).

Graph A



Graph B



We perform the Augmented Dickey-Fuller test for both equal-weighted and value-weighted time series of average idiosyncratic volatility in order to check for the check the presence of stochastic trends. We reject the null hypothesis of unit root at the 1% significance in both the constant and trend specifications. For both specifications, we choose the number of lags using the Schwartz-Bayesian criterion which suggests the best model is the one including 1 lag. Similar to Guo & Savickas (2008) and Bekaert et al. (2012) we conclude that the both equal-weighted and value-weighted time series of idiosyncratic volatility are stationary.

From Figure 2.1, we observe the highest level of idiosyncratic volatility during the recent financial crisis. This observation is in line with the literature (Fox, Fox and Gilson, 2016; Bartram, Gregory and Stulz, 2018). Long lasting periods of higher volatility are also evident earlier in the sample from 1998 till early 2003 due to the Russian financial crisis in 1998, Dot-com bubble in 2000, economic repercussions of the 9-11 attacks in 2001 and the worldwide stock market downturn in 2002. During crisis periods, it is visible that equal-weighted IV is higher than the value-weighted IV. During the non-crisis periods, both the measures move closely with one another. Nevertheless, the striking observation is that the aggregate IV has dropped substantially after the recent financial crisis. This pattern is very similar to that of US reported in Bartram, Gregory and Stulz, (2018). The results on the role of firm-characteristics in the post-crisis IV regime is explored in detail in Section 4.

2.4.2 Firm characteristics

We collect semi-annual data from Bloomberg to compute the firm characteristics measures Jan 1998 and Jun 2015. In the UK, public firms are required to prepare and file audited interim reports every 6 months. Interim reports should include condensed financial statements and a ‘management report’, which summarises important events that had occurred during the 6 months, the impact of these events on financial statements and a description of principle risks and uncertainties for the remaining 6 months of the financial year (LSE, 2020). Semi-annual reports provides important information to investors regarding the firm, which in turn affects stock returns. Therefore, this study incorporates this additional disclosure information available for firm-level data at semi-annual frequency.

The firm characteristics used in this study are defined as follows; firm size is the logarithm of market capitalization, book-to-market is the ratio of book value to market value of equity, turnover is the ratio of trading volume to total number of shares outstanding over the previous period, earnings per share, leverage is the logarithm of 1 plus long term debt divided by total assets, firm age is the logarithm of 1 plus number of semi-annual periods since the firm's incorporation and 2 indicator variables; the first identifies whether the firm operates in a non-regulated industry[14] (i.e. industries other than utilities and financials) and the second identifies whether the firm is a dividend payer. To mitigate the impact of outliers, we exclude observations at both above and below 1% of the distribution for each variable by each semi-annual period. Table 2.1 provides the descriptive statistics of IV and firm characteristics. Additionally, in Table 2.2 we also provide a breakdown of the descriptive statistics before and after the financial crisis.

[14] Regulated and non-regulated industries are defined based on whether the firms in the industry are free to make its operational and capital structure choices. This distinction is widely followed in the corporate finance literature, which classifies utility and financial industry as regulated industries (Rubin and Smith, 2011).

Table 2. 1 – Descriptive Statistics

This table presents summary statistics of individual firm idiosyncratic volatility (IV) and firm characteristics for FTSE All-Share stocks which are used in cross-sectional tests. The sample period is Jan 1999 to Jun 2015. Firm IV is estimated relative to FF-3 model detailed in equations (1) and (2). The firm characteristics are as follows; book-to-market (BM) is the ratio of book value to market value of equity, firm size is the logarithm of market capitalisation, turnover is the ratio of trading volume to total number of shares outstanding over the previous period, EPS is earnings per share, leverage is the logarithm of 1 plus long term debt divided by total assets, firm age (Age) is the logarithm of 1 plus number of bi annual periods since the firm's incorporation and an indicator variable of whether the industry where the firm operates is regulated.

	Mean	SD	Median	Min	Max
IV	0.006	0.003	0.012	0.000	0.631
Book-to-market	0.610	0.447	0.780	0.001	41.152
Size	6.763	6.616	1.831	1.525	12.564
Turnover	0.410	0.314	0.339	0.000	4.579
EPS	0.198	0.099	1.067	-32.673	44.400
Leverage	2.267	2.742	1.390	0.000	5.122
Age	3.619	3.638	1.257	0.000	5.613

Mean IV is 0.06 for our sample and it is comparable with existing literature (Angelidis and Tessaromatis, 2008; Guo and Savickas, 2008; Bekaert, Hodrick and Zhang, 2012; Cotter, Sullivan and Rossi, 2015). While post-crisis IV is higher than the pre-crisis levels, the difference is not statistically significant. We find that the means of book-to-market ratio, firm size, and firm age during post-crisis period are significantly higher and turnover is significantly lower than pre-crisis levels. The 16% increase in book-to-market levels after the financial crisis appears to be contrasting from US data reported by Bartram, Gregory and Stulz, (2018). They report a decrease in book-to-market ratio from the period 1996-2000 to 2013-2017. Therefore, we expect this increase in the mean book-to-market ratio for UK stocks might have an impact on the explanatory power after the crisis.

Table 2. 2 – Difference in firm characteristics before and after the financial crisis

	Mean Before Crisis	Mean After Crisis	Difference	*t*-value
IV	0.560	0.586	0.026	1.270
Book-to-market	0.542	0.627	0.085	5.798***
Size	6.494	7.026	0.532	14.392***
Turnover	0.481	0.296	-0.186	-32.398***
EPS	0.215	0.208	-0.007	-0.313
Leverage	2.229	2.272	0.043	1.496
Age	3.593	3.641	0.048	2.219**
	No of Obs. Before Crisis	No of Obs. After crisis		
Not regulated	5,389	4,121		
Div.paying	5,286	2,592		

2.4.3 Firm idiosyncratic volatility (IV) and firm characteristics by industry

In this section, we provide descriptive statistics of firm IV and characteristics based on their industries. We use the Industry Classification Benchmark (ICB) system of 10 industries to identify the industry of a firm. Table 2.3 presents the univariate comparison of the pooled sample means of IV and firm characteristics by industry. High levels of IV are pronounced in technology, basic materials, health care, oil and gas and telecommunication industries which are considered to be high growth industries (Chan et al., 2001; Grullon et al., 2012). As expected in high growth industries, the book-to-market ratios appear to be quite low. Firm size is high in industries with a larger asset base and appears to be comparable across industries. Turnover appears comparable across industries with the highest turnover observed in utilities and the lowest in financials industries. Technology and telecommunication industries have lower earnings-per-share while the highest is the oil and gas. Leverage appears comparable across industries with the lowest leverage seen in some of the high growth industries such as technology and health care. Finally, firm age appears comparable across industries with a general pattern of young firms concentrated in high growth industries.

Table 2. 3 – Univariate comparison of firm characteristics by industries

This table presents the pooled sample means of firm idiosyncratic volatility (IV) and firm characteristics for FTSE All-Share stocks sorted based on industries. We use the Industry Classification Benchmark (ICB) system to classify firms into industries. Sample period is Jan 1999 to Jun 2015. Firm IV is estimated relative to FF-3 model detailed in equations (1) and (2). The firm characteristics are as follows; book-to-market (BM) is the ratio of book value to market value of equity, firm size is the logarithm of market capitalisation, turnover is the ratio of trading volume to total number of shares outstanding over the previous period, EPS is earnings per share, leverage is the logarithm of 1 plus long term debt divided by total assets, firm age (Age) is the logarithm of 1 plus number of semi-annual periods since the firm's incorporation and an indicator variable of whether the industry where the firm operates is regulated.

	IV	BM	Size	Turnover	EPS	Leverage	Age
Technology	0.0148	0.392	5.997	0.406	0.082	1.168	3.280
Basic Materials	0.0110	0.622	7.395	0.441	0.305	2.249	3.426
Health Care	0.0094	0.356	7.184	0.349	0.295	1.784	3.238
Oil and Gas	0.0088	0.622	8.100	0.456	0.382	1.982	3.033
Telecommunication	0.0087	0.632	8.252	0.408	0.080	2.742	3.013
Consumer Service	0.0084	0.531	6.833	0.494	0.174	2.501	3.505
Industrials	0.0079	0.539	6.077	0.392	0.135	2.287	3.885
Consumer Goods	0.0071	0.690	6.918	0.455	0.218	2.164	3.894
Utilities	0.0040	0.426	8.546	0.579	0.260	3.402	3.080
Financials	0.0037	0.835	6.918	0.336	0.237	2.230	3.617

2.5 Methodology, findings and discussion

2.5.1 Baseline empirical specification

We examine the conditional relationship between firm IV and firm characteristics using Fama-MacBeth (1973) cross-sectional estimations. The dependent variable in these regressions is firm IV estimated using FF-3 model as detailed in Section 2.4.1. In order to merge the monthly IV series with the semi-annual firm characteristics, we take the average IV within the semi-annual period as suggested by the literature (See for instance Brown and Kapadia, 2006; Vozlyublennaia, 2013 among others). The explanatory variables are one period lagged firm characteristics as defined in Section 2.4.2. Lagged independent variables are used in all our empirical estimations to avoid potential endogeneity concerns. We also control for high persistence of IV by including one period lagged IV as an independent variable (see Brandt et al., 2010; Fink et al., 2010; Vozlyublennaia, 2013).

The model for Idiosyncratic Volatility (IV) of firm *j* at semi-annual period *h* is as follows;

$$IV_{j,h} = \omega_{0,h} + \omega_{1,h}.IV_{j,h-1} + \omega_{2,h}.Size_{j,h-1} + \omega_{3,h}.Book-to-market_{j,h-1} + \omega_{4,h}.Turnover_{j,h-1} + \omega_{5,h}.EPS_{j,h-1} + \omega_{6,h}.Leverage_{j,h-1} + \omega_{7,h}.Age_{j,h-1} + \omega_{8,h}.d.not\ regulated_{j,h-1} + \omega_{9,h}.d.dividend\ paying_{j,h-1} + e_{j,h} \quad (5)$$

We estimate the regressions in (5) semi-annually and report the time series means of the coefficient estimates along with *t*-statistics obtained using Newey-West autocorrelation and heteroscedasticity-consistent standard errors always allowing up to 4 lags.

While the existing literature has predominantly focussed on data before the financial crisis, we aim to find any sensitivity in the explanatory power of the determinants of IV after the crisis. For this, we follow Huang, Lin and Yang, (2015) to define the financial crisis period as Jul 2007 to Dec 2008. The period from Jan 1998 to Jun 2007 is defined as 'pre-crisis' and the period from Jan 2009 to Jun 2015 as 'post-crisis'. We re-run the same estimation in (5) for 3 sub-sample periods; pre-crisis, during crisis and post-crisis. The regression results are provided in the next section.

2.5.2 Results of baseline specification

Table 2.4 summarizes the results of our baseline estimation in (5). In order to investigate the impact of a certain firm characteristic on firm IV with and without the remaining characteristics, we do the following; we first run the baseline model with all the characteristics together and report the results in the first column. The subsequent columns include only one firm characteristic at a time and the results are reported in the appropriate columns. The baseline model is able to explain the highest cross-sectional variation of 37% in firm IV compared to the remaining models of single firm characteristics. All considered firm characteristics in the baseline model are statistically significant except for leverage and firm age. When considered alone, firm age becomes highly significant at 1% whereas leverage is not significant. The sign of the coefficient estimates of dividend paying dummy is negative and significant in the baseline model but positive and significant when considered alone. All of the remaining firm characteristics have stable coefficients.

Table 2. 4 – Idiosyncratic Volatility and Firm Characteristics

This table presents the Fama-MacBeth (1973) cross-sectional regressions of individual firm idiosyncratic volatility (IV) on lagged firm characteristics and lagged IV for FTSE All-Share stocks. Sample period is Jan 1998 to Jun 2015.The dependent variable is Firm IV is estimated relative to FF-3 model detailed in equations (1) and (2). The independent variables are book-to-market (BM), firm size, turnover, EPS, leverage, firm age (Age), an indicator variable if the industry is not regulated (Not Regulated) and whether the firm is a dividend payer (Div.paying). "*l*" indicates one period lagged value. We estimate the regressions semi-annually and report time series means of coefficient estimates along with *t*-statistics obtained using Newey-West autocorrelation-and-heteroscedasticity-consistent standard errors of coefficient estimates in parentheses. *** indicates significance at 1%, ** at 5% and * at 10%. R^2 refers to average semi-annualR^2.

		*l*_BM	*l*_Size	*l*_TO	*l*_EPS	*l*_Lev	*l*_Age	Not.Reg	D.payer
*l*_IV	0.412***	0.476***	0.468***	0.494***	0.487***	0.498***	0.502***	0.456***	0.496***
	(7.55)	(9.12)	(7.10)	(7.63)	(9.29)	(9.13)	(8.09)	(7.25)	(7.79)
*l*_BM	0.126**	0.125**							
	(2.31)	(2.43)							
*l*_Size	-0.027**		-0.045***						
	(-2.07)		(-3.91)						
*l*_TO	0.175*			0.080					
	(1.91)			(1.17)					
*l*_EPS	-0.117**				-0.164***				
	(-2.55)				(-3.13)				
*l*_Lev	-0.011					-0.018			
	(-1.33)					(-1.51)			
*l*_Age	-0.006						-0.034***		
	(-0.36)						(-3.84)		
Not.reg	0.132***							0.268***	
	(6.57)							(8.79)	
D.payer	-0.409***								0.070**
	(-3.99)								(2.47)
Constant	0.827***	0.348***	0.728***	0.369***	0.434***	0.443***	0.434***	0.185***	0.266***
	(7.43)	(6.34)	(6.52)	(6.41)	(7.99)	(8.95)	(7.90)	(5.72)	(7.94)
N	9002	9759	10496	11063	9976	9968	13968	15164	15164
No. *t's*	33	33	33	33	33	33	33	33	33
R^2	0.3730	0.279	0.279	0.2517	0.2566	0.2483	0.2895	0.3065	0.2793

Table 2. 5 – Idiosyncratic Volatility and Firm Characteristics: Before and after the financial crisis

This table presents the Fama-MacBeth (1973) cross-sectional regressions of individual firm idiosyncratic volatility (IV) on lagged firm characteristics and lagged IV for FTSE All-Share stocks. Sample period is Jan 1998 to Jun 2015. We define the period before financial crisis as Jan 1998 to Jun 2007 and period after crisis as Jan 2009 to Jun 2015. The dependent variable is Firm IV is estimated relative to FF-3 model detailed in equations (1) and (2). The independent variables are book-to-market (BM), firm size, turnover, EPS, leverage, firm age (Age), an indicator variable if the industry is not regulated (Not Regulated) and whether the firm is a dividend payer (Div.paying). "*l*" indicates one period lagged value. We estimate the regressions semi-annually and report time series means of coefficient estimates along with *t*-statistics obtained using Newey-West autocorrelation-and-heteroscedasticity-consistent standard errors of coefficient estimates in parentheses. *** indicates significance at 1%, ** at 5% and * at 10%. R^2 refers to average semi-annual R^2.

	Baseline model	Before crisis Jan 1999: Jun 2007	During crisis Jul 2007: Dec 2008	After crisis Jan 2009:Jun 2015
*l*_IV	0.412***	0.379***	0.620	0.406***
	(7.55)	(4.34)	(1.63)	(5.39)
*l*_BM	0.126**	0.0566	0.182	0.203**
	(2.31)	(0.79)	(1.19)	(3.01)
*l*_Size	-0.0265**	-0.00901	-0.0510	-0.0438***
	(-2.07)	(-0.47)	(-0.93)	(-10.84)
*l*_Turnover	0.175*	0.272**	0.0936	0.0675
	(1.91)	(2.25)	(1.01)	(0.45)
*l*_EPS	-0.117**	-0.174**	0.0763	-0.0877**
	(-2.55)	(-2.29)	(1.45)	(-2.64)
*l*_Leverage	-0.0107	-0.0168	-0.0113	-0.00250
	(-1.33)	(-1.25)	(-0.53)	(-0.21)
*l*_Age	-0.00570	-0.0177	0.0715	-0.00782
	(-0.36)	(-1.37)	(0.99)	(-0.33)
Not regulated	0.132***	0.123***	0.0795	0.155***
	(6.57)	(5.14)	(1.99)	(4.05)
Div.paying	-0.409***	-0.577***	-0.487	-0.171***
	(-3.99)	(-4.28)	(-1.97)	(-3.22)
Intercept	0.827***	0.911***	1.169*	0.637***
	(7.43)	(6.60)	(3.45)	(5.61)
N	9002	3684	909	4409
No. *t's*	33	17	3	13
R^2	0.3730	0.3542	0.2719	0.4208

In Table 2.5, we re-run our cross-sectional regressions for three different cohorts; pre-crisis, during crisis and post-crisis. The cohorts are defined as detailed in Section 2.5.1. One prominent observation is that none of the firm characteristics is significant during the financial crisis period. Although not statistically significant, the coefficient estimate on previous period IV has almost doubled during the crisis compared to before crisis period. However, we observe some significant variability in the explanatory power of firm characteristics before and after the crisis period. Before the crisis, all considered firm characteristics are able to explain 35% of variation in IV. However only turnover, EPS, non-regulated industry indicator, dividend paying indicator and previous period IV are statistically significant. After the crisis, the explanatory power of the model has increased to 42%. Book-to-market ratio and firm size enters the regression as statistically significant drivers whereas turnover loses its significant explanatory power.

Book-to-market ratio has a statistically significant, positive and stable coefficient in the UK cross-section. The coefficient is significant at 5% with and without controlling for remaining characteristics. Our results differ from the empirical evidence based on US data that suggest a negative relationship. This is because an increase in book-to-market could indicate that a stock is less likely to be a growth stock and therefore low IV. We argue alongside Brandt et al., (2010) and Vozlyublennaia, (2013) that stocks with increasing book-to-makret ratio are particularly attrcative to speculative trading due to their low prices and therefore tend to have high IV. We find that the 16% increase in mean book-to-market after the crisis corresponds with 3.6 times increase in the book-to-market coefficient estimate. Further the coefficient is statistically significant at 5% after the crisis. This significant increase is particular to UK stocks compared to US stocks where mean levels in book-to-market ratio has relatively remained the same in the US (Bartram, Gregory and Stulz, 2018). We therefore suggest that the positive coefficient reflects the unique firm composition in the UK equity market.

Our results confirm the negative association between firm size and IV well established in the literature (See Brown and Kapadia, 2006; Cao et al., 2008; Fink et al., 2010; Bekaert et al., 2012 among others). The coefficients on firm size is negative and statistically significant in the baseline model. When we split the sample, we find a similar effect to that of book-to-market. Post-crisis mean firm size is significantly higher and the coefficient estimate is almost 5 times higher and highly statistically significant compared to pre-crisis levels. Although negative, pre-crisis firm size is not statistically significant. The increase in firm size after the crisis is line with US evidence.

We find that stocks with high turnover correspond to high IV. Although weakly significant at 10% when we control for the remaining firm characteristics, it loses its significance completely when considered alone. We find that post-crisis mean turnover is significantly lower than pre-crisis levels. In line with the drop, we also find it loses its explanatory power completely after the crisis. Rubin and Smith, (2011) finds that, in the US, mean turnover increases almost twice after 1995 corresponding to a positive and significant coefficient in explaining cross-sectional IV. Our results therefore suggest that the significant explanatory power of turnover is due to increased trading activity in the pre-crisis period.

Our findings confirm the negative relationship between earnings and IV well established in the current literature. When considered on its own, earnings-per-share explains 16% of the variation and loses the explanatory power partly when we control for the remaining characteristics. However, it is statistically significant at 5% in the baseline model. While average earnings have dropped after the financial crisis, the drop is not statistically significant. We also find consistent evidence in terms of the explanatory power of earnings. The coefficient estimates has almost halved after the crisis but remains statistically significant at 5%; similar to pre-crisis levels. Our results suggest that earnings are a stable and robust determinant of cross-sectional IV.

Leverage enters the regression with a negative coefficient and the sign of the coefficient has remained stable across different specifications. While Brandt *et al.*, (2010) reports a negative but significant coefficient of leverage for US stocks, we do not find statistical significance in any of our specifications for UK stocks. Similarly, firm age enters the regression with a negative coefficient. Although when considered alone, firm age is statistically significant at 1% level, it loses the explanatory power when considered with remaining characteristics. While average age of our sample firms has increased after the financial crisis, we do not find any corresponding statistical significance explanatory power.

Throughout all our specifications, both the indicator variables are highly statistically significant. Our first indicator variable is non-regulated firms. In general, we find that firms operating in non-regulated industries tend to have approximately 12% higher IV compared to firms operating in regulated industries (financial and utility industries). This difference has increased to 16% post crisis. Rubin and Smith, (2011) reports similar findings for US stocks, however the difference is at most 6%. The systematic difference between non-regulated and regulated stocks in the UK therefore imply unique characteristics of the equity market. The second indicator variable is dividend paying firms. Our cross-sectional analysis suggests that dividend paying firms in general have 41% lower IV compared to firms that do not pay dividends. While the difference was at most 58% before the crisis, this has reduced to 17% post crisis. This drop corresponds with the significant drop in observations of dividend paying firms after the crisis. We suggest this could be a result of increased financial constraints faced by firms following the crisis. All our findings are robust to alternative specifications of IV[15].

