An empirical analysis of the impact of financial stress and quantitative easing on U.K. financial markets

by

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Abstract

This thesis consists of four chapters that contribute to studies in empirical finance, macroeconomics, monetary policy and asset-pricing. In particular, this thesis examines the interaction between Quantitative Easing, asset pricing, asset volatility and financial stress.

In chapter 2 the financial market impact of QE on asset pricing is analysed. The channels of QE are introduced and pricing relationships between gilts, exchange rates, corporate bonds, commercial-bank bonds and equities are examined to determine whether the gilt purchase programme was translated effectively into the pricing of other assets. This chapter finds the effects of QE are inconsistent and weak enough in scale to be lost in the turbulence of the financial crisis period.

Chapter 3 creates a financial stress index of the UK to examine asset pricing in terms of risk, uncertainty and constrained financial conditions. The chapter reviews the most relevant financial stress indices and uses these precedents to create a continuous financial stress variable.

Chapter 4 uses univariate and multivariate GARCH methodologies to examine asset return levels and volatility during the financial crisis and subsequent QE programme. Financial stress is modelled and the impact of QE on key stress indicators is measured. QE is found to have had a strong effect on the pricing and volatility of UK gilts, and to a lesser extent corporate bonds, however UK equities and systemic financial stress were largely unaffected.

Chapter 5 explores the interaction between the market efficiency of UK equities and the business and financial cycles and whether variations in market efficiency explain the lack of impact of QE on equities. Stock return predictability is the metric through which market efficiency is judged, using both economic indicators and technical trading rules as predictors. Stock return predictability is found to be positively related to both the business and financial cycles.

To my family and my ever-patient Renske

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1.Introduction

This thesis examines financial asset pricing in the United Kingdom, focussing on the interaction between asset pricing and financial conditions over various time-horizons. Financial stress, uncertainty, risk and asset pricing are therefore key concerns of the dissertation. The examination of the unconventional monetary policy regime known as Quantitative Easing (QE) also takes precedence, with the assets analysed being linked heavily to the markets that were primarily affected by QE. Although the primary purpose of QE was macroeconomic in scale, this thesis focuses on the less-discussed financial market impact, and specifically focuses on the impact of the purchases of government gilts on the pricing and market efficiency of other asset types. The close connection between Quantitative Easing and financial conditions is therefore a recurrent theme for the thesis. Each chapter of this thesis includes an in-depth examination of relevant literature, which is then followed in typical style with an overview of the data and methodology before moving on to the discussion of results. Finally, each chapter then offers some intermediate concluding remarks to sum up the chapter.

Chapter 2 can be summarised as an introductory analysis into the financial market impact of QE, where the chapter examines the pricing relationships between gilts, exchange rates, bonds and equities to determine whether depress gilt yields translated effectively into the pricing of other assets. Discussion of the potential effects on bank lending also occurs through the analysis of commercial bank bond yields and thereby the cost of lending for UK institutions. The focus of the empirical analysis is on short-term causality between QE auctions and thereby to other assets, using multivariate autoregressive models. This chapter demonstrates that there are links that are stable and significant enough to allow for the transmission of QE, however the effects are inconsistent and weak enough in scale to be lost in the turbulence of the financial crisis period.

Chapter 3 is a brief practical chapter that introduces and creates a Financial stress index for the United Kingdom to be used in the following chapters. Chapter 2's presents results that suggests that there were several contradictory factors at play in the asset pricing of equities and corporate bonds in particular. Chapter 3 therefore creates a financial stress index in order to examine asset pricing in terms of risk, uncertainty and constrained financial conditions in order to shed further light on the factors that may explain the contradictory results of Chapter 2. The chapter reviews the most prominent and relevant financial stress indices from other countries and uses these precedents to create a workhorse continuous financial stress variable.

Chapter 4 examines asset return levels and volatility during the financial crisis and subsequent QE programme using univariate and multivariate GARCH methodologies. Continuing the procedure set in chapters 2 and 3, the focus of the study is examining whether QE affected assets in ways not captured by the level of prices. The chapter presents the case that a successful QE policy would reduce financial stress and volatility in UK financial markets, and that this objective, while not stated by the Bank of England, is an important step in the expansionary economic goals of the Bank. The focus of the empirical analysis is therefore modelling risk, volatility and financial stress reactions to QE. The chapter demonstrates that QE had a strong effect on the pricing and volatility of UK gilts, and to a lesser extent corporate bonds, however UK equities were overall unaffected by the programme. The chapter also finds little evidence that QE reduced financial stress on a systemic level, with the financial stress index created in Chapter 3 reporting insignificant reactions to QE events.

Chapter 5 focuses on more analysis of UK equities in an attempt to clarify the lack of response of this asset type to QE intervention. This final chapter explores market efficiency of UK equities through analysis of stock return predictability. The intention of this chapter is to determine whether market efficiency varies with financial stress, and whether the lack of impact of QE can be attributed to reduced market efficiency. The sample period of this section is much broader, encompassing a period between 1975 and 2017, and uses a lower periodicity. This chapter analyses the interaction between the UK business cycle, financial stress and QE in terms of its effect on the market efficiency of equity pricing, demonstrating that the financial cycle plays a significant part in reducing market efficiency and allowing the possibility of stock return forecasting. These results leave implications on the importance of QE in restoring efficient market function.

In terms of scope, this thesis focuses on the United Kingdom’s experience of the financial crisis and QE. The dissertation includes references to the US’, EU’s and Japan’s experiences of QE and financial crisis, but these references are viewed through the lens of probable impacts upon the UK or points of comparison. Therefore, the conclusions of this thesis should not be taken as a generalisation for all QE policies, but rather a focused study on UK’s experience. In a similar vein, studies with a variety of periodicities have been cited in this thesis, however the focus of this thesis is the short term and the conclusions drawn cannot be extrapolated to overall effects over the long-term.

While QE and asset pricing are areas rich in theoretical literature, this thesis is focused on empirical examination, and models its approach as theoretically agnostic. The attempt thereby is to capture all potential effects of QE through using methods unrestricted by theoretical modelling, with a focus on finding rigorously evidenced results regardless of their implication on the effectiveness of QE as a policy tool. This thesis will remark at several points upon the predictions made by theory associated with QE, however the intent of the work is to provide evidence as to the outcomes of the policy and the financial crisis in the UK, rather than to conclude whether QE achieved its objectives successfully.

Chapter.2

An Examination of Financial Market Relationships in the UK in the Presence of Quantitative Easing

2.1 Introduction

By September 2008, the UK financial sector was in a full crisis state. In order to mitigate the real effects of the global financial crisis, the Bank of England resorted to unconventional monetary policy instruments, in particular to large-scale purchases of public and private assets using central bank money. The main objective of such Quantitative Easing measures (henceforth QE) had been to boost nominal spending and thus help achieve the 2 percent inflation target (Bank of England, 2011).

The Bank of England conducted this policy in two main phases, one between March 2009 and February 2010 (QE1) and another between October 2011 and November 2012 (QE2).[1] The Bank purchased via reverse-auctions government gilts of maturities mostly between 5 and 25 years to the value of £375 billion pounds, with additional purchases of high-rated corporate bonds and other financial assets. The Bank expected these measures to be transmitted through the financial sector by pushing up asset prices, lowering borrowing costs and increasing wealth (Bank of England 2011). For this to work out, the Bank relied upon its ability to affect financial asset prices and yields in a predictable way and thus on stable relationships between financial market variables – a bold presumption as the financial sector was in a severe crisis state.

The objective of this chapter is twofold. First, this chapter models the empirical relationships between major financial market variables in the UK as they present themselves since the onset of the crisis in the second half of 2007 until the end of 2014, focusing on causality, significance and stability. Second, it is assessed whether, and to what extent, these relationships provide for QE measures to be effective in the way the Bank of England was hoping for. These are important empirical questions which should not be taken for granted in evaluating unconventional monetary policy. Relationships between financial variables that offer favourable conditions for QE have to exist, be significant and stable during the period of such unconventional monetary policy, and not at some point in time prior to the crisis or after the economy has already recovered.

This chapter considers yields on government gilts and on commercial bank debt, corporate debt, stock prices and exchange rates. Since the Bank of England purchased gilts and

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[1] Some split the latter period into two separate waves of QE, denoted QE2 and QE3 (Joyce et al. 2012).

bonds along the term structure, gilts and bonds are also differentiated by 5, 15 and 25 years to maturity. The empirical approach is a data driven methodology to explore financial market relationships by using VAR modelling with exogenous dummies, which capture the actual auction dates for the Bank's gilts purchases. This approach is chosen for two reasons. One is that theory tells little about the transmission of unconventional monetary policy measures in periods of crisis. The other is that, since the Bank of England's objective was to boost nominal spending and not to achieve certain yields or asset prices per se, it is arguable that QE measures are best modelled as exogenous variables.

In the first stage of the analysis the focus is on determining the existence of long-term relationships between the pricing of gilts, bank/corporate debt and equities. Using the Johansen and Juselius (1993) methodology, this chapter tests for cointegration relationships between these assets, and determines whether shocks to government yields translate through to the other assets over the long term. This chapter finds that long run cointegrating relationships exist in both models between government debt and commercial bank or corporate debt yields respectively, however UK equities and exchange rates did not exhibit significant long-term relationships with government yields over the period. These findings are commensurate with other results from the literature, which find equities responses to QE to be the weakest of all asset types (Joyce et al, 2011)

After analysing the long-term, the focus of the analysis moves on to the short-term price relationships, where this chapter assumes that gilt purchases have a direct, significant and predictable effect on the yield of the gilts bought by the Bank and explores how shocks to those yields translate into changes of other financial variables. The results from this are that yields for 5-year gilts are Granger causal for stock prices and 5 and 15-year commercial bank bonds as well as for 15-year gilts, while yields for 25-year gilts are Granger causal for 15 and 25-year commercial bank bonds. Interestingly, a decrease in 25-year gilt yields causes an increase in 25-year bond yields. In addition, this chapter finds there are significant differences between the results for commercial bank bond yields and general corporate bonds, with the key interactions going on between the 15 and 25 government yields in the case of the latter. Although all variables have been found to be non-stationary, the impulse response functions of a VAR with all yields in levels are also considered. These show that all yields respond to changes in 5-year gilt yields, but these effects last no longer than eight weeks, while changes in the 25-year gilt yields appear to have no effects altogether there. In sum, these findings indicate that, provided the Bank of England's interventions lead to a lower yield for short-term government gilts, the Bank could also steer other yields in the same direction. Bringing down long-term gilt yields through asset purchases however, may have increased the cost of long-term funding for private borrowers.

In the final stage of the analysis the effects of the QE dummies on financial variables are considered. Without differentiating between the different types of interventions, it appears that asset purchases did not have any effect on commercial bank bond or gilt yields or on exchange rates. However, the purchases however seem to have significantly affected longer corporate bond yields, with 15-year yields being reduced, with the effect being the most pronounced during the QE1 period. Stock prices went up in weeks when QE transactions took place, but only during the QE1 period. Distinguishing between the market segments in which the Bank intervened provides a somewhat differentiated picture. Purchases of gilts with 5 years to maturity lead to changes in the yields for 25-year corporate bonds and gilts. However, such purchases appear to have increased the borrowing costs. Buying 25-year gilts only had an effect on the value of the pound, both in US Dollar and in EURO. Purchases of 15-year gilts had no effects at all. If there were any effects, they were mostly contemporaneous or died out after at most two weeks. Overall, the found empirical relationships between major UK financial variables do not appear to provide the necessary framework for QE to be effective over the short term at least.

The rest of the chapter is organised as follows. Section 2 introduces the literature surrounding QE and asset price channels, and then discusses the methodologies of the studies that have attempted to quantify QE's effects. Section 3 presents this chapter's methodology. Section 4 presents the results. Finally, section 5 summarizes the chapter and concludes with some critical remarks.

2.2 Literature Review

The theoretical foundations for empirical studies of QE go back predominantly to macroeconomic portfolio theory developed by Tobin (1958, 1969), Brainard and Tobin (1963), and Brunner and Meltzer (1973). The starting point is that money, financial and real assets are not perfect substitutes. If they were, all yields would be the same in an arbitrage-free equilibrium and a central bank, by swapping one asset for another, would not have any effect on rates or prices. If money and gilts are imperfect substitutes, however, a change in their relative quantities available to the private sector matters.[2] How this change is transmitted into

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[2] Other reasons for why QE could affect asset prices are related to changes in market liquidity (Shleifer and Vishny 2011), to expectations about the future course of monetary policy (Eggertson and Woodford 2003) or to the ability

changes of asset prices and yields depends on the degree of substitutability between gilts and other assets. If gilts and corporate bonds were perfect substitutes, their returns would always move in tandem. Tobin, however, also pointed out that investors may consider private bonds, stocks and public debt as complements rather than substitutes because they carry different risks that are not perfectly correlated. If the central bank takes public debt off the market in exchange for risk-free, non-interest-bearing money, holding everything else equal the risk of the market portfolio may increase for there is less scope for investors to diversify. This could induce risk-averse investors to reduce their demand for private bonds, leading to an increase in bond yields.

In a similar vein, Andrés et al. (2004) introduce the notion of imperfect asset substitutability in an otherwise standard New-Keynesian dynamic stochastic general equilibrium model. They consider short-term and long-term government bonds as imperfect substitutes due to constraints for some investors to directly trade long-term bonds while both, short and long-term rates matter to intertemporal optimizing agents. In this framework, the quantity of money in addition to the short rate determines the term structure of interest rates and thus output and inflation.

The Bank of England report a range of ‘channels’ through which QE can theoretically affect the economy, with some having stronger implications for financial markets than others. The Portfolio Balance channel was first proposed by Tobin and is loosely based on Keynes' Liquidity Preference model (Tobin, 1958, p.71). It is a popular theoretical concept in Keynesian monetary economics, and is recurrent discussion point in articles that analyse central banking policy (Andrés et al., 2004). Since the outbreak of the financial crisis in 2007, most articles that cover 'unconventional' monetary policy in some way have referred to this channel (E.g. in Inkinen et al, 2010). Theoretically the portfolio balance channel reflects the impact of changing asset quantities in a market on its’ relative expected return. A change in quantity of one asset, ceteris paribus, will alter its relative expected return in comparison to competing assets. For example, decreased quantity in one type of asset increases its price, thereby lowering its yield (interest rate) and will induce portfolio operators to switch out the affected asset for other relatively more profitable assets. In effect portfolios are rebalanced away from the asset affected by the quantity change, increasing demand and therefore the prices of other assets.

For the policy-maker this provides a lever for intervention to increase asset prices by modifying the quantity of a particular asset. For the Bank of England, the Bank’s purchases

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of banks to fund their lending business (Bernanke and Blinder 1988). Regardless which effect is emphasized, a necessary condition is that assets are imperfect substitutes.

drastically reducing the amount of long-term gilts available to the public, having an effect on the remaining gilt's rates of return relative to assets which were not targeted. As Tobin's theory suggested, the effects of these gilt purchases can cross several asset types, a decrease in the amount of available UK gilts causes the relative price of corporate bonds to be low in comparison, driving up demand for corporate bonds. Equities prices should also be positively affected, with investors being incentivised to sell their gilt holdings to the Bank of England and to purchase equities whose rates of return have improved relative to these gilts. The effects of the portfolio balance channel are resultantly very widespread, as almost all asset types will see their rates of return relative to UK gilts change with large-scale Bank of England intervention.

In terms of the price relationships between secondary assets, defined here as assets that are not directly affected by QE intervention but are rather affected by the changing quantities of UK gilts, portfolio balance theory suggests that pricing relationships should stay relatively constant. QE purchases could however alter the portfolio decisions made by an economic agent when choosing between two secondary assets, corporate bonds and equities, if the reduced availability of low-risk gilts induces investors to reduce their holdings in higher-risk equities in favour of less risky corporate bonds. In this way investors would be attempting to reduce their risk profile down to a level that meets their requirements. However, conceivably since there is no dramatic change in the quantity available of either equities or corporate bonds available during the period, there should be no large-scale change in price relationships between them. In addition, as high-quality corporate bonds and equities can be considered competing assets, an increase in the price of one type should coincide with a decreasing price in the other. In this way, portfolio balance theory suggests that both corporate bond and equity prices should be positively affected by decreasing gilt yields but be negatively associated with changes to their rates of return relative to each other.

The second potential channel that QE has been expressed to work through is the so called 'Signalling channel' and the similar ‘Expectations channel’ the latter of which has also been referred to as the ‘macro/policy news channel’ and ‘policy signalling effects’ in a Bank of England publication (Joyce et al., 2011). The Signalling Channel reflects the impact on expectations that occurs when a monetary authority makes a statement of intent about a certain macro policy. In these circumstances, individuals can be reassured or worried by the news, and alter their expectations of future asset values and yields accordingly (Kapetanios et al., 2012). This channel uses the assumption that investors are rational and forward looking, using central bank announcements to make market-based decisions. This leads to important implication that a large part of the quantitative easing effect will be recorded in the first few days around and announcement. Many of the articles published in the last few years have argued that the expectations effect QE creates is just as important as the portfolio balance effect; and as such this theory is discussed to a great extent by the articles discussing optimal monetary policy (Bernanke et al, (2004) Adam and Billi (2006), etc.). The signalling effect is related to the expectations channel but operates in a different way: Eggertsson and Woodford (2003) amongst other claim that if the zero-bound interest rate policy of QE is seen to be a credible commitment by the Central Bank, individual expectations of future asset performances will be revised upwards. A realistic sounding commitment made by a central bank will have ramifications before the policy measure has been enacted and will have lingering effects well after the intervention has been concluded.

The Liquidity channel is discussed by many of the same academics who discuss the portfolio balance effect, as the two channels are often inter-connected or occur in tandem. As such it is mentioned in official publications made by both the Federal Reserve and the Bank of England. (See Clouse et al., 2003 and Joyce et al., 2011). This channel covers the results of a Central bank being a significant and secure buyer of assets in a market which is suffering from market failure resulting from liquidity issues and uncertainty. The central bank provides a steady demand and thereby makes the sale of assets less costly to the seller, allowing market participants to conduct trading more frequently and with more certainty that there will be a buyer if the participant decides to trade. The central bank also provides a steady stream of excess liquidity that pervades the market, reducing or nullifying the effects illiquidity had on asset prices and yields. Shleifer and Vishny (2011) discuss the importance of the liquidity channel as the primary method to avoid dramatic undervaluing of assets through ‘fire-sales’.

The credit or bank lending channel the final possible transmission mechanism for the effects of QE purchases, where the injection of liquidity by the central bank, increases the size of a bank’s portfolio, inducing them to lend more at a reduced interest rate. This cheap credit theoretically improves the financial ‘health’ of firms and households and supports asset prices (Joyce et al. 2011). The financial ‘health’ of the banking sector is particularly relevant for this channel, given that the majority of QE purchases are aimed to impact bank balance sheets. Clouse et al. (2003) discusses this channel and while they note that due to the zero-bound on interest rates lending is unlikely to increase substantially, arguing that banks will absorb this excess liquidity in an effort to prepare for future monetary shocks, they concede that an increase in lending is likely to manifest in slightly higher asset prices. (Clouse et al 2003). Furthermore, with lower interest rates, the relative value of future dividends for equities should increase, increasing demand for such assets. In this way, the credit channel could result in a small increase in prices for equities, corporate bonds but the prices for commercial bank bonds in particular.

For the purposes of this chapter, the effects of the signalling/expectations, bank-lending and liquidity channels should reinforce the effects of the portfolio balance channel. Apart from the general improvement in market prices across all assets that will be associated with central bank intervention, announcements of gilt purchases should encourage the same portfolio re-balancing behaviour from agents as the actual purchases themselves. Given the mutually reinforcing nature of these channels, the intention of this chapter is to at least properly capture the entirety of the effects, limiting itself by not attempting to isolate the individual channel effects. However, the inclusion of both corporate debt and commercial bank debt in this chapter is an attempt to quantify the effects of the bank lending channel beyond the effects of the other channels.