Our findings are broadly consistent with the overall evidence from the US, especially before the financial crisis. While none of the firm characteristics is significant during the financial crisis period, there is a significant increase in the explanatory power firm characteristics after the financial crisis compared to pre-crisis period. Especially, Book-to-market ratio and firm size is not a significant determinant of idiosyncratic volatility before the financial crisis, but it is significant in post-crisis period. Before the crisis, all considered firm characteristics are able to explain 35% of variation in idiosyncratic volatility. However, post-crisis evidence reveal that the explanatory power of the same variables has increased to 42% overall, suggesting improvement in the information content of firm characteristics

[15] As part of robustness checks, we estimate IV relative to CAPM and Carhart 4-factor (1997) models. Our results largely remain the same as detailed in appendix A and B.

2.6 Conclusions

Using a large cross-section of UK stocks, we provide first empirical evidence on the determinants of IV for the UK equity market. Our cross-sectional analysis suggests that, firm characteristics can explain over 37% of the variation in idiosyncratic volatility (IV) of UK stocks. A given security is likely to have high IV if it is associated with high book-to-market ratio, small firm size, high share turnover, low earnings, has paid dividend and operates in a non-regulated industry. While the aggregate IV has dropped significantly after the financial crisis and has returned to pre-crisis levels, average firm-level IV has remained relatively the same. Despite, we find that firm characteristics better explain the variation in post-crisis IV and is 7% higher than pre-crisis levels. While the explanatory power of book-to-market ratio, firm size, non-regulated firms and previous period IV have significantly increased after the crisis, turnover, earnings and dividend paying firms has dropped. This implies that the role of firm-specific factors that drive cross-sectional variation in IV has shifted significantly after the financial crisis. The sign of the coefficient estimates is in line with the theoretical priori and empirical evidence reported in relevant literature and they appear to be stable to alternative specifications of IV.

This chapter provides first empirical evidence of the idiosyncratic volatility determinants based using UK data. We use a comprehensive sample period that captures the recent 2007-08 Global financial crisis to examine whether the explanatory power of the chosen firm characteristics have changed post-crisis compared to the pre-crisis period. Therefore, this study contributes to the literature by reducing the biases that may in the empirical evidence due to data snooping

The next empirical chapter will examine the relationship between financial constraints and idiosyncratic volatility. While the idiosyncratic volatility literature suggests that small and young firms have high idiosyncratic volatility due to risky and volatile fundamentals, financial constraints literature suggests that small and young firms tend to be financially constrained. Therefore, the next chapter will empirically examine the role of financial constraints in explaining the cross-sectional variation in idiosyncratic volatility.

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2.8 Appendix

2.8.1 Appendix A: Idiosyncratic volatility relative to CAPM

Table 2. 6 – Idiosyncratic Volatility and Firm Characteristics: Before and after the financial crisis

This table presents the Fama-MacBeth (1973) cross-sectional regressions of individual firm idiosyncratic volatility (IV) on lagged firm characteristics and lagged IV for FTSE All-Share stocks. Sample period is Jan 1998 to Jun 2015. We define the period before financial crisis as Jan 1998 to Jun 2007 and period after crisis as Jan 2009 to Jun 2015. The dependent variable is Firm IV is estimated relative to CAPM that includes a momentum factor. The independent variables are book-to-market (BM), firm size, turnover, EPS, leverage, firm age (Age), an indicator variable if the industry is not regulated (Not Regulated) and whether the firm is a dividend payer (Div.paying). "*l*" indicates one period lagged value. We estimate the regressions semi-annually and report time series means of coefficient estimates along with *t*-statistics obtained using Newey-West autocorrelation-and-heteroscedasticity-consistent standard errors of coefficient estimates in parentheses. *** indicates significance at 1%, ** at 5% and * at 10%. R^2 refers to average semi-annual R^2.

	Baseline model	Before crisis Jan 1999: Jun 2007	During crisis Jul 2007: Dec 2008	After crisis Jan 2009:Jun 2015
*l*_IV (CAPM)	0.437***	0.399***	0.682	0.431***
	(7.52)	(4.32)	(1.71)	(5.38)
*l*_BM	0.123**	0.0482	0.202	0.203***
	(2.17)	(0.64)	(1.32)	(3.07)
*l*_Size	-0.00345	0.00578	0.0330	-0.0239***
	(-0.26)	(0.27)	(0.34)	(-3.87)
*l*_Turnover	0.250***	0.321**	0.280	0.149
	(2.87)	(2.50)	(2.82)	(1.07)
*l*_EPS	-0.125**	-0.182**	0.0956	-0.102**
	(-2.60)	(-2.28)	(1.34)	(-2.91)
*l*_Leverage	-0.0138*	-0.0203	-0.0239	-0.00296
	(-1.78)	(-1.59)	(-0.91)	(-0.24)
*l*_Age	0.000669	-0.0141	0.0938	-0.00146
	(0.04)	(-1.10)	(1.34)	(-0.05)
Not regulated	0.106***	0.104***	0.0148	0.130**
	(4.16)	(5.04)	(0.20)	(2.43)
Div.paying	-0.421***	-0.590***	-0.554	-0.169***
	(-4.01)	(-4.32)	(-1.76)	(-3.21)
Intercept	0.691***	0.843***	0.662	0.497***
	(6.22)	(5.54)	(1.23)	(5.76)
N	9002	3684	909	4409
No. *t's*	33	17	3	13
R^2	0.3766	0.3625	0.2825	0.4167

2.8.2 Appendix B: Idiosyncratic volatility relative to Carhart 4-factor model

Table 2. 7 – Idiosyncratic Volatility and Firm Characteristics: Before and after the financial crisis

This table presents the Fama-MacBeth (1973) cross-sectional regressions of individual firm idiosyncratic volatility (IV) on lagged firm characteristics and lagged IV for FTSE All-Share stocks. Sample period is Jan 1998 to Jun 2015. We define the period before financial crisis as Jan 1998 to Jun 2007 and period after crisis as Jan 2009 to Jun 2015. The dependent variable is Firm IV is estimated relative to Carhart 4-factor (1997) model that includes a momentum factor. The independent variables are book-to-market (BM), firm size, turnover, EPS, leverage, firm age (Age), an indicator variable if the industry is not regulated (Not Regulated) and whether the firm is a dividend payer (Div.paying). "*l*" indicates one period lagged value. We estimate the regressions semi-annually and report time series means of coefficient estimates along with *t*-statistics obtained using Newey-West autocorrelation-and-heteroscedasticity-consistent standard errors of coefficient estimates in parentheses. *** indicates significance at 1%, ** at 5% and * at 10%. R^2 refers to average semi-annual R^2.

	Baseline model	Before crisis Jan 1999: Jun 2007	During crisis Jul 2007: Dec 2008	After crisis Jan 2009:Jun 2015
*l*_IV (4-factor)	0.425***	0.401***	0.650	0.405***
	(7.28)	(4.13)	(1.68)	(4.99)
*l*_BM	0.105*	0.0283	0.161	0.191***
	(1.71)	(0.32)	(0.95)	(3.09)
*l*_Size	-0.00877	0.00665	0.0231	-0.0363***
	(-0.64)	(0.31)	(0.23)	(-5.44)
*l*_Turnover	0.199*	0.307**	0.0781	0.0867
	(1.92)	(2.42)	(0.37)	(0.51)
*l*_EPS	-0.118**	-0.181**	0.114	-0.0891**
	(-2.42)	(-2.27)	(1.31)	(-3.04)
*l*_Leverage	-0.0149*	-0.0205	-0.0274	-0.00462
	(-2.01)	(-1.60)	(-0.88)	(-0.44)
*l*_Age	-0.00522	-0.0181	0.0763	-0.00718
	(-0.34)	(-1.43)	(1.15)	(-0.32)
Not regulated	0.126***	0.111***	0.0458	0.165***
	(6.41)	(4.11)	(0.83)	(6.01)
Div.paying	-0.435***	-0.616***	-0.547	-0.174**
	(-3.92)	(-4.24)	(-1.74)	(-2.96)
Intercept	0.906***	1.025***	1.057	0.715***
	(7.18)	(6.69)	(2.84)	(3.84)
N	9002	3684	909	4409
No. *t's*	33	17	3	13
R^2	0.3696	0.3672	0.2551	0.3991

3. CHAPTER 3 – FIRM SIZE, FIRM AGE AND IDIOSYNCRATIC VOLATILITY: THE ROLE OF FINANCIAL CONSTRAINTS

3.1 Abstract

This paper shows that the effect of firm size and firm age on Idiosyncratic Volatility (IV) is moderated by the presence of financial constraints. Using UK stock data for the period 1996 to 2017, we confirm that firm size and firm age are significant drivers of cross-sectional variation in IV and this relationship remains robust in the presence of financial constraints. While financial constraints are not a significant predictor of IV, the relationship between firm size-IV and firm age-IV is stronger for firms with greater financial constraints. As the level of financial constraints reduce, this relationship gets weaker and in fact it even reverses for lower levels of financial constraints. These results are robust for alternative measures of financial constraints.

3.2 Introduction

Li and Zhang (2010) show that theories of investment frictions and limits-to-arbitrage are unlikely to be mutually exclusive since both theories focus on different frictions that coexists in firms. Using financial constraints as a proxy for investment frictions and Idiosyncratic Volatility (IV) for limits-to-arbitrage, they show that these two are correlated and that the effect of IV dominates the effect of financial constraints in the returns-investment relationship. On the other hand, based on theories of information asymmetry, Opler et al., (1999) suggest that small and distressed firms with poor access to external funds depend on cash to finance investment needs. In line with their finding, Li and Luo (2016) provides convincing evidence that high levels of cash holding is apparent in firms with high IV. Although these findings do not provide direct evidence of a link between financial constraints and IV, we believe, similar to Li and Zhang (2010), that information on financial constraints and IV overlaps in firm-level data. We believe so since financial constraints are typically measured using observable firm characteristics that aims to capture changes in investment plans or funding situation of a firm and these firm characteristics are also drivers of the variation in firm specific uncertainty, i.e. IV. Our study empirically examines the link between IV and financial constraints and by doing so provides additional evidence to discriminate between the effect of firm characteristics and financial constraints on firm-specific uncertainty.

Idiosyncratic Volatility (IV) plays a major role in the financial markets. The idiosyncratic component of firms' uncertainty arises due to asset price variation that is specific to the security and has a negative price in the cross-section of UK stock returns (Cotter, Sullivan and Rossi, 2015). The positive trend in IV first reported by Campbell *et al.* (2001) in the US is largely attributed to increasing proportion of riskier firms in the economy (Fama and French, 2004; Brown and Kapadia, 2007), increasing competition (Miguel, Massa and Massa, 2006; Irvine and Pontiff, 2009), growth in small firms (Bennett, Sias and Starks, 2004) and the decline in the age of a typical firm at IPO (Fink *et al.*, 2010). Moreover, small and young firms demonstrate high IV since they are considered riskier, opaque with volatile fundamentals and likely to be poorly diversified in their operating, financing and investing activities (Rajgopal and Venkatachalam, 2005; Wei and Zhang, 2006; Brown and Kapadia, 2007; Li and Zhang, 2010).

Furthermore, Li and Luo (2016) shows that high levels of cash holding is apparent in firms with high IV. The propensity to save cash is highlighted in the financial constraints literature which suggests that high levels of cash provides constrained firms a value increasing response to costly external financing (Opler *et al.*, 1999; Almeida, Campello and Weisbach, 2004; Dennis and Strickland, 2004; Faulkender and Wang, 2006; Pinkowitz, Stulz and Williamson, 2006). Since financial constraints confine firms from making variety of firms' decisions such as optimal investments and capital structure choices (Hennessy and Whited, 2007), it should have substantial effects on firm value and thus subsequent returns. Consequently, empirical evidence suggests that that financially constrained firms' stock returns do move together (Lamont, Polk and Saa-Requejo, 1998; Gomes, Yaron and Zhang, 2003; Whited and Wu, 2006).

While firm size, firm age and financial constraints are not perfectly correlated, scattered evidence suggests a plausible relationship between financial constraints and IV since small and young firms with high IV demonstrate characteristics of a financially constrained firms. We, therefore, formally examine two important questions: (1) Can financial constraints explain the cross-sectional variation in IV? (2) Does the presence of financial constraints impact the relationship between firm size, firm age and IV? We use five widely used proxies in the literature to measure financial constraints; Dividends (dummy), cash holding, KZ index, WW index and HP index. Following a number of studies, we estimate IV relative to Fama-French 3-factor (FF-3) model (E.g. Xu and Malkiel, 2003; Bali *et al.*, 2005; Ang *et al.*, 2006; Fu, 2009). Using UK stock data from 1996 to 2017, we provide first evidence that the presence of financial constraints moderates the relationship between firm IV and its well-known determinants; firm size and firm age.

The rest of this paper is organized as follows. Section 2 provides a review of related literature, Section 3 describes the measures of IV, financial constraints and the data used in this study. Section 4 introduces the methodology and presents the empirical results along with the additional robustness tests. Section 5 concludes the paper.

3.3 Literature Review

Idiosyncratic Volatility (IV) measures the firm-specific risk that is driven by changes in the fundamentals of the firm as opposed to systematic volatility which is driven by systematic factors common to all securities in the market (Becchetti, Ciciretti and Hasan, 2015). The prominence of positive deterministic trend of aggregate IV between 1960s and the late 1990s first highlighted by Campbell *et al.*, (2001) and the others (Xu and Malkiel, 2003; Fama and French, 2004; Jin and Myers, 2006; Wei and Zhang, 2006) led to extensive subsequent research exploring the determinants of this trend and the implications of IV for firm behaviour.

The asset pricing literature, on the other hand, finds convincing evidence that IV is a common risk factor in stock returns among other well-known factors such as the size, value, momentum and liquidity factors. While Ang *et al.* (2006) show that US stocks with high IV earn abysmally low average returns, which is also well known as the idiosyncratic volatility puzzle, the puzzle remains unsolved as to why high IV stocks systematically earn low average returns. Similarly, Cotter, Sullivan and Rossi (2015) finds that IV has a negative price in the cross-section of stock returns in the UK.

At aggregate level, the literature leans towards an argument that the increasing trend in IV can be attributed to increasing proportion of riskier firms in the economy (Fama and French, 2004; Brown and Kapadia, 2007), increase in competition (Miguel, Massa and Massa, 2006; Irvine and Pontiff, 2009), growth in small firms (Bennett, Sias and Starks, 2004), decline in the age of a typical firm at IPO (Fink *et al.*, 2010), increases in growth options (Cao, Simin and Zhao, 2008b; Guo and Savickas, 2008) and volatile cash flows and corporate earnings (Wei and Zhang, 2005; Irvine and Pontiff, 2009). At firm-level, it is a stylized fact in the literature that small firms and young firms with high growth opportunities generally have high IV levels (Pastor and Veronesi, 2003;

Cao, Simin and Zhao, 2008b; Fink *et al.*, 2010; Bartram, Gregory and Stulz, 2012; Vozlyublennaia, 2013; Li and Luo, 2016).

Financial constraints are a by-product of capital market imperfections. These imperfections are largely attributed to information asymmetry (Greenwald, Stiglitz and Weiss, 1984; Myers and Majluf, 1984) or agency problems (Jensen and Meckling, 1976; Grossman and Hart, 1982; Jensen, 1986; Stulz, 1990), suggesting that all firms are constrained to some extent. According to Modigliani-Miller theorem which states the irrelevance of capital structure and financial policies for firm value under perfect capital markets, external funds provide a perfect substitute for internal capital. An influential paper by Fazzari *et al.* (1988) argue that due to capital market imperfections such as information asymmetry, internal capital cannot be perfectly substituted by external funds which makes it difficult for the providers of external finance to assess firm value and investment opportunities. They suggest that financial constraints influence the availability of internal capital and therefore firm’s investment decisions. Subsequently, a large literature examines how financial frictions affect firm value and investment decisions.

So, what are financial constraints? There are some definitions provided in the literature for financially constrained firms, while majority of the studies tend to describe this phenomenon using the behaviour of a financially constrained firm. Based on the notion first suggested by Fazzari *et al.* (1988), Kaplan and Zingales (1997, p.172) present a broad classification that a firm is likely to be “financially constrained if they face a wedge between the internal and external costs of fund”. Despite the fact that any firm can be classified as financially constrained according to this definition, it is used as a framework to evaluate the degree of financial constraints faced by a firm (Farre-Mensa and Ljungqvist, 2016).

Alternatively, another strand of the literature define financially constrained firms based on frictions on the external capital supply. Whited and Wu (2006) suggest that constrained firms are associated with external finance constraints and Almeida, Campello and Weisbach (2004) observe that financially constrained firms have an inelastic capital supply curve. On similar vein, Lamont, Polk and Saa-Requejo (1998, p.529) defines financial constraints as any "frictions that prevent the firm from funding all desired investments" excluding financial distress, economic distress or bankruptcy risk.

Since financial constraints confine firms from funding desirable value-increasing investments, it should affect firm value and thus stock returns. Therefore it is plausible to expect that the degree of financial constraints in the economy might be captured by factor structures in stock returns. Lamont, Polk and Saa-Requejo (1998), Gomes, Yaron and Zhang (2003) and Whited and Wu (2006) provides evidence of a financial constraints factor in stock returns and that returns of financially constrained firms move together. While Lamont, Polk and Saa-Requejo (1998) and Gomes, Yaron and Zhang (2003) find that there is no risk premium associated with holding constrained stocks, Whited and Wu (2006) provides evidence that constrained firms earn a higher return. The degree of financial constraints also varies over time reflecting shocks to the macroeconomic environment such as economic cycles, credit conditions and changes in monetary policy (Gertler and Gilchrist, 1994; Kashyap, Lamont and Stein, 1994; Lamont, Polk and Saa-Requejo, 1998).

Understanding financial constraints are important to firms since it affects the ways in which firms responds to shocks. Myers and Majluf (1984) predicts that accumulating internal resources allow firms to finance investment needs when obtaining external finance is costly. Similarly, Opler *et al.* (1999) suggest that information asymmetry induces firms to increase their cash holding for precautionary motives. This evidence points to the importance of holding cash especially in financially constrained firms. Almeida and Campello (2002) argues that in the absence of financial constraints, there is very little use for cash and no cost of holding it and thus cash holding policies for unconstrained firms should not demonstrate systematic patterns. In line with this notion, Dennis and Strickland (2004), Faulkender and Wang (2006) and Pinkowitz, Stulz and Williamson (2006) also show that financially constrained firms hold high levels of cash in order to finance their investment needs as a value increasing response to increased difficulty and high costs associated with obtaining external finance.

Fazzari *et al.* (1988) study the influence of financing frictions on firms' investment behaviour by focusing on the sensitivity between cash flows and investment. They argue that investment decisions of constrained firms depend on the availability of internal capital and therefore demonstrate higher investment-cash flow sensitivities compared to unconstrained firms. However, the ability of investment-cash flow sensitivity to capture financial constraints has been challenged by a number of studies theoretically (Kaplan and Zingales, 1997; Povel and Raith, 2001; Almeida and Campello, 2002) and empirically (Cleary, 1999; Erickson and Whited, 2000; Kaplan and Zingales, 2000).

Moreover, other studies suggest that constrained firms are small (Erickson and Whited, 2000; Almeida, Campello and Weisbach, 2004; Dennis and Strickland, 2004; Whited and Wu, 2006; Acharya, Almeida and Campello, 2007; Hennessy and Whited, 2007), young (Fink *et al.*, 2010; Li and Luo, 2016), pay low dividends (Almeida, Campello and Weisbach, 2004; Dennis and Strickland, 2004; Farre-Mensa and

Ljungqvist, 2016) and have poor or no credit ratings (Almeida, Campello and Weisbach, 2004; Dennis and Strickland, 2004; Farre-Mensa and Ljungqvist, 2016).

On the other hand, literature has also provided evidence that indexes constructed using linear combinations of observable firm characteristics are superior in capturing the degree of financial constraints compared to single characteristic. The widely used index measures are the KZ index (Lamont, Polk and Saa-Requejo, 1998; Almeida, Campello and Weisbach, 2004; Farre-Mensa and Ljungqvist, 2016), WW index (Whited and Wu, 2006; Farre-Mensa and Ljungqvist, 2016) and the HP index; also known as the SA index (Hadlock and Pierce, 2010; Farre-Mensa and Ljungqvist, 2016). Nevertheless, the literature is not conclusive in terms the optimal measure that can capture financial constraints and therefore, it is common practice to use a range of proxies for robustness.

Literature documents several interesting behaviours of small firms. They have common variation in stock returns (Fama and French, 1993); sensitive to macroeconomic fluctuations (Willem Thorbecke, 1997; Perez-Quiros and Timmermann, 2000) and are vulnerable to capital market imperfections (Dennis and Strickland, 2004). Gertler and Gilchrist, (1994) and Bernanke, Gertler and Gilchrist (1996) show that in times of adverse macroeconomic shocks, small firms are able to reduce their economic activity earlier and more sharply than larger firms. Firm-level evidence suggest that small and young firms tend to have higher IV since they are riskier (Brown and Kapadia, 2007) and opaque (Rajgopal and Venkatachalam, 2005) with more volatile fundamentals (Wei and Zhang, 2006).

Financial constraints and firm size in not perfectly correlated. While some evidence suggest that firm size if not a good proxy for financial constraints (Fazzari *et al.*, 1988;

Kashyap, Lamont and Stein, 1994), literature provides ample evidence to suggest that small firms tend to be financially constrained. For instance, in line with theories of information asymmetry, Hennessy and Whited (2007) show that small firms demonstrate profound adverse selection problems compared to large and mature firms which in turn exposes these small firms to greater cost of external financing. Using an index constructed with only firm size and firm age, Hadlock and Pierce (2010) provides evidence that this simple measure is robust in capturing financial constraints faced by a firm. A number of other studies also confirm that small firms are more constrained (Erickson and Whited, 2000; Almeida, Campello and Weisbach, 2004; Dennis and Strickland, 2004; Acharya, Almeida and Campello, 2007; Hennessy and Whited, 2007).

While it is a stylized fact that small and young firms have high idiosyncratic volatility, corporate financial literature use these variables to characterise financially constrained firms. Therefore, we suspect that information on financial constraints and idiosyncratic volatility might overlap in firm-level data due to the unobservable nature of these variables. This study contributes to the literature in the following ways. First, it shows that financial constraints cannot independently explain the cross-sectional variation in idiosyncratic volatility. Second, it provides empirical evidence that financial constraints exacerbates idiosyncratic volatility of small and young firms.

3.4 Data

3.4.1 Measure of Idiosyncratic Volatility

Following a number of studies in the literature, we estimate IV using the Fama and French (1993) three-factor model (hereafter FF3) (See for instance, E.g. Xu and Malkiel, 2003; Bali *et al.*, 2005; Ang *et al.*, 2006; Fu, 2009). We use the daily residuals of the FF3 model below which is estimated on a monthly frequency in order to compute our annual IV measure.

$$\mathrm{R}_{j,t} = b_{0,j,m} + b_{1,j,m}\mathrm{MKT}_t + b_{2,j,m}\mathrm{SMB}_t + b_{3,j,m}\mathrm{HML}_t + u_{j,t} \quad (1)$$

where $\mathrm{R}_{j,t}$ is the excess return of firm j on day t. MKT_t is the excess market return of FTSE ALL-Share index over the risk-free rate, SMB_t is the size factor which captures the difference in the returns between small versus big stocks and HML_t is the value factor which captures the difference in the returns between high versus low book to market equity stocks, $u_{j,t}$ is the residual idiosyncratic return on firm j on day t. We calculate monthly IV as the variance of daily residuals $u_{j,t}$ within a given month and annual IV as the annualized average of 12-month IV within a given year.

3.4.2 Measures of Financial Constraints

The degree of financial constraints faced by a firm is not directly observable. Therefore, the empirical literature has relied on various indirect proxies that could identify the degree of financial constraints the firm faces. Similarly, we use 5 proxies of financial constraints in this study; cash holding, Dividend payout dummy, Kaplan-Zingales (KZ) index, Hadlock-Pierce (HP) index and Whited-Wu (WW) index.

1. Cash holding: Consistent with the studies that suggest high level of cash holdings are valuable to constrained firms as it allows them to finance operating and investing activities specially when obtaining external funding could be costly and

or difficult, we use cash holding as a measure of financial constraints. It is measured as the amount of cash held by the firm in proportion to its total assets, i.e. cash-ratio (Opler *et al.*, 1999; Almeida, Campello and Weisbach, 2004; Dennis and Strickland, 2004; Pinkowitz, Stulz and Williamson, 2006; Li and Luo, 2016). High levels of cash holding implies high levels of financial constraints.

For further tests, we create categories of financially constrained and unconstrained firms by sorting our sample firms equally into terciles every year based on their cash ratio. Firms that belong to the top tercile is categorised as constrained and the bottom tercile as unconstrained. In this categorisation, we do not include the observations that belong to the middle tercile.

2. Dividends (dummy): Dividend policies of a firm could be an important indicator of the level of financial constraints faced by them. For instance, constrained firms may pay low dividends to their shareholders because they are in need of accumulating internal funds to facilitate investment needs since it is cheaper source of finance compared to external funding. Alternatively, constrained firms may have less (or no) income left to distribute to shareholders and hence have low (or no) dividend pay-out (Fazzari *et al.*, 1988; Lamont, Polk and Saa-Requejo, 1998; Denis and Sibilkov, 2010; Farre-Mensa and Ljungqvist, 2016). Therefore, we identify the level of financial constraints based on whether or not a firm has paid dividends. We create an indicator variable which takes the value of 1 if the firm has paid dividends and 0 otherwise.
3. KZ index: The KZ index is one of the first influential index proxy for financial constraints. Based on Kaplan and Zingales (1997), the actual KZ index was constructed by Lamont *et al*. (2001) using linear combination of five accounting variables; cash flow, market-to-book ratio, leverage, dividends and cash holdings.

While KZ index is one of the widely used measures of financial constraints, some studies criticise its inability to capture cross-sectional variation of cash policies between constrained and unconstrained firm categories (e.g. Almeida, Campello and Weisbach, 2004; Dennis and Strickland, 2004; Faulkender and Wang, 2006). Following common practice in the literature (see for instance, Farre-Mensa and Ljungqvist (2016)), we construct KZ index based on the reported coefficients as in Lamont, Polk and Saa-Requejo (1998). A higher value of KZ index indicates that the firm is more constrained.

For further tests, we create categories of financially constrained and unconstrained firms by sorting our sample firms equally into terciles every year based on their KZ index. Firms that belong to the top tercile is categorised as constrained and the bottom tercile as unconstrained. In this categorisation, we do not include the observations that belong to the middle tercile.

4. WW index: Another popular indexing approach to measure financial constraints is the Whited and Wu (2006) index; see for instance, Hennessy and Whited (2007), Li (2011), Farre-Mensa and Ljungqvist (2016). The WW index uses firm-level characteristics such as cash flow to assets, whether a firm pays dividend through a dummy, long-term debt to total assets, size, sales growth and industry sales growth. Following academic convention, we use the reported coefficients in Whited and Wu (2006) to construct the WW index for our sample firms. Firms with a higher WW index value are considered more financially constrained.

For further tests, we create categories of financially constrained and unconstrained firms by sorting our sample firms equally into terciles every year based on their WW index. Firms that belong to the top tercile is categorised as constrained and the bottom tercile as unconstrained. In this categorisation, we do not include the observations that belong to the middle tercile.

5. HP index: Hadlock and Pierce (2010) provides a simple alternative approach to constructing a financial constraints index based on firm size and firm age; the HP index. They argue that these two exogenous variables are important predictors of financial constraints and thus a credible proxy compared to other proxies that reflect endogenous choices of the firm such as leverage, cash holding, dividend pay-out policies etc. or indexes such as KZ and WW index that uses one or more of these endogenous variables. Number of studies uses HP index (also known as WW index) as proxies of financial constraints (e.g. Li, 2011; Farre-Mensa and Ljungqvist, 2016). Following these studies, we construct HP index using reported coefficient estimates from Hadlock and Pierce (2010). A higher index value suggests that a firm is more constrained.

   For further tests, we create categories of financially constrained and unconstrained firms by sorting our sample firms equally into terciles every year based on their HP index. Firms that belong to the top tercile is categorised as constrained and the bottom tercile as unconstrained. In this categorisation, we do not include the observations that belong to the middle tercile.

3.4.3 Main data sources and Descriptive Statistics

The sample include UK FTSE All-Share Index constituent firms for the period January 1996 to December 2017. The sample period was chosen in order to allow for sufficient years of observations before and after the 2007-08 Global Financial crisis. Despite the availability of a higher frequency data (semi-annually) for some of the firm-level variables, this study uses annual data since the proxies for financial constraints proxies are measured at an annual frequency. The KZ, WW and HP indices are measured using pre-determined coefficients in line with the literature and are estimated at annual frequency (Hadlock and Pierce, 2010; Kaplan and Zingales, 1997; Whited and Wu, 2006). Therefore, in order to maintain consistency, this study uses annual data in all of its estimations."

To construct our IV measure, we obtain daily stock price from DataStream, daily factor returns and risk-free rates from Kenneth French's Library website[16]. We use the Industry Classification Benchmark (ICB) to identify the industry the firm operates in. Consistent with other studies, we exclude firms that belong to the Utilities and Financial industries from the sample due to these firms facing regulatory constraints[17]. Firm characteristics and the accounting variables used to calculate measures of financial constraints are from Datastream and Worldscope. In order to eliminate the effect of extreme values, we trim all variables at the 1st and the 99th percentiles. The resulting sample consists of 9,504 firm-year observations. We present a summary of the descriptive statistics in table 3.1, for variables that are part of any of our estimations.

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[16] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

[17] Regulated and non-regulated industries are defined based on whether the firms in the industry are free to make its operational and capital structure choices. This distinction is widely followed in the corporate finance literature, which classifies utility and financial industry as regulated industries (Rubin and Smith, 2011).

Table 3. 1 – Descriptive Statistics

This table presents summary statistics of individual firm idiosyncratic volatility (IV) and firm characteristics for FTSE All-Share stocks used in our estimations. The sample period is Jan 1996 to Dec 2017 and we exclude from all of our estimations any financial or utility firms. IV is estimated relative to FF-3 model detailed in equations (1). The firm characteristics are as follows; Market capitalisation is the product of number of shares outstanding and end of day share price, Firm size is the logarithm of market capitalisation, Firm age is the number of years since the firm's incorporation, Book-to-Market is the ratio of book value to market value of equity, Dividends are common dividends paid to shareholders, Cash Ratio is the ratio of cash held by firm and total assets and financial constraints indexes; Kaplan-Zingales (KZ) index, Hadlock and Pierce (HP) index and Whited and Wu (WW) index. The construction of these index measures is detailed in Section 2.3.

	Mean	SD	Median	Min	Max	Obs.
IV	0.783	0.381	9.910	0.000	712.053	5267
Market capitalisation (£m)	6283.201	682.642	23.300	1.490	309000	5260
Firm size (log market cap)	13.585	13.434	1.880	7.307	19.547	5260
Firm age (since founding)	37.63339	23	35.13666	0	134	5709
Book-to-Market	0.600	0.403	2.610	-33.333	100.000	5035
Dividends (£m)	147.993	6.100	749.705	0.000	18400.000	7084
Cash Ratio	0.095	0.060	0.110	0.000	1.000	5529
KZ index	2.678	17.331	392.468	-20452.830	1755.481	5409
HP index	-1.213	-0.640	1.395	-5.360	0.000	7084
WW index	0.924	-0.671	18.492	-844.270	139.186	5605

The mean of annualised IV measured using daily data is 0.78% in our sample and is comparable to those reported in Cotter *et al*. (2015)[18]. The mean market capitalisation (firm size as the log of market capitalisation) is £6.3 billion (13.7) and the mean age is 38. Table 3.2 provides a summary of Pearson's correlation coefficients for our independent variables; firm size, firm age and the measures of financial constraints used in our study. In general, the reported correlation coefficients range from 0 to 0.2.

[18] The sample period in Cotter et al. (2015) is Jan 1990 and Dec 2009 for which the annualised mean Idiosyncratic Risk is 8.39%. Their measure of risk is the standard deviation as opposed to variance in our study.

Table 3. 2 – Correlation Matrix of firm size, firm age and financial constraints proxies

This table presents Pearson correlation coefficients of Firm Size, Firm Age and all five proxies of financial constraints; Dividends (dummy), Cash Ratio, KZ index, HP index and WW index. The sample period is Jan 1996 to Dec 2017 and we exclude from all of our estimations any financial or utility firms. Firm Size is the logarithm of market capitalisation, Firm age is the logarithm of 1 + number of years since the firm's incorporation, Dividends (dummy) is an indicator variable which takes the value of 1 if firm has paid dividend in the given year or 0 otherwise, Cash Ratio is the ratio of cash held by firm and total assets and financial constraints indexes; Kaplan-Zingales (KZ) index, Hadlock and Pierce (HP) index and Whited and Wu (WW) index. The construction of these index measures are detailed in Section 2.3.

	Firm Size	Firm Age	Dividends (dummy)	Cash Ratio	KZ index	HP index	WW index
Firm Size	1.00						
Firm Age	0.03	1.00					
Dividends (dummy)	0.15	0.16	1.00				
Cash Ratio	-0.13	-0.18	-0.20	1.00			
KZ index	0.03	0.05	-0.01	-0.07	1.00		
HP index	-0.06	-0.91	-0.13	0.18	-0.05	1.00	
WW index	0.03	-0.01	-0.01	0.00	0.00	0.01	1.00

Correlation coefficients between firm size and the financial constraints measures range from -0.13 to 0.15. Correlation coefficients between firm age and the financial constraints measures ranges between -0.18 to 0.16with one exception reported with HP index at -0.91; a very high negative correlation. The main reason for this high correlation is that firm age is one of the variables used in constructing the HP index. High correlations could indicate a potential issue of multicollinearity and therefore we formally test for it using both Variance Inflation Factors (VIFs) (Chatterjee, Hadti and Price, 2000; Dennis and Strickland, 2004; Baum, 2006; Luo and Bhattacharya, 2009; Mishra and Modi, 2013) and the Condition index (or the characteristic-root-ratio test) by Belsley, Kuh and Welsch (1980) (Guo and Savickas, 2006, 2008). Both tests confirm that there is no evidence for multicollinearity in our data (See section 4.3 for detailed results of the tests). Further, we find weak correlation coefficients among the measures of financial constraints ranging from-0.20 to 0.18. The KZ index and WW index reports the lowest correlations with the remaining financial constraints measures. This suggests that these proxies potentially capture different information about the financial constraints faced by a firm. We include one proxy at a time in all of our remaining estimations.

Table 3.3 provides the univariate comparisons of firm characteristics among subsamples of constrained and unconstrained firms according to the 5 proxies of financial constraints. We create these subsamples following academic convention of sorting the sample firms into terciles; For cash ratio, KZ index, WW index and HP index, firms in the top tercile are coded as constrained and those in the bottom tercile as unconstrained. For the dividend dummy, firms that do not pay dividend is coded as constrained while firms that pay dividend as unconstrained.

One of the important observations from table 3.3 is that mean IV is higher in constrained firms compared to unconstrained firms. The median values also point to the same direction (except for KZ index where median IV of constrained firm is slightly lower). In general, constrained firms also reports smaller market capitalisation and therefore smaller firm size and appears to be younger than unconstrained firms. Book-to-Market ratio is on average lower in constrained firms with an exception in dividend dummy where both mean and median values are higher in constrained firms compared to unconstrained firms. Lower Book-to-Market values observed in the constrained firms are consistent with the convention that constrained stocks tend to be growth stocks whereas one would expect value stocks to be unconstrained.

Table 3. 3 - Univariate comparison of firm characteristics by financial constraints

This table presents the pooled sample mean and median statistics of our sample sorted by the each of our five financial constraints proxies; Dividends (dummy), Cash Ratio, KZ index, HP index and WW index. The sample period is Jan 1996 to Dec 2017 and we exclude from all of our estimations any financial or utility firms. We sort our sample firms into terciles based on each of the financial constraints proxy. Firms that belong to the top tercile of Cash Ratio, KZ index, HP index and WW index is categorised as constrained (Constr.) and the bottom tercile as unconstrained (Unconstr.). Firms that pay dividends are considered constrained or unconstrained otherwise. IV is estimated relative to FF-3 model detailed in equations (1). Market capitalisation is the product of number of shares outstanding and end of day share price, Firm size is the logarithm of market capitalisation, Firm age is the number of years since the firm's incorporation, Book-to-Market is the ratio of book value to market value of equity. Dividends (dummy) is an indicator variable which takes the value of 1 if firm has paid dividend in the given year or 0 otherwise, Cash Ratio is the ratio of cash held by firm and total assets and financial constraints indexes; Kaplan-Zingales (KZ) index, Hadlock and Pierce (HP) index and Whited and Wu (WW) index. The construction of these index measures are detailed in Section 2.3.

		Financial Constraints criteria									
		Dividends (dummy)		Cash Ratio		KZ index		HP index		WW index	
		Unconstr.	Constr.	Unconstr.	Constr.	Unconstr.	Constr.	Unconstr.	Constr.	Unconstr.	Constr.
IV	Mean	0.516	2.395	0.581	0.759	0.821	0.939	0.503	2.028	0.707	1.146
	Median	0.342	0.769	0.351	0.436	0.494	0.322	0.317	0.545	0.391	0.420
Market Cap	Mean	7053.964	1489.175	10200.000	3414.862	6274.699	5516.702	4543.247	12800.000	5167.473	4993.871
	Median	740.811	383.330	711.184	540.819	490.211	935.468	796.089	749.385	494.907	507.918
Firm size	Mean	13.710	12.811	13.745	13.272	13.281	13.896	13.744	13.684	13.268	13.299
	Median	13.516	12.857	13.475	13.201	13.103	13.749	13.587	13.527	13.112	13.138
Firm age	Mean	42.280	22.475	44.376	29.754	36.454	39.523	71.744	2.981	38.233	37.286
	Median	28	13	31	18	25	23	67	3	24	23
Book-to-market	Mean	0.535	1.018	0.697	0.472	1.067	0.259	0.605	0.585	0.614	0.587
	Median	0.398	0.449	0.510	0.325	0.658	0.240	0.448	0.343	0.418	0.407

3.5 Methodology, findings and discussion

We first verify the negative relationship between firm size and firm age with IV documented in extensive literature holds in our sample of UK firms. We are specifically interested in the cross-sectional relationship between firm characteristics and IV and therefore estimate Fama and MacBeth (1973) cross-sectional regressions of firm-level IV on firm size and firm age along with lagged IV and book-to-market ratio as control variables in equation (2).

$$IV_{j,t} = \alpha_t + \beta_t Size_{j,t-1} + \gamma_t Age_{j,t-1} + \delta_t FC_{j,t-1} + \overrightarrow{\omega_t} x_{j,t-1} + e_{j,t} \quad (2)$$

IV is defined in equation (1) in section 2.1. Following the common practice in the IV literature, we define firm size as log of market capitalisation and age as the log of 1 + number of years of existence of the firm from the year of incorporation. Since log 0 is undefined and some of the firms in our sample was incorporated during the sample period and have age=0 in certain years, we use log 1+age to avoid this problem. Book-to-market ratio is the book value to market value of equity. We use one period-lagged independent variables in all our empirical estimations to avoid potential endogeneity concerns. We also control for high persistence of IV by including one period lagged IV as an independent variable (see Brandt et al., 2010; Fink et al., 2010; Vozlyublennaia, 2013).

Fama and MacBeth cross-sectional regressions involves a two-step procedure. The first step involves estimation of yearly cross-sectional regressions and the second step estimates time series mean of the coefficients from yearly cross-sectional regressions from the first step. In all our estimations, we use autocorrelation and heteroscedasticity consistent Newey-West standard errors with 4 lags. The results of Equation (3) is presented in table 3.4.

Table 3. 4 – Baseline model with Financial Constraints

This table presents the Fama-MacBeth (1973) cross-sectional regressions of individual firm idiosyncratic volatility (IV) on firm size, firm age, financial constraints proxy and control variables; lagged IV (*l*_IV), and book-to-market. All the independent variables are lagged by one period. The first column shows the baseline model and subsequent columns indicate separate estimations that includes one financial constraints proxy at a time. The sample period is Jan 1996 to Dec 2017 and we exclude from all of our estimations any financial or utility firms. Firm IV is estimated relative to FF-3 model detailed in equations (1). Firm Size is the logarithm of market capitalisation, Firm age is the logarithm of 1 + number of years since the firm's incorporation, Dividends (dummy) is an indicator variable which takes the value of 1 if firm has paid dividend in the given year or 0 otherwise, Cash Ratio is the ratio of cash held by firm and total assets and financial constraints indexes; Kaplan-Zingales (KZ) index, Hadlock and Pierce (HP) index and Whited and Wu (WW) index. We standardize each of the financial constraints proxy by subtracting its in-sample mean and dividing the difference by in-sample standard deviation. The construction of these index measures are detailed in Section 2.3. We estimate the regressions annually and report time series means of coefficient estimates along with *t*-statistics obtained using Newey-West autocorrelation-and-heteroscedasticity-consistent standard errors in parentheses. *** indicates significance at 1%, ** at 5% and * at 10%. R^2 refers to average annual R^2.

		Proxy for Financial Constraints				
	Baseline Model	Dividends (dummy)	Cash Ratio	KZ index	HP index	WW index
Firm size	-0.0415***	-0.0343***	-0.0370***	-0.0326**	-0.0426***	-0.0413***
	(-4.39)	(-2.92)	(-3.29)	(-2.69)	(-4.34)	(-4.16)
Firm age	-0.0443***	-0.0287**	-0.0387***	-0.0436***	-0.0740**	-0.0428***
	(-3.78)	(-2.40)	(-3.59)	(-3.57)	(-2.64)	(-3.70)
Dividend (dummy)		-0.108***				
		(-2.93)				
Cash Ratio			0.0351			
			(1.12)			
KZ index				0.151***		
				(3.47)		
HP index					-0.0277	
					(-1.24)	
WW index						0.0477
						(1.34)
Control variables						
*l*_IV	0.534***	0.504***	0.530***	0.547***	0.534***	0.536***
	(7.83)	(7.36)	(7.43)	(6.91)	(7.82)	(7.87)
Book-to-market	-0.0213	-0.0143	-0.0121	0.0139	-0.0217	-0.0207
	(-0.59)	(-0.47)	(-0.37)	(1.03)	(-0.60)	(-0.58)
Intercept	1.011***	0.894***	0.935***	0.845***	1.115***	1.003***
	(7.87)	(5.93)	(6.12)	(5.68)	(6.43)	(7.50)
Observations	4686	4682	4623	4631	4686	4686
Avg. R^2	0.3609	0.3952	0.3713	0.3485	0.3649	0.3668
No. of years	21	21	21	21	21	21

The first column in Table 3.4 corresponds to the baseline model and the subsequent columns indicate separate estimations that includes one financial constraints proxy (*FC*) at a time. The baseline model in the first column confirms the well-established negative relationship between firm size and IV and similarly firm age and IV. The negative relationship is statistically significant in our sample. When we include the financial constraints proxy as an explanatory variable, the negative firm size-IV and firm age-IV relationship remains statistically significant across all proxies of financial constraints.