However, it should be noted that the liquidity channel could potentially have an effect on the price relationships between relatively liquid equity assets and the more illiquid government and corporate bonds. During periods of financial duress, it can be expected that economic agents will attempt to have portfolios that are relatively more liquid than under normal circumstances. Holding liquid assets allows agents to respond to changing market circumstances quicker, which is beneficial when asset markets are volatile. This chapter can therefore expect there to be a higher liquidity premium associated with holding longer-term bonds and gilts relative to holding equities and more liquid debt assets. With QE intervention it could be expected that the excess liquidity injected into the economy will lessen the value of holding equities as a liquid asset and therefore lower equity prices compared to bond and gilts. A possible expectation of the liquidity channel is therefore that equity prices relative to bond and gilts prices will be negatively affected by QE intervention.

Having established the theoretical routes of QE intervention, this chapter will now briefly highlight the empirical studies that have attempted to quantify the impact. When compared to the literature discussing the theoretical foundations for QE's interaction with asset prices, there is a relative dearth of studies that have attempted to quantify the effect of the policy during the recent financial crisis. For the US, Krishnamurthy and Vissing-Jorgensen (2011) study the effect of QE1 and QE2 on interest rates, using an event-study methodology[3]. They find that yields on Mortgage-backed securities were significantly lowered by QE1, with corporate yields being reduced in the same manner. However, they find QE2 to have a much

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[3] It should be noted that the dates of QE1 and QE2 in the US do not correspond to their equivalents in the UK.

smaller impact, with the purchases of treasuries during QE2 only having a moderate impact through the signalling channel. Gagnon et al (2011) find that the term premium was significantly reduced by US QE or Large-Scale Asset Purchases, with the estimated effect being between 30 and 100 basis points.

For the UK Joyce et al. (2011) find that QE1 lowers gilt yields and bond yields by some 85bps on average. They deploy a VAR model incorporating also changes in quantities (gilt shares) in addition to yields. They also find a substantial effect on corporate yields, with mixed responses from UK equities. Bridges and Thomas (2012) estimate changes in the supply of broad money as a result of QE1 using a co-integrated structural VAR and look how asset prices and nominal spending would need to adjust to clear money market. They find that yields should have dropped by 150bps and asset prices increased by 20 per cent. Based on those findings, Kapetanios et al. (2012) study the wider effects of such changes in yields on UK output and inflation. Cloyne et al. (2015) find that such effects crucially depend on whether and to what extent QE promotes bank lending.

While these studies present encouraging evidence for the positive effect of QE, they also leave unanswered issues. First of all, the aforementioned Joyce et al (2011) article is one of the few studies to consider the impact on financial assets outside the impact on treasury yields. Neely (2010) considers the effect of US 2008-2009 QE on long bond yields and exchange rates, finding evidence in support of a portfolio balance model. Breedon et al (2012) analyse the effect of QE1 in the UK on equities and corporate bonds using an event study technique and find the effects of QE to be muted compared to the effect on gilt yields. Apart from these, almost no studies exist that examine the effects of QE on corporate bonds or equities in detail, with the common assumption that depressed yields will translate to other assets through investor portfolio rebalancing. A more general concern with the QE financial market literature is the selection of data and time period. Most studies on UK and US QE have opted to use pre-crisis data when analysing the potential outcome of QE on asset prices. The assumption therein that asset price relationships are consistent pre and post-financial crisis. Joyce et al. (2011), for example, focus solely on QE1 as does Breedon et al (2012). This presents the issue as to whether QE2 and QE3 demonstrate the same effects as the initial bout of purchases, or indeed whether the price relationships are consistent throughout all three intervention periods.

In the next section, this chapter outlines its own contribution to QE literature, discussing how this chapter models price relationships between 2007 and 2014.

2.3 Methodology

2.3.1 Data selection

The data selected for this chapter includes the log of the FTSE100 index closing price (AVCLOSE100), A-rated corporate bond yields (CORP5, CORP15 and CORP30) and government gilt yields each with 5, 15 and 25 years to maturity, as well as the USD-GBP and the EUR-GBP exchange rates. This chapter also includes commercial bank bond yields as a subset of corporate debt (COMM5, COMM15 and COMM25), aiming to draw some additional inferences on UK bank stability and lending by looking at the cost of bank debt. As a concise description, this chapter defines UK government gilts as the primary assets involved with QE, while corporate bonds, commercial bank yields, exchange rates and the FTSE stock index are defined as secondary assets. This distinction is made due to the gilts being directly purchased by the APF, while the secondary assets were only to affected indirectly. Yields and prices rather than excess returns are considered because of difficulties in differentiating between short-term government bond yields and risk-free returns. Moreover, this allows to compare findings directly with other studies. The FTSE 100 is obtained from Bloomberg, the corporate bond yield data is taken from Reuters Datastream and commercial bond and gilt yields for maturities ranging from 1 year to 30 years from the Bank of England's yield curve data. Exchange rates are also available from the Bank of England's statistical database.

Data for all variables are weekly averages of daily figures. This choice is driven by the relatively short time window in which QE purchases were conducted, implying that modelling with monthly data would have been limited to less than 25 observations. The weekly format strikes the balance between data availability and model performance. Rather than weekly closing data this chapter uses weekly averages of daily figures as it is more representative of the volatility from week to week. Data is from 7th of July 2007 to 29th of December 2014, a time window which includes all QE purchases as well as the main events of the global financial crisis. Many other studies use pre-crisis data for estimating relationships between financial variables to infer the impact of QE on financial markets. However, this requires that the pre-crisis relationships were unchanged by the financial crisis and the Bank of England's interventions. This chapter avoids such an assumption and lets the data from the crisis period speak for itself.

This chapter includes dummy variables to capture QE gilt auction dates, differentiating between the maturities of assets purchased. This information is publicly available from the Bank of England's website. The purpose of these dummies is to see whether purchases of gilts of distinct maturities affect secondary assets differently. Accordingly, dummy variables are assigned the value of 1 in the weeks when the Bank of England purchased gilts of each respective years to redemption, and 0 otherwise. These are denoted as D5purchase, D15purchase and D25purchase. This chapter also includes a dummy which is valued 1 when assets of any maturity are purchased, and 0 otherwise, denoted as DQEAllPurchases. The latter is further split into two dummies to distinguish the overall effects for the two phases of QE. Accordingly, DQE1 is valued 1 for purchases between 2009 and 2010 and zero otherwise, while DQE2 is valued 1 for purchases between 2011 and 2012 and zero otherwise. These dummies are used in auxiliary regression which are the same in all other respects as the primary analysis. Given that these dummies coincide with the D5purchase, D15purchase and D25purchase, and are intended to capture the same effects, the statistical significance of all dummies would be expected to be reduced if all were included in one regression model.

2.3.2 Time series properties of the data

Table 2.1 presents the summary statistics for the endogenous variables, as well as the results of the specification tests for variable normality and the presence of unit roots. Table 2.2 presents the summary statistics for the dummy variables used in the analysis. According to the Jarque-Bera statistics, all variables are non-normal. This seems to be driven for most of the variables by large kurtosis. As for unit roots, the Augmented Dickey-Fuller (ADF) test was employed. The results were then for robustness checked by an ADF test from a GLS regression (GLS-ADF). All tests cannot reject the null hypothesis of a unit root at the 5% significance level, the only exception being the exchange rate to the Euro which was a borderline case when considering the standard ADF test. Regarding their first differences, strong rejections of the null hypothesis of a unit root are found for all variables. Hence, all variables are I(1) non-stationary.

As is general practice after determining the presence of non-stationarity amongst these variables, testing for cointegration was conducted. Tables 2.3 and 2.4 summarize the result from a Johansen and Juselius (1990) test for cointegration for both the commercial bank yield model and the corporate bond yield model. Lag-orders were chosen in both cases based on information criterions, and serial correlation in the lags is tested with a LM test. Selection was also made with reference to studies such as Ivanov and Kilian (2005) that test the various information criterion's robustness to small sample sizes, non-normality and the issues connected with various data intervals. Cointegration rank tests are performed on all types of unit-root processes to identify the nature and number of cointegrating variables. For almost all specifications, the maximum recommended cointegration rank is one for the commercial yield model, meaning there are long-term relationships between variables. However, there is a large degree of discrepancy between the recommended rank of cointegration between Trace test and the Max-Eigenvalue statistics. Trace tests suggest a maximum rank of two or even three for certain unit root specifications, however the Max-Eigenvalue do not corroborate with these results consistently, finding a maximum of two rank in the corporate yield model. Given these results, the commercial yield model is specified with one cointegrating equation, and two cointegrating equations for the corporate yield model. Both models are specified with a constant in the VAR model and the cointegrating equation, corresponding to the results in the final two columns of tables 2.3 and 2.4. In addition, seeing as there is a large amount of debate whether yields can be non-stationary, VAR specifications of each model are included as well as the VEC.

Table 2.1 Summary Statistics

	AVCLOSE 100	**COMM5**	**COMM15**	**COMM25**	**DOLLAR**	**EURO**	**GOVT5**	**GOVT15**	**GOVT25**	**CORP5**	**CORP15**	**CORP30**
Mean	8.649	2.759	3.734	3.814	1.651	1.210	2.370	3.765	4.016	4.002	5.190	5.399
Median	8.670	2.348	3.845	3.932	1.605	1.196	2.073	3.972	4.235	3.635	5.280	5.467
Max.	8.833	6.129	5.534	5.070	2.095	1.491	5.584	5.150	4.865	7.945	7.308	7.264
Min.	8.180	0.919	2.138	2.318	1.383	1.029	0.561	2.234	2.631	1.655	3.480	0.000
Std. Dev.	0.140	1.420	0.862	0.617	0.161	0.084	1.284	0.819	0.554	1.651	1.012	1.006
Skew.	-1.011	0.848	0.132	-0.062	1.359	1.272	0.764	-0.198	-0.351	0.511	0.159	-1.199
Kurtosis	3.611	2.663	1.818	1.901	3.817	5.012	2.680	1.665	1.757	1.895	1.920	8.136
Jarque -Bera	72.819	48.819	23.980	19.966	131.652	171.909	39.800	31.698	33.267	36.971	20.717	524.808
Prob.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	3390.551	1081.615	1463.792	1495.243	647.123	474.246	929.213	1475.690	1574.327	1568.891	2034.606	2116.472
Sum Sq. Dev.	7.660	788.499	290.468	148.716	10.174	2.759	644.221	261.986	119.870	1065.270	400.351	395.921
Obs.	392	392	392	392	392	392	392	392	392	392	392	392
ADF P-Value	0.374	0.086	0.094	0.251	0.559	0.044	0.197	0.233	0.233	0.~~6748~~675	0.~~8814~~882	0.~~8125~~813
~~PP~~ GLS-ADF Test P-Value	0.~~448~~191	~~0.078~~0.417	~~0.097~~0.184	~~0.209~~0.289	0.707~~543~~	0.~~03~~702~~3~~	0.~~190~~468	0.~~253~~633	0.~~253~~732	0.~~7092~~743	0.~~8165~~980	0.~~0001~~337

Notes. ADF and GLS-ADF tests were performed with an intercept in the test equation.

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Table 1.2 Dummy Variable Summary Statistics

	D5PURCHASE	D15PURCHASE	D25PURCHASE	DQEALLPURCHASES	DQE1	DQE2
Mean	0.181	0.179	0.023	0.247	0.110	0.138
Median	0	0	0	0	0	0
Maximum	1	1	1	1	1	1
Minimum	0	0	0	0	0	0
Std. Dev.	0.386	0.383	0.150	0.432	0.313	0.345
Skewness	1.656	1.679	6.370	1.170	2.498	2.102
Kurtosis	3.742	3.817	41.579	2.370	7.239	5.419
Jarque-Bera	188.164	194.982	26960.770	95.992	701.210	384.287
Probability	0	0	0	0	0	0
Sum	71	70	9	97	43	54
Sum Sq. Dev.	58.140	57.500	8.793	72.997	38.283	46.561
Observations	392	392	392	392	392	392

Table 2.3 Cointegration Rank Testing Commercial Yield model

	No Intercept or No Trend in CE or test VAR		**Intercept in CE, No intercept in test VAR, -No Trend**		**Intercept in CE and test VAR, -No Trend**	
	Trace	**Max-Eigenvalue**	**Trace**	**Max-Eigenvalue**	**Trace**	**Max-Eigenvalue**
None *	189.58**	53.46*	214.96**	56.23*	205.36**	55.94*
At most 1	136.12	42.87	158.73	43.40	149.42	41.07
At most 2	93.24	30.07	115.33	30.24	108.35	29.89
At most 3	63.17	25.51	85.10	27.26	78.45	25.81
At most 4	37.66	22.33	57.84	25.25	52.64	23.77
At most 5	15.33	9.38	32.59	17.41	28.88	15.38
At most 6	5.95	5.28	15.18	9.32	13.50	9.25
At most 7	0.67	0.66	5.86	5.22	4.25	3.88
At most 8	0.01	0.01	0.64	0.64	0.37	0.37
Rank	None*	None*	None*	None*	None*	None*

*Notes. ** Signifies rejection at 5% level of a maximum of the number of cointegrating equations described in Column 1 of the table.*

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Table 2.4 Cointegration Rank Testing Corporate Bond Yield Model

	No Intercept or No Trend in CE or test VAR~~No Intercept No Trend~~		Intercept in CE, No intercept in test VAR, No Trend~~Intercept No Trend~~		Intercept in CE and test VAR, No Trend~~Intercept No Trend~~	
	Trace	**Max-Eigenvalue**	**Trace**	**Max-Eigenvalue**	**Trace**	**Max-Eigenvalue**
None *	210.08***	59.72**	240.85***	59.72**	236.09***	58.26*
At most 1 *	150.36**	50.99**	181.13**	51.25*	177.83***	51.25*
At most 2	99.37	35.67	129.87*	44.90*	126.58**	44.90*
At most 3	63.70	23.64	84.97	26.78	81.67	26.62
At most 4	40.06	17.00	58.19	21.95	55.06	21.37
At most 5	23.06	11.97	36.24	15.83	33.69	15.73
At most 6	11.09	9.70	20.42	10.78	17.96	9.33
At most 7	1.40	1.14	9.64	8.63	8.63	8.63
At most 8	0.25	0.25	1.01	1.01	0.00	0.00
Rank	At most 1 *	At most 1 *	At most 1 *	At most 1	At most 1 *	At most 1

*Notes. ** Signifies rejection at 5% level of a maximum of the number of cointegrating equations described in Column 1 of the table.*

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2.3.3 Specification of a VAR model with exogenous variables

A VAR is a model in which K variables are specified as linear functions of p of their own lags, p lags of the other $K-1$ variables and in this case additional exogenous variables. A standard p-order VAR model is given by

$$\boldsymbol{y}_{\boldsymbol{t}} = \boldsymbol{v} + \boldsymbol{A}_1 \boldsymbol{y}_{t-1} + \cdots + \boldsymbol{A}_p \boldsymbol{y}_{t-p} + \boldsymbol{u}_t \tag{1}$$

Where $\boldsymbol{y}_t$ is a $K \times 1$ vector of variables, $\boldsymbol{v}$ is a $K \times 1$ vector of parameters, $\boldsymbol{A}_1 - \boldsymbol{A}_p$ are $K \times K$ matrices of parameters and $\boldsymbol{u}_t$ is a $K \times 1$ vector of disturbances which has mean 0 and is i.i.d. normal over time. If during cointegration rank testing, cointegration between non-stationary variables are found, this VAR(p) can be rewritten as a VECM

$$\Delta \boldsymbol{y}_t = \boldsymbol{v} + \boldsymbol{\Pi} \boldsymbol{y}_{t-1} + \sum_{i=1}^{p-1} \boldsymbol{\Gamma}_i \Delta \boldsymbol{y}_{t-i} + \boldsymbol{u}_t \tag{2}$$

Where $\boldsymbol{\Pi} = \sum_{\boldsymbol{j=1}}^{\boldsymbol{j=p}} \boldsymbol{A}_j - \boldsymbol{I}_k$ and $\boldsymbol{\Gamma}_i = -\sum_{j=i+1}^{j=p} \boldsymbol{A}_j$. The $\boldsymbol{v}$ and $\boldsymbol{u}_t$ are identical to the VAR case. Cointegration can occur when the variables included in $\boldsymbol{y}_t$ I(1). If this is the case, the matrix $\boldsymbol{\Pi}$ has rank between $0 \leq r \leq K$ where r is the number of linearly independent cointegrating vectors. If cointegration is found between the non-stationary variables, then a VAR model is misspecified because it does not include the lagged level term $\boldsymbol{\Pi} \boldsymbol{y}_{t-1}$.

There are several reasons to be concerned with whether to use a stationary VAR model or a VEC model when looking at the data discussed in this chapter. As noted before on a theoretical basis bond yields of any category should not be correspond to a non-stationary process over a large enough sample, given the constraints on the values interest rate yields can take. Furthermore on an empirical basis the unit root tests shown before present some evidence of stationarity if the 10% significance level is to be considered. Finally, ~~A~~as the results of Johansen cointegration rank testing are unclear as to the true number of cointegrating vectors in each respective model. As Conducting cointegration tests and thence estimating a VEC model can produce results that are as inaccurate as using a VAR when variables are non-stationary,~~,~~ both VAR and VEC models are specified to then compare differences in results, therefore producing robust results in either scenario. In addition, as mentioned above, exogenous dummy variables are included in both VAR and VEC models. In the case of the VAR(p) model, including exogenous variables changes the equation to the following form

$$\boldsymbol{y}_{\boldsymbol{t}} = \boldsymbol{v} + \boldsymbol{A}_1 \boldsymbol{y}_{t-1} + \cdots + \boldsymbol{A}_p \boldsymbol{y}_{t-p} + \boldsymbol{B}_0 \boldsymbol{x}_t + \boldsymbol{B}_1 \boldsymbol{x}_{t-1} + \cdots + \boldsymbol{B}_s \boldsymbol{x}_{t-s} + \boldsymbol{u}_t \tag{3}$$

Where in addition to the already discussed variables, $\boldsymbol{x}_t$ is an $M \times 1$ vector of exogenous variables and $\boldsymbol{B}_0 - \boldsymbol{B}_s$ are $K \times M$ matrices of coefficients. For this chapter, the exogenous variables are restricted to dummy variables to capture the effects of monetary policy intervention.

Having specified the usage of both VAR and VEC models, all models were specified with sufficient lags to remove serial correlation in the residuals. For the commercial yield model Information criterion recommended 4 lags according to both AIC and FPE. LM tests for autocorrelation found there was no autocorrelation in the residuals at 4 lags, so this lag level is chosen for analysis. The corporate bond model was selected to use 5 lags using the same procedure. All models retain the issues of heteroscedasticity and non-normal residuals but satisfy stability conditions to allow for forecasting. Newey-West standard errors are used to correct residual estimates.

Given the primary interest in causality and significance of the relationships between the financial variables, it is important to test the stability of the models and therein the accuracy of the results. As such, structural break testing of the model is used to determine whether there are any changes in any of the relationships during the sample.

2.3.4 Structural break analysis

Due to the unstable nature of financial markets over the time period, and the sometimes-erratic behaviour of financial market participants, it is possible that the relationships that exist between different financial assets during normal market function change during crisis periods. It is also plausible that during financial crisis periods investors have different preferences for the composition of their portfolios, such as the well-known flight-to-quality behaviour, again meaning that price relationships may have changed over the course of the time UK financial crisis. This chapter pre-emptively tests the validity of the results by testing for structural breaks in the coefficient and residuals over the sample period. As an addition, this chapter also interprets these structural breaks to determine whether any have links to the QE programme. An important possibility for examination of QE is whether any changes in asset relationships can be attributed to QE purchases or announcements, or whether they are unrelated to the Bank of England's monetary policy.