Since financial constraints faced by a firm is also a firm-specific risk, we hypothesise that high levels of financial constraints should indicate high IV thus a positive relationship. The coefficient estimates of financial constraints proxies is statistically significant only for dividend dummy and KZ ratio and enters the regressions with the expected sign. The only proxy that reports an unexpected negative coefficient is the HP index, however, this coefficient is not statistically significant. Only 2 out of 5 proxies suggest that financial constraints has significant explanatory power in explaining cross-sectional variations in IV. While it is stylized fact that small and young firms tend to have high IV, financial constraints literature also suggest that small and young firms tend to be financially constrained. Since financial constraints faced by a firm is not directly observable and is measured using various firm characteristics, we suggest that information regarding cross-sectional variation in IV could co-exists with information regarding financial constraints. Therefore, we test whether financial constraints play a role of a moderator, which strengthen the relationship between firm size and IV or firm age and IV. For instance, we expect the negative relationship between IV and firm size (or firm age) to be stronger in firms with more financial constraints compared to firms with less financial constraints.

In the financial constraints literature, studies aim to categorise constrained and unconstrained firms by sorting the sample firms into terciles based on the selected financial constraints criteria. While our study is not aimed at a binary categorisation of constrained vs unconstrained firms, rather we are interested in studying how varying degrees of financial constraints (either increasing or decreasing) affect the cross-sectional dynamics of IV. We therefore use interaction terms to derive our main findings in the next section. In section 3.6-robustness tests, we provide additional evidence to our main findings by performing our estimations for constrained vs unconstrained firm groups.

3.5.1 Firm size, IV and the impact of Financial Constraints

In this section, we test our hypothesis of the moderating role of financial constraints in the relationship between firm size and IV. To do this, we use an interaction term between firm size and each proxy for financial constraints, one at a time, using the following Fama-Macbeth (1973) cross-sectional regressions:

$$IV_{j,t} = \alpha_t + \beta_t Size_{j,t-1} + \gamma_t Age_{j,t-1} + \delta_t FC_{j,t-1} + \nu_t FC_{j,t-1}.Size_{j,t-1} + \overrightarrow{\omega_t} x_{j,t-1} + e_{j,t} \quad (3)$$

β_t is the sensitivity of IV for changes in firm size for a firm whose financial constraints are equal to the sample mean. The coefficient estimates of the interaction term $\nu_{1,t}$ would indicate the strength of the IV-firm size relationship for different levels of financial constraints faced by a firm. In order to allow for an intuitive interpretation, we standardize each of the financial constraints proxy by subtracting its sample mean and diving the result by its in-sample standard deviation. The estimation results of equation (3) is given in table 3.5.

Table 3. 5 – Firm size, IV and financial constraints

This table presents the Fama-MacBeth (1973) cross-sectional regressions of individual firm idiosyncratic volatility (IV) on firm characteristics as per equation (3). The first column shows the baseline model and subsequent columns indicate separate estimations that includes one financial constraints proxy at a time. The sample period is Jan 1996 to Dec 2017 and we exclude from all of our estimations any financial or utility firms. Firm IV is estimated relative to FF-3 model detailed in equations (1). All variables are defined per section 3.4. We standardize each of the financial constraints proxy by subtracting its in-sample mean and dividing the difference by in-sample standard deviation. We estimate the regressions annually and report time series means of coefficient estimates along with *t*-statistics obtained using Newey-West autocorrelation-and-heteroscedasticity-consistent standard errors in parentheses. *** indicates significance at 1%, ** at 5% and * at 10%. R^2 refers to average annual R^2. We also present a summary of the economic effects of financial constraints on firm size-IV relation. Low (high) financial constraints means that the effect of firm size on IV is calculated using the value of the proxy for financial constraints at two standard deviations below (above) the mean. 'Big' size refers to firm size that is two-standard deviations above the mean.

		Proxy for Financial Constraints				
	Baseline Model	Dividends (dummy)	Cash Ratio	KZ index	HP index	WW index
Firm size	-0.0415***	-0.0443***	-0.0388***	-0.0147	-0.0467***	-0.0434***
	(-4.39)	(-3.09)	(-3.82)	(-1.56)	(-4.57)	(-4.12)
Firm age	-0.0443***	-0.0295**	-0.0397***	-0.0439***	-0.0708**	-0.0430***
	(-3.78)	(-2.49)	(-3.73)	(-3.86)	(-2.44)	(-3.69)
Dividend (dummy)		-0.642**				
		(-2.38)				
Size*Dividend (dummy)		0.0433**				
		(2.09)				
Cash Ratio			0.190			
			(1.07)			
Size*Cash Ratio			-0.0148			
			(-1.09)			
KZ index				1.742**		
				(2.37)		
Size*KZ index				-0.138**		
				(-2.13)		
HP index					0.108	
					(1.47)	
Size*HP index					-0.00991**	
					(-2.28)	
WW index						0.642**
						(2.15)
Size*WW index						-0.0456*
						(-2.08)
Control variables						
*l*_IV	0.534***	0.487***	0.527***	0.539***	0.530***	0.534***
	(7.83)	(9.38)	(7.15)	(7.17)	(7.84)	(7.82)
Book-to-market	-0.0213	-0.0116	-0.00582	0.0156	-0.0186	-0.0202
	(-0.59)	(-0.46)	(-0.22)	(1.21)	(-0.52)	(-0.59)
Intercept	1.011***	1.014***	0.949***	0.638***	1.156***	1.031***
	(7.87)	(5.07)	(6.57)	(5.30)	(6.51)	(7.25)
Observations	4686	4682	4623	4631	4686	4686
Avg. R^2	0.361	0.427	0.386	0.364	0.370	0.370
No. of years	21	21	21	21	21	21
Total effect of Size on IV						
Low financial constraints		0.0423	-0.0092	0.2613	-0.0285	0.0478
High financial constraints		-0.1309	-0.0684	-0.2907	-0.0649	-0.1346

Impact of big Size on IV					
Low financial constraints	0.73%	-0.16%	4.53%	-0.49%	0.83%
High financial constraints	-2.27%	-1.19%	-5.04%	-1.13%	-2.34%

The first column in Table 3.5 corresponds to the baseline model and the subsequent columns indicate separate estimations that includes one financial constraints proxy (FC) at a time. In the bottom panel of the table, we also present a summary of the economic effects of financial constraints on firm size-IV relationship. The 'Total effect of firm size on IV' summarises the overall effect of the firm size-IV relationship for firms that have low or high financial constraints. The effect of Low (high) financial constraints is calculated as two standard deviations below (above) the mean value of the financial constraints proxy. The 'Impact of big size on IV' summarises the strength of the firm size-IV relationship for firms that have low or high financial constraints. 'Big' size refers to firm size that is two-standard deviations above the mean.

The coefficients on firm size (β_t) are negative and highly statistically significant across 4 out of 5 proxies of financial constraints. Although negative, the firm size coefficient is not statistically significant for KZ index. β_t is interpreted as the sensitivity of IV for changes in firm size for a firm whose financial constraints are equal to the sample mean and the highest sensitivity is reported for HP index with a coefficient of -0.05. The interaction term between firm size and the financial constraints proxies are statistically significant across 4 out of 5 proxies. These coefficients indicate the strength of the IV-firm size relationship for various levels of financial constraints. For instance, according to the literature that suggest firms that pay dividends are likely to be less financially constrained, we find in our results that the coefficient on dividend dummy is negative and statistically significant indicating that paying dividend (i.e., the less financially constrained the firm becomes), results in lower firm IV. The coefficient on size remains negative and statistically significant in the presence of financial constraints. The positive and statistically significant interaction term between firm size and dividends is in line with our hypothesis that the more financially constrained a firm is, stronger the negative relationship between IV and firm size. One standard deviation increase in dividends (i.e. decreasing financial constraints) is associated with 0.04 increase in IV-firm size relationship. In other words, a two standard deviation positive shock to firm size would result, on average, in a 2.27% decrease in annual IV for firms with high financial constraints, compared to a 0.73% increase for firms with low financial constraints.

The coefficient of the interaction term between firm size and cash ratio is not statistically significant but it enters the model with the correct sign. The coefficient of the interaction term between firm size and KZ index is -0.14, implying that one standard deviation increase in KZ index is associated with a 0.14 decrease in the IV-firm size relation. In other words, a two-standard-deviation positive shock to firm size would result, on average, in a 5.04% decrease in annual IV for with high financial constraints, compared to 4.35% increase for firms with less financial constraints. We find similar results on HP index and WW index as well. Overall, our findings suggest that while firm size is negatively related to firm IV, the relationship gets stronger for firms that faces high financial constraints.

3.5.2 Firm age, IV and the impact of Financial Constraints

In this section, we test our hypothesis of the moderating role of financial constraints in the relationship between firm age and IV. This time we use an interaction term between firm age and each proxies for financial constraints, one at a time, using the following Fama-Macbeth cross-sectional regressions:

$$IV_{j,t} = \alpha_t + \beta_t Size_{j,t-1} + \gamma_t Age_{j,t-1} + \delta_t FC_{j,t-1} + \nu_{2,t} FC_{j,t-1}.Age_{j,t-1} + \overrightarrow{\omega_t} x_{j,t-1} + e_{j,t} \quad (4)$$

γ_t is the sensitivity of IV for changes in firm age for a firm whose financial constraints are equal to the sample mean. The coefficient estimates of the interaction term $\nu_{2,t}$ now indicates the strength of the IV-firm age relationship for different levels of financial constraints faced by a firm. We standardize each of the financial constraints proxy to allow intuitive interpretation. The estimation results of equation (4) is given in table 3.6.

The first column in Table 3.6 corresponds to the baseline model and the subsequent columns indicate separate estimations that includes one financial constraints proxy (*FC*) at a time. In the bottom panel of the table, we also present a summary of the economic effects of financial constraints on firm age-IV relationship. The 'Total effect of firm age on IV' summarises the overall effect of the firm age-IV relationship for firms that have low or high financial constraints. The effect of Low (high) financial constraints is calculated as two standard deviations below (above) the mean value of the financial constraints proxy. The 'Impact of big age on IV' summarises the strength of the firm age-IV relationship for firms that have low or high financial constraints. 'Big' age refers to firm age that is two-standard deviations above the mean.

Table 3. 6 – Firm age, IV and Financial constraints

This table presents the Fama-MacBeth (1973) cross-sectional regressions of individual firm idiosyncratic volatility (IV) on firm characteristics as per equation (4). The first column shows the baseline model and subsequent columns indicate separate estimations that includes one financial constraints proxy at a time. The sample period is Jan 1996 to Dec 2017 and we exclude from all of our estimations any financial or utility firms. Firm IV is estimated relative to FF-3 model detailed in equations (1). All variables are defined per section 3.4. We standardize each of the financial constraints proxy by subtracting its in-sample mean and dividing the difference by in-sample standard deviation. We estimate the regressions annually and report time series means of coefficient estimates along with *t*-statistics obtained using Newey-West autocorrelation-and-heteroscedasticity-consistent standard errors in parentheses. *** indicates significance at 1%, ** at 5% and * at 10%. R^2 refers to average annual R^2. We also present a summary of the economic effects of financial constraints on firm age-IV relation. Low (high) financial constraints means that the effect of firm age on IV is calculated using the value of the proxy for financial constraints at two standard deviations below (above) the mean. 'Big' age refers to firm age that is two-standard deviations above the mean.

		Proxy for Financial Constraints				
	Baseline Model	Dividends (dummy)	Cash Ratio	KZ index	HP index	WW index
Firm size	-0.042***	-0.035***	-0.037***	-0.0318**	-0.043***	-0.041***
	(-4.39)	(-2.98)	(-3.32)	(-2.71)	(-4.45)	(-4.07)
Firm age	-0.044***	-0.034***	-0.044***	-0.026	-0.106	-0.041***
	(-3.78)	(-3.04)	(-3.78)	(-1.69)	(-1.46)	(-3.38)
Dividend (dummy)		-0.176**				
		(-2.64)				
Age*Dividend (dummy)		0.027				
		(1.43)				
Cash Ratio			0.131***			
			(3.19)			
Age* Cash Ratio			-0.035***			
			(-4.29)			
KZ index				0.502***		
				(2.88)		
Age* KZ index				-0.157**		
				(-2.16)		
HP index					-0.142	
					(-0.68)	
Age* HP index					0.0209	
					(0.58)	
WW index						-0.053
						(-0.58)
Age* WW index						0.037
						(1.29)
<u>Control variables</u>						
l_IV	0.534***	0.504***	0.530***	0.546***	0.534***	0.536***
	(7.83)	(7.63)	(7.38)	(6.88)	(7.84)	(7.79)
Book-to-market	-0.021	-0.016	-0.014	0.016	-0.022	-0.019
	(-0.59)	(-0.51)	(-0.42)	(1.26)	(-0.60)	(-0.55)
Intercept	1.011***	0.904***	0.946***	0.789***	1.225***	0.994***
	(7.87)	(5.97)	(6.32)	(5.65)	(4.27)	(7.61)
Observations	4686	4682	4623	4631	4686	4686
Avg. R2	0.361	0.401	0.376	0.352	0.367	0.371
No. of years	21	21	21	21	21	21
<u>Total effect of Age on IV</u>						
Low Financial constraints		0.0206	0.0262	0.2884	-0.1478	-0.1149
High financial constraints		-0.0878	-0.1134	-0.3396	-0.0642	0.0323
<u>Impact of big Age on IV</u>						
Low Financial constraints		0.11%	0.14%	1.57%	-0.80%	-0.62%
High financial constraints		-0.48%	-0.62%	-1.85%	-0.35%	0.18%

The coefficient estimates of firm age, γ_t is negative and statistically significant for firms with average financial constraints where financial constraint proxy dividend dummy, cash ratio and WW index are used as a proxy. When using cash ratio as a proxy for financial constraints, the coefficient estimate of firm age suggests that, the sensitivity of firm IV for changes in firm age for a firm with average financial constraints is -0.04. Overall, our results show that the negative relationship between firm size-IV and firm-IV gets stronger as the level of financial constraints faced by the firm increases.

Overall, our findings are broadly consistent with the idiosyncratic volatility literature that small and young firms have high idiosyncratic volatility. While corporate financial literature uses firm size and firm age to characterise financially constrained firms, in this chapter, we formally test whether financial constraints are associated with idiosyncratic volatility. Using a cross-sectional research design, we find that financial constraints are cannot independently explain the cross-sectional variation in idiosyncratic volatility. Further, we also show that financial constraints exacerbates idiosyncratic volatility of small and young firms

3.6 Robustness test

3.6.1 Financially unconstrained vs constrained firms

We provide additional support to our main findings by running Fama and MacBeth (1973) cross-sectional regressions (equations 3 and 4) on two sub-samples, financially unconstrained firms and financially constrained firms. By comparing the coefficient estimates between the two sub-samples, we intend to test whether the firm size-IV and firm age-IV sensitivities are different for constrained and unconstrained firms. In line with the extant literature, we sort our sample firms each year into terciles based on their index values in the previous year and assign the top and bottom tercile-firms into financially constrained or unconstrained according to the financial constraints criteria. For instance, according to cash holding, KZ index, WW index and HP index measures, firms at the top tercile are classified as constrained and firms at the bottom tercile as unconstrained and according to the dividends (dummy), firms that do not pay dividends is classified as constrained or unconstrained otherwise. Note that we do not include the firms in the middle tercile in our estimations since we intend to highlight the difference between constrained and unconstrained firms. The results of our estimations are summarized in table 3.7.

Table 3. 7 – Firm size, firm age and IV: financially unconstrained vs constrained firms

This table presents the Fama-MacBeth (1973) cross-sectional regressions of two sub-smaples; constrained vs unconstrained firms. We sort our sample firms into terciles based on each of the financial constraints proxy. Firms that belong to the top tercile of Cash Ratio, KZ index, HP index and WW index is categorised as constrained (Constr.) and the bottom tercile as unconstrained (Unconstr.). Firms that pay dividends are considered constrained or unconstrained otherwise. Individual firm idiosyncratic volatility (IV) is regressed on firm size, firm age, financial constraints proxy and control variables; lagged IV (*l*_IV), and book-to-market. All the independent variables are lagged by one period. The first panel shows the estimations for unconstrained firms and the second panel for constrained firms. The sample period is Jan 1996 to Dec 2017 and we exclude from all of our estimations any financial or utility firms. Firm IV is estimated relative to FF-3 model detailed in equations (1). Firm Size is the logarithm of market capitalisation, Firm age is the logarithm of 1 + number of years since the firm's incorporation, Dividends (dummy) is an indicator variable which takes the value of 1 if firm has paid dividend in the given year or 0 otherwise, Cash Ratio is the ratio of cash held by firm and total assets and financial constraints indexes; Kaplan-Zingales (KZ) index, Hadlock and Pierce (HP) index and Whited and Wu (WW) index. We standardize each of the financial constraints proxy by subtracting its in-sample mean and dividing the difference by in-sample standard deviation. The construction of these index measures are detailed in Section 3.4. We estimate the regressions annually and report time series means of coefficient estimates along with *t*-statistics obtained using Newey-West autocorrelation-and-heteroscedasticity-consistent standard errors in parentheses. *** indicates significance at 1%, ** at 5% and * at 10%. R^2 refers to average annual R^2.

	Unconstrained Firms				
	Dividends (dummy)	Cash Ratio	KZ index	HP index	WW index
Firm size	-0.0197	-0.0259***	-0.00782	-0.0375***	-0.0342***
	(-1.47)	(-3.23)	(-0.49)	(-11.18)	(-3.20)
Firm age	-0.0236*	-0.0477**	-0.00466	-0.0667***	-0.0498***
	(-1.84)	(-2.34)	(-0.25)	(-3.60)	(-3.77)
Control Variables					
*L*_IV	0.532***	0.544***	0.592***	0.492***	0.512***
	-10.54	-5.52	-8.42	-19.67	-13.87
Book-to-market	0.0344***	0.03	0.0830**	0.0257***	0.0953
	-3.09	-0.66	-2.65	-6.99	-0.95
Intercept	0.590**	0.783***	0.334	0.963***	0.879***
	-2.79	-4.36	-1.54	-12.61	-7.3
Observations	4076	1654	1524	2086	1627
R^2	0.3084	0.3908	0.4803	0.3706	0.482
No. of years	21	21	21	21	21
	Constrained Firms				
	Dividends (dummy)	Cash Ratio	KZ index	HP index	WW index
Firm size	-0.121***	-0.0431***	-0.0168**	-0.0218	-0.0385*
	(-3.17)	(-3.22)	(-2.36)	(-1.56)	(-2.02)
Firm age	-0.0439	-0.0499***	-0.0537***	-0.0412*	-0.0361
	(-0.95)	(-3.20)	(-2.96)	(-2.45)	(-1.50)
Control Variables					
*L*_IV	0.545**	0.519***	0.668***	0.479***	0.656***
	-2.51	-7.76	-3.94	-5.99	-5.12
Book-to-market	-0.316*	-0.0422	-0.0992	-0.131*	0.107
	(-1.89)	(-1.02)	(-1.50)	(-2.38)	-1.27
Intercept	2.334***	1.059***	0.689***	0.846**	0.822***
	-4.87	-4.39	-6.81	-3.15	-3.6
Observations	606	1455	1535	1053	1505
R^2	0.5262	0.552	0.4897	0.360	0.4778
No. of years	21	21	21	21	21

The sign of the coefficient estimates confirms the negative firm size-IV and firm age-IV relationship across all five proxies. In line with our expectations, 4 out of 5 proxies of financial constraints; dividend dummy, cash holding, KZ index and WW index measures, confirm larger coefficient estimates on firm size for constrained firms compared to unconstrained firms. Coefficients are statistically significant at 1% for dividend dummy, cash holding and KZ index and 10% for WW index. However, for the remaining proxy; HP index, we find the opposite result. For constrained firms, the firm size coefficient is smaller and not statistically significant whereas for unconstrained firms, the coefficient is larger and statistically significant at 1%. Overall the results confirm that constrained firms report a higher sensitivity of IV to changes in firm size compared to unconstrained firms.

Similarly, for 3 out of 5 proxies, firm age reports a higher coefficient for constrained firms compared to unconstrained firms, out of which 2 are statistically significant at 1% level. The remaining 2 proxies report an opposite result, where coefficient on firm age is smaller for constrained firms than unconstrained firms. Overall, the results point towards higher sensitivity of constrained firms' IV to changes in firm maturity. Additionally, the average R^2 of the estimations indicates that the model fit is higher for financially constrained firms compared to unconstrained firms and it is robust across all five proxies.

3.6.2 Total assets as a measure of firm size

We derive our main findings in section 3.5.1 and 3.5.2 using log of market capitalization as a measure of firm size. We prefer this measure due to the exogenous nature of market capitalisation (Hadlock and Pierce, 2010). However, it is also common in the literature to use firms' total assets as a measure of firm size (for instance, Grullon, Lyandres and Zhdanov, 2012). Therefore, we run our estimations in equation 3 and equation 4, using log of total assets as a measure of firm size which we indicate as $\overline{Size}$. We present the results in table 3.8 and 3.9.

According to table 3.8, we confirm that firm $\overline{Size}$-IV relationship is negative and statistically significant in the baseline model. In the remaining estimations, which includes financial constraints proxy and the interaction, term, firm $\overline{Size}$ remains a robust and statistically significant predictor for four out of five proxies. When we include KZ index, the statistical significance on firm $\overline{Size}$ disappears similar to our main estimation in 3.5, where market capitalisation is used as a measure of firm size. The coefficient estimate reported on $\overline{Size}$ is very small (close to zero) and both KZ index and the interaction term are not statistically significant. As expected, we find a positive coefficient on the interaction term between $\overline{Size}$ and dividend (dummy), as well as negative coefficients on the cash holding, KZ index, HP index and WW index. Four out of five proxies are statistically significant indicating that firm $\overline{Size}$ –IV relationship gets stronger as the level of financial constraints increases. Firm age appears consistently significant when we control for financial constraints across all five proxies.

Table 3. 8 – Firm size, IV and financial constraints

This table presents the Fama-MacBeth (1973) cross-sectional regressions of individual firm idiosyncratic volatility (IV) on firm characteristics as per equation (4) with the only exception of firm $\overline{Size}$, which we measure as the logarithm of total assets. The first column shows the baseline model and subsequent columns indicate separate estimations that includes one financial constraints proxy at a time. The sample period is Jan 1996 to Dec 2017 and we exclude from all of our estimations any financial or utility firms. Firm IV is estimated relative to FF-3 model detailed in equations (1). All variables are defined per section 3.4. We standardize each of the financial constraints proxy by subtracting its in-sample mean and dividing the difference by in-sample standard deviation. We estimate the regressions annually and report time series means of coefficient estimates along with *t*-statistics obtained using Newey-West autocorrelation-and-heteroscedasticity-consistent standard errors in parentheses. *** indicates significance at 1%, ** at 5% and * at 10%. R^2 refers to average annual R^2.

		Proxy for Financial Constraints				
	Baseline Model	Dividends (dummy)	Cash Ratio	KZ index	HP index	WW index
Firm $\overline{Size}$	-0.034***	-0.031***	-0.030***	-0.000	-0.038***	-0.036***
	(-5.67)	(-3.89)	(-3.78)	(-0.01)	(-5.43)	(-5.32)
Firm age	-0.039***	-0.025**	-0.037***	-0.039***	-0.058**	-0.039***
	(-3.36)	(-2.27)	(-3.77)	(-3.50)	(-2.10)	(-3.33)
Dividend (dummy)		-0.698***				
		(-2.90)				
$\overline{Size}$*Dividend (dummy)		0.050**				
		(2.60)				
Cash Ratio			0.287**			
			(2.36)			
$\overline{Size}$*Cash Ratio			-0.024**			
			(-2.39)			
KZ index				1.945		
				(1.59)		
$\overline{Size}$*KZ index				-0.166		
				(-1.53)		
HP index					0.153	
					(1.63)	
$\overline{Size}$*HP index					-0.0128**	
					(-2.14)	
WW index						0.985*
						(2.05)
$\overline{Size}$*WW index						-0.073*
						(-1.96)
<u>Control variables</u>						
*l*_IV	0.549***	0.502***	0.541***	0.535***	0.545***	0.545***
	(7.40)	(7.98)	(6.80)	(8.14)	(7.47)	(7.29)
Book-to-market	-0.012	0.001	0.010	0.023	-0.006	-0.009
	(-0.34)	(0.02)	(0.42)	(1.65)	(-0.19)	(-0.27)
Intercept	0.879***	0.799***	0.794***	0.430***	0.975***	0.896***
	(8.63)	(7.41)	(7.88)	(3.51)	(9.06)	(8.21)
Observations	4715	4708	4647	4644	4715	4715
Avg. R^2	0.3643	0.4306	0.3920	0.3710	0.3735	0.3755
No. of years	21	21	21	21	21	21

According to table 3.9, our results reinforce the negative firm $\overline{\text{Size}}$-IV and firm age-IV relationship. Firm age is highly statistically significant at 1% when cash holdings and WW index proxies financial constraints and weakly significant at 10% when dividends (dummy) and HP index proxies financial constraints. When KZ index is used, firm age is not statistically significant. The coefficient estimates on the interaction term between firm age and financial constraints is statistically significant at 5% for cash holding and KZ index. This finding reinforces that the sensitivity of IV for changes in firm maturity gets stronger when the level of financial constraints faced by a firm increases. The model fit denoted by the average R^2 is also comparable to our main model, which uses log of market capitalization as a measure of firm size. Overall, using log of total assets as an alternative measure of firm size, we confirm our main findings provided in Section 3.5.

Table 3. 9 – Firm age, IV and financial constraints

This table presents the Fama-MacBeth (1973) cross-sectional regressions of individual firm idiosyncratic volatility (IV) on firm characteristics as per equation (4) with the only exception of firm $\overline{\text{Size}}$, which we measure as the logarithm of total assets. The first column shows the baseline model and subsequent columns indicate separate estimations that includes one financial constraints proxy at a time. The sample period is Jan 1996 to Dec 2017 and we exclude from all of our estimations any financial or utility firms. Firm IV is estimated relative to FF-3 model detailed in equations (1). All variables are defined per section 3.4. We standardize each of the financial constraints proxy by subtracting its in-sample mean and dividing the difference by in-sample standard deviation. The construction of these index measures are detailed in Section 2.3. We estimate the regressions annually and report time series means of coefficient estimates along with *t*-statistics obtained using Newey-West autocorrelation-and-heteroscedasticity-consistent standard errors in parentheses. *** indicates significance at 1%, ** at 5% and * at 10%. R^2 refers to average annual R^2.

			Proxy for Financial Constraints			
	Baseline Model	Dividends (dummy)	Cash Ratio	KZ index	HP index	WW index
Firm $\overline{\text{Size}}$	-0.034***	-0.026***	-0.028***	-0.022***	-0.036***	-0.033***
	(-5.67)	(-4.02)	(-3.63)	(-2.86)	(-6.05)	(-5.34)
Firm age	-0.039***	-0.024*	-0.040***	-0.021	-0.111*	-0.037***
	(-3.36)	(-2.02)	(-3.64)	(-1.30)	(-1.75)	(-3.12)
Dividend (dummy)		-0.139**				
		(-2.45)				
Age*Dividend (dummy)		0.013				
		(0.69)				
Cash Ratio			0.117**			
			(2.81)			
Age*Cash Ratio			-0.032***			
			(-3.98)			
KZ index				0.468**		
				(2.56)		
Age*KZ index				-0.164**		
				(-2.14)		
HP index					-0.189	
					(-1.03)	
Age*HP index					0.0300	
					(0.93)	
WW index						0.005
						(0.06)
Age*WW index						0.019
						(0.74)
<u>Control variables</u>						
*l*_IV	0.549***	0.520***	0.547***	0.564***	0.549***	0.550***
	(7.40)	(7.14)	(7.19)	(6.66)	(7.40)	(7.35)
Book-to-market	-0.012	-0.009	-0.001	0.024*	-0.012	-0.011
	(-0.34)	(-0.28)	(-0.03)	(1.86)	(-0.33)	(-0.31)
Intercept	0.879***	0.745***	0.796***	0.631***	1.122***	0.855***
	(8.63)	(8.77)	(8.05)	(8.37)	(5.22)	(8.44)
Observations	4715	4708	4647	4644	4715	4715
Avg. R^2	0.3643	0.4026	0.3757	0.3540	0.3698	0.3737
No. of years	21	21	21	21	21	21

3.6.3 Muticollinearity tests

The correlation statistics in table 3.2 in section 3.4.3 indicates potential multicollinearity problem in our independent variables. In order to ensure the validity of our results, we formally test for multicollinearity using two tests; first, by examining the Variance Inflation Factors (VIF) and condition index of characteristic-root-ratio test by Belsley, Kuh and Welsch (1980). The results of these two tests are provided in table 3.10 and 3.11.

First, we start by examining the VIF of our regressors. VIF measures the degree to which the variance has been inflated due to collinearity in regressors. As per the rule of thumb, VIFs greater than 10 is considered as evidence of collinearity (Chatterjee, Hadti and Price, 2000; Dennis and Strickland, 2004; Baum, 2006; Luo and Bhattacharya, 2009; Mishra and Modi, 2013). For this, we run an OLS regression as per equation (3), which includes one financial constraints proxy at a time followed by examining the VIFs post estimation. Table 3.10 indicates that the highest VIF across all proxies of financial constraints is 5.77, a number way below the benchmark of 10 indicating no evidence of multicollinearity.

Next, we estimate the condition index, also known as the characteristic-root-ratio test. This test provides collinearity diagnostics based on the interrelationship among regressors. Belsley, Kuh and Welsch (1980) suggests that a condition index greater than 30, there may be potential collinearity issues (Guo and Savickas, 2006, 2008). Condition index is derived post estimation of OLS regression of our regressors as per equation (3) which includes one financial constraints proxy at a time. According to Table 3.11 the highest condition index is 25.67 a number below the benchmark of 30. This suggests that there is no evidence of multicollinearity among our regressors.

Table 3. 10 – Variance Inflation Factors (VIF) of regressors

This table presents simple Ordinary Least Squares (OLS) regressions of individual firm idiosyncratic volatility (IV) on firm size, firm age, financial constraints proxy (which we include one at a time) and control variables; lagged IV (*l*_IV), and book-to-market and their Variance Inflation Factors (VIFs) post estimation. All the independent variables are lagged by one period. The sample period is Jan 1996 to Dec 2017 and we exclude from all of our estimations any financial or utility firms. Firm IV is estimated relative to FF-3 model detailed in equations (1). Firm size is the logarithm of market capitalisation, Firm age is the logarithm of 1 + number of years since the firm's incorporation, Dividends (dummy) is an indicator variable which takes the value of 1 if firm has paid dividend in the given year or 0 otherwise, Cash Ratio is the ratio of cash held by firm and total assets and financial constraints indexes; Kaplan-Zingales (KZ) index, Hadlock and Pierce (HP) index and Whited and Wu (WW) index. We standardize each of the financial constraints proxy by subtracting its in-sample mean and dividing the difference by in-sample standard deviation. The construction of these index measures are detailed in Section 2.3.

Variable	Estimate	Standard Error	*t*-Statistic	VIF
	Financial Constraints Criteria - Dividends (dummy)			
Intercept	1.690	0.095	17.73	na
*l*_IV	0.161	0.008	19.12	1.08
Firm size	-0.071	0.006	-11.04	1.06
Firm age	-0.066	0.012	-5.55	1.04
Book-to-market	0.006	0.004	1.28	1.01
Dividends (dummy)	-0.134	0.013	-10.16	1.09
	Financial Constraints Criteria - Cash Holdings			
Intercept	1.777	0.099	18.00	na
*l*_IV	0.173	0.008	20.44	1.06
Firm size	-0.076	0.007	-11.58	1.06
Firm age	-0.078	0.012	-6.29	1.06
Book-to-market	0.011	0.005	2.25	1.01
Cash Ratio	0.040	0.014	2.87	1.08
	Financial Constraints Criteria - KZ index			
Intercept	1.709	0.093	18.3	na
*l*_IV	0.182	0.009	20.35	1.05
Firm size	-0.069	0.006	-11.13	1.04
Firm age	-0.086	0.012	-7.37	1.01
Book-to-market	0.013	0.004	2.99	1.01
KZ index	-0.003	0.015	-0.21	1.00
	Financial Constraints Criteria - HP index			
Intercept	2.005	0.127	15.81	na
*l*_IV	0.176	0.008	20.93	1.05
Firm size	-0.079	0.006	-12.27	1.06
Firm age	-0.140	0.028	-4.94	5.76
Book-to-market	0.009	0.005	1.89	1.01
HP index	-0.055	0.026	-2.12	5.77
	Financial Constraints Criteria - WW index			
Intercept	1.827	0.095	19.17	na
*l*_IV	0.176	0.008	21.01	1.05
Firm size	-0.078	0.006	-12.1	1.05
Firm age	-0.085	0.012	-7.17	1.02
Book-to-market	0.008	0.005	1.88	1.01
WW index	0.002	0.012	0.13	1.00

Table 3. 11 – Condition Index of regressors (characteristic-root-ratio test)

This table presents simple Ordinary Least Squares (OLS) regressions of individual firm idiosyncratic volatility (IV) on firm size, firm age, financial constraints proxy (which we include one at a time) and control variables; lagged IV (*l*_IV), and book-to-market and their Condition Index (or characteristic-root-ratio test) by Belsley, Kuh and Welsch (1980) post estimation. All the independent variables are lagged by one period. The sample period is Jan 1996 to Dec 2017 and we exclude from all of our estimations any financial or utility firms. Firm IV is estimated relative to FF-3 model detailed in equations (1). Firm size is the logarithm of market capitalisation, Firm age is the logarithm of 1 + number of years since the firm's incorporation, Dividends (dummy) is an indicator variable which takes the value of 1 if firm has paid dividend in the given year or 0 otherwise, Cash Ratio is the ratio of cash held by firm and total assets and financial constraints indexes; Kaplan-Zingales (KZ) index, Hadlock and Pierce (HP) index and Whited and Wu (WW) index. We standardize each of the financial constraints proxy by subtracting its in-sample mean and dividing the difference by in-sample standard deviation. The construction of these index measures are detailed in Section 2.3.

Intercept	*l*_IV	Firm size	Firm age	Book-to-market	Dividends (dummy)	Condition Index (characteristic-root-ratio test)
0	0.02	0	0.01	0.01	0	1.00
0	0.15	0	0	0.07	0.53	1.68
0	0.07	0	0	0.9	0.03	1.88
0	0.71	0	0	0.02	0.41	2.22
0.03	0.01	0.07	0.94	0	0.01	7.65
0.97	0.04	0.93	0.05	0	0.02	19.67

Intercept	*l*_IV	Firm size	Firm age	Book-to-market	Cash Ratio	Condition Index (characteristic-root-ratio test)
0	0.02	0	0.01	0.01	0	1.00
0	0.13	0	0	0.04	0.66	1.73
0	0.02	0	0	0.93	0.02	1.87
0	0.78	0	0	0.02	0.26	2.12
0.03	0.01	0.07	0.93	0	0.03	7.72
0.97	0.05	0.92	0.06	0.01	0.03	19.86

Intercept	*l*_IV	Firm size	Firm age	Book-to-market	KZ index	Condition Index (characteristic-root-ratio test)
0	0.02	0	0.01	0.01	0	1.00
0	0.03	0	0	0.09	0.84	1.8
0	0.01	0	0	0.89	0.1	1.88
0	0.88	0	0	0	0.06	2.08
0.03	0.01	0.07	0.94	0	0	7.74
0.97	0.05	0.93	0.05	0	0	19.79

Intercept	*l*_IV	Firm size	Firm age	Book-to-market	HP index	Condition Index (characteristic-root-ratio test)
0	0.02	0	0	0.01	0	1.00
0	0.25	0	0	0.34	0.05	1.89
0	0.21	0	0	0.65	0.02	1.95
0	0.48	0	0	0	0.1	2.34
0.01	0.01	0.51	0.41	0	0.32	14.55
0.99	0.04	0.48	0.59	0	0.51	25.67

Intercept	*l*_IV	Firm size	Firm age	Book-to-market	WW index	Condition Index (characteristic-root-ratio test)
0	0.02	0	0.01	0.01	0	1.00
0	0	0	0	0	1	1.79
0	0	0	0	0.98	0	1.86
0	0.91	0	0	0	0	2.02
0.03	0.01	0.07	0.95	0	0	7.59
0.97	0.06	0.93	0.04	0	0	19.46

3.7 Conclusion

While it is a stylized fact in the IV literature that small and young firms have high IV due to risky and volatile fundamentals, financial constraints literature suggests that small and young firms tend to be more financially constrained. Yet, firm size, firm age and financial constraints are not perfectly correlated. Therefore, it is plausible to expect that the cross-sectional firm size-IV and firm age-IV relationship is influenced by the presence of financial constraints. Consistent with our prediction, we find that the negative relationship between firm size and IV gets stronger as the level of financial constraints increase, and the relationship gets weaker and even reverses for firms with low levels of financial constraints. We observe a similar relationship between firm age and IV; the relationship between firm age and IV gets stronger as the level of financial constraints increase. However, our results suggest that financial constraints are not an independent factor that can explains cross-sectional variation in IV.

Using data from UK listed firms for the period 1996 to 2017, we capture the moderating role of financial constraints using interaction terms between firm size and financial constraints, and firm age and financial constraints. We derive our empirical findings using Fama and MacBeth (1973) cross-sectional regressions using alternative measures of financial constraints; Dividends (dummy), cash holding, KZ index, WW index and HP index. The results provide important implications to the literature that the presence of greater financial constraints reinforces and strengthens the well-known negative firm size-IV or firm age-IV relationship. As the sensitivity of IV for changes in firm size and firm age depends on the level of financial constraints the firm faces, studies involving firm-specific uncertainty should account for financial constraints in any estimations.

By bringing together idiosyncratic volatility and financial constraints literature, this chapter provides first empirical evidence on the moderating role of financial constraints in explaining cross-sectional variation in idiosyncratic volatility. The findings of this study points towards the need for better corporate policies relating to investing and financing. For instance, in order to reduce firm-specific uncertainty, smaller and younger firms should work towards alleviating their financial constraints by reviewing their financing and investment policies.

The next empirical chapter will examine the impact of firm-specific uncertainty in firms' corporate investment decisions. Using firms listed in London Stock Exchange's (LSE) Alternative Investment Market (AIM), a junior exchange, this chapter will highlight the role of firm's competitive position in modulating the relationship between investment and uncertainty.

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4. CHAPTER 4 – FIRM INVESTMENT BEHAVIOUR AND UNCERTAINTY IN THE ALTERNATIVE INVESTMENT MARKET (AIM)

4.1 Abstract

Firm-specific uncertainty may discourage firms to invest in capital assets as 'real option' value is created by waiting until new information arrives. However, cutting back capital expenditure makes the firm too vulnerable to its rivals especially when competition is intense. Using a unique dataset on UK's Alternative Investment Market (AIM), a market that is established to stimulate economic growth by helping smaller and growing companies to raise capital, we explore the relationship between uncertainty and investment and how competition modulates this nexus. We empirically document that firm-specific uncertainty slows down capital accumulation in AIM-listed firms in line with real options theory. However, this relationship gets weaker as the firm increases its market share or market power. The tendency of firms with stronger competitive position to extract monopolistic rents by exploiting investment opportunities under uncertainty calls for effective competition policies that would stimulate corporate investments particularly in a secondary market such as the Alternative Investment Market (AIM).

4.2 Introduction

Understanding the impact of uncertainty on firm's investment decisions has been one of the extensively debated topics in corporate finance literature. Despite diverse theoretical and empirical findings, how uncertainty affects investments still remains ambiguous. While uncertainty slows down accumulation of capital according to real options theory, imperfect competition adds to the complexity of the underlying relationship between uncertainty and investment. In this paper, we examine how firm's competitive position modulates the impact of firm-specific uncertainty on corporate investment decisions using firms listed in London Stock Exchange's (LSE) Alternative Investment Market (AIM), a junior exchange.

AIM was launched in 1995 with the goal of helping smaller growing firms to access growth capital. Despite high level of investor protection assured by primary exchanges, countries are considering alternative regulatory structures to lower the cost of raising capital and their effective monitoring (Gerakos, Lang and Maffett, 2012). AIM is considered one of the most lightly regulated market among the developed world with concise principle-based rules (Campbell and Tabner, 2014). In fact, Piotroski and Srinivasan, (2008) predict that smaller foreign firms are likely to choose AIM-listing over a regulated exchanges in the US in favour of less stringent governance. Regardless of the benefits of regulatory environment, performance of AIM-listed firms has been subject to scrutiny. While Revest and Sapio (2013) empirically show that AIM-listed firms grows faster than comparable private companies in term of employees, they underperform in terms of productivity. On the other hand, Piotroski, (2012) document considerably lower returns earned by investors on the AIM compared to those on publicly regulated exchanges. Our study is the first to provide empirical evidence on the investment behaviour of AIM firms.

Using various measures of uncertainty, early research provides evidence of a negative influence of uncertainty on corporate investment decisions. While a firm will exercise the best investment option presented to them until it reaches the optimal level of capital stock and thus maximum firm value, uncertainty presents an interesting perspective to firm's investment decisions. The results of Pindyck (1993) and Dixit and Pindyck (1994) show that when capital is irreversible, uncertainty creates 'option value' for waiting and thus firms delay their investment decisions until uncertainty is resolved or until new information arrives. This negative relationship between investment and uncertainty is well established in the literature (Baum et al., 2008; Bulan, 2005; Panousi and Papanikolaou, 2012). We formally test whether AIM-listed firms, which are relatively smaller, younger and are less regulated compared to firms listed on the primary exchange, demonstrate real option behaviour when faced with increasing firm-specific uncertainty.

Early theoretical research explores the role of competition on the investment behaviour of rival firms (Caballero, 1991; Kulatilaka and Perotti, 1998). While uncertainty encourages firms to delay investment plans, intuition suggest that product market competition will erode the option value of waiting and thus the incentive to wait due to fear of pre-emption by rivals. On the other hand, Dixit and Pindyck (1994) and (Novy-Marx (2007) argue that the degree of competition does not erode the value of the option to wait. The controversial nature of competition has prompted for empirical support from researchers but yet remains ambiguous (Ghosal and Loungani, 1996; Guiso and Parigi, 1999; Henley et al., 2003; Bulan, 2005; Drakos and Goulas, 2006; Shima, 2016). For instance, Guiso and Parigi (1999) and Bulan (2005) finds that competition weakens the negative relationship between uncertainty and investment, Henley et al. (2003) argues that competition encourages investment under uncertainty.

Further, the existing empirical findings seem to be sensitive to the choice of proxies used by the authors to capture product market competition.