The methodology employed by this chapter follows the structural break tests outlined in (Bai and Perron, 2003), which introduces an adaptation to the Quandt-Andrews (Andrews, 1993) test for an unknown structural break allowing for several unknown breakpoints to be tested for simultaneously. Each test tested for breakpoints of the respective independent variables and their lags, resulting in the computation of dates after which the coefficient relationship between variables changed significantly. The tests were used in both corporate and commercial bond models, both displaying similar results.

In both models, the relationships between the variables were relatively stable over the sample period, with structural breaks mostly occurring before the onset of QE in March 2009. In addition, there appears to be no breakpoints that can be interpreted as having links to QE purchases, except for 25-year government yields, where a breakpoint occurs around the 19th of January 2009. This date saw the British government authorise the Asset Purchase Facility, effectively announcing QE would be taking place, but with no mention of the scale of the purchases. Additional breakpoints for 5 and 15-year commercial yields around this time may be associated with this announcement, however apart from this there is insufficient evidence to suggest QE caused structural breaks in the relationships between financial assets. Overall the evidence suggests that the asset relationships are stable enough to make the results of the models accurate. The assets show surprising stability over the period, with most variables only breaking with at most one other variable.

2.4 Results

2.4.1 VECM Results

Having established the presence of cointegrating relationships between the variables, the most interesting area of study becomes to determine whether gilt yields significantly contribute to these long run relationships, and therefore whether QE could impact other assets over a period which is not captured by short-run analysis. It is also of interest to this chapter to test whether commercial bank and corporate bond yields contributed differently to the cointegrating relationships found earlier. Using the LR test this chapter looks for which variables identify and contribute to the long-term relationship over the sample. Through restricting $\beta = 0$ for certain variables and then testing using the LR statistic it is possible determine whether the FTSE, the exchange rates and the various yields contribute to a long run relationship. It was found in all cases that the FTSE and both exchange rates were significant contributors towards the cointegrating relationship in the Commercial bank yield model and the first cointegrating equation in the corporate bond model. It was also found that restricting 5 and 25-year government yields to zero were not binding restrictions for these first cointegrating equations in both models, with the corporate yield model also accepting restricting 15-year gilts to zero. Imposing the restriction on the 15-year gilt yields in the commercial bank model did decrease the performance of the model according to the LR statistic, however it should be noted that the LR statistic was only borderline significant. This suggests that the yield does contribute to the equation, but only weakly. Finally, it was also found that restricting 15-year commercial/corporate yields to zero was not a binding restriction in both cointegrating equations. This means that private debt of 5 and 25 years to maturity, contribute to the first long-term relationship.

For the second cointegrating relationship in the corporate yield model, the FTSE and exchange rates could robustly be restricted to zero without binding the model. This suggests there are two exclusive long-term equations for corporate yields, one relating private debt and equities to the value of the pound and the long-term UK interest rate, while the other deals with the long-term relation between corporate and government debt. Restricting any of the other variables in addition to these are considered binding by the LR statistic, and therefore yield a worse performing model.

Table 2.5 Long-Run Cointegrating Relationships

	FTSE100	**Comm5**	**Comm15**	**Comm25**	**Dollar**	**Euro**	**Govt5**	**Govt15**	**Govt25**
CE1	1.000	0.337	0.000	0.251	-0.965	-0.965	0.000	-0.709	0.000
T-stat	*0.000*	*9.294*	*0.000*	*2.081*	*-4.259*	*-4.259*	*0.000*	*-6.960*	*0.000*
LR stat		*24.191*		*11.480*	*22.799*	*22.800*		*21.590*	
P-Value		*0.000*		*0.022*	*0.000*	*0.000*		*0.000*	
ECT_{t-1}	-0.017*	0.022	0.000	0.017	-0.014*	-0.044***	0.000	-0.151***	0.000
	-1.424	*1.162*	*0.000*	*0.944*	*-1.089*	*-3.536*	*0.000*	*-4.122*	*0.000*
	FTSE100	**Corp5**	**Corp15**	**Corp30**	**Dollar**	**Euro**	**Govt5**	**Govt15**	**Govt25**
CE1	1.000	0.663	0.000	-1.069	-1.931	-2.547	0.000	0.000	0.000
T-stat	*0.000*	*9.900*	*0.000*	*-8.647*	*-4.503*	*-3.369*	*0.000*	*0.000*	*0.000*
LR stat		*22.657*		*26.358*	*18.052*	*24.541*			
P-Value		*0.000*		*0.000*	*0.006*	*0.001*			
CE2	0.000	1.000	-0.649	-0.764	0.000	0.000	-1.229	2.165	-1.406
T-stat	*0.000*	*0.000*	*-7.788*	*-8.049*	*0.000*	*0.000*	*-12.211*	*7.516*	*-4.845*
LR stat			*19.449*	*13.817*			*22.667*	*22.224*	*12.817*
P-Value			*0.003*	*0.032*			*0.001*	*0.001*	*0.046*
$ECT1_{t-1}$	-0.019***	-0.032	0.000	-0.363*	0.003	0.001	0.000	0.000	0.000
	-3.617	*-1.100*	*0.000*	*-2.659*	*0.351*	*0.168*	*0.000*	*0.000*	*0.000*
$ECT2_{t-1}$	0.000	0.015	-0.116***	-0.047	0.000	0.000	-0.132***	-0.151***	-0.088
	0.000	*0.285*	*-4.369*	*-0.400*	*0.000*	*0.000*	*-3.604*	*2.447*	*-2.430*

*Notes. *, **, *** denote significance at the 10, 5 and 1% level respectively. T-stats are given in the second element of each row.*
Binding restriction LR Chi-Squared statistics and P-values are reported. Non-binding restrictions do not always produce valid LR statistics.

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Table 2.5 shows the long-run cointegrating equations, normalized to the FTSE100 in CE1 for both models, and normalized to 5-year corporate yield for CE2. For the commercial yield model Table 2.5 shows that there is a positive long-run relationship between the FTSE and both exchange rates, as well as the yield for 15-year government debt. Commercial bank yields however have a negative long run relationship with the FTSE. As the ECT_{t-1} statistics indicate, the FTSE's price level, the exchange rates and the government 15-yield all have the correct negative sign and are significant, meaning that they adjust if their values are too high. However, the commercial yields do not adjust quickly if they are too high in value. The results for the first cointegrating equation in the corporate bond model are mostly similar to the commercial model. Interestingly, extreme long-term corporate yields have a positive relationship with the FTSE, which is the opposite of the longer commercial debt. Overall, the first cointegrating equations suggest there is a long run relationship between the value of UK private debt, equity and the demand for sterling, a relationship where equity values make the largest adjustments to restore equilibrium. The lack of involvement of the other government yields in this equation suggests that over the long-term FTSE prices do not react to the level of short or very long government yields, with the implication that any QE purchases of these assets in the long run would not have an effect on the FTSE. Furthermore, it appears that commercial bank bond yields also do not have a long-term relationship with government gilt yields of 5 and 25 years to maturity, which again suggests that depression of gilt yields of these maturities does little to impact commercial bank debt.

The second cointegrating equation presents some evidence for the efficacy of QE in affecting corporate bond yields. As Table 2.5 shows, there exists a positive long run relationship between government and corporate bonds. The adjustments coefficients are significant and of the correct sign for the 5 and 15-year government debt, and for the 15-year corporate debt. The other maturities appear to adjust slowly to this long run cointegrating relationship. This suggests that QE purchases that reduce gilt yields at the shorter end of the term structure will, over the long run, cause a similar reaction from corporate bonds.

It is difficult to determine what these cointegrating relationships represent. One possible interpretation of the second cointegrating equation (CE2) in the corporate bond model is the relationships between bonds and gilts implied by the liquidity premium or preferred habitat theories. The inclusion of just the gilt and corporate bonds in the cointegrating equation implies there is a balance between risk and maturities characteristics over time. The other cointegrating equations, CE1 in both the commercial and corporate yield models, could also be interpreted as the balance between the risk and return characteristics of the other assets apart from the gilt market. The relevance of the exchange rates in this long-term relationship also indicates an important international element in the consideration of the valuation of equities, bonds and gilts. ~~Overall~~ In terms of policy analysis, these significant cointegrating relationships~~results~~ also present evidence that QE purchases depressing gilt yields would have a significant impact on corporate/commercial bank yields over the long term. Purchases at the shorter and longer ends of the maturity structure are the main drivers of a QE effect. There does not appear to be such a mechanism, however, for gilt yields to affect UK equities and sterling exchange rates.

2.4.2 Granger Causality

Finding that there are significant long term relationships between the government and private debt variables, this chapter moves on to determining the causality and the response to shocks over the short run. To demonstrate the significance of the relationships between these variables Tables, 2.6-2.9 show the results of granger causality tests over the entire sample for both VAR and VECM specifications for each model. Each cell of these tables contains the relevant P-value of the granger causality test with values under 0.05 signifying rejections of the null hypothesis of granger non-causality. It can be seen that the results of the VAR and VECM in each case are mostly identical in significance, which is expected as in both cases Granger Causality tests are conducted in the same way. Tables 2.7 and 2.9 are therefore included as a robustness check of these different model specifications.

Starting with the government yields, which are the focus of any study analysing QE, the finding is that 5-year yields are the most granger causal to the rest of the variables in the commercial bank yield model. Commercial bank debt of maturities of 5 and 15 years are significantly affected, with the 25-year debt being marginally significant at the 10% level. The FTSE100 is also significantly granger caused by 5-year government yields. However, exchange rates are not affected by these yields of any maturity, except the 15-year yields, suggesting that QE depressing gilt yields did not cause the sterling to depreciate. 25-year government yields also exhibit granger causality with commercial bank yields, however apart from these caveats 15 and 25 yields do not significantly impact the other variables, at least at the 5% significance level. At the 10% level, these longer yields have an impact on commercial debt of similar maturities. This suggests that QE purchases at the long end of the term structure had limited impact on private debt, exchange rates and equity. In the corporate bond yield model, the results show that in contrast 5-year gilt yields do not significantly Granger cause corporate bonds of any maturity, however the longer maturity gilt yields are more significant in their causal relationships with corporate debt. It appears that commercial bank debt is more responsive to shorter-term government yields, while more generalised corporate debt responds to yield movements of long maturity. The discrepancy could also be because of the additional lag in the corporate yield model, which could suggest that the significant causal relationships occur after a significant time-lag. Apart from these differences in the significance of 5-year government yields, most of the results are comparable between the two models. In summary of both models, it is clear that the strongest relationships are between government and private debt, with equities and exchange rates being significantly more exogenous.

Looking at the price relationships the FTSE100 is only significantly affected by the 5-year yields of commercial bank debt, and the two exchange rates. In addition, the index's price level did not significantly change the yields on either debt types, with a marginally significant effect on the euro/sterling exchange rate. It also seems that the FTSE was not significantly affected by corporate debt yields of any maturity, but Granger caused the 15 and 30 year corporate yields. This interaction is interesting and suggests that equity prices would be more responsive to bank lending or debt issuance than to the pricing of general corporate debt.

For commercial bank debt, only changes to the 5-year yields have significant effects on other asset values. In addition to the aforementioned effect on the FTSE price level, commercial bank debt yields of relatively short maturities significantly impact gilt yields across the maturity spectrum, however longer commercial bank yields did not exhibit significant causal relationships with equities, exchange rates or even gilts of similar maturities. Corporate yields largely behaved in the same way, with short maturity corporate yields impacting government yields of all maturities, however in addition to this 5-year corporate debt yields also significantly impact the Dollar/Sterling exchange rate, a relationship that is not found significant for commercial bank yields. Again this discrepancy could be caused by the additional lag in the corporate yield model.

The exchange rates show bi-directional causality with one another, being affected by only the FTSE and the 15-year government yields in the case of the Euro. Longer maturity government yields are also significantly affected by these exchange rates, but this effect is not present in commercial bank yields. All variables in the system were found to not be granger exogenous at the 10% level, with the exception of the 5-year government yield, with the 3 government gilt yields being only significantly responsive to the 5-year commercial bank yields. It is also interesting to note the longer maturity yields are the most responsive for both commercial bank and government debt.

The results of the Granger tests suggest that commercial bank bond yields and UK equities exhibit the strongest relationships with short-term government debt, while longer maturity yields were only significantly related to commercial and corporate debt of comparative maturities. The implication of this for QE is that assuming the purchases lowered gilt yields, the purchases at both ends of the maturity spectrum would impact financial assets differently. Another interesting implication to note is that according to these results, depressed gilt yields of any maturity would not translate through to devaluation of the sterling, at least not in the short-term. This outcome was a predicted outcome of the QE policy according to much of the theoretical literature, however there appears to be no significant short-term link.

Table 2.6 Commercial Bank Bond Granger Causality (VAR)

VAR Granger Causality Statistics	**FTSE100**	**Comm5**	**Comm15**	**Comm25**	**Dollar**	**Euro**	**Govt5**	**Govt15**	**Govt25**
FTSE100		0.~~2028~~203	0.872~~2~~	0.~~2226~~223	0.162~~1~~	***0.039~~1~~***	0.~~1308~~131	0.~~4047~~405	0.~~4739~~474
Comm5	***0.~~0017~~002***		0.102	0.175	0.~~5577~~556	0.598~~1~~	***0.014~~4~~***	***0.010~~3~~***	***0.025~~46~~***
Comm15	0.~~7417~~742	0.701~~1~~		0.827~~3~~	0.~~2009~~201	0.797~~66~~	0.694~~39~~	0.865~~1~~	0.815
Comm25	0.~~3461~~346	0.840	0.429~~1~~		0.243~~2~~	0.569~~87~~	0.339~~87~~	0.122~~19~~	0.164~~2~~
Dollar	***0.~~0466~~047***	0.538	0.523~~26~~	0.71~~16~~2		***0.012~~15~~***	0.214	***0.037~~66~~***	0.123~~29~~
Euro	***0.~~0016~~002***	0.~~9196~~920	0.252~~2~~	0.074~~3~~	***0.~~0479~~048***		0.574	0.146~~3~~	***0.035~~49~~***
Govt5	***0.000~~3~~***	***0.001~~4~~***	***0.008~~4~~***	0.070~~698~~	0.~~7669~~767	0.687~~4~~		***0.050~~498~~***	0.282~~4~~
Govt15	0.~~6095~~610	0.129~~89~~	0.073~~4~~	0.061~~3~~	0.~~5481~~548	***0.015~~2~~***	0.192~~19~~		0.278~~4~~
Govt25	0.~~2116~~212	0.204~~36~~	***0.019~~4~~***	***0.013~~27~~***	0.~~9343~~933	0.122~~4~~	0.307~~66~~	0.109~~88~~	
All	***0.000***	***0.027***	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	0.078~~78~~	***0.024~~37~~***	***0.012***

Notes. Dependent Variables are given in each column of the table. Granger causality P-values are given in the first row of each section. Elements italicised and in bold show significance at 5% level.

Table 2.7 Commercial Bank Bond Granger Causality (VECM)

VECM Granger Causality Statistics	**FTSE100**	**Comm5**	**Comm15**	**Comm25**	**Dollar**	**Euro**	**Govt5**	**Govt15**	**Govt25**
FTSE100		0.203~~28~~	0.741~~07~~	0.178~~3~~	0.214~~36~~	0.129~~1~~	0.111~~05~~	0.265~~3~~	0.264~~38~~
Comm5	***0.002~~18~~***		0.1051	0.166~~1~~	0.577~~3~~	0.542~~17~~	***0.022~~4~~***	***0.008~~76~~***	***0.019~~1~~***
Comm15	0.762~~18~~	0.680~~3~~		0.818~~2~~	0.211~~05~~	0.817~~67~~	0.616~~1~~	0.838~~1~~	0.809~~85~~
Comm25	0.358~~75~~	0.833~~4~~	0.430		0.247~~2~~	0.564~~2~~	0.298~~77~~	0.116	0.153~~29~~
Dollar	***0.043~~3~~***	0.503~~25~~	0.530~~2~~	0.655~~1~~		***0.022~~2~~***	0.238~~76~~	***0.047~~65~~***	0.139~~1~~
Euro	***0.001~~2~~***	0.953~~25~~	0.295~~48~~	0.098	0.066~~3~~		0.688~~1~~	0.149~~86~~	0.051~~05~~
Govt5	***0.000~~3~~***	***0.001~~3~~***	***0.007~~4~~***	0.067~~68~~	0.765~~48~~	0.642~~15~~		***0.036~~4~~***	0.257~~66~~
Govt15	0.639~~3~~	0.103~~3~~	***0.050~~498~~***	***0.050***	0.578~~1~~	***0.021~~2~~***	0.138~~2~~		0.175~~2~~
Govt25	0.206~~1~~	0.200	***0.019~~88~~***	***0.013~~2~~***	0.931~~4~~	0.105~~48~~	0.275~~2~~	0.093	
All	***0.000~~0~~***	***0.027~~2~~***	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	0.082~~4~~	***0.011~~08~~***	***0.009~~1~~***

Notes. Dependent Variables are given in each column of the table. Granger causality P-values are given in the first row of each section. Elements italicised and in bold show significance at 5% level.

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Table 2.8 Corporate Bond Granger Causality (VAR)

VAR Granger Causality Statistics	**FTSE100**	**Corp5**	**Corp15**	**Corp30**	**Dollar**	**Euro**	**Govt5**	**Govt15**	**Govt25**
FTSE100		***0.000~~1~~***	***0.0144***	0.358~~1~~	***0.004~~39~~***	***0.045~~45~~***	***0.008***	0.691~~06~~	0.715
Corp5	0.768~~77~~		***0.000~~0~~***	0.763~~29~~	***0.026~~55~~***	0.279~~85~~	***0.001~~05~~***	***0.004~~2~~***	***0.015~~3~~***
Corp15	0.847~~69~~	0.079~~86~~		0.595~~2~~	0.760~~599~~	0.285~~1~~	0.421~~2~~	0.2044	0.345~~3~~
Corp30	0.961~~2~~	0.792~~2~~	0.9014		0.8094	0.063~~27~~	0.614~~39~~	0.515~~48~~	0.177~~2~~
Dollar	***0.010~~1~~***	0.516	0.177~~67~~	0.723~~27~~		***0.002~~19~~***	0.2624	0.1974	0.450~~498~~
Euro	***0.045~~2~~***	0.148~~77~~	0.644~~36~~	***0.017~~67~~***	***0.023~~2~~***		0.606~~55~~	0.099~~3~~	***0.026~~3~~***
Govt5	0.419~~86~~	0.702~~2~~	0.115~~45~~	0.589~~3~~	0.340~~7~~	***0.013~~29~~***		0.264~~38~~	0.111~~2~~
Govt15	0.5744	0.353~~2~~	***0.007~~68~~***	0.976~~56~~	0.478~~78~~	0.191~~3~~	0.3114		***0.001***
Govt25	0.187~~3~~	***0.009~~89~~***	***0.046~~57~~***	0.611~~7~~	0.839~~88~~	0.259~~85~~	0.759~~86~~	***0.017~~66~~***	
All	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	***0.031~~09~~***	***0.025~~46~~***	***0.005***

Notes. Dependent Variables are given in each column of the table. Granger causality P-values are given in the first row of each section. Elements italicised and in bold show significance at 5% level.

Table 2.9 Corporate Bond Granger Causality (VECM)

VECM Granger Causality Statistics	**FTSE100**	**Corp5**	**Corp15**	**Corp30**	**Dollar**	**Euro**	**Govt5**	**Govt15**	**Govt25**
FTSE100		***0.000~~02~~***	***0.037~~68~~***	0.37	***0.005~~49~~***	0.072~~3~~	***0.008***	0.724~~2~~	0.6934
~~Comm5~~Corp5	0.~~7649~~765		***0.000~~0~~***	0.770~~699~~	0.026~~1~~	0.300~~3~~	***0.0000~~0.0005~~***	***0.004***	***0.015~~2~~***
~~Comm15~~Corp15	0.887~~69~~	0.095~~45~~		0.597~~67~~	0.761~~07~~	0.261~~89~~	0.433~~27~~	0.188~~3~~	0.3274
~~Comm25~~Corp30	0.961~~1~~	0.752~~16~~	0.877~~2~~		0.815	0.071~~05~~	0.611~~06~~	0.564~~39~~	0.1954
Dollar	***0.004~~38~~***	0.350~~496~~	***0.029~~88~~***	0.738~~8~~		***0.003~~28~~***	0.2694	0.169~~87~~	0.402~~2~~
Euro	***0.0044***	0.093~~1~~	0.273~~28~~	***0.037~~1~~***	***0.023~~3~~***		0.605~~47~~	0.161~~06~~	***0.047~~3~~***
Govt5	0.5504	0.602~~17~~	0.069~~86~~	0.610~~097~~	0.3854	***0.040~~398~~***		0.194~~3~~	***0.089~~86~~***
Govt15	0.808~~77~~	0.526~~58~~	***0.046~~1~~***	0.976~~58~~	0.508~~3~~	0.283~~1~~	0.323~~28~~		***0.0000~~0.0008~~***
Govt25	0.344~~36~~	***0.012~~15~~***	0.111~~1~~	0.616~~57~~	0.853~~1~~	0.376~~55~~	0.774~~3~~	***0.012~~18~~***	
All	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	***0.000~~0~~***	***0.032***	***0.0304***	***0.006~~57~~***

Notes. Dependent Variables are given in each column of the table. Granger causality P-values are given in the first row of each section. Elements italicised and in bold show significance at 5% level.

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2.4.3 Impulse Response Functions

To further illustrate this analysis, this chapter uses impulse response functions to represent the transmission of shocks to each variable. The ordering of variables in VAR is frequently discussed as having significant effects on Cholesky impulse response functions, therefore this chapter opted to use Generalised impulses, following Pesaran & Shin (1998). These are insensitive to ordering of the VAR, which is appropriate given this chapter intended to approach the VAR ordering without any theoretical structures. The shocks graphed from the impulse variable is a one standard deviation innovation with the confidence intervals being set at two asymptotic standard errors. Monte Carlo confidence intervals were also computed but demonstrated no different implications in significance from the standard asymptotic standard errors. The responses were graphed to 20 periods, but most responses are insignificantly different to zero after 5-8 periods. This suggests that shocks during the sample period were of a very short-term nature, with most responses dying out after 2 periods, however it should be noted that bands of plus or minus two standard error~~.~~s is reasonably stringent in considering whether the shocks had effects significantly different from zero. For the majority of the plots discussed below the same conclusions would hold using a different specification of error bands. ~~Impulse responses from each respective VEC model are also displayed following the results of the VAR model.~~

Recalling that the focus of this chapter is analysing financial asset price relationships and their implications on QE, the discussion here will focus on the impact of shocks to gilt yields, and thereby the transmission to other financial assets, rather than include impulse responses from every variable. As mentioned before, the main focus of this chapter is to examine whether significant, stable relationships existed in the financial crisis period to facilitate a successful QE policy. Significant responses to gilt yield shocks suggest that QE could be translated through to the different asset types, providing evidence towards the efficacy of QE.

For the commercial bank yield VAR, Figures 2.1, 2.2 and 2.3 corroborate the findings of the granger causality tests. It can be seen that 5-year yields shown in Figure 2.1 solicit positive initial responses from all commercial yields, an initially positive, then negative response from the FTSE, and a small but positive response from both exchange rates. Once again, it seems the difference in the significance for the granger causality comes down to magnitude of this initial response, with the 25-year commercial yields showing a quantitatively smaller response than the 5 and 15-year yields. Figure 2.2 shows that shocks to 15-year government yields caused qualitatively similar responses from the other variables to that of the 5-year yield, however the

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effects are smaller in all cases, hence the insignificance of the Granger causality tests. An exception to this is the 25-year government yield. This provides evidence that QE purchases of this maturity bracket would have had little to no impact on the wider financial markets.

Figure 2.1 GOVT5 Impulse Responses Commercial Bank Bond Model

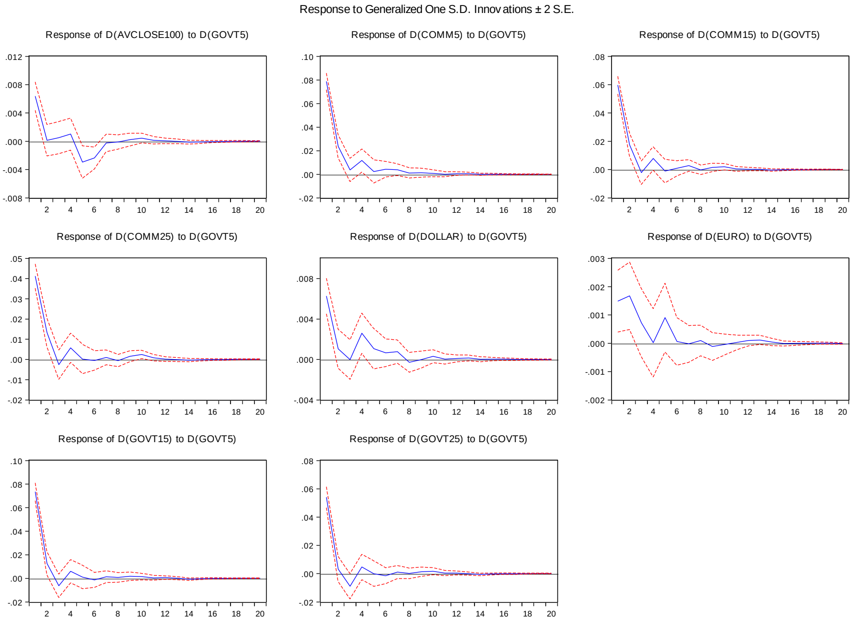


Figure 2.2 GOVT15 Impulse Responses Commercial Bank Bond Model

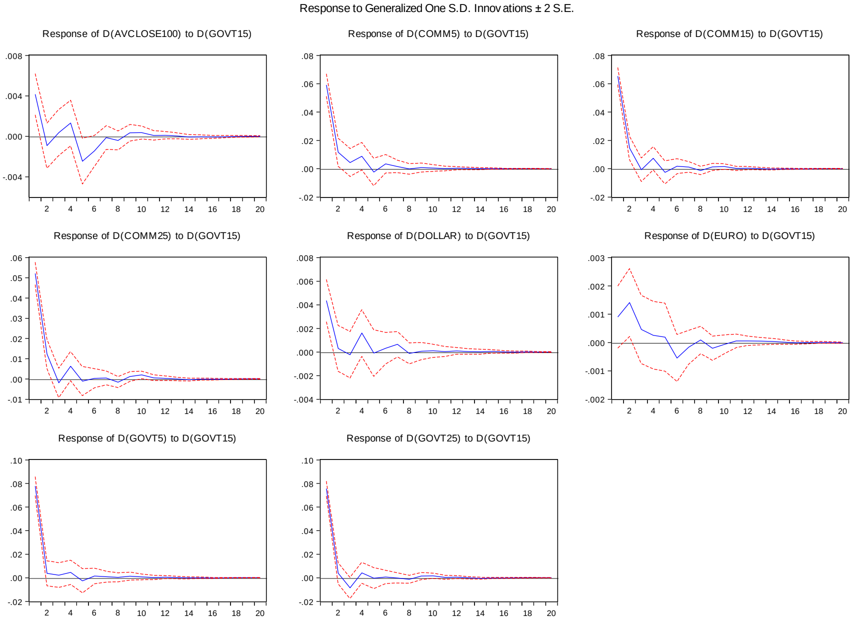
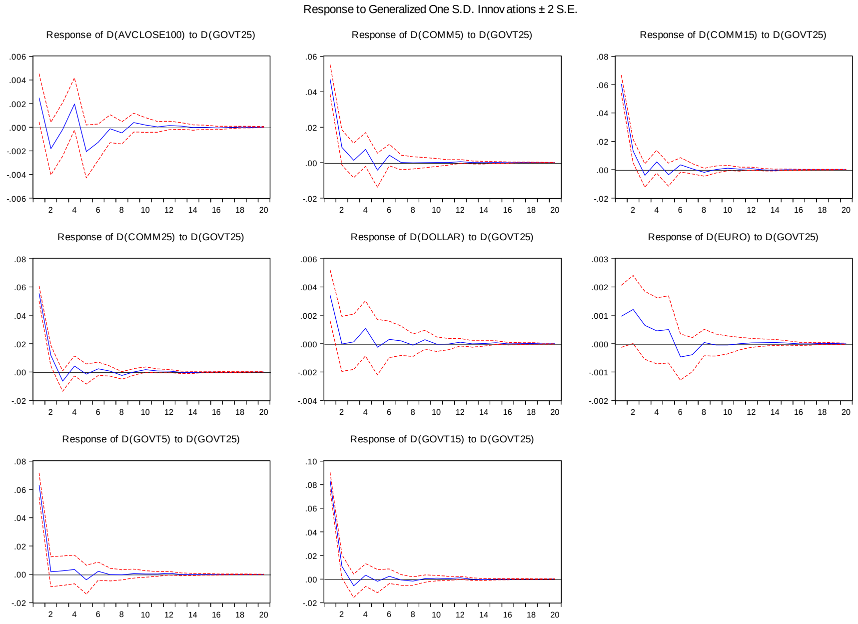


Figure 2.3 GOVT25 Impulse Responses Commercial Bank Bond Model



The results of the corporate yield model are largely the same as those found in the commercial model for the FTSE, exchange rates and gilt yields. However, the impact on corporate yields is very different for certain maturities. To start, corporate yields of 30 years to maturity do not respond significantly to any of the shocks to government yields of any maturity, with the initial positive effects being small in scale and counteracted by negative effects in the periods after. This corroborates with the Granger tests that found 30-year corporate debt to unaffected by everything except the Euro sterling exchange rate. For the other corporate debt yields, the effects from shocks to 5-year government yields occur in both an initial positive response and then a secondary positive response after about 7 periods. These effects appear to be too small in scale to found be significant by the Granger tests, however. Impulses from the 15 and 25-year government yields interestingly causes a similar response as shocks to the 5-year yield on 5-year corporate debt but causes a significant negative impact 3 periods after the initial positive response for 15-year corporate yields. This means that any depression in gilt yields of 15 and 25 years raised corporate yields several weeks later.

Figure 2.4 GOVT5 Impulse Responses Corporate Bond Model

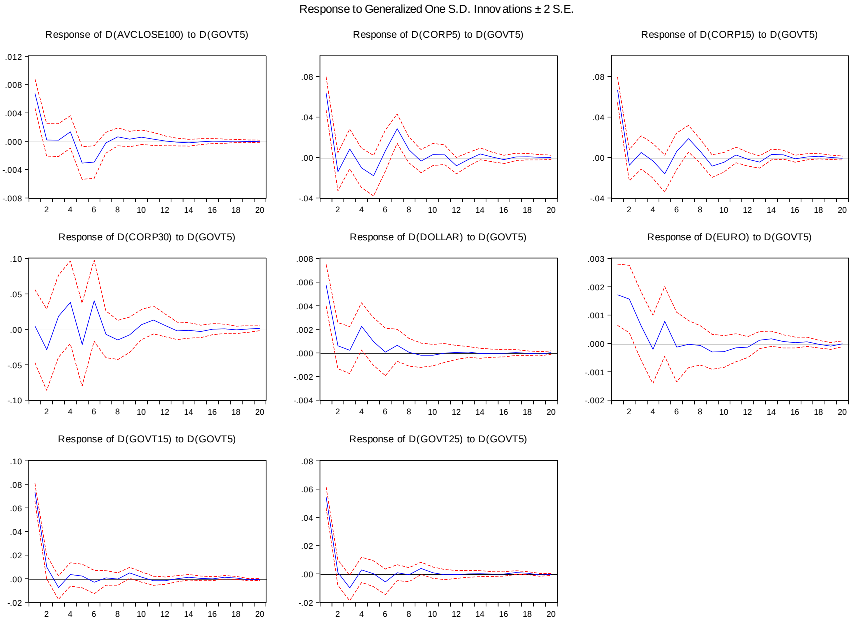


Figure 2.5 GOVT15 Impulse Responses Corporate Bond Model

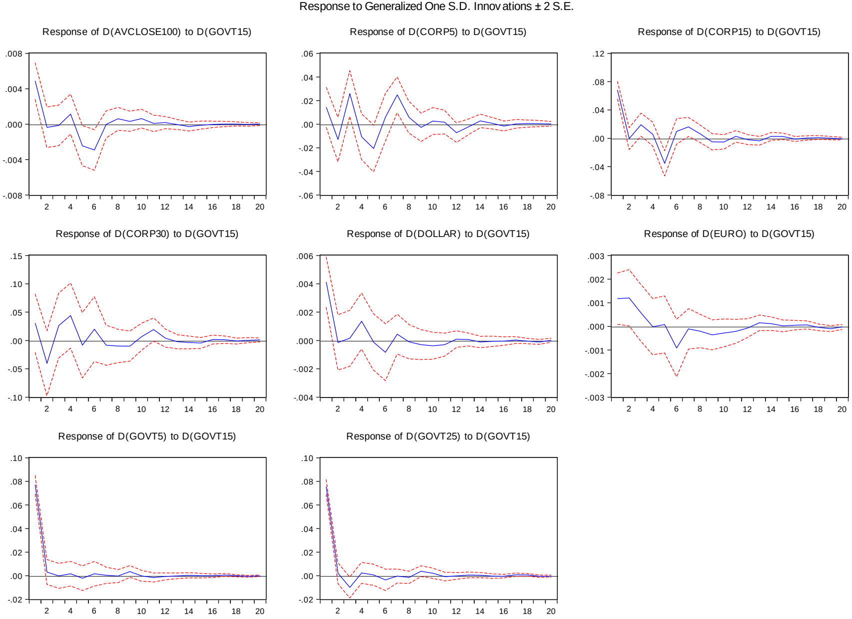
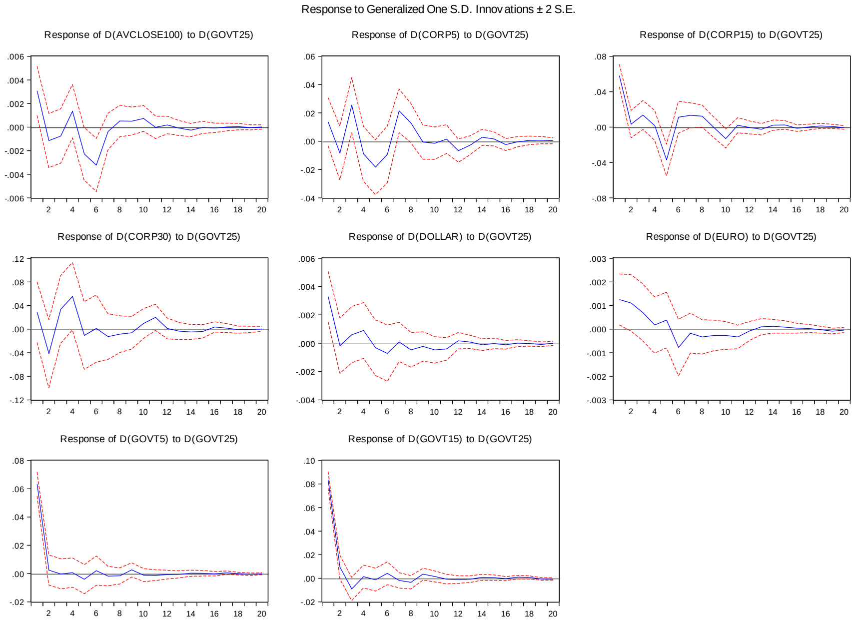


Figure 2.6 GOVT25 Impulse Responses Corporate Bond Model



While testing found the government and commercial bank yields to be non-stationary processes over the financial crisis period, other commentators have used yields in levels in their models. To ensure robustness of the results, and to help comparison, this chapter computes the same VAR model with all yields at levels but the equity and exchange rate variables in differences. Below are the computed impulse response functions from this auxiliary model. Appendix Figures A-1.1-6 show that the relationships between the differenced variables are the same as in the standard model and so will not be discussed at any length here. Focusing on the debt yields for both commercial and corporate debt, government yield innovations cause positive responses from private debt of all maturities. These effects are all significant for over ten periods. It appears the effects of these impulses are also stronger on commercial yields than corporate bond yields, especially in the case of the 30-year corporate bond yields, where the effects are comparatively small. In addition, it appears that shocks to the short end of the term structure appear to have the quantitatively strongest effects on both commercial and corporate yields. Overall these results reinforce the findings of the two standard models, showing that the short end of the term structure demonstrates the strongest impact on the other assets, with quantitatively smaller effects coming from innovations to yields of a longer maturity.

In summary of all of the impulse-response results, it is clear that the strongest relationships between government yields and equities, private debt yields and exchange rates comes at the short end of the term structure. The causal links between both government and commercial debt and the other variables weakens as maturity increases. For QE to have an effective transmission mechanism, government gilt yields would have to have a strong causal relationship with high-quality equities and commercial bank bond yields. A successful QE policy would have required decreasing gilt yields to have decreased commercial bank bond yields and increased equity prices. While decreasing short-term gilt yields are shown to decrease their commercial bank equivalents, yield changes of longer maturity gilts had little to no effect on any of the other variables in the system over the short run, suggesting that QE purchases of longer-term gilts had an insubstantial effect on other asset types.

2.4.4 Dummy Variable results

As discussed earlier dummy variables were used to approximate the effect of QE auction events on the various financial assets. Using a methodology similar to the Granger causality section described above, this chapter tested the null hypothesis that the effect of these dummies was zero using Wald coefficient restriction tests. Table 2.10 and 2.11 show the coefficient estimates and t-stats, with significant coefficients denoted by *, **, *** for 10, 5 and 1 percent levels of significance respectively. As can be seen from both tables, most dummy variables are found to have statistically insignificant effects at the 5% level. Very few of the coefficients are found to be significant at even the 10% level. This suggests that these purchases did not have any of the intended short run effects, or effects small enough to be lost in the general volatility of the period. The response of the financial assets to the auctions can be seen in Figures 2.7-18 As can be seen from Figures 2.7-18 these responses corroborate with the Wald tests in showing the effects of the QE dummies to be relatively small in all cases, with most effects not being significantly different from zero and all responses fading away in less than 5 periods.

Neither the FTSE nor the exchange rates, exhibit any significant relationship with QE purchases, with the exception of the QE1 dummy variable for the FTSE, and the purchases of 25 years-to-maturity gilts for the exchange rates. It seems that the first bout of QE purchases had the desired effect of increasing the price level of the FTSE, but whether this is because of portfolio re-balancing or from improved investor confidence is unclear. Fig.2.7 shows that purchases of long-term gilts caused the FTSE to increase after a short lag, an effect which dissipates rapidly. It also shows that QE1 purchases also had a positive impact on the FTSE price level, with the effects being more instantaneous but decaying more rapidly. All other indicators caused insignificant responses from the FTSE, with the overall purchases effect being small and positive. This suggests that the FTSE was not significantly affected by QE, with no systematic increase in prices resulting from QE auctions. The significance of the QE1 variable could suggest that the effects of QE were over-estimated by equity market participants during the first phases, an attitude that disappeared for the second phase.