Extant evidence points to the importance of researchers taking into consideration the product market structure when assessing the investment behaviour of firms. Thus sample selection is a crucial factor that is able to capture unique characteristics of strategic interaction among rival firms in the relevant market. For the UK market, the limited evidence based on primary-exchange listed firms has explored the effect of both macroeconomic and firm-specific uncertainty on investments. While Beaudry et al. (2001) show that aggregate price uncertainty adversely affects the investment allocation process, Bloom et al. (2007) document that firms become cautious to invest when firm-specific demand is uncertain. On the contrary, Henley et al. (2003) document a positive relationship between firm-specific uncertainty and investment for primary-exchange listed UK firms between 1973 and 1995. They argue that while firm-specific uncertainty stimulates investment, industry-wide uncertainty depresses the level of investments and the effect is stronger only for firms operating in a highly concentrated industry. Note that their findings are based on a sample-split methodology, which restricts the uncertainty-investment dynamics to the pre-defined groups. In contrast, we allow the competition variable to freely interact with uncertainty and hence test the combined effect of competition and uncertainty on investment decisions of AIM-listed firms.

In this paper we develop alternative measures of firm-specific uncertainty using stock returns which captures the total return volatility and the idiosyncratic return volatility. Further, using firm's market share as a proxy for firm's competitive position, we test the combined effect of competition and uncertainty on investment decisions. Therefore, we first establish the nature of the relationship between investment and uncertainty as a benchmark model and then augment the baseline model with the competition variable. Our empirical work exploits a panel data set covering a large number of UK firms over the period of 1999 to 2018 listed on the alternative exchange – AIM. Similar to the bulk of the evidence which are mainly derived from primary exchange-listed firms in developed markets, we first document a robust negative effect of firm-specific uncertainty on corporate investment. The goal of our empirical work is to further examine the impact of product market competition in the AIM, a junior exchange that was established to help smaller and growing companies to raise capital and claims to be the most successful growth market in the world (London Stock Exchange, 2019).

The remainder of this paper is laid out as follows; Section 2 reviews the relevant prior literature, Section 3 describes the data and the empirical specification used in our study, Section 4 reports and discusses the estimation results and Section 5 concludes the paper.

4.3 Literature Review

While it is common understating that uncertainty will slow down accumulation of capital, there are many other factors known to influence the way in which firms respond to shocks, such as, assumptions about production function, investment lags, level of financial frictions (Gilchrist et al., 2014), degree of irreversibility, management's attitude towards risk (Miao and Wang, 2007), ownership structure (Panousi and Papanikolaou, 2012), use of managers' compensation contracts (Glover and Levine, 2015), market structure, competition, demand uncertainty and economic fluctuations (Beaudry et al., 2001).

The literature on the relationship between uncertainty and investment can be categorised into two main strands. The first is based on the standard real options theory framework which predicts that increased uncertainty will lower the level of investments by firms. The intuition of the irreversibility channel is that when installed capital is irreversible, reflecting high sunk cost, an increase in uncertainty will lead to lowering capital accumulation of firms until the uncertainty is resolved or at least until new information relating to the uncertainty becomes available to the firm. Therefore, it is rational to expect that a risk-neutral firm will lower or delay its investment plans when faced with increased uncertainty about the future. By delaying an investment decision and waiting until the uncertainty is resolved, managers of such firms may be able to avoid large potential losses as opposed to exercising the option immediately with uncertain consequences. For competitive industries, Pindyck (1993) and Dixit and Pindyck (1994) show that when capital investments are irreversible, uncertainty generates real option value of waiting and hence incentivises firms to delay their investments plans.

The role of irreversibility in shaping investment decisions of firms was discussed in some early studies by Bernanke (1983) and McDonald and Siegel (1986). In his theoretical model, Bernanke (1983) shows that when there is new information arriving continually over time and given that investments are strictly irreversible, the important factor in making investment decision is the 'option' or flexibility to delay the investment decision rather than the static NPV of the project itself. Based on the assumptions of risk-averse investors who hold a well-diversified portfolio, McDonald and Seigel (1986) show that the value of option to delay investment decisions are significant to a firm and suggest that the optimal timing to invest is when the present value of future benefits is twice higher than investment costs.

Extant empirical evidence supports the irreversibility explanation and find that the coefficient on uncertainty variable is negative. Baum et al, (2008); Bulan, (2005); Panousi and Papanikolaou, (2012) find that higher uncertainty lowers investment for US firms while Leahy and Whited (1996), also report a negative relationship between uncertainty and investment contingent on the inclusion of Tobin's Q in the model. Using a sample of Italian manufacturing companies Guiso and Parigi (1999) shows that the effect of uncertainty on corporate investment is negative even for firms with low degree of irreversibility.

The second strand of the literature suggests a positive relationship between investment and uncertainty. Early work in this area by Hartman (1972) and Abel (1983) show that uncertainty increases investments in risk-neutral firm. Under constant returns to scale assumption, they argue that since the marginal product capital is a convex function with respect to price, greater uncertainty will increase the marginal valuation of capital and therefore result in firms increasing their level of investment. According to Lee and Shin, (2000) this positive relationship is strengthened in the presence of high labour share, a variable output, as it convexifies the profit function. Using simulations, they show that the when labour share is high, increased uncertainty raises the optimal level of investments.

On the other hand, Ghosal and Loungani (1996) identify imperfect competition as a factor that drives investment in firms when uncertainty is high. Firms especially in the oligopolistic industry face fears of pre-emptive behaviour by rival firms in the market and therefore are urged to act faster to remain competitive in the industry. For instance, while there are incentives to delay investments according to the irreversibility channel, when firms expect its rivals to invest, it will act faster as a strategic response to face competition. This in turn suggest that firms would capitalise on investment opportunities when faced with uncertainty especially when there is fears of pre-emption by rivals.

On a similar vein, Kulatilaka and Perotti (1998) provide theoretical evidence of competition and the uncertainty-investment relationship between duopoly firms. They show that high volatility reduces the investment trigger of firms and thus incentivise strategic investments. Similarly, Grenadier, (2002) shows that the option value generated by delaying an investment is a diminishing function of the number of competitors of the firm. He also argues that increased competition lowers the investment trigger of firms and hence accelerates investment.

While irreversibility is an important factor that determines the sign of the relationship between uncertainty and investment, the presence of imperfect competition adds to the complexity of how uncertainty feeds through investment decisions of firms. Caballero (1991) derives a theoretical model explaining that imperfect competition affects the "asymmetric" adjustment-cost mechanisms which moderates the relationship between uncertainty and capital investments. He also argues that in the presence of imperfect competition and decreasing returns to scale makes the investment-uncertainty relationship more likely to be negative.

However, empirical evidence on the role of competition on firm's investment behaviour is by far inconclusive. Further, the inherently unobservable nature of competition has also added to the complexity of inconclusive findings. The mainstream finding in this limited empirical literature supports the view that competition weakens the relationship between uncertainty and investment, where firm's competitive position is either measured by industry concentration such as Herfindahl-Hirschman Index (Shima, 2016), four-firm concentration ratios (Ghosal and Loungani, 1996), number of firms within industry Bulan, 2005) or firm's price-cost margin (Drakos and Goulas, 2006; Guiso and Parigi, 1999). On the contrary, Henley et al. (2003) find a positive relationship between firm-specific volatility and investment, which tends to be more pronounced for firms in highly concentrated industries. Using a different proxy of competition, firms' market share, Shima (2016) also finds a positive uncertainty-investment relationship. It is important to note that the use of the competition proxy also depends on the focus of the study whether it is conducted at the industry or firm-level. While industry-level proxies are relevant to study the behaviour of a group of firms, firm-level proxies are able to capture the firm-level heterogeneity within an industry group. Since this study focuses on the investment behaviour at firm-level, we employ the firm level proxies in all our empirical specifications. The mixed empirical findings provide the motivation to our study in understanding the wedge between irreversibility and firms' strategic considerations as it affects the way in which uncertainty feeds through investment decisions of firms.

While it might be harder to identify the source of uncertainty, it is an even harder task to measure it (see Koetse et al., 2009). In this study, we are concerned with the firm-level impact of uncertainty on investment, and, therefore, we employ the idiosyncratic component of firms' volatility (Bo, 2002; Carruth et al., 2000; Leahy and Whited, 1996). Early evidence identifies idiosyncratic uncertainty as an important determinant of corporate investment as well at the aggregate level (Dixit and Pindyck, 1994). The literature measures idiosyncratic volatility in many ways. For instance, Baum et al. (2008, 2010a, 2010b) use the standard deviation of raw returns, Panousi and Papanikolaou (2012), Henley et al. (2003) and Bulan (2005) use the standard deviation of residual returns from the regression of firms' excess returns on aggregate stock market returns, a simple CAPM model, and Leahy and Whited (1996) use forecasts of stock returns' volatility derived from a vector autoregressive model. Other studies also obtain proxies for firm-specific uncertainty using changes in firms' sales (Bo, 2002; Shima, 2016), as well as survey data (Guiso and Parigi, 1999).

The typical approach to formally capture effect of firm-specific uncertainty on investment, both in terms of the sign and magnitude, we start a standard reduced-form Tobin's Q-model of investment which we then then augment with the uncertainty proxy used in our study. Following Hayashi (1982), the corporate investment literature has heavily relied on Tobin's Q as a proxy for investment opportunities, despite criticisms of being noisy (see for instance, Almeida, Campello and Weisbach (2004)). On the other hand, cash flow variable is also included in investment models as they not only capture the level of financial constraints faced by firms (Fazzari et al., 1988), but also the investment opportunities which are not fully captured by Tobin's Q (Gilchrist and Himmelberg, 1995). The level of corporate debt is also emphasized by several empirical work such as Brown and Petersen (2009) and Panousi and

Papanikolaou (2012) due to debt overhang. In addition, dynamic investment models also include a lagged investment variable in order to capture the persistence of the investment adjustment process (Eberly et al., 2012). In the analysis that follows, we develop our baseline estimation model with the above variables which we then augment by firm-level uncertainty and then by firm-level competitive position.

Firm-specific uncertainty may discourage firms to invest in capital assets as 'real option' value is created by waiting until new information arrives. However, cutting back capital expenditure makes the firm too vulnerable to its rivals especially when competition is intense. Using a unique dataset on UK's Alternative Investment Market (AIM), a market that is established to stimulate economic growth by helping smaller and growing companies to raise capital, this study contributes to the literature in the following ways. First, it provides first empirical evidence of the investment behaviour of firms listed on the AIM. Second, it shows how competitive position affects the way in which uncertainty feeds through firm's investment decisions.

4.4 Data and Empirical Specification

We examine the role of firms' competitive position on how corporate investment decisions respond to firm-specific uncertainty. Using firm level data, we examine the investment behaviour of AIM firms for the period of 1999 to 2018. Given the establishment of AIM in June 1995, Datastream reports most of the firm-level data from 1999. Therefore, we have chosen this sample period in line with data coverage. Despite the availability of a higher frequency data (semi-annually) for some of the firm-level variables, this study uses annual data since AIM firms are regulated by a different set of rules as opposed to the main market. The standard 'Listing Rules' and 'Disclosure and Transparency Rules' do not apply to AIM firms and as a result, the requirements for semi-annual reporting differs from that of an average firm listed on the main exchange (UKAP, 2020). For instance, AIM companies are not subject to providing 'management reports' which summarises material events that had occurred during the 6 months along with their impact on financial statements and a description of principle risks and uncertainties for the remaining 6 months. Therefore, in order to match the impact of complete disclosure of firm-related information with firm-level uncertainty, this study uses annual data.

Our sample consists of 658 non-financial FTSE AIM ALL-Share index-constituent firms for which we obtain annual firm-data from Datastream/Worldscope. We use the Industry Classification Benchmark (ICB) to identify the industry that a firm operates in. ICB categorizes the firms into one of the 10 broad industries and we exclude firms that belong to regulated industries such as financials and utility in all our estimations (i.e. firms excluding ICB industry code prefix 7 and 8)[19]. We exclude firms with

[19] Regulated and non-regulated industries are defined based on whether the firms in the industry are free to make its operational and capital structure choices. This distinction is widely followed in the

missing data on capital expenditure, cash flow, property plant and equipment or long-term debt and as well firms with less than four consecutive years of observations. We also trim the observations which are at one percent tails of all variables. This results in an unbalanced panel with 5,662 firm-year observations.

The empirical strategy of our baseline model follows extant empirical literature (see, for example, Baum et al., 2008, 2010a, 2010b; Carpenter and Guariglia, 2008; Panousi and Papanikolaou, 2012) to allow compatibility of our results with existing findings. We use a standard panel investment model augmented with a proxy for firm-level uncertainty and market power. We consider two alternative measures of firm-specific uncertainty obtained from stock returns. Particularly, we use the annual volatility of stock returns à la Merton (1980) employed in Baum (2008, 2010a, 2010b), and the volatility of residual returns from a market model used in Panousi and Papanikolaou (2012) and Henley et al. (2003). We further explore the strength of this investment-uncertainty relationship for varying levels of product market competition by including an interaction term for each firm's competitive position. Further, we include a lagged investment variable in order to capture the persistence of investment adjustment process. Eberly et al. (2012), in fact, provide empirical evidence that lagged investment is a superior predictor of firms' capital investment which outperforms the combined effect of firms' Tobin's Q and cash flows. Finally, in order to assure that the results are not driven by the variables used in our estimations, we use two alternative proxies to measure firm's competitive position; firm's market share and firm's price cost margin.

corporate finance literature, which classifies utility and financial industry as regulated industries (Rubin and Smith, 2011).

The baseline model includes firms' investment (*I*) as dependent variable and lagged investment, Tobin's Q (*Q*), cash flows (*CF*) and long-term debt (*D*) as independent variables. Lagged independent are used in all our empirical estimations order to avoid potential endogeneity concerns. Except for Tobin's Q, we scale all variables by the beginning-of-year capital (*K*). The details relating to the construction of variables are provided in Appendix 7.1. To control for firm-specific effect of investment policies that might have an impact on firms' investment behaviour, we include firm-fixed effects in our baseline and all subsequent equations. We estimate the baseline investment model using panel fixed effects specification as follows;

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_0 + \alpha_1 . \frac{I_{i,t-1}}{K_{i,t-2}} + \alpha_2 . \frac{CF_{i,t-1}}{K_{i,t-2}} + \alpha_3 . Q_{i,t-1} + \alpha_4 . \frac{D_{i,t-1}}{K_{i,t-2}} + \nu_i + \varepsilon_{i,t} \quad (1)$$

where *i* denotes firm and *t* denotes year and ν_i is the firm fixed effect and $\varepsilon_{i,t}$ is the error term of the investment model.

To test the role of uncertainty in firm's corporate investment behaviour, we augment the baseline model with firm-level uncertainty. We use two measures of firm-level uncertainty in this paper; total volatility and idiosyncratic volatility. The first measure - total volatility of firm *i* in year *t* is the volatility of firm's equity returns measured as the annualized standard deviation of firm's daily returns within the year *t*, similar to Leahy and Whited (1996). We denote total volatility as λ^F. The second measure - Idiosyncratic volatility of firm *i* in year *t* is the volatility of residual returns (after controlling for market returns) that are orthogonal to market volatility similar to Henley et al. (2003). Thus, idiosyncratic volatility is a much robust measure of firm-specific uncertainty since it is free from the stock's co-movement with the market. We measure idiosyncratic volatility by the annualized standard deviation of the daily error term ε within year t, which we derived based on a standard CAPM as follows[20];

$$R_{i,\tau} - Rf_{\tau} = \beta_{i,t} + \beta_{i,t}.(Rm - Rf)_{\tau} + \varepsilon_{i,\tau} \tag{2}$$

where R is firm i's return, Rf is risk-free rate and Rm is market's return measure by the return on the FTSE AIM ALL-Share index on day τ within year t. We denote idiosyncratic volatility as λ^{IV}. Data on risk-free rate for the UK market is obtained from the Xfi Centre for Finance and Investment following Gregory et al., (2013). Generally, uncertainty measures should be forward-looking as it would capture important information on firm's future profitability. However, since our volatility measure are constructed using ex-post estimates, under the assumption of rational expectations, we use one-period lagged volatility (i.e. realized volatility) as a proxy for expected volatility. Hence, in all our estimations, volatility enters the regressions as a lagged variable. The subsequent uncertainty augmented empirical model to be estimated is,

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_0 + \alpha_1.\frac{I_{i,t-1}}{K_{i,t-2}} + \alpha_2.\frac{CF_{i,t-1}}{K_{i,t-2}} + \alpha_3.Q_{i,t-1} + \alpha_4.\frac{D_{i,t-1}}{K_{i,t-2}} + \alpha_5.\lambda_{i,t-1} + \nu_i + \varepsilon_{i,t} \tag{3}$$

where $\lambda_{i,t-1}$ denotes uncertainty variables λ^{F} and λ^{IV} and the remaining variables are as explained before in equations (1) and (2).

Next, we formally capture the effect of firm's competitive position in influencing firm investment response to uncertainty by using an interaction term between our firm-level uncertainty measure and firm's competitive position in the industry. We measure firm's competitive position annually using firm's market share (MS), i.e. the

[20] This is different to the previous Chapters 2 and 3 that uses the Fama-French three-factor model (1993). We use CAPM in this study because the risk factor data available on Xfi Centre for Finance and Investment is constructed based on stocks listed on the main exchange (Gregory et al., 2013).

proportion of firm's sales relative to the total sales the firms operating within the same industry. In order to allow for intuitive interpretation of the results, we standardise our market share variable to have mean 0 and standard deviation 1. Since asset specificity has a differential effect in various industries and both our competition proxies are measured relative to their industry, we control for industry concentration using Herfindahl-Hirschman Index (*HHI*). The subsequent equation to be estimated is,

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_0 + \alpha_1 . \frac{I_{i,t-1}}{K_{i,t-2}} + \alpha_2 . \frac{CF_{i,t-1}}{K_{i,t-2}} + \alpha_3 . Q_{i,t-1} + \alpha_4 . \frac{D_{i,t-1}}{K_{i,t-2}} + \alpha_5 . \lambda_{i,t-1} + \alpha_6 . \lambda_{i,t-1} . MS_{i,t-1} + \alpha_7 . HHI_{j,t-1} + \nu_i + \varepsilon_{i,t} \quad (4)$$

where *j* denotes the industry that the firm operates in, and the remaining variables are as explained in equations (1), (2) and (3). The coefficient estimate of the interaction term between uncertainty and competitive position, α_6, captures the moderating effect of competitive position on the investment-uncertainty relationship. Consequently, the coefficient estimate of the uncertainty variable, α_5, is now interpreted as the sensitivity of investment to uncertainty for a firm with average competitive position.

We estimate our baseline and subsequent specifications; i.e. equations (1), (3) and (4), using panel fixed effects with a robust variance-covariance estimator. The robust standard errors we use, clustered at firm-level, accounts for unobserved cross-sectional heteroscedasticity and within-panel autocorrelation.

4.5 Empirical Results

4.5.1 Baseline Empirical specification

Table 4.1 reports the descriptive statistics for the variables used in our empirical analysis. Our sample includes non-financial FTSE AIM all share index-constituent firms for the period 1999 to 2018. Detailed description of the variable construction is provided in Appendix 7.1.

Table 4. 1 – Descriptive Statistics

This table presents summary statistics of variables used in our estimations. The sample includes FTSE AIM all-share index constituents for the period 1999 to 2018. We exclude financial firms from all of our estimations. I_t/K_{t-1} is investment to capital ratio, CF_t/K_{t-1} is cash flow to capital ratio, Q_t is Tobin's Q, D_t/K_{t-1} is debt to capital ratio, λ^F is firm's total uncertainty, λ^{IV} is firm's idiosyncratic uncertainty estimated using equation (2) and MS_t is market share relative to industry. Variables' description is provided in Appendix 4.8.1.

	Mean	Median	SD	p25	p75
I_t/K_{t-1}	0.8786	0.2814	2.8572	0.0791	0.8246
CF_t/K_{t-1}	-0.0215	0.0029	0.4282	-0.0088	0.0212
Q_t	11.0070	3.1024	22.8431	1.5909	8.6240
D_t/K_{t-1}	2.6293	0.0109	11.1491	0.0000	0.6069
λ^F	0.0350	0.0307	0.0197	0.0203	0.0452
λ^{IV}	0.0346	0.0303	0.0195	0.0200	0.0446
MS_t (%)	1.8434	0.3700	4.5446	0.0864	1.4307

Capital expenditure to beginning of the year capital, Tobin's Q, for our sample AIM firms are higher than primary exchange-listed firms in the UK (Machokoto *et al.*, 2019). However note that the variable definition is different in Machokoto *et al.* (2019). Similarly, these are still higher than primary exchange-listed firms in the US. The cash flow to beginning of the year capital on average is negative in our sample. The median value is at 0.003 which indicates that almost half the sample in our study have negative cash flows, bringing down the overall mean to -0.022. Negative cash flows partly represent the low profitability concerns of AIM firms which tend to be smaller, growing firms. This is in line with the findings by Gerakos, Lang and Maffett (2012) who report underperformance of AIM firms compared to the main market. On the other hand the average debt to beginning of the year capital appears to be higher than the primary exchange-listed firms in the US (Baum et al., 2008). However, this corresponds to high debt levels of firms above the median. Firm-specific uncertainty is lower than the UK and US primary exchange-listed firms as reported in Bekaert, Hodrick and Zhang (2012).