For exchange rates it seems that purchases at the far end of the term structure caused a slight depreciation in the pound against both the dollar and the euro, however this effect is not present in purchases of shorter maturities. Figures 2.11 and 2.12 show that the exchange rates were unaffected by other QE purchases, with this small depreciation of the pound being the only significant effect.

Bank of England purchases of UK gilts with 5-year to maturity, totalling around £24billion of the total purchases over the course of the intervention, had borderline significant and positive effects on the yields of the longer maturity commercial and government debt. This relationship can possibly be explained by participants selling their holdings in 15 and 25-years to maturity gilts in order acquire shorter maturity assets, but in any case, does not reflect the expected depressed yields outcome. Figures 2.8-10 show that the commercial bank bonds with 5, 15 and 25 years to maturity were almost entirely unaffected by QE purchases, with only the

25-year commercial bank bond yields showing any statistically significant reaction. Bond yields of this maturity increased when gilts of 5-years to maturity were purchased by the central bank, which suggests that investors sold long-term commercial bank bonds in order to acquire shorter-term more liquid assets, however the effect that is only significant at the 10% confidence level. Tables 2.10-11 and figure 2.13 show that short-term gilt yields were unaffected by QE purchases, like their commercial bank equivalents, and were unresponsive even to the direct purchases of gilts of their maturity bracket.

In the corporate yield model, the results tell the same story. In addition to the effects on the FTSE is QE1 and the exchange rates from auctions of long maturity gilts, the only significant auction effects appear to be at the long end of the term structure. 15-year corporate yields were decreased overall by QE purchases in both phases of QE, with all of these dummies being significant. It appears the overall effect of all purchases cumulatively reduced longer maturity yields but this appears not to as a result of purchases of its own maturity. 30-year corporate yields increased due to all purchases over both QE phases, however QE1 is the most significant contributor to this effect.

For all of these results, it is unclear whether QE itself is causing these effects, or rather that QE intervention occurred during periods when external factors were causing these reactions. In either case, it is clear that QE auctions were not sufficient to drive up FTSE prices, or drive down yields over the short-term. While depreciating sterling was an anticipated effect of QE, this only happened on a localised sections of QE purchases, meaning the effects were limited. Once again, this does not conclusively determine that QE had no effect on these assets, as the effects might have taken place over a longer period than captured by these dummy variables, however these results do support the conclusion that over the short-term QE auctions had little effect in the manner predicted by theory.

Table 2.10 QE Auction Indicator Results Commercial Yields

Coefficients	**AVCLOSE100**	**Comm5**	**Comm15**	**Comm25**	**Dollar**	**Euro**	**Govt5**	**Govt15**	**Govt25**
D5PURCHASE	0.001	0.021	0.028	0.031*	0.004	-0.001	0.000	0.027	0.043*
	0.270	*0.920*	*1.458*	*1.868*	*0.876*	*-0.480*	*-0.010*	*1.169*	*2.072*
D15PURCHASE	-0.001	0.000	0.008	0.007	0.000	-0.001	0.015	0.023	0.014
	-0.130	*0.008*	*0.459*	*0.462*	*-0.045*	*-0.276*	*0.638*	*1.019*	*0.709*
D25PURCHASE	0.001	-0.016	-0.009	-0.015	-0.009***	-0.006***	-0.027	-0.026	-0.057
	0.175	*-0.480*	*-0.307*	*-0.611*	*-1.319*	*-1.494*	*-0.754*	*-0.765*	*-1.826*
DQEALLPURCHASES	0.006	-0.015	-0.021	-0.020	0.000	0.003	-0.002	-0.031	-0.037
	1.015	*-0.621*	*-1.004*	*-1.085*	*0.037*	*0.849*	*-0.077*	*-1.233*	*-1.631*
DQE1	0.010**	-0.003	0.005	0.007	0.002	0.000	0.010	0.004	-0.004
	2.714	*-0.212*	*0.384*	*0.630*	*0.598*	*-0.138*	*0.618*	*0.223*	*-0.245*
DQE2	0.004	0.001	0.006	0.008	0.003	0.001	0.003	0.003	0.005
	1.292	*0.084*	*0.487*	*0.808*	*0.960*	*0.667*	*0.205*	*0.218*	*0.360*

Notes. Dependent Variables are shown along the first row. T-stats are given in the second row of each section, and are shown in italics.

Table 2.11 QE Auction Indicator Results Corporate Yields

Coefficients	**AVCLOSE100**	**Corp5**	**Corp15**	**Corp30**	**Dollar**	**Euro**	**Govt5**	**Govt15**	**Govt25**
D5PURCHASE	-0.003	0.007	0.048	0.020	0.001	-0.003	-0.024	0.001	0.014
	-0.658	*0.161*	*1.440*	*0.157*	*0.226*	*-1.063*	*-0.991*	*0.039*	*0.697*
D15PURCHASE	0.005	-0.100	0.037	-0.064	0.003	-0.001	0.040	0.041**	0.033
	0.924	*-2.321*	*1.097*	*-0.491*	*0.610*	*-0.291*	*1.627*	*1.771*	*1.560*
D25PURCHASE	-0.002	-0.072	0.008	0.006	-0.008***	-0.006***	-0.041	-0.038	-0.065
	-0.218	*-1.129*	*0.162*	*0.030*	*-1.163*	*-1.580*	*-1.126*	*-1.122*	*-2.107*
DQEALLPURCHASES	0.003	0.061	-0.094*	0.099**	0.000	0.004	-0.009	-0.030	-0.031
	0.566	*1.288*	*-2.544*	*0.692*	*0.049*	*1.170*	*-0.343*	*-1.174*	*-1.330*
DQE1	0.008***	-0.011	-0.038**	0.071**	0.003	0.000	0.006	-0.001	-0.005
	2.121	*-0.367*	*-1.631*	*0.798*	*0.950*	*-0.042*	*0.374*	*-0.070*	*-0.357*
DQE2	0.002	-0.012	-0.028**	0.066	0.002	0.001	-0.007	-0.004	0.000
	0.482	*-0.460*	*-1.336*	*0.832*	*0.673*	*0.366*	*-0.481*	*-0.299*	*0.031*

Notes. Dependent Variables are shown along the first row. T-stats are given in the second row of each section, and are shown in italics.

Figure 2.7 Dynamic Multiplier Response of FTSE100

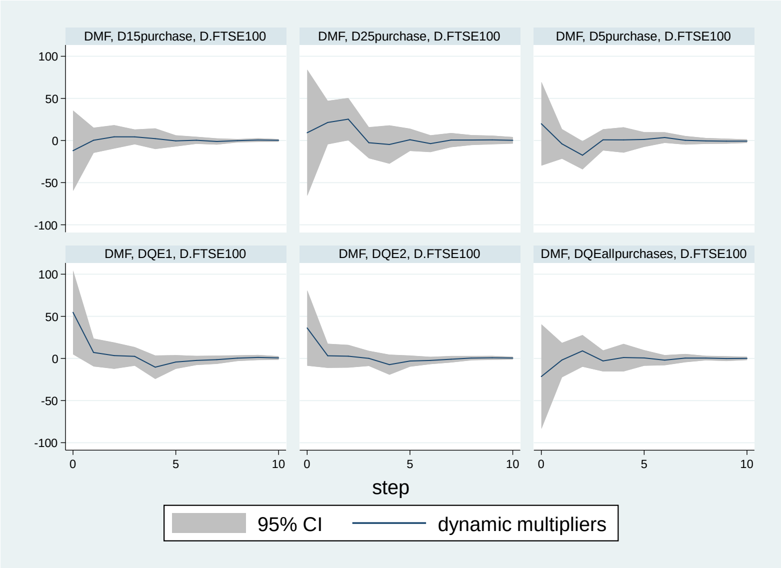


Figure 2.8 Dynamic Multiplier Response of Comm(5)

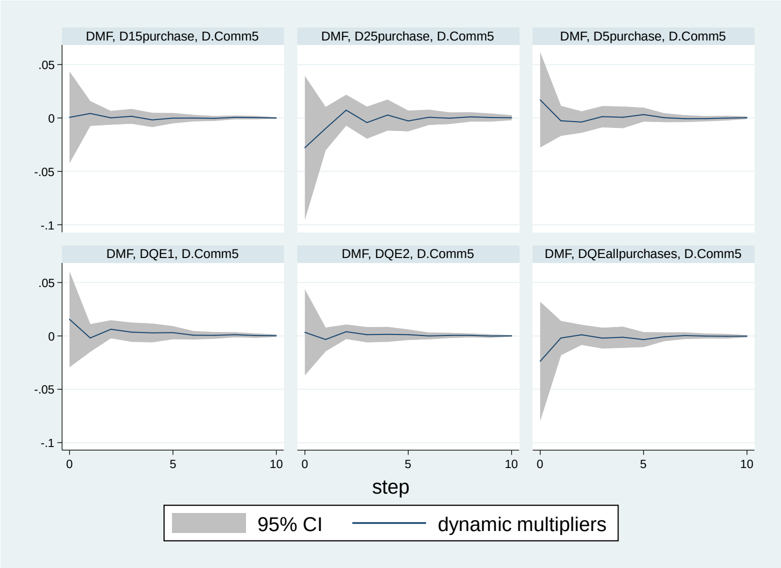


Figure 2.9 Dynamic Multiplier Response of Comm(15)

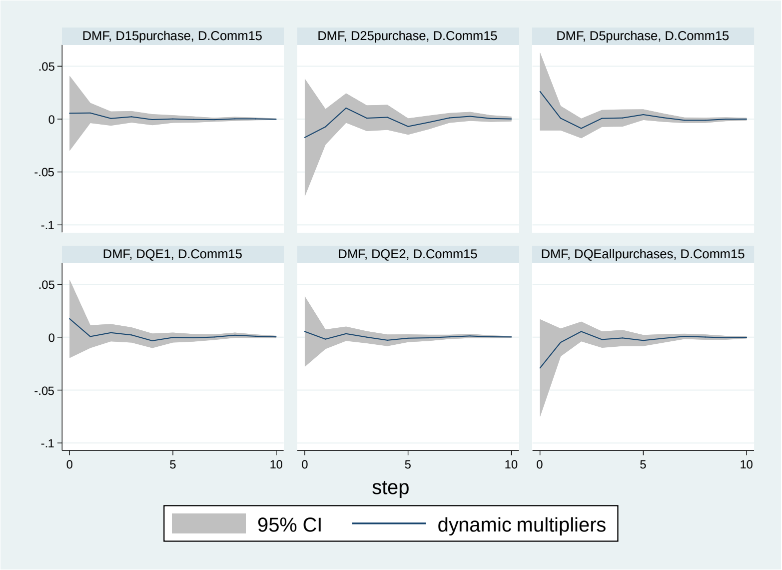


Figure 2.10 Dynamic Multiplier Response of Comm(25)

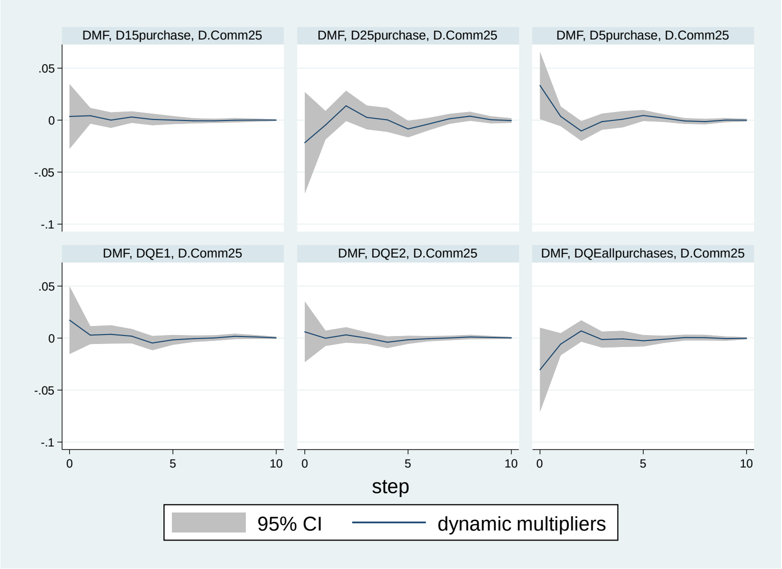


Figure 2.11 Dynamic Multiplier Response of Dollar

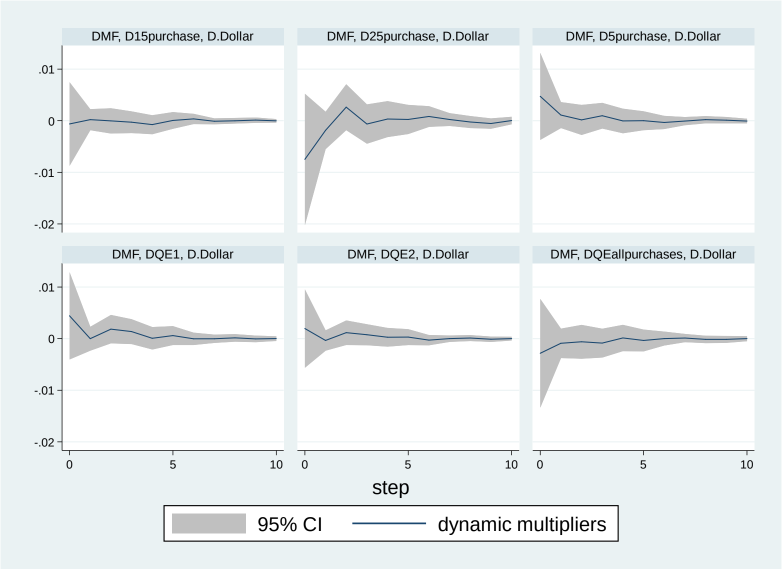


Figure 2.12 Dynamic Multiplier Response of Euro

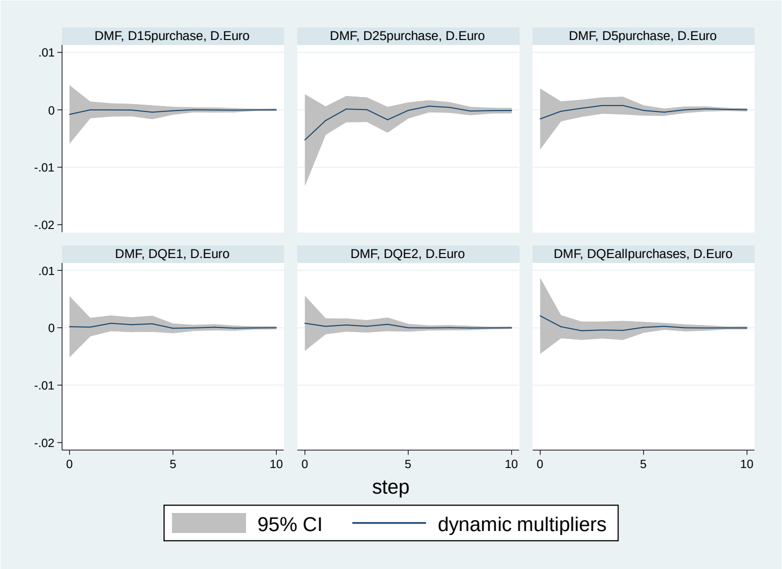


Figure 2.13 Dynamic Multiplier Response of Govt(5)

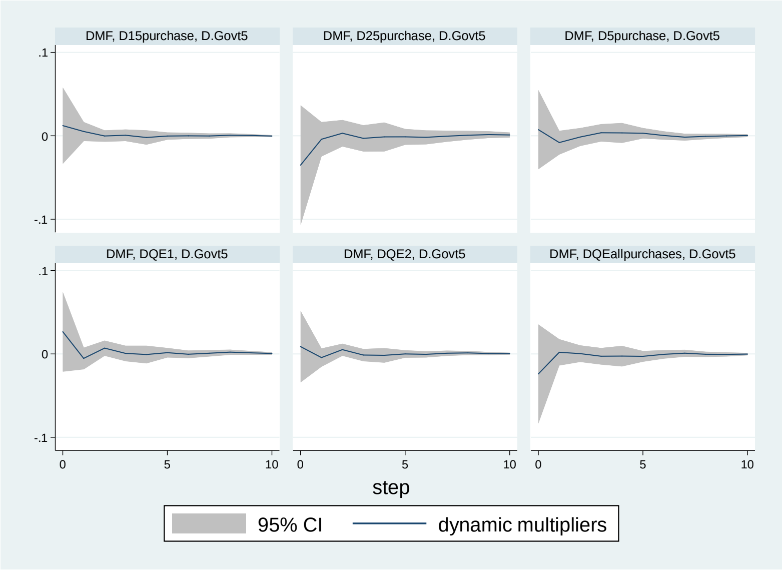


Figure 2.14 Dynamic Multiplier Response of Govt(15)

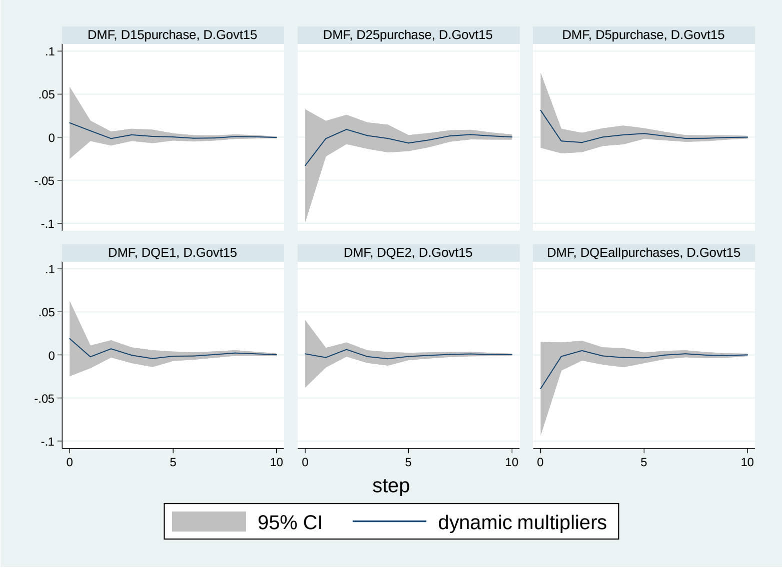


Figure 2.15 Dynamic Multiplier Response of Govt(25)

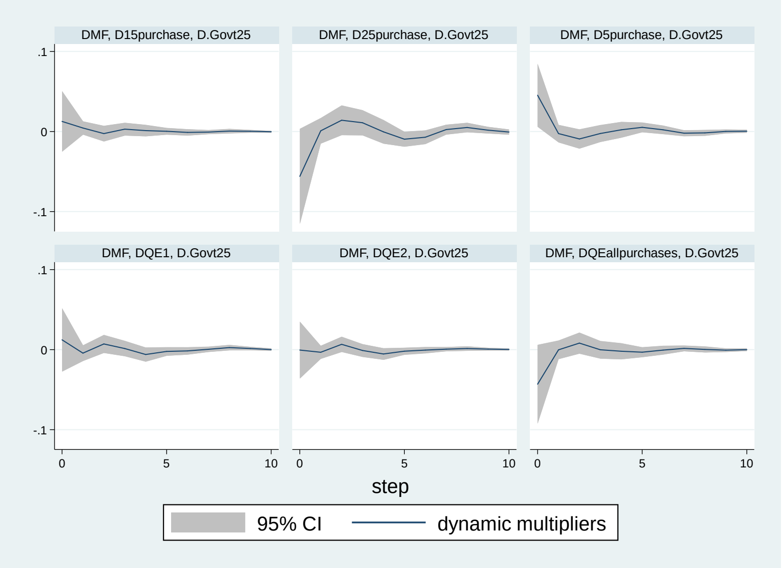


Figure 2.16 Dynamic Multiplier Response of Corp(5)

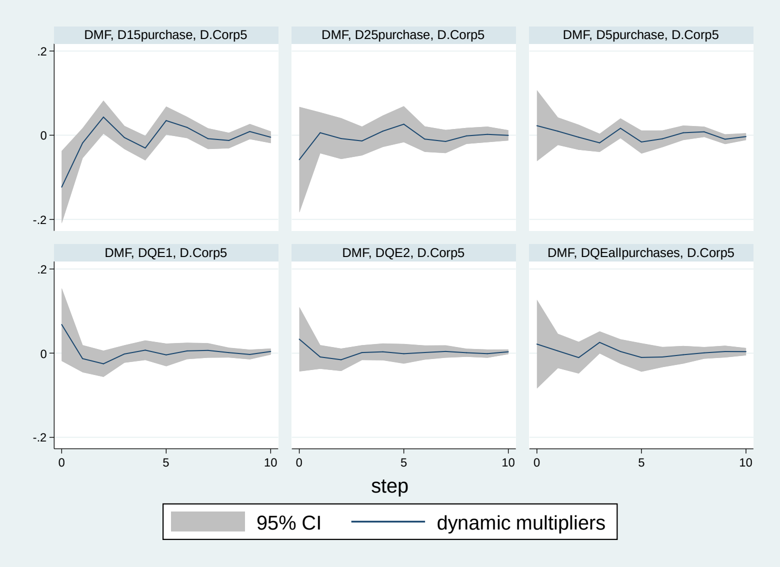


Figure 2.17 Dynamic Multiplier Response of Corp(15)

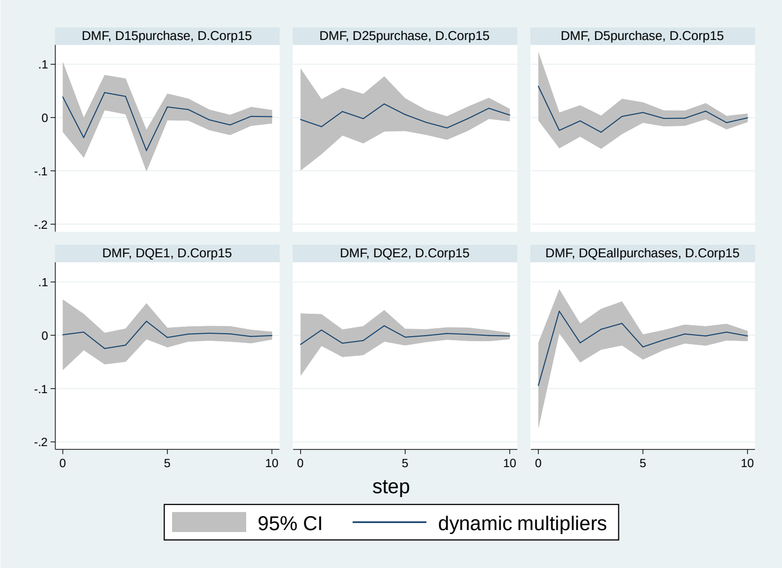
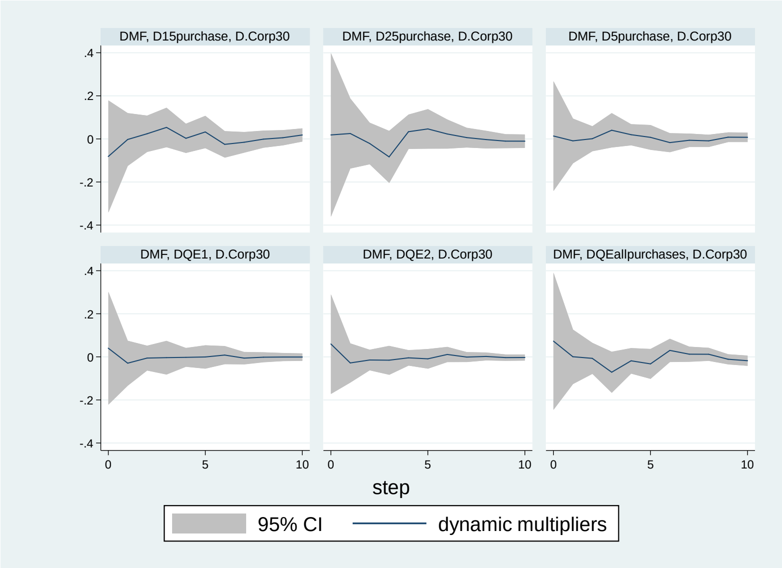


Figure 2.18 Dynamic Multiplier Response of Corp(30)



2.5 Conclusions

The analysis of this chapter has centred on modelling the short and longer-term effects relationships between gilts, equities, exchange rates and the corporate and bank debt, and from these models extrapolating the efficacy of QE in affecting all these assets. From the evidence presented in this chapter, QE's effect on financial assets is difficult to interpret but there exists a clear discrepancy between the intended outcomes of QE and actual events.

The clearest answers are the effects on UK equities, where this chapter has finds that over the long and short term, gilt yields and thereby QE did not have a significant effect on equity prices. As stated earlier, a successful QE policy resulting in lower gilts yields should have raised equity prices through a variety of channels. The weekly evidence presented here suggests no such relationship existed over the period, with gilt yields of longer maturities having consistently insignificant effects on the FTSE's price level. Only the 5-year gilt yields shared a significant relationship with equities prices but considering the negligible effect of QE on 5-year yields, this relationship is unlikely to have been a significant vector for raising prices. While the sterling exchange rates are found to be an important factor for UK equity prices, the evidence suggests that neither of these two variables exhibited strong enough relationships with government gilt yields to be a vector for QE's transmission. It should be noted however, that the QE1 purchases did have a positive impact on the FTSE's price level. This may demonstrate a positive macro-economy news effect, i.e. that financial market participants viewed the announcements and reverse-auctions made by the Bank of England as positive news on the outlook for equity markets and the British economy. This argument is reinforced by the evidence that QE2 and the overall purchases were insignificant, suggesting that there was a not a systematic positive reaction to the actual gilt purchases and corresponding yield decreases, but rather a temporary improvement in investor outlook which boosted FTSE prices. Overall, this chapter finds little to suggest that QE had a significant impact on equity prices, rather that the FTSE was largely exogenous to government gilts and QE intervention in general. In a similar manner there is little evidence to suggest that QE auctions had an impact on the value of sterling. Both the long and short run evidence points towards insignificant links between UK gilt yields over the period, with the only significant impact occurring during the purchases of extremely long-maturity government debt.

On a more positive note, it appears that commercial and corporate bond yields are significantly linked with gilt yields, presenting positive evidence for QE purchases to translate its effects through to these assets. The long run cointegration evidence presents a clear link between the yields of corporate bonds and government gilts of all maturities, with commercial bond yields having a long-term significant relationship with at least the 15-years to maturity gilts. Over the short term these yield relationships still exist, government gilt yields have significant positive relationships with commercial and corporate yields. This evidence suggests there is indeed an existing mechanism by which lowered gilt yields will translate to private debt assets, however it is also important to note that at least over the very short-term, this chapter finds little evidence that QE auctions systematically reduced gilts yields. While it should not be interpreted from these results that QE did not reduce gilt yields overall, this chapter concludes that over the short term the effects of QE were not immediately transferred onto other asset types.

Overall the results of this chapter do not, like most of the other studies on Quantitative Easing, point to a clear conclusion to the efficacy of QE channels for financial markets. There is strong evidence that the FTSE100 was exogenous to UK gilt yields and therefore QE intervention. It also seems that sterling value was also largely unaffected by the £375 billion of bond purchases. The conclusions of this chapter are that QE channels did not operate as anticipated for these financial variables, with there being no appreciable effect on the FTSE or the sterling through the portfolio balance, liquidity, credit or macro-news channels. The implications of these conclusions are not catastrophic for the success of QE, granting that the policy was aimed at more macroeconomic targets than influencing asset prices. However, as these asset prices were considered to be important vectors for the transmission of QE's effects through to the rest of financial sector and thence to the wider economy, such insignificant results over the short term present a disappointing conclusion for the policy. At least, the failure of QE to significantly impact equity prices and exchange rates should be a cause for some theoretical revision of the strength of monetary policy channels on asset pricing. However, this being said, there is some evidence that QE did affect commercial bank and corporate bond yields through their gilt purchase programme. This caveat suggests that QE channels did operate, however the effects were far less widespread than anticipated by the Bank of England.

Chapter.3

A Simple Financial Stress Index for the United Kingdom

3.1 Introduction

After the onset of the global financial crisis the UK experienced a period of significant financial stress. In response, the Bank of England lowered its bank rate to 0.5% and undertook significant balance sheet intervention in order to stabilise financial markets and ensure that this period of financial stress did not lead to a long-term downturn for the UK economy. While the Bank of England has not credited financial stress as a significant motivation for this policy intervention, monetary policy decisions undeniably have been calculated with reference to their impact on the UK's large and complex financial markets. In addition, as the previous chapter found meagre evidence of the Bank achieving its objectives in affecting asset ~~pricing~~prices, examining the policy's impact on general financial conditions is a useful point of further analysis. QE could easily be considered a success if financial market conditions improved under the programme, even if the overall impact on asset prices was modest in scale.

However, while often cited in connection to the wider economy, analysis of financial stress has been rarely discussed in terms of metrics and measurable impacts. Most frequently financial stress has been treated as a binary variable; either the economy is in a state of financial stress, or alternatively financial conditions are relaxed. Furthermore, the dating of these stress events is typically down to the analyst's discretion, rather than any empirically ascertained method. Ivashina & Scharfstein (2010) and Radelet & Sachs (1998) amongst many other studies on financial crises use such an approach, which gives no measure of the severity of financial stress, or indeed an effective comparison to stressful events that came before or after. This creates an issue for policy-makers such as the Bank of England, as the decision to remove liquidity from the economy or to reverse the previous expansive monetary policies will have a short run effect on the stability of financial markets, a potentially dangerous prospect if the level of financial stress in the UK is unknown.

This chapter introduces a financial stress index for the United Kingdom, using precedents from the literature to identify and measure financial systemic distress as an ongoing, continuous index. The purpose of this is be able to capture risk, uncertainty and constrained financial conditions in asset pricing, and to determine the impact of QE on systemic financial stress. The creation of such an index is necessary due to the lack of sources currently available in the literature for the United Kingdom. While other studies such as Balakrishnan et al (2011) and Corbet & Twomey (2014) have created indexes for the UK, neither include the length of sample and the variety of indicators to make them well-suited for capturing the interaction between QE and financial stress. Therefore, in this chapter a variety of financial stress indicators are selected that are commonly available, relevant to UK financial markets and frequently cited in the literature. The indicators are also selected on the basis that they contain information from the various sectors of UK financial markets and hence financial stress, including foreign exchange, equity and government & corporate debt markets. This selection style not only ensures this measure captures all aspects of UK financial stress, it also links this index to the asset markets QE was intended to impact. The overall intention with this index is to create a workhorse approximation of financial stress, using the empirically successful techniques employed in the literature that study financial stress in developed economies. This financial stress index is then employed in different ways in the analysis of the following chapters, aiding in the examination of the financial market impact of QE in the UK.

The chapter is organised as follows, firstly this chapter overviews the theoretical basis for the study and measurement of financial stress. Then the chapter discusses changing trends in financial stress, or the ‘financial cycle’, with regards to its relationship with the wider economy. The different types of financial stress are overviewed in terms of the sectors and element of the financial sector that are involved. The second section then moves onto the practical overview of the financial stress indicators, focusing on the measures this chapter has chosen to include, and the rationale for each individual’s inclusion. As the basis for each indicators inclusion, the key elements of the literature who have also included such variables are discussed in brief. The third section overviews the methods of aggregation for these individual indicators into a financial stress index, again highlighting the literature that have utilised similar methodologies. Section four discusses the performance of this UK financial stress index, comparing it with known stressful events. This section also highlights the practical approaches used in the literature in isolating stressful periods. Finally, the conclusion of this chapter is made with some remarks on the overall use and performance of this created stress index, and how overall it can be used with regards to analysis of UK QE.

3.2 Literature Review

As a starting point, it is important to define what financial stress means for an advanced economy like the UK. This chapter defines financial stress as any factor related to risk and uncertainty about future financial and economic prospects that leads to constrained market conditions and the departure of asset pricing away from the levels based on asset fundamentals. A financial crisis is therefore defined as periods when these factors become extreme enough for the issue to affect multiple markets simultaneously and risk the survivability of otherwise well-performing financial institutions. A key issue with financial stress literature has been the designation of these financial stress periods. In approach, many studies have simply modelled stress as a binary variable or a threshold at which an economy goes from normal financial circumstances to a financial crisis period. This approach is problematic as neglects episodes that approach but do not exceed crisis conditions, and additionally it makes no distinction between crises in terms of severity once past this threshold. Furthermore, while most episodes of financial stress are relatively short-term in nature, systemic financial stress can alter economic behaviour and change the outcome of normal economic decision-making, making the study of periods not extreme enough to be classified as crises, but still having relatively high stress levels, a useful exercise. Since the financial volatility surrounding the early 2000s, with the stock market downturns and the financial impact of the attack on the World Trade Centre, several studies have sought to re-model financial stress as a time-series variable, where the extreme values are called a crisis. Oet et al (2011) and Illing and Liu (2006) are two such examples of studies that remark on the weakness of a financial stress binary variable.

Systemic risk has been defined as the risk of correlated failure of otherwise unrelated financial institutions leading to negative effects firstly on the liquidity and risk capital of other financial institutions and thenceforth on to the real economy (Oet et al, 2011). The difficulty in the creation of a stress variable lies with the fact that each financial stress episode is different, and there appears to be relatively few characteristics that are systematically present in most or all financial crises, especially when comparing across different countries. Discussion of the most recurrent characteristics are therefore the starting point when measuring financial stress. One of the most frequently cited characteristics is an abrupt increase in perceptions of risk and uncertainty in a financial system. Here market participants, particularly lenders, become rapidly unwilling to hold risky financial assets, and will often attempt to move their portfolios into holdings of relatively safe assets. This drives up the return demanded for risky assets, while simultaneously reducing returns of ‘safe’ assets. As discussed by Hakkio and Keeton (2009), this flight to quality occurs because of a general underestimation of risk during periods of economic boom, and subsequent overestimation of risks during busts. When the turning point between boom and bust occurs, perceptions of risk sky-rocket. This ties in with another characteristic of financial stress: large shifts in asset prices. Balakrishnan et al (2011) cite this as a prominent example of financial stress and is closely tied in with the valuation of risk in a market, when risk-aversion increases, or perceptions of risk increase, asset prices adjust rapidly as investors fly to quality.

Constraints on liquidity is another frequently cited characteristic of financial stress. Liquidity in this case being defined as the relative ease an investor has in buying or selling assets quickly and without large transaction costs. Market participants with uncertain expectations of the future defend themselves from potential adverse circumstances by acquiring assets that are highly liquid, rather than focus on non-liquid assets that tend to have higher returns. This effect is once again discussed by Hakkio & Keeton (2009) and causes the same rapid asset price changes and return spreads, focusing on the liquid and non-liquid assets rather than the quality of assets. Another fundamental characteristic of financial stress, linked to both the features described above, is increased asymmetrical information between parties. This leads to the varied valuations of risk and outlook that drives flight to liquidity and quality and is an important characteristic that often follows government and monetary authority policy actions, especially if the policy action will affect the health of the banking system and/or investor preferences.

These financial stress characteristics do not always affect different financial sectors homogenously or systematically. Because of this, several studies examining financial stress separate financial stress characteristics by the type of financial markets that are affected. The most frequently cited sectors tied to financial stress shocks include foreign exchange markets, banking sectors, debt markets and equity markets (Ishihara, 2005). Caprio and Klingebiel (1996) discuss banking sector stress and define a crisis qualitatively as an instance where bank failures exhaust the supply of bank capital for lending to other financial market participants, thereby affecting other sectors. Quantitative measures include the ratio of non-performing loans as a percentage of total assets. Foreign exchange stress is usually captured by significant devaluations, affecting holders of currency, in addition to large shifts in foreign exchange reserves or intervention from monetary authority in terms of interest rate manipulation, which affects the wider financial system Illing and Liu (2006). Debt market stress is characterised by Bordo and Schwartz (2000) as circumstances that prevent private or public institutions from being able to service debt. This factor then plays into the risk spreads discussed above, leading to a flight-to-quality and rapidly adjusting asset prices. Equity crises are similar in nature to debt crises and occur when there is uncertainty about probability of loss or the profitability of firms. It is usually captured by sharp declines in representative equity indices or other return-volatility measures Illing and Liu (2006). All of these sectors can have individual crises, but more often interrelate due to the complex interlinkages of modern financial institutions.

Financial stress is of concern to financial market participants primarily, however when this stress can manifest in reduced economic output, unemployment or recession financial stress becomes a larger concern. Earlier it was mentioned that financial stress considerations can alter monetary policy, this is discussed in Hakkio and Keeton (2009) amongst others. Davig and Hakkio (2010) discuss the relationship between real activity and financial stress, finding that the US exhibits two distinct states, periods of high economic activity and low financial stress, and periods of low activity and high financial stress. They present evidence that financial stress has a much stronger dampening effect on real activity during these distressed periods and that heightened financial stress plays a significant role in moving the economy between the two states. In addition, they discuss two potential theoretical frameworks through which financial stress affects the wider economy. First, the Real Option Framework incorporates uncertainty into the timing of investment, with firms holding off on real investment during periods of high financial uncertainty and investing during periods of low stress. The second framework is the Financial Accelerator model, initially discussed in Bernanke, Gertler and Gilchrist (1999), which links real investment to the availability of credit or the creditworthiness of borrowers, which becomes constrained during periods of financial stress, forcing borrowers to de-leverage and thereby amplifying downturns (Hakkio and Darig, 2010). Cardarelli et al (2011) also follow this financial accelerator framework as the basis for the impact of financial stress on economic activity. Hubrich and Tetlow (2015) Use a regime change model to link financial stress, monetary policy and the wider economy and find that stress events are precursors to adverse economic events in the US economy. They also find that financial stress has a negligible effect on the economy in normal circumstances, but of high significance during high-stress periods. A final finding is that monetary policy is not particularly effective during periods of high financial stress.

Overall, there exists a significant literature that defines financial stress, relates it to separate sectors of financial markets and form theoretical frameworks for its impact on the wider economy. For this chapter the focus is on creating an index that captures financial stress in different sectors and for different asset types, while giving a balanced overall measure of stress. The next section outlines the methodology that achieves this aim, while discussing the elements of the literature the variables and calculations are drawn from.

3.3 Methodology

3.3.1 Indicator Selection

As mentioned above, there are several prominent stress indexes for the US, Canada and the Euro area that share methodologies. Some of the most prominent examples are the Illing &

Liu Canadian Financial Stress Index (2006), the Composite Indicator for systemic stress (CISS) in the Euro area, the Kansas City Financial Stress Index (KCFSI) and Cleveland Financial Stress Index (CFSI) for the US. Since this chapter does not attempt to empirically prove the accuracy of its FSI in capturing stressful events, this chapter attempts to closely follow the procedure of these commentators who have tested their FSIs. Many commentators such as Illing and Liu (2006) established stressful events by surveying financial experts on the events that the experts viewed as stressful for financial markets. They then compare the perceived severity of these events with the results of their FSI to confirm the latter's accuracy. Failure to capture a stressful event or falsely indicating stressful periods are both considered failures of an FSI in this case. This approach is like the one taken by the Federal Reserve Bank of Kansas City, but rather than surveying financial experts, they select stressful events based on academic consensus. They then test whether their FSIs stressful events correspond to known periods of financial stress. Once again, failure to capture stressful events or exhibiting false positives are considered failures. By utilising the same methodologies and variables for this chapter's FSI, this chapter relies on the accuracy of these studies to establish a reasonable approximation of UK financial stress.