4.5.2 Investment, uncertainty and firm's competitive position at the firm level

In order to assess the impact of uncertainty on investment, we first run our baseline investment model as per equation (1) and then augment the baseline model with firm-specific uncertainty proxies as in equation (3). Since we are interested in within-group variation and aim to isolate from unobserved firm-specific heterogeneity which are correlated with our regressors, we estimate our empirical specification using panel fixed effects methodology. Additionally, the effect of time-invariant factors such as firm-specific investment and financial policies including any other omitted variables will be removed by the fixed effects estimator[21]. This is one of the widely used methodologies in estimating empirical investment models in this strand of the literature (for instance, Ghosal and Loungani, 1996; Panousi and Papanikolaou; 2012). We have merged the results of equation (1) and (3) and presented in Table 4.2. Column (a) represents the baseline model, whereas columns (b) and (c) represent the

[21] We perform the Hausman specification test in order to confirm that our data fits the panel fixed effects estimation in order to overcome the issues of endogenous repressors. The results of Hausman test is presented in the Appendix 6.2.

uncertainty-augmented investment model using two of our proxies for firm-specific uncertainty; total volatility λ^F and idiosyncratic volatility λ^{IV} respectively.

The baseline model serves as benchmark in order to check the predictive power of the control variables with and without the influence of uncertainty. Lagged investment enters the regression with a negative and significant coefficient. The parameter estimates for Tobin's Q is positive and statistically significant confirming the Q theory of investment. The significance of Q gets stronger when firm-specific uncertainty is included in the regression. The Cash flow and debt regressors report a positive coefficient and are in line with previous literature (e.g. Bulan, 2005; Drakos and Goulas, 2006). However, they are statistically insignificant. The control variables such as industry concentration (*HHI*) and the dummy variable controlling for financial crisis (*FC*) are also not statistically significant.

Having established the baseline specification for AIM firms, we now proceed to examine how investment responds to firm-specific uncertainty. In our uncertainty-augmented models in column (b) and (c), the main findings report a strong negative effect of firm-specific uncertainty on investment, statistically significant at 5%. Both the proxies of firm-specific uncertainty; total and idiosyncratic uncertainty, yields similar results. In turn this finding supports the real option behaviour of firms, where greater uncertainty significantly reduces firm's investment. Tobin's Q and the lagged investment variable are now significant at 5%, better than the baseline model.

Table 4. 2 – Investment and Uncertainty

This table presents the results of estimating equations (1) and (3) using panel fixed effects methodology. The dependent variable is investment rate and the independent variables include lagged investment rate, cash flow to capital ratio, Tobin's Q, debt to capital ratio, firm's total uncertainty, firm's idiosyncratic uncertainty, Herfindahl-Hirschman Index and a dummy variable capturing the financial crisis period. All independent variables are lagged by one period. The first column shows the baseline model as per equation (1), columns (a) and (b) include only the uncertainty proxies; total uncertainty and idiosyncratic uncertainty respectively, and the final columns (c) and (d) shows the baseline model augmented with each uncertainty proxy separately as per equation (3). The sample includes FTSE AIM all-share index constituents for the period 1999 to 2018. We exclude financial firms from all of our estimations. Variables' description is provided in Appendix 4.8.1. We estimate the regressions annually using robust standard errors clustered at firm-level, controlling for unobserved cross-sectional heteroscedasticity and within-panel autocorrelation. *** indicates significance at 1%, ** at 5% and * at 10%.

	Baseline model	(a)	(b)	(c)	(d)
$I_{i,t-1}/K_{i,t-2}$	-0.035*	-0.0308	-0.0309	-0.0443**	-0.0443**
	(-1.68)	(-1.36)	(-1.36)	(-2.04)	(-2.05)
$CF_{i,t-1}/K_{t-2}$	0.116			0.123	0.123
	(0.60)			(0.65)	(0.65)
$Q_{i,t-1}$	0.0134*			0.0157**	0.0156**
	(1.69)			(2.02)	(2.01)
D_{t-1}/K_{t-2}	0.0105			0.0105	0.0105
	(1.24)			(1.21)	(1.22)
$\lambda^{F}_{i,t-1}$		-0.247***		-0.222**	
		(-2.68)		(-2.42)	
$\lambda^{IV}_{i,t-1}$			-0.247***		-0.225**
			(-2.61)		(-2.44)
<u>*Controls*</u>					
$HHI_{j,t-1}$	-0.00472	-0.0858**	-0.0854**	0.0145	0.0146
	(-0.15)	(-2.28)	(-2.27)	(0.53)	(0.53)
FC(Dummy)	-0.120	-0.193	-0.197*	-0.0996	-0.102
	(-0.98)	(-1.62)	(-1.66)	(-0.80)	(-0.82)
Constant	0.707***	0.455	1.135***	-0.220	0.388**
	(3.68)	(1.09)	(4.69)	(-0.57)	(1.98)
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes
No. of obs	4,714	5491	5488	4,584	4,582

Next we assess the impact of firm's competitive position on the sensitivity of investment-uncertainty relationship among AIM-listed firms using equation (4). The results of the estimation are provided in Table 4.3. Again, we run the analysis for both the proxies of firm-specific uncertainty. Column (a) and (c) shows the uncertainty-augmented investment model for our uncertainty proxies-firm's total volatility and idiosyncratic volatility whereas columns (b) and (c) includes the interaction terms between uncertainty and firm's competitive position. We identify firm's competitive position using their market share relative to its total industry. To allow for an intuitive interpretation of the interaction term, we standardise the market share variable to have 0 mean and 1 standard deviation. We find a negative relationship between uncertainty and investment for firms with average market power, which is is robust across both the firm-specific uncertainty proxies, λ^F and λ^{IV}. Our finding for AIM-listed firms is at odds with the findings of Henley et al. (2003) shows that higher uncertainty stimulates investments for UK firms listed on the primary exchange.

The interaction term between uncertainty and market share is positive and statistically significant which indicates that the negative uncertainty-investment relationship gets weaker for firms with high market share. This finding suggests that when firm-specific uncertainty is high, average market share firms delay investments while high market share firms are able to increase investment levels in order to exploit the potential future investment opportunities. This finding is consistent with Guiso and Parigi (1999) and Bulan (2005) who also document a moderating effect of competition on the relationship between uncertainty and investment. Further, we also observe that the statistical significance of Tobin's Q is reduced to 10% level in the presence of interaction term. This shows that the interaction term captures further investment opportunities which Tobin's Q is unable to capture, further reinforcing our main finding.

The fundamental structural relationship between uncertainty and investment for AIM-listed firms are in line with existing literature that has predominantly focused on firms listed only on the primary exchange (Panousi and Papanikolaou, 2012; Shima, 2016). In particular, firms delay their investment plans when faced with uncertainty about future. While this is the case for firms with average market share, high market share-firms increase their level of investments as a strategic pursuit to increased competition. Our findings on the moderating effect of competition is broadly consistent with the view of strategic behaviour of rival firms under uncertainty (Guiso and Parigi, 1999; Bulan, 2003, 2005; Shima, 2016).

Table 4. 3 – Investment, Uncertainty and Competitive position

This table presents the results of estimating equation (4) using panel fixed effects methodology. The dependent variable is investment rate and the independent variables include lagged investment rate, cash flow to capital ratio, Tobin's Q, debt to capital ratio, firm's total uncertainty, firm's idiosyncratic uncertainty, the interaction terms between uncertainty and firm's market share, Herfindahl-Hirschman Index and a dummy variable capturing the financial crisis period. All independent variables are lagged by one period. In order to allow for an intuitive interpretation, we standardise our market share variable to have mean 0 and standard deviation 1. The first column (a) shows the uncertainty augmented investment model as per equation (3) and column (b) shows the model with the interaction term between uncertainty and market share as per equation (4) for the first uncertainty proxy – total uncertainty, and subsequent columns (c) and (d) shows the same estimation results for the second uncertainty proxy – idiosyncratic uncertainty.The sample includes FTSE AIM all-share index constituents for the period 1999 to 2018. We exclude financial firms from all of our estimations. Variables' description is provided in Appendix 4.8.1. We estimate the regressions annually using robust standard errors clustered at firm-level, controlling for unobserved cross-sectional heteroscedasticity and within-panel autocorrelation. *** indicates significance at 1%, ** at 5% and * at 10%.

	(a)	(b)	(c)	(d)
$I_{i,t-1}/K_{i,t-2}$	-0.0443**	-0.0434**	-0.0443**	-0.0435**
	(-2.04)	(-2.00)	(-2.05)	(-2.00)
$CF_{i,t-1}/K_{t-2}$	0.123	0.111	0.123	0.110
	(0.65)	(0.59)	(0.65)	(0.59)
$Q_{i,t-1}$	0.0157**	0.0154*	0.0156**	0.0154*
	(2.02)	(1.96)	(2.01)	(1.96)
D_{t-1}/K_{t-2}	0.0105	0.00934	0.0105	0.00936
	(1.21)	(1.08)	(1.22)	(1.08)
$\lambda^{F}_{i,t-1}$	-0.222**	-0.212**		
	(-2.42)	(-2.27)		
$\lambda^{F}_{i,t-1} * MS_{i,t-1}$		0.0219**		
		(2.17)		
$\lambda^{IV}_{i,t-1}$			-0.225**	-0.215**
			(-2.44)	(-2.29)
$\lambda^{IV}_{i,t-1} * MS_{i,t-1}$				0.0557**
				(2.01)
<u>*Controls*</u>				
$HHI_{j,t-1}$	0.0145	0.0276	0.0146	0.0237
	(0.53)	(0.91)	(0.53)	(0.81)
FC(Dummy)	-0.0996	-0.0846	-0.102	-0.0875
	(-0.80)	(-0.67)	(-0.82)	(-0.70)
Constant	-0.220	-0.250	0.388**	0.357*
	(-0.57)	(-0.63)	(1.98)	(1.73)
Firm-fixed effects	Yes	Yes	Yes	Yes
No. of obs	4584	4484	4582	4482

4.5.3 Robustness and some further issues

In this section, we conduct additional robustness checks to our main findings in section 4.2. First, we ensure that our main findings on competition is not driven by the choice of proxy we have used in the study. As an alternative measure of firm's competitive position, we use firm's Excess Price-Cost Margin (EPCM), which is the ability of the firm to price its products above marginal cost compared to their rivals in the same industry. We rename EPCM as Market Power (MP). This measure is based on the Lerner Index, also known as the Price-Cost Margin (PCM) in the industrial organisation literature which has been used to capture firm's product market power. While PCM captures the pricing power of the overall firm, it does not isolate firm-specific factors from the industry factors common to all firms specific within the industry. Therefore, we use the industry-adjusted PCM in order to capture firm-specific product market power, measured as the difference between firm's PCM and sales-weighted PCM of all firms operating within an industry. This process takes in to account structural differences in profit margins across industries that are unrelated to intra-industry differences in market power. Similar to Gaspar and Massa (2006) and Datta et al. (2013), we measure firm's MP (or EPCM) as follows;

$$MP_{i,j,t} = EPCM_{i,j,t} = PCM_{i,t} - \sum_{j=1}^{N} \omega_{i,t} * PCM_{i,t} \quad (5)$$

where,

$\omega_{i,t} = \frac{Sales_{i,t}}{\sum_{j=1}^{N} Sales_{i,t}}$ and *j* is the ICB industry that firm *i* belongs to.

Now, we estimate our main empirical specification as outlined in equation (4) and use MP as a proxy for firm's competitive position. The results of this estimation is reported in table 4.4. When we introduce competition as a moderating factor, the magnitude of the coefficient estimate on the uncertainty variable is reduced compared to the baseline model. This confirms our view that competition weakens the relationship between uncertainty and investment. Yet, the coefficient estimate of uncertainty is negative and statistically significant for firms with average market power. The interaction term enters the regression with a positive coefficient, similar to our main findings, confirming the moderating effect of competition on the relationship between uncertainty and investment. However, the coefficient estimate is not statistically significant. All other findings remain the same as our main findings in section 4.2.

As the next robustness check, we validate our findings in section 4.2 by performing a sub-sample analysis where firms are split in to two groups based on their degree of competitive position. We use both our proxies, market share and market power individually in order to split our sample firms into low versus high market share/market power groups each year. The median values of the proxy for firm's competitive position in the previous period is used as the sorting criteria. We then run our estimation in equation (3) by the sub-sample group created based on market share and market power separately. The results of the estimation are provided in tables 4.5 and 4.6 respectively. In both tables, columns (a) and (b) reports the uncertainty-augmented baseline model and the subsequent columns indicate the sample group (either low or high) created based on market share (MS) or market power (MP).

Table 4. 4 – Using Market Power (MP) as a proxy for firm's competitive position

This table presents the results of estimating equation (4) using panel fixed effects methodology. The dependent variable is investment rate and the independent variables include lagged investment rate, cash flow to capital ratio, Tobin's Q, debt to capital ratio, firm's total uncertainty, firm's idiosyncratic uncertainty, the interaction terms between uncertainty and firm's market power, Herfindahl-Hirschman Index and a dummy variable capturing the financial crisis period. All independent variables are lagged by one period. We measure market power as the firm's ability to price above marginal cost relative to its industry, as per equation (5). In order to allow for an intuitive interpretation, we standardise our market power variable to have mean 0 and standard deviation 1. The first column (a) shows the uncertainty augmented investment model as per equation (3) and column (b) shows the model with the interaction term between uncertainty and market power as per equation (4) for the first uncertainty proxy – total uncertainty, and subsequent columns (c) and (d) shows the same estimation results for the second uncertainty proxy – idiosyncratic uncertainty. The sample includes FTSE AIM all-share index constituents for the period 1999 to 2018. We exclude financial firms from all of our estimations. Variables' description is provided in Appendix 4.8.1. We estimate the regressions annually using robust standard errors clustered at firm-level, controlling for unobserved cross-sectional heteroscedasticity and within-panel autocorrelation. *** indicates significance at 1%, ** at 5% and * at 10%.

	(a)	(b)	(c)	(d)
$I_{i,t-1}/K_{i,t-2}$	-0.0442**	-0.0472**	-0.0443**	-0.0473**
	(-2.04)	(-2.17)	(-2.04)	(-2.17)
$CF_{i,t-1}/K_{t-2}$	0.123	0.286	0.123	0.286
	(0.65)	(1.41)	(0.65)	(1.41)
$Q_{i,t-1}$	0.0157**	0.0191*	0.0156**	0.0189*
	(2.02)	(1.94)	(2.01)	(1.93)
D_{t-1}/K_{t-2}	0.0105	0.0102	0.0105	0.0102
	(1.21)	(1.09)	(1.22)	(1.09)
$\lambda^{F}_{i,t-1}$	-0.222**	-0.218**		
	(-2.42)	(-2.31)		
$\lambda^{F}_{i,t-1} * MP_{i,t-1}$		0.0144		
		(1.38)		
$\lambda^{IV}_{i,t-1}$			-0.225**	-0.216**
			(-2.44)	(-2.33)
$\lambda^{IV}_{i,t-1} * MP_{i,t-1}$				0.0858
				(1.07)
Controls				
$HHI_{j,t-1}$	0.0140	0.0241	0.0141	0.0255
	(0.51)	(0.82)	(0.51)	(0.82)
FC(Dummy)	-0.0997	-0.108	-0.103	-0.110
	(-0.80)	(-0.82)	(-0.82)	(-0.84)
Constant	-0.218	-0.267	0.391**	0.330
	(-0.57)	(-0.66)	(1.98)	(1.44)
Firm-fixed effects	Yes	Yes	Yes	Yes
No. of obs	4583	4407	4581	4405

Table 4. 5 – Investment-Uncertainty: High vs Low Market Share

This table presents the results of estimating equation (3) for low and high market share groups using panel fixed effects methodology. We split our sample firms each year into low and high market share groups based on whether their market share is below or above the median market share of firms within the respective industry that firms belongs to. The dependent variable is investment rate and the independent variables include lagged investment rate, cash flow to capital ratio, Tobin's Q, debt to capital ratio, firm's total uncertainty, firm's idiosyncratic uncertainty, Herfindahl-Hirschman Index and a dummy variable capturing the financial crisis period. All independent variables are lagged by one period. The first column (a) shows the uncertainty augmented investment model as per equation (3) and columns (a.1) and (a.2) shows the sub-sample results for low and high market share groups respectively for the first uncertainty proxy – total uncertainty, and subsequent columns (b), (b.1) and (b.2) shows the same estimation results for the second uncertainty proxy – idiosyncratic uncertainty. The sample includes FTSE AIM all-share index constituents for the period 1999 to 2018. We exclude financial firms from all of our estimations. Variables' description is provided in Appendix 4.8.1. We estimate the regressions annually using robust standard errors clustered at firm-level, controlling for unobserved cross-sectional heteroscedasticity and within-panel autocorrelation. *** indicates significance at 1%, ** at 5% and * at 10%.

	(a)	(a.1) Low MS	(a.2) High MS	(b)	(b.1) Low MS	(b.2) High MS
$I_{i,t-1}/K_{i,t-2}$	-0.0443**	-0.128***	-0.0496	-0.0443**	-0.128***	-0.0496
	(-2.04)	(-3.36)	(-1.55)	(-2.05)	(-3.36)	(-1.55)
$CF_{i,t-1}/K_{t-2}$	0.123	0.219	0.0867	0.123	0.219	0.0867
	(0.65)	(0.82)	(0.26)	(0.65)	(0.82)	(0.26)
$Q_{i,t-1}$	0.0157**	0.00443	0.0208	0.0156**	0.00435	0.0207
	(2.02)	(0.42)	(1.57)	(2.01)	(0.41)	(1.57)
D_{t-1}/K_{t-2}	0.0105	0.0254	0.00874	0.0105	0.0255	0.00874
	(1.21)	(1.45)	(1.49)	(1.22)	(1.45)	(1.49)
$\lambda^{F}_{i,t-1}$	-0.222**	-0.380**	-0.0114			
	(-2.42)	(-2.45)	(-0.08)			
$\lambda^{IV}_{i,t-1}$				-0.225**	-0.383**	-0.0118
				(-2.44)	(-2.45)	(-0.08)
<u>*Controls*</u>						
$HHI_{j,t-1}$	0.0145	0.125	-0.00650	0.0146	0.124	-0.00650
	(0.53)	(1.58)	(-0.14)	(0.53)	(1.57)	(-0.14)
FC(Dummy)	-0.0996	-0.0854	-0.152	-0.102	-0.0902	-0.153
	(-0.80)	(-0.41)	(-0.96)	(-0.82)	(-0.44)	(-0.96)
Constant	-0.220	-1.277*	0.623	0.388**	-0.229	0.654*
	(-0.57)	(-1.67)	(1.04)	(1.98)	(-0.45)	(1.93)
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs	4584	2223	2261	4582	2222	2260

When we split our firms into distinctive groups based on their degree of competitive positive in their industry, we find that the negative uncertainty coefficient is statistically significant only for the low MS (or MP) group. However, the magnitude of the coefficient estimate shows that firms with lower competitive position cut down investments significantly than those with higher competitive position when exposed to firm-specific uncertainty. As such, firms with high market share or market power are able to capitalise on investment opportunities presented by increased uncertainty as a strategic response to competition. Our findings are robust across both our measures of firm-specific uncertainty and consistent with our main findings in section 4.2.

Table 4. 6 – Investment-Uncertainty: High vs Low Market Power

This table presents the results of estimating equation (3) for low and high market power groups using panel fixed effects methodology. We split our sample firms each year into low and high market power groups based on whether their market power is below or above the median market power of firms within the respective industry that firms belongs to. The dependent variable is investment rate and the independent variables include lagged investment rate, cash flow to capital ratio, Tobin's Q, debt to capital ratio, firm's total uncertainty, firm's idiosyncratic uncertainty, Herfindahl-Hirschman Index and a dummy variable capturing the financial crisis period. All independent variables are lagged by one period. We measure market power as the firm's ability to price above marginal cost relative to its industry, as per equation (5). The first column (a) shows the uncertainty augmented investment model as per equation (3) and columns (a.1) and (a.2) shows the sub-sample results for low and high power share groups respectively for the first uncertainty proxy – total uncertainty, and subsequent columns (b), (b.1) and (b.2) shows the same estimation results for the second uncertainty proxy – idiosyncratic uncertainty. The sample includes FTSE AIM all-share index constituents for the period 1999 to 2018. We exclude financial firms from all of our estimations. Variables' description is provided in Appendix 4.8.1. We estimate the regressions annually using robust standard errors clustered at firm-level, controlling for unobserved cross-sectional heteroscedasticity and within-panel autocorrelation. *** indicates significance at 1%, ** at 5% and * at 10%.

	(a)	(a.1) Low MP	(a.2) High MP	(b)	(b.1) Low MP	(b.2) High MP
$I_{i,t-1}/K_{i,t-2}$	-0.0442**	-0.0276	-0.0850***	-0.0443**	-0.0276	-0.0851***
	(-2.04)	(-0.95)	(-2.64)	(-2.04)	(-0.95)	(-2.64)
$CF_{i,t-1}/K_{t-2}$	0.123	0.326	0.307	0.123	0.327	0.306
	(0.65)	(1.34)	(0.78)	(0.65)	(1.34)	(0.78)
$Q_{i,t-1}$	0.0157**	0.0186	0.0190	0.0156**	0.0186	0.0189
	(2.02)	(1.54)	(1.24)	(2.01)	(1.53)	(1.23)
D_{t-1}/K_{t-2}	0.0105	0.000821	0.0279	0.0105	0.000820	0.0279
	(1.21)	(0.08)	(1.56)	(1.22)	(0.08)	(1.56)
$\lambda^{F}_{i,t-1}$	-0.222**	-0.298*	-0.131			
	(-2.42)	(-1.86)	(-1.01)			
$\lambda^{IV}_{i,t-1}$				-0.225**	-0.300*	-0.133
				(-2.44)	(-1.87)	(-1.02)
<u>*Controls*</u>						
$HHI_{j,t-1}$	0.0140	0.0125	0.128	0.0141	0.0124	0.127
	(0.51)	(0.29)	(0.88)	(0.51)	(0.29)	(0.88)
FC(Dummy)	-0.0997	0.0694	-0.246*	-0.103	0.0657	-0.248*
	(-0.80)	(0.32)	(-1.67)	(-0.82)	(0.30)	(-1.68)
Constant	-0.218	-0.386	-0.717	0.391**	0.433	-0.347
	(-0.57)	(-0.59)	(-0.62)	(1.98)	(1.40)	(-0.36)
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs	4583	2407	2000	4581	2406	1999

4.6 Conclusion

In this paper, we demonstrate a robust negative and likely causal relationship between firm-specific volatility and corporate investment for small and growing firms listed in the AIM, a junior exchange in the UK. Our findings are broadly consistent with the real option behaviour of firms under uncertainty documented in the literature, generally using data from primary-exchange listed firms. We find evidence that the negative effect of firm-specific volatility on corporate investment is weaker when a firm's competitive position is high, such as having high market share or high market power. This is consistent with the view that while firms with average competitive position are willing to wait until uncertainty is resolved, firms with stronger competitive position are able to capitalise on investment opportunities in the face of uncertainty as a strategic response to competition.