A second factor this chapter considers when choosing FSI variables is the intention to capture financial stress in different sectors of financial markets, specifically equity markets, foreign exchange, the banking sector and both private and government debt markets. By capturing these different elements within a FSI, more information can be gleaned about the nature and cause of financial stress periods. Thirdly, the variables of this chapter's FSI follows the literature on FSIs that most accurately match the UK's financial markets and economy. To be specific, subject to the other factors described above, this chapter intends to use stress indicators that are likely to be important for a relatively large open economy with complex and developed financial markets. Finally, this chapter's intention was to create a stress index from data that is available on a daily basis. This periodicity was used because it allows the FSI to capture the most stressful periods of the financial crisis and ensuing QE intervention in a way that lower frequency data would miss. The section below outlines the calculation of each variable used in this chapter's FSI, as well as giving a brief argument for its inclusion and discussion of its prevalence in the literature.

Banking Sector Stress

Given that the most recent financial crisis involved a large amount of uncertainty and stress for the UK's banking sector, measures capturing banking stress specifically are included in the index. A frequently cited and used measure is the banking sectors β, a measure of the relative equity-return volatility between a countries banking sector and the general market. This measure is included in Illing and Liu (2006), Oet et al. (2011), and Balakrishnan et al. (2011) amongst others. The financial sector β is calculated as

$$\beta = \frac{\operatorname{cov}(r,m)}{\operatorname{var}(m)} \tag{1}$$

Where r and m are the total returns, at annualized rates, to the banking sector index and the overall market index, respectively. In this case the market index is the FTSE ALLSHARE index and the FTSE ALLSHARE Financials is the banking sector index. When β is greater than 1 the volatility of bank share returns is greater than the volatility of market total returns over the past year. Volatility is interpreted as a measure of risk in this case, meaning that greater volatility of the banking sector index means that the banking sector is relatively riskier. It should also be noted that while popular, the financial β may capture many other factors than financial stress. As Illing and Liu (2006) comments, what could be interpreted as higher financial stress from a large β, could actually be the result of good news about the financial industry and bullish markets. Individual economic sensitivity and regulation changes to the financial sector could also cause the β to have a large value, but not reflect actual financial stress. Because of this, Illing and Liu (2006) also include a refined measure that is not used elsewhere where they impose two adjustments on the standard measure. The first is that stressful periods are denoted by $\beta > 1$ and the second that the return to the bank index is lower than the market return. These two conditions together suggest periods where the banking sector is riskier because of stress rather than being riskier for being in a bullish market. When these two conditions are not met, the variable is assigned the value of 0, indicating low stress. While this chapter considers the use of this refined measure, there are drawbacks that justify its omission. Primarily the drawback of its formulation, where the indicator is valued at zero except for in extreme circumstances, is that it creates an almost binary measure of stress. As discussed earlier, such binary measures of stress are specifically avoided in this chapter in order to model stress as a continuous variable. Furthermore, inclusion of the indicator within the index tends to cause the index to exaggerate or underestimate stress levels. Illing and Liu (2006) include both the standard and refined version of this β and remark on how the refined version is not significantly superior in any particular context.

Another measure this chapter uses to approximate banking stress is the spread between commercial bank bonds and government bonds. In the literature this is proxied in several ways, for example Illing and Liu (2006) use the spread between AA corporate and Government of

Canada bond yields, Oet et al. (2011) use the spread between A-rated bank bond yields and treasury yields. Choice of bank bond yield to use is typically based on the credit rating of the particular countries banking sector. This chapter uses the spread between commercial bank yields and government bond yields both of 10-years to maturity, data which is available from the Bank of England. This variable is intended to capture the difficulty of commercial banks in acquiring finance in debt markets, which typically only occurs for creditworthy institutions like bank when lending in a country is particularly constrained. While this spread contains both risk and liquidity components, the high-quality nature of bank bonds ensure that the risk component is relatively small, and that significant changes in the spread are down to liquidity conditions primarily.

The final two banking sector variables are the spreads between the 3-month LIBOR rate and the 3-month Treasury Bill and Bank of England Base Rates, respectively. Equivalent spreads are included in Oet et al. (2011), Hakkio and Keeton (2009) and Corbet and Twomey (2014). Both of these measures capture liquidity and counterparty risk in interbank lending and high spreads are therefore indicative of financial stress.

Foreign Exchange Stress

This chapter employs a very commonly cited foreign-exchange market stress measure, using the CMAX calculation on the trade-weighted UK effective exchange rate. This CMAX calculation is used by the majority of the most frequently cited FSI studies, including Illing and Liu (2006) and Oet et al. (2011), and captures the flight from Pound Sterling towards foreign currencies, which occurs during periods of UK-specific financial stress. The CMAX calculation is as follows,

$$Weighted\ Sterling\ Crash_t = \frac{x_t}{\max\left[x \in x_{t-j} \middle| j=0,1,\ldots,365\right]} \tag{2}$$

Where x is the trade-weighted £UK Exchange rate index. The calculation represents period t’s exchange rate as a ratio of its one-year high. Rapid reductions in this value indicate strong depreciations in the pound, an indicator of flight from sterling-denominated assets.

Debt Market Stress

The most commonly used measures for debt market stress are the spreads between risky and risk-free bond yields. The spread between these assets being a function of expected losses and therefore risk. When these spreads widen, investors require higher returns to compensate for higher perceived probable loss. This chapter and others uses a variety of debt-market spreads as indicators for overall stress. This chapter’s approach is agnostic in this regard, attempting to accommodate as many of the various spread types that are frequently included in the literature, given that there is no clear correct spread to use.

The first measure this chapter uses is the covered UK-US 90-day treasury bill spread, which proxies uncertainty and captures limited arbitrage in government debt markets. This chapter uses the US T-bill rate as it is one of the most competitive rates for UK denominated assets. Given that treasury bills have very low probability of default, Covered interest parity (CIP) states that with arbitrage there should be no difference or spread between the two treasury bill yields. Any movement away from this parity suggest limited arbitrage or investor uncertainty and therefore stress. This chapter argues that either a negative or positive spread between UK and US debt is indicative of financial stress, meaning that only the absolute size of the following equation is taken as the measure,

$$Covered\ Interest\ Spread_t = (1 + r_t^*) - (\tfrac{F_t}{S_t^*})(1 + r_t) \tag{3}$$

Where r^* is the 90-day US Treasury Bill rate, F is the 90-day forward rate for the US-UK exchange rate, $S^*$is the spot US-UK exchange rate, and r is the 90-day UK Treasury Bill rate. This measure is included in Illing and Liu (2006), Oet et al (2011) and Corbet (2014), for their respective country's debt.

The second measure is the spread between 10-year UK AA-rated corporate yields and 10-year UK government benchmark yields. Like the commercial bank yield spread above, this measure captures the risk in corporate debt markets. Greater spreads indicate periods of greater financial stress in corporate debt markets. In addition, this chapter also includes the spread between BBB and AAA rated corporate debt to further capture increases in risk for lower-quality debt.

Yield Curve Stress Measure

An inverted yield-curve is typically viewed as indicating future slow economic growth or recession. In addition, i.e. when the short rate is higher than the long-rate stress is exerted on investors as there is an increasing cost in servicing short-term debt obligations. Therefore this chapter, amongst many others, includes an inverted yield curve measure as an indicator for financial stress. The spread between the 10-year UK government bond yield and the 3-month government bond yield is used to represent the yield curve, with periods where this spread is zero or negative indicating stress and periods with large positive spreads indicating normal market function.

Equity Markets

Stress in equity markets has most frequently in the literature been captured by large price decreases, or periods of high price volatility. The CMAX calculation is used by Illing and Liu (2006), Oet et al (2011), Hollo et al (2012) amongst others to capture price levels relative to the 1-year high. Large negative deviations in prices compared to this maximum are viewed as indicating equity market stress, similar to the case for the effective exchange rate measure. A second popular measure, used by Corbet (2014) and Hakkio & Keeton (2009), is Option-Implied Volatility or VIX option prices. High values of options on equities suggest investor uncertainty about fundamentals or the behaviour of other investors. This chapter uses the FTSE100 VIX price level, with periods of high prices indicating periods of high financial stress and uncertainty.

Other Measures

In addition to the above measures, this chapter followed Illing and Liu (2006) in considering three GARCH stress measures. Modelling each variable as a GARCH(1,1) this chapter used the FTSE ALLSHARE price index, the FTSE ALLSHARE Financials as a share of the FTSE ALL SHARE, and the US/UK Exchange rate. As in Illing and Liu (2006) other specifications of GARCH models were considered and tested, but the GARCH(1,1) performed the best. In any case, the results of the other GARCH specifications yielded similar results. Periods of high volatility correspond to periods of high risk and therefore financial stress. These variables were not however included in the final FSI. Illing and Liu (2006) find the measures to perform poorly when capturing Canadian financial stress, with larger type one failures, i.e. failure to report high stress during a stressful period, than most other measures. Examining plots of the three measures in Fig. 3.1, it can be seen that very few periods exhibit high volatility, with the 2008 financial crisis being the only period with high volatility as registered by all three measures. All the measures considered are summarised in table 3.1. Tables 3.2 and 3.3 summarise the indicators included in the respective indexes, as discussed below.

Figure 3.1 GARCH Time Plots

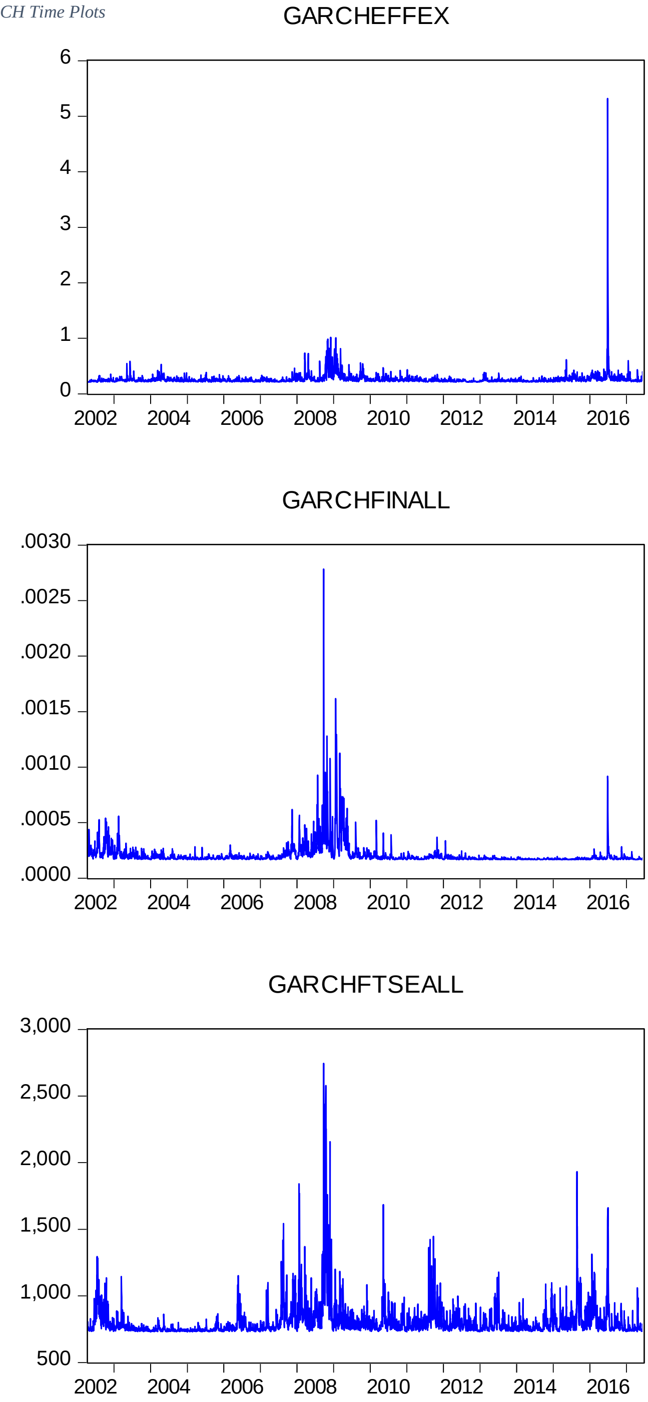


Table 3.1a All Considered Financial Stress Indicators

Market	**Variable**	**Aspect of Financial Stress represented**	**Calculation**	**Source**
Interbank	Bank Beta (BETAFTAS)	Strain on bank profitability and stability	$\beta = \frac{\text{cov}(r,m)}{\text{var}(m)}$	Datastream
	Commercial Bank Bond Spread (BNKBDSPR)	Risk in bank debt markets	10-year Commercial bank yields minus 10-year government bond yields	Datastream, Bank of England Interactive Database
	Interbank Liquidity Spread (LIBORTBILL)	Liquidity and counterparty risk in interbank lending	3-month LIBOR minus 3-month UK Treasury Bill rate	Datastream, Bank of England Interactive Database
	Interbank Cost of Borrowing (LIBORBANK)	Risk premium in interbank borrowing	3-month LIBOR minus BoE Bank rate	Datastream, Bank of England Interactive Database
	Interbank Liquidity Spread (LIBORGOVT)	Liquidity and counterparty risk in interbank lending	3-month LIBOR minus 3-month UK government bond rate	Datastream, Bank of England Interactive Database
	GARCH(1,1) of ratio between FTSE ALLSHARE financials and total market indexes	Volatility and risk in banking sector equities	GARCH(1,1) of daily price ratio of FTSE ALLSHARE financials and FTSE ALLSHARE total market index	Datastream
Foreign Exchange	Weighted Sterling Crashes (CMAXEFFEX)	Flight from sterling towards foreign currencies	$\frac{x_t}{\max\left[x \in x_{t-j} \middle| j = 0,1,\ldots,365\right]}$	Datastream, Bank of England Interactive Database
	GARCH(1,1) Sterling Effective Exchange Rate	Volatility and risk in Sterling exchange rates	GARCH(1,1) of daily Sterling Effective Exchange rate	Datastream, Bank of England Interactive Database

Table 3.1b All Considered Financial Stress Indicators (continued)

Market	Variable	Aspect of Financial Stress represented	Calculation	Source
Debt	Covered Interest Spread (CIPUKUS)	Limited arbitrage and uncertainty in government bond markets	$(1+r_t^*)-(\frac{F_t}{S_t^*})(1+r_t)$	Datastream, Bank of England Interactive Database
	UK-US Government Bond Spread (UKGOVTBUSGOVTB)	Limited arbitrage and uncertainty in government bond markets	10-year UK Government Bond Yield minus 10-year US Government Bond Yield	Datastream, Bank of England Interactive Database
	AAA-Corporate Bond Spread (AAACPSPR)	Risk in corporate sector debt markets	10-year AAA-rated Corporate bond yields minus 10-year government bond yields	Datastream
	AA-Corporate Bond Spread (AACPSPR)	Risk in corporate sector debt markets	10-year AA-rated Corporate bond yields minus 10-year government bond yields	Datastream
	BBB-AAA Corporate Bond Spread (BBB-AAACPSPR)	Risk in corporate sector debt markets	10-year BBB-rated Corporate bond yields minus 10-year AAA-rated Corporate bond yields	Datastream
	BBB Corporate Bond Spread (BBBCPSPR)	Risk in corporate sector debt markets	10-year BBB-rated Corporate bond yields minus 10-year government bond yields	Datastream
	Yield Curve Spread (YLDCURVE10-3)	Long-term uncertainty and cost of short-term borrowing.	10-year government bond yield minus 3-month government bond yield	Bank of England Interactive Database
Equity	Stock Market Crash Index (CMAX100) (CMAXALL)	Uncertainty in equity valuation and expectations of future bank profitability	$\frac{x_t}{\max[x \in x_{t-j} \mid j=0,1,\ldots,365]}$ x_t=FTSE100 price index $\frac{x_t}{\max[x \in x_{t-j} \mid j=0,1,\ldots,365]}$ x_t=FTSEALLSHARE price index	Datastream
	Equity Option-Implied Volatility (FTSE100VIX)	Uncertainty in equity valuation and fundamentals	Daily price level of FTSE100 VIX index	Datastream
	GARCH(1,1)	Volatility and risk in equities	GARCH(1,1) of FTSEALLSHARE price level	Datastream

3.3.2 Aggregation Methods

There is a wide array of approaches in combining the individual stress indicators into a FSI, each having inherent advantages and disadvantages. Illing and Liu (2006) provide an overview of the different weighting methods and tests each method for its impact on the effectiveness of the resulting FSI in correctly capturing financially stressful events. For this reason, Illing and Liu's article (2006) is frequently used as a basis or comparison for other FSIs created in other studies. As mentioned before, this chapter bases the effectiveness of its FSI on the performance of the FSIs it emulates, for this reason this chapter adopts the most frequently used approaches and weighting methods, being heavily influenced by Illing and Liu (2006) in particular. These methods are summarised below.

Variance-equal Weights

One of the simplest methods of weighting is equal-weighting, where all variables are averaged to give a point in time estimate of financial stress. This method is problematic because it gives variables with higher variance greater precedence in the resulting FSI. To correct for this variance-equal weighting is used, being one of the most frequently cited weighting methods in the literature. In this case the variables are all standardised, i.e. the mean is subtracted from each observation and then the result is divided by its sample standard deviation. The resulting variable is a measure whose unit is its standard deviation. This approach therefore gives each variable equal-weighting. A downside of this approach is that it assumes the variables are normally distributed, meaning that the sample mean and deviation are appropriate. Given the nature of financial data, especially in periods of financial duress, this assumption is often viewed as inaccurate.

Transformation using sample CDFs

Because of the normality problem with the variance-equal weighting, many papers use cumulative distribution functions (CDFS) rather than assuming normality in standardised variables. To generate CDFs takes a few steps. For variable j the CDF is the following,

$$CDF_{jt} = \int_{-\infty}^{x_j} f(x_{jt})\, dx_{jt} \tag{4}$$

To calculate this equation, the first stage is to calculate the $Rank(x_{jt})$, the rank ordering of the date in the series. The top rank is given to the largest value in the data series, while the smallest rank is given the value of one. The CDF for each variable at each point in time is then computed by the following equation:

$$CDF_{jt} = f(x_{jt}) = \frac{Rank(x_{jt})}{number\ of\ observations} \tag{5}$$

Where the number of observations is the total number of observations in the sample. For example, the largest daily observation in a sample of 6908 daily observations would be ranked 6908 and would therefore yield a CDF of one. For some of the variables listed above, the reverse of this ranking system is calculated, where 1 is the largest daily observation and 6908 given to the smallest daily observation. The CMAX calculation of the UK exchange rate, the CMAX of the FTSE ALLSHARE and the Yield curve variables are all given this reverse rank. The reason for this is that for these variables the smallest values correspond to the highest levels of financial stress. For example, the CMAX calculation produces values closer to zero when there are large drops in the UK's exchange rate compared to its one-year maximum, meaning that small values indicate large foreign exchange stress. Finally, in cases where a certain value occurs twice or more in the sample, the ranking number assigned to each observation is set to the average rankings involved.

By using this calculation, the stress indicators are transformed into variables that are unit-free and measured on an ordinal scale between zero and one. This does not require the assumption that the variables are normal. The CDFs can then be averaged to create the FSI CDF for each period.