Our findings are robust across alternative measures of firm-specific uncertainty, such as firm's total volatility and idiosyncratic volatility and measures of firm's competitive position, such as firm's market share and market power. The limited empirical evidence on corporate investment behaviour of UK firms are by far inconclusive. While Bloom et al. (2007) shows that increase in firm-level demand shocks depresses firm's irreversible investments as firms become cautious to invest, Henley et al. (2003) document that firm-specific uncertainty stimulates investments in UK firms. Note that these studies examine only the primary-exchange listed firms in a specific sector; manufacturing and industrials sector respectively. This paper studies the investment behaviour under uncertainty for firms listed on a junior exchange, a market that is generally overlooked by researchers. In addition, we test the combined effect of competition and uncertainty on investment decisions and find that the negative uncertainty-investment relationship is weaker for firms with strong competitive position. Our results contradict those of Henley et al. (2003), who find the opposite using industry-specific uncertainty.

The implications of the model also receive empirical support from the sub-sample analysis which evaluates the uncertainty-investment relationship across groups with high versus low competitive position. We find that the magnitude of the coefficient estimate of firm-specific uncertainty for the firms with weak competitive position is higher than those firms with strong competitive position, pointing to an attenuating effect of competition on the relationship between firm-specific uncertainty and corporate investment.

Piotroski, (2012) and Gerakos, et al., (2013) argue that AIM firms underperform compared to firms listed in the traditionally regulated exchange. In line with this, we suggest that AIM firms' underperformance might be due to the under-investment problem suggested by our findings. Therefore, we argue that competition policies should be targeted in order to encourage risk-taking behaviour of firms in the AIM market, which would in turn stimulate investment activity and prevent monopolistic behaviour of some stronger firms.

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4.8 Appendix

4.8.1 Variable definition

Table 4. 7 – Variable description

Variable	Definition	Datastream code
Investment (*I*)	Capital Expenditures that represent the funds used to acquire fixed assets other than those associated with acquisitions. It includes but is not restricted to: Additions to property, plant and equipment, Investments in machinery and equipment.	WC04601
Cash Flows (*CF*)	Product of Cash flows/Sales and Net sales or Revenues.	WC08311*WC01001
Cash flows/Sales	Funds from Operations / Net Sales or Revenues * 100.	WC08311
Net sales or revenue	Net Sales or Revenues represent gross sales and other operating revenue less discounts, returns and allowances.	WC01001
Tobin's Q (*Q*)	Ratio of the sum of market capitalisation and total liabilities to the sum of book value of equity and total liabilities.	(WC08001+WC03351)/(WC03501+WC03351)
Market capitalisation	Market Price-Year End times Common Shares Outstanding.	WC08001
Book value of equity	Common shareholders' investment in a company.	WC03501
Total Liabilities	All short- and long-term obligations expected to be satisfied by the company.	WC03351
Beginning of the year capital (*K*)	Firm's beginning of the year capital, obtained as the end of the year net property, plant and equipment minus the capital expenditure for the year.	WC02501-WC04601
Property, plant and equipment	Gross Property, Plant and Equipment less accumulated reserves for depreciation, depletion and amortization.	WC02501
Long term debt (*D*)	All interest-bearing financial obligations, excluding amounts due within one year.	WC03251

4.8.2 Hausman specification test

Simple Ordinary Least Squares (OLS) methodology will produce biased estimators if the predictor variables in a regression model are correlated with unique error terms. Since we expect there might be firm-specific heterogeneity and time-invariant factors that might affect firms' investment behaviour, we control this in our estimation using panel fixed effects methodology. Thus, this estimation method also eliminates any omitted variable bias. To formally confirm that our data fits the panel fixed effects model, we perform the Hausman specification test. The Hausman specification test is able to identify endogenous regressors in a regression model and helps to decide between a fixed effects and random effects specification. The null hypothesis is that the preferred model is random effects. Essentially the null hypothesis is that there is no correlation between the unique error terms and the regressors in the model.

Table 1- Hausman specification test; Total volatility

	____Coefficients____			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	fixed	random	Difference	S.E.
$I_{i,t-1}/K_{i,t-2}$	-0.0442021	0.0398932	-0.0840953	0.0059088
$CF_{i,t-1}/K_{t-2}$	0.1226241	0.1905753	-0.0679512	0.0677402
$Q_{i,t-1}$	0.0156911	0.0201558	-0.0044647	0.0025948
D_{t-1}/K_{t-2}	0.0105121	0.0183197	-0.0078076	0.0022199
$\lambda^F_{i,t-1}$	-0.2220347	-0.0082	-0.2138347	0.0625661
$HHI_{j,t-1}$	0.0139728	0.0364962	-0.0225233	0.0292939
FC(Dummy)	-0.099748	-0.1027898	0.0030418	0.0221539

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 237.06

Prob>chi2 = 0.0000

We perform the Hausman specification test with both our proxies of firm-specific uncertainty. The results of the Hausman specification test is reported in the below, where table 26 includes total volatility and table 27 includes idiosyncratic volatility. The *p* values of both the tests highly statistically significant and therefore, we reject the null hypothesis and accept the alternative hypothesis that the preferred model for our data is panel fixed effects.

Table 2- Hausman specification test; idiosyncratic volatility

	____Coefficients____			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	fixed	random	Difference	S.E.
ce_k_tr	-0.0442728	0.039927	-0.0841997	0.0059118
cf_k_tr	0.122578	0.1904564	-0.0678784	0.0677413
q_tr	0.01563	0.0201558	-0.0045259	0.0025974
d_k_tr	0.0105233	0.0183339	-0.0078106	0.0022207
ln_iv	-0.2253181	-0.0091943	-0.2161238	0.0629277
ln_hhi	0.0140839	0.0365155	-0.0224317	0.0293109
crisis	-0.1025883	-0.1030574	0.0004691	0.0220563

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 237.34

Prob>chi2 = 0.0000

5. CHAPTER 5 – CONCLUSION

5.1 Conclusion

This thesis has studied the idiosyncratic volatility dynamics in the UK equity market with specific focus on exploring the cross-sectional determinants, understanding the role of financial constraints on firm size and age and examining the investment behaviour of small and growing firms listed on the London Stock Exchange's (LSE) Alternative Investment Market (AIM). The thesis has examined the aforementioned relationships in the light of the extant literature. The empirical evidence from this thesis provides useful insights to add to other researchers' efforts towards understanding the importance of idiosyncratic volatility.

5.2 Cross-sectional determinants of idiosyncratic volatility

Idiosyncratic volatility is the component of a firm's total volatility driven by risk factors specific to a firm as opposed to common risk factors in the market (Becchetti et al., 2015; Cotter et al., 2015). Since IV is firm-specific and is not directly observable, extant literature has explained the variation in this component using firm fundamentals. In light of Bartram, Gregory and Stulz's (2018) emphasis on the recent historically low idiosyncratic volatility in US due to dramatic changes in the number and composition of listed stocks, the second chapter of this thesis tests this phenomenon for the UK equity market. Specifically, it explores the cross-sectional determinants of idiosyncratic volatility and whether there is a shift in the explanatory power of firm-specific characteristic in explaining its cross-sectional variation.

Despite the high correlation between UK and US, studies have reported different behaviour of aggregate idiosyncratic volatility among these countries (Guo and Savickas, 2008; Bekaert, Hodrick and Zhang, 2012). Bekaert, Hodrick and Zhang, (2012) for instance show that idiosyncratic volatility levels in the UK is much lower than US and it does not display a deterministic trend as reported by Campbell *et al.*, (2001). Given the differences in aggregate level, we argue that firm-level determinants of idiosyncratic volatility will also vary. While the empirical evidence on the determinants of idiosyncratic volatility is predominantly based on US data (see for instance Rubin and Smith, 2011; Bekaert, Hodrick and Zhang, 2012; Vozlyublennaina, 2013; Bartram, Gregory and Stulz, 2018 among others), our study focuses on the UK market. Further, this study attempts to update the empirical evidence for a recent sample period covering the recent 2007-08 financial crisis.

Examining the evolution of aggregate idiosyncratic volatility in the UK equity market show that the volatility level has dropped significantly after the 2007-08 financial crisis and has returned to pre-crisis levels. This evidence is in line with Bartram, Gregory and Stulz (2018) who report a similar drop in idiosyncratic volatility in the US. Further, using Fama-Macbeth (1973) cross-sectional regressions, this study finds that firm characteristics can explain over 37% of the variation in idiosyncratic volatility of UK stocks. A stock is likely to have high idiosyncratic volatility if it has paid dividend, operates in a non-regulated industry and is associated with high book-to-market ratio, small firm size, high share turnover and low earnings. Our cross-sectional analysis suggests that the role of these characteristics has changed significantly over the course of the recent financial crisis, increasing by a 7% compared to pre-crisis levels. The sign of the coefficient estimates is in line with theoretical priori and empirical evidence reported in relevant literature and appear to be stable to alternative specifications of idiosyncratic volatility.

5.3 Financial constraints and idiosyncratic volatility

It is a stylized fact in the literature that small and young firms have high idiosyncratic volatility. They demonstrate high firm-specific uncertainty since they are considered riskier, opaque with volatile fundamentals and likely to be poorly diversified in their operating, financing and investing activities (Opler *et al.*, 1999; Rajgopal and Venkatachalam, 2005; Wei and Zhang, 2006; Brown and Kapadia, 2007; Li and Zhang, 2010). We now know that financially constrained firms typically hold high levels of cash in order to finance their investment needs as a value increasing response to increased difficulty and high costs associated with obtaining external finance (Dennis and Strickland, 2004; Faulkender and Wang, 2006; Pinkowitz, Stulz and Williamson, 2006). Since financial constraints confine firms from funding desirable value-increasing investments, it affects firm value and thus stock returns, suggesting uncertainty at firm level. In line with our intuition, Li and Luo (2016) provide convincing evidence that high levels of cash holding are apparent in firms with high idiosyncratic volatility. However, this evidence is produced in the absence of a 'financial constraints' framework, suggesting the possibility of financial constraints being captured by this firm-specific uncertainty component of uncertainty. While the mosaic of evidence suggest that financial constraints might be associated with idiosyncratic volatility, surprisingly there is little empirical research in understating this nexus.

Both financial constraints and idiosyncratic volatility are unobservable phenomena arising at firm level. Using financial constraints as a proxy for investment frictions and Idiosyncratic Volatility (IV) for limits-to-arbitrage, Li and Zhang (2010) show that these frictions coexist in firms. Motivated by this, we argue that financial constraints and idiosyncratic volatility are not mutually exclusive frictions. Further we argue that the proxies used by researchers to measure these frictions might be capturing, to certain extent, overlapping information in firm-level data.

The third chapter of this thesis empirically examines the link between idiosyncratic volatility and financial constraints. Using a large cross-section of UK stocks, we first test whether financial constraints can explain the cross-sectional variation in idiosyncratic volatility. Motivated by the findings of Brown and Kapadia (2006), Denis and Sibilkov (2010) and Panousi and Papanikolaou (2012) that small firms are generally young, opaque, financially constrained and have increasingly begun to issue equity earlier in their business life cycles and are more vulnerable to market imperfections, we next examine the effect of financial constraints on firm size and firm age. Specifically, we test whether financial constraints moderate the relationship between firm size, firm age and idiosyncratic volatility.

The results showed that firm size and firm age are significant predictors of idiosyncratic volatility even in the presence of financial constraints. We confirm that financial constraints are not an independent factor that can explains cross-sectional variation in idiosyncratic volatility. Next, we test whether financial constraints act as moderating factors between firm characteristics and idiosyncratic volatility. For this, we interact firm size and firm age with proxies of financial constraints. We use five different proxies of financial constraints including the widely used index-measures such as Kaplan-Zingales (KZ) index, Hadlock-Pierce (HP) index and Whited-Wu (WW) index. The findings suggest that the negative relationship between firm size and idiosyncratic volatility gets stronger as the level of financial constraints increase, and it gets weaker and even reverses for firms with low levels of financial constraints. We observe a similar relationship between firm age and idiosyncratic volatility; the relationship between firm age and idiosyncratic volatility gets stronger as the level of financial constraints increase.

5.4 Corporate investments and idiosyncratic volatility

The ex-ante role of competition in the relationship between uncertainty and investment has been studied extensively in theoretical work, with inconsistent results (e.g. Caballero, 1991; Kulatilaka and Perotti, 1998). While delaying investments until uncertainty is resolved or new information arises may seem preferable when capital is irreversible, failing to exploit investment opportunities might make the firm vulnerable to its competitors. However, the empirical evidence on contentious role of product market competition as a moderating factor of corporate investment decisions under uncertainty is by far inconclusive. For instance, Bulan (2005) and Guiso and Parigi (1999) find that competition mitigates the negative relationship between uncertainty and investment while Henley et al. (2003) finds the opposite. Shima (2016) finds that negative investment-uncertainty relationship is less pronounced for firms with higher market share.

According to real options theory, Pindyck (1993) and Dixit and Pindyck (1994) show that when capital is irreversible, uncertainty creates 'option value' for waiting and thus encourage firms to delay their investment plans. This negative relationship between investment and uncertainty is well established in the literature (Baum et al., 2008; Bulan, 2005; Panousi and Papanikolaou, 2012). Despite, Henley et al. (2003) empirically document a positive relationship between investment and uncertainty for UK firms. Ghosal and Loungani (1996) identify imperfect competition as a factor that drives investment in firms when uncertainty is high. Firms especially in the oligopolistic industry face fears of pre-emptive behaviour by rivals in the market and therefore are forced to act faster to remain competitive in the industry.

However, the findings on the effect of competition on firm's investment behaviour is ambiguous the unobservable nature of competition has added to this complexity. The mainstream finding in this limited empirical literature supports the view that competition weakens the relationship between uncertainty and investment (Ghosal and Loungani, 1996; Guiso and Parigi, 1999; Bulan, 2005; Drakos and Goulas, 2006; Shima, 2016). The aforementioned studies have used a number of different proxies to capture firm's competitive environment. It is important to note that the use of the competition proxy also depends on the focus of the study whether it is conducted at the industry or firm-level. While industry-level proxies are relevant to study the behaviour of a group of firms, firm-level proxies are able to capture the firm-level heterogeneity within an industry group.

To the best of our knowledge, there is no empirical evidence on the investment behaviour of firms listed alternative exchanges. Our fourth chapter of this thesis attempts to contribute to this strand of literature by exploring the investment behaviour of London Stock Exchange's (LSE) Alternative Investment Market (AIM), a platform established to help small and growing firms to raise capital. Since this study focuses on the investment behaviour at firm-level, we employ the firm level proxies of competition and uncertainty in all our empirical specifications.

The findings of our study are broadly consistent with the real option behaviour of firms under uncertainty. This evidence on firms listed in an alternative exchange, supports the empirical body of literature which is generally derived from firms listed on primary exchanges. The results suggest that when firm-specific uncertainty rises, corporate investment falls. However, as the competitive position of the firm increases relative to its industry, it is better placed to capitalise investment opportunities and therefore, corporate investment rises. While average firms in the AIM are small and growing, our results suggest an empire-building behaviour of stronger firms as a strategic response to increased competition. By providing first empirical evidence on the investment behaviour of firms listed in an alternative exchange, our study points to the importance of effective competition policies for stimulating corporate investment in the AIM.

5.5 The Potential impact of Survivorship Bias

Survivorship bias is particularly acute in performance-related studies where the true performance of a given mutual fund is overstated due to its survivors and failure to correct for fund attrition (See for instance, Brown et al., (1992), Malkiel (1995), Elton, Gruber and Blake (1996), and Davis (1996)). How the mutual funds industry operate may have added to the severity of this bias, since large mutual complexes tend to merge a poorly performing funds with successful in order to sell it to the public. This in turn overstates the success of mutual fund management and creates a tendency for the most successful funds to survive. Malkiel (1995) argue that the main concern is the inability of commonly employed estimates such as CAPM beta to adequately measure the risk associated with the funds. While investors are clearly not interested in the funds that no longer exists, most of the commonly used data sets typically show the past returns of all funds that exist on a date and therefore creates significant biases in calculating the returns.

Survivorship bias does not have a direct impact in this thesis for the following reasons. Firstly, the focus of the thesis is to measure the firm level risk and explore its association with financial constraints and corporate investment decisions and not to directly provide investment advice. Secondly, the implication of this thesis highlights how corporate actions and decisions would affect idiosyncratic risk such that investors, who are exposed to idiosyncratic risk, can make an informed decision when making an equity investment. Thirdly, incorporating delisted firms (known as ‘dead’ firms) along with ‘active’ firms creates an inconsistent sample due the difference in the underlying assumptions in preparing the financial statements.

Some of the variables used in this thesis are measured using accounting data disclosed in periodic financial statements. IAS1 and IAS 10 require public firms to prepare financial statements on a ‘going concern’ basis, which assumes that a firm is financially stable enough to meet its obligation and continue its business for the foreseeable future. However, when companies do not meet the going concern criteria due to reasons such as liquidation of the entity or it ceases trading or it has no realistic alternative but to do so, they are required to prepare financial statements on an alternative basis reflecting the departure from going concern. Some of the examples include writing assets down to their recoverable amount, creating provisions for contractual commitments, which may have become onerous because of the decision to liquidate the entity or to cease trading, etc. (Grant Thornton, 2018).

See below extracts from IAS 1 and IAS 10;

i. *“When preparing financial statements, management shall make an assessment of an entity’s ability to continue as a going concern. An entity shall prepare financial statements on a going concern basis unless management either intends to liquidate the entity or to cease trading, or has no realistic alternative but to do so. When an entity does not prepare financial statements on a going concern basis, it shall disclose that fact, together with the basis on which it prepared the financial statements and the reason why the entity is not regarded as a going concern”* (IAS 1.25).

ii. *“an entity shall not prepare its financial statements on a going concern basis if management determines after the reporting period date either that* *it intends to liquidate the entity or to cease trading, or that it has no realistic alternative but to do so"*(IAS 10.14).

Note that neither IAS 1 nor IAS 10 provide details of how to prepare financial statements on an alternative basis and how it differs from going concern basis. Rather, it requires companies at their discretion, to select accounting policies that will reflect the most relevant and reliable financial information of the company's situation and full disclosure of such change. Since the fundamental assumption of preparing financial statements are different for 'active' firms and 'dead' firms, including these firms together in the sample will therefore result in inconsistent accounting data, leading to incorrect generalisation of overall findings.

While it might be possible to identity the year in which delisting occurred for a 'dead' firm, a case-by-case treatment is required for all the sample firms in order to delete the observations proceeding the delisting year. Further, firms without five consecutive year observations are deleted as part of our sample filtering approach. Therefore, we follow the most popular approach in the literature to exclude all 'dead' firms in our empirical estimations in order to avoid inconsistent accounting data prepared based different assumptions for 'dead' and 'active' firms.

Further, we acknowledge that survivorship bias may exist in the data source itself. Ince and Porter (2006) argue that it would be difficult to rectify this bias without a reliable secondary source. Hence, they warn researchers to be aware of this when designing tests that use these data. Further, a recent study by Landis and Skouras (2018) recommend that this bias is not severe in Datastream for pricing and accounting data in UK firm samples starting from December 1984. Given that our sample period starts from a relatively recent period; 1996, and Datastream being a widely used source for

UK data, we assume that the concern of data coverage will not have a significant impact on our findings.

5.6 Recommendations for future research

Chapter 2 of this thesis explores the cross-sectional determinants of idiosyncratic volatility using data from the UK equity market. The cross-sectional research design allows one to understand the variation in idiosyncratic volatility across firms. However, it does not provide evidence of the explanatory power of the determinants over time. Therefore, future studies could explore the time-series dynamics of idiosyncratic volatility.

Chapter 4 of this thesis explores how AIM firms make capital investment decisions under uncertainty. Future research could extend this study by testing whether the investment behaviour of AIM firms are different from firms that are listed on the traditional exchange. This might provide additional insights on the underperformance of AIM firms reported by Piotroski, (2012) and Gerakos, et al., (2013).

In addition, AIM firms are governed by private regulations where the primary oversight is delegated Nominated Advisors (Nomads). The rationale behind this regulatory structure is to increase flexibility at a lower compliance cost. Nomads are chosen by the firms and are registered with the London Stock Exchange (LSE). They typically provide advice to AIM firms disclosure requirements such they comply with the listing rules of the LSE. The literature has generally focused on either the firms listed on the primary exchange or the AIM separately. Therefore, future research could also combine these firms together and explore the impact of their unique regulatory environments on corporate investment decisions."

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