Factor Analysis

The final method considered by this chapter is the use of factor analysis, specifically principal component analysis, to combine the variables into an FSI index. The concept behind principal component analysis is to extract a weight linear combination of factors from the individual variables, each factor containing the combined information from each variable. The first factor is constructed in principal component analysis to capture the maximum co-movement in all of the variables, i.e. to account for as much variability in the data as possible, with each following component capturing the highest variability under the constraint that it is orthogonal to the preceding component. By doing this principal component analysis combines the information from n variables and produces k factors with $k < n$, accounting for as much cumulative variance in the data as possible. For financial stress analysis, the principal components are intended to parsimoniously capture the financial stress elements of each variable, while filtering out the idiosyncratic elements of the each.

Practically calculating the principal components requires the following steps. First, each variable is standardised, i.e. the mean is subtracted and then divided by the standard deviation. Then k principal components are extracted from the variables that account for approximately 75-85% of the variability in the data. The k components are then combined into a weighted vector by taking the weighted-sum of the components at time t. The weightings in this weighted-sum come from the proportion of the variance explained by each component. For example, if $k = 3$ and the first principal component explains 35%, the second 20% and the third 10%, principal component one at time t is multiplied by 0.35 and then added to the other weight-adjusted components. This method follows Oet et al. (2011). The benefit of using this method is that it combines financial stress information while ignoring idiosyncratic factors from each of the individual variables, which neither CDF or variance-equal weighting does. The downside to principal components as a method of variable weighting is that it requires the weightings for each variable in each component stays constant, forcing relationships to hold constant when in reality they may not, especially during periods of financial uncertainty.

Weighting Comparisons

The three methods discussed above are some of the most frequently cited weighting methods utilised in the literature. Variance-equal weighting is the most common, often being used as a baseline, point of comparison or preliminary analysis before commentators move onto more computationally intensive methods. Balakrishnan et al. (2011) use this method as their principal analysis as it is the simplest, allowing them to compute FSIs for a large amount of economies in their study. It is also used by Illing and Liu (2006) and Oet et al (2011), where they both use it as a simple point of comparison between weighting methods. It should be noted that although this method is computationally simple, Illing and Liu (2006) compare several different weighting methods and find that Variance-Equal weighting outperforms most others when it comes to correctly identifying stressful periods. Only the credit-weighted index performs better in their study of Canadian data (Illing and Liu, 2006). CDF weighting is used for the CISS index in Hollo et al. (2012), Illing and Liu (2006) and Oet et al (2011), and performs well in each case, having slightly higher failure rates than Variance-Equal in both type I and II errors in Illing and Liu's examination (2006). The principal component method is also used by Illing and Liu (2006) and Oet et al (2011), as well as Hakkio et al (2009), where they use it as their primary analysis. Principal components weighting appears to perform the worst compared to the other weighting methods, having a larger amount of errors in the testing of both Illing and Liu (2006) and Oet et al (2011).

Calculation of the index

The sample period for the calculation of the index is an important choice for all FSI literature. Data availability is primary concern, especially for emerging market FSIs, and as the majority of FSI papers define financial stress with reference to previous stressful periods, data samples that include several stressful episodes is another requirement. While the majority of UK financial series are available from the 1980s onwards one problem for this chapter is the availability of corporate benchmark spreads for different credit ratings. Benchmark corporate yields are only available after 2002, meaning that inclusion of any variables related to these are restricted to a shorter sample size. This problem is particularly restrictive as the CDF and principal component weighting methods require a common set of dates in order to produce an interpretable index. To strike a balance between including as many relevant variables as possible, and as long a sample as possible, this chapter calculates the index for two samples. The first, beginning on the second of January 1991, does not include any of the corporate bond spreads or the FTSE100 VIX measure, which only became available in 1996. The variables included in this long index are outlined in Table 3.2. The second shorter sample, begins on the 12th of April 2002, and contains all of the financial variables outlined above. Both samples end in June 2017. Table 3.3 summarises the variables included in this short index. Figure 3.2 below shows a time plot of all the standardised variables, using the 2002 sample.

Once the two sample periods were determined, the Variance-Equal, Cumulative Distribution Function and Principal Component weightings were used to create the three versions of the FSI, denoted VEFSI, CDFFSI and PCFSI respectively. To see how much the omission of the corporate spread and VIX measures have on the long-sample FSI Figures 3.3, 3.4 and 3.5 plot the values of the short-sample FSIs against the longer counterparts. As can be seen in these figures, for each weighting method the difference between the long and short sample calculations are not significant qualitatively, especially in the case of the CDF aggregation. In general, inclusion of the corporate spreads and VIX leads to lower estimates of stress between 2004 and 2007, but higher estimates of stress between 2009 and 2013. It is especially noticeable for the principal component formulation, where post-2009 the short sample FSI is consistently higher until 2013. As the results of the long and short samples are qualitatively similar, this chapter continues the discussion of the FSI with the long sample as the reference for the remaining tables and charts.

Table 3.2 Long Sample Financial Stress Indicators

Market	Variable	Aspect of Financial Stress represented	Calculation	Source
Interbank	Bank Beta (BETAFTAS)	Strain on bank profitability and stability	$\beta = \frac{\text{cov}(r,m)}{\text{var}(m)}$	Datastream
	Commercial Bank Bond Spread (BNKBDSPR)	Risk in bank debt markets	10-year Commercial bank yields minus 10-year government bond yields	Datastream, Bank of England Interactive Database
	Interbank Liquidity Spread (LIBORTBILL)	Liquidity and counterparty risk in interbank lending	3-month LIBOR minus 3-month UK Treasury Bill rate	Datastream, Bank of England Interactive Database
	Interbank Cost of Borrowing (LIBORBANK)	Risk premium in interbank borrowing	3-month LIBOR minus BoE Bank rate	Datastream, Bank of England Interactive Database
Foreign Exchange	Weighted Sterling Crashes (CMAXEFFEX)	Flight from sterling towards foreign currencies	$\frac{x_t}{\max[x \in x_{t-j} \mid j = 0,1,\ldots,365]}$	Datastream, Bank of England Interactive Database
Debt	Covered Interest Spread (CIPUKUS)	Limited arbitrage and uncertainty in government bond markets	$(1 + r_t^*) - (\frac{F_t}{S_t^*})(1 + r_t)$	Datastream, Bank of England Interactive Database
	UK-US Government Bond Spread (UKGOVTBUSGOVTB)	Limited arbitrage and uncertainty in government bond markets	10-year UK Government Bond Yield minus 10-year US Government Bond Yield	Datastream, Bank of England Interactive Database
	Yield Curve Spread (YLDCURVE10-3)	Long-term uncertainty and cost of short-term borrowing.	10-year government bond yield minus 3-month government bond yield	Bank of England Interactive Database
Equity	Stock Market Crash Index (CMAXALL)	Uncertainty in equity valuation and expectations of future bank profitability	$\frac{x_t}{\max[x \in x_{t-j} \mid j = 0,1,\ldots,365]}$ x_t=FTSEALLSHARE price index	Datastream

Table 3.3 Short Sample Financial Stress Indicators

Market	Variable	Aspect of Financial Stress represented	Calculation	Source
Interbank	Bank Beta (BETAFTAS)	Strain on bank profitability and stability	$\beta = \frac{\mathrm{cov}(r, m)}{\mathrm{var}(m)}$	Datastream
	Commercial Bank Bond Spread (BNKBDSPR)	Risk in bank debt markets	10-year Commercial bank yields minus 10-year government bond yields	Datastream, Bank of England Interactive Database
	Interbank Liquidity Spread (LIBORTBILL)	Liquidity and counterparty risk in interbank lending	3-month LIBOR minus 3-month UK Treasury Bill rate	Datastream, Bank of England Interactive Database
	Interbank Cost of Borrowing (LIBORBANK)	Risk premium in interbank borrowing	3-month LIBOR minus BoE Bank rate	Datastream, Bank of England Interactive Database
Foreign Exchange	Weighted Sterling Crashes (CMAXEFFEX)	Flight from sterling towards foreign currencies	$\frac{x_t}{\max[x \in x_{t-j} \mid j = 0,1, \ldots ,365]}$	Datastream, Bank of England Interactive Database
Debt	Covered Interest Spread (CIPUKUS)	Limited arbitrage and uncertainty in government bond markets	$(1 + r_t^*) - (\frac{F_t}{S_t^*})(1 + r_t)$	Datastream, Bank of England Interactive Database
	UK-US Government Bond Spread (UKGOVTBUSGOVTB)	Limited arbitrage and uncertainty in government bond markets	10-year UK Government Bond Yield minus 10-year US Government Bond Yield	Datastream, Bank of England Interactive Database
	AA-Corporate Bond Spread (AACPSPR)	Risk in corporate sector debt markets	10-year AA-rated Corporate bond yields minus 10-year government bond yields	Datastream
	BBB-AAA Corporate Bond Spread (BBB-AAACPSPR)	Risk in corporate sector debt markets	10-year BBB-rated Corporate bond yields minus 10-year AAA-rated Corporate bond yields	Datastream
	Yield Curve Spread (YLDCURVE10-3)	Long-term uncertainty and cost of short-term borrowing.	10-year government bond yield minus 3-month government bond yield	Bank of England Interactive Database
Equity	Stock Market Crash Index (CMAXALL)	Uncertainty in equity valuation and expectations of future bank profitability	$\frac{x_t}{\max[x \in x_{t-j} \mid j = 0,1, \ldots ,365]}$ x_t=FTSEALLSHARE price index	Datastream
	Equity Option-Implied Volatility (FTSE100VIX)	Uncertainty in equity valuation and fundamentals	Daily price level of FTSE100 VIX index	Datastream

Figure 3.2 Indicator Time Plots

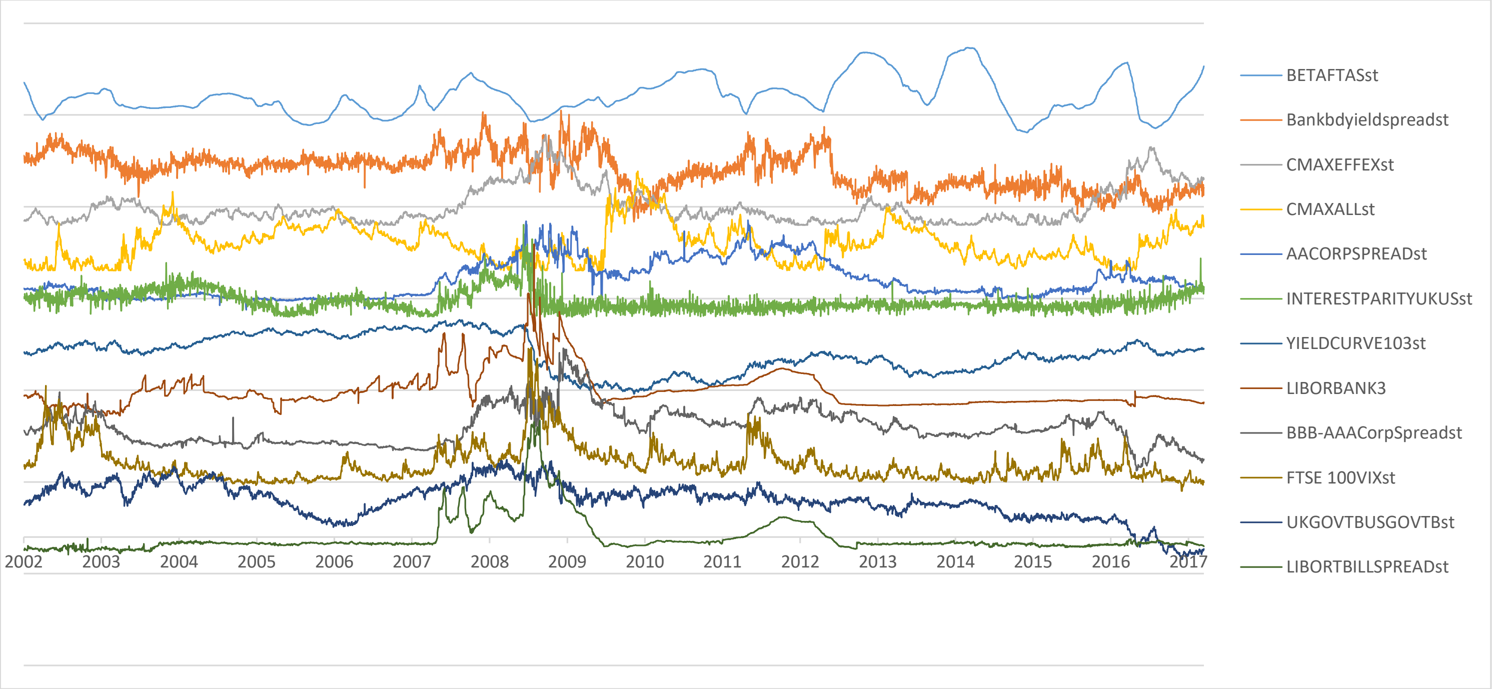


Figure 3.3 Variance-Equal Short and Long Model Comparisons

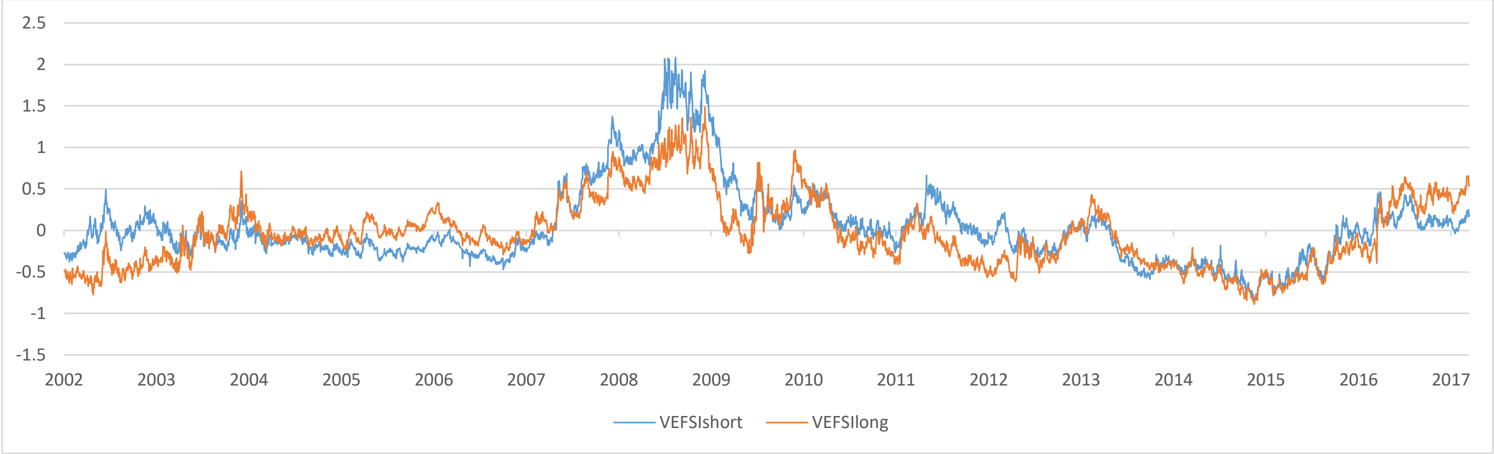


Figure 3.4 Principal Component Short and Long Model Comparisons

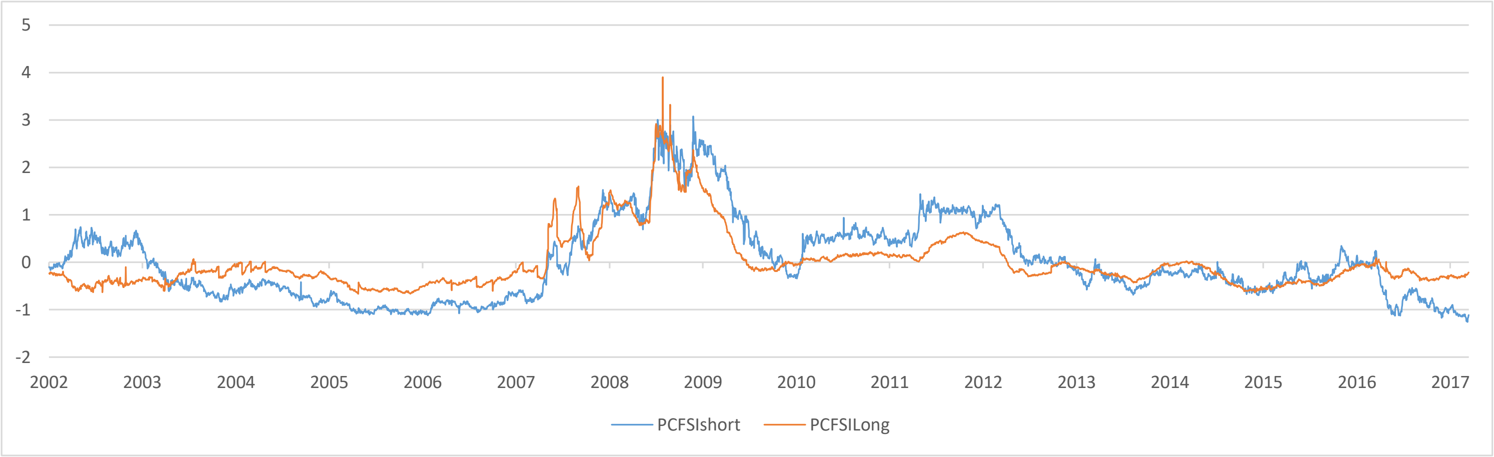


Figure 3.5 Cumulative Distribution Function Short and Long Model Comparisons

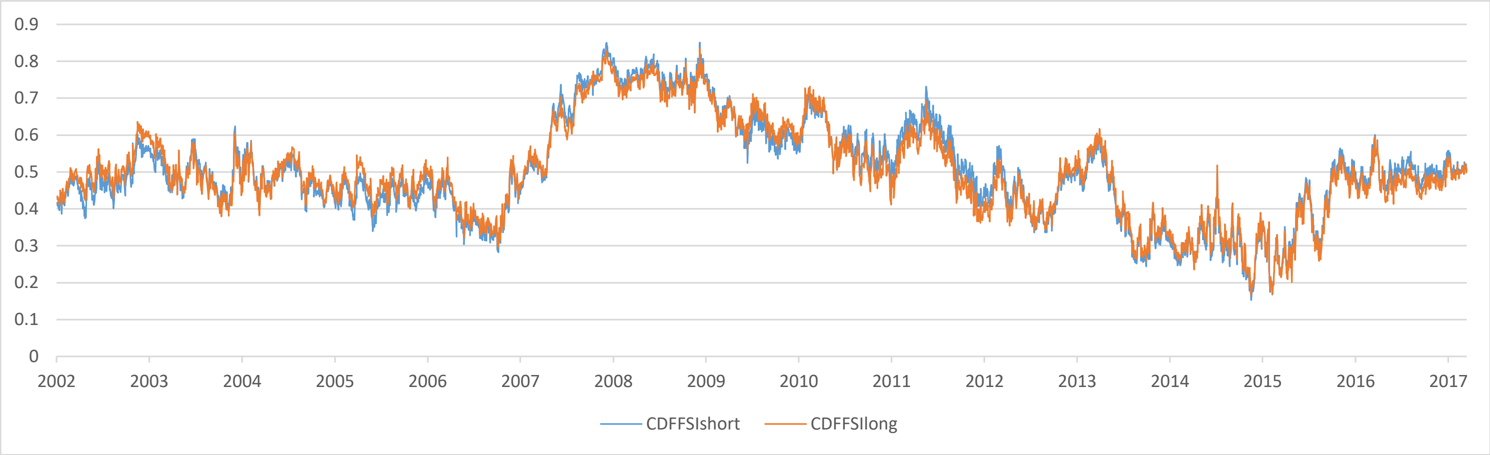


Figure 3.6 FSI Comparisons (Levels)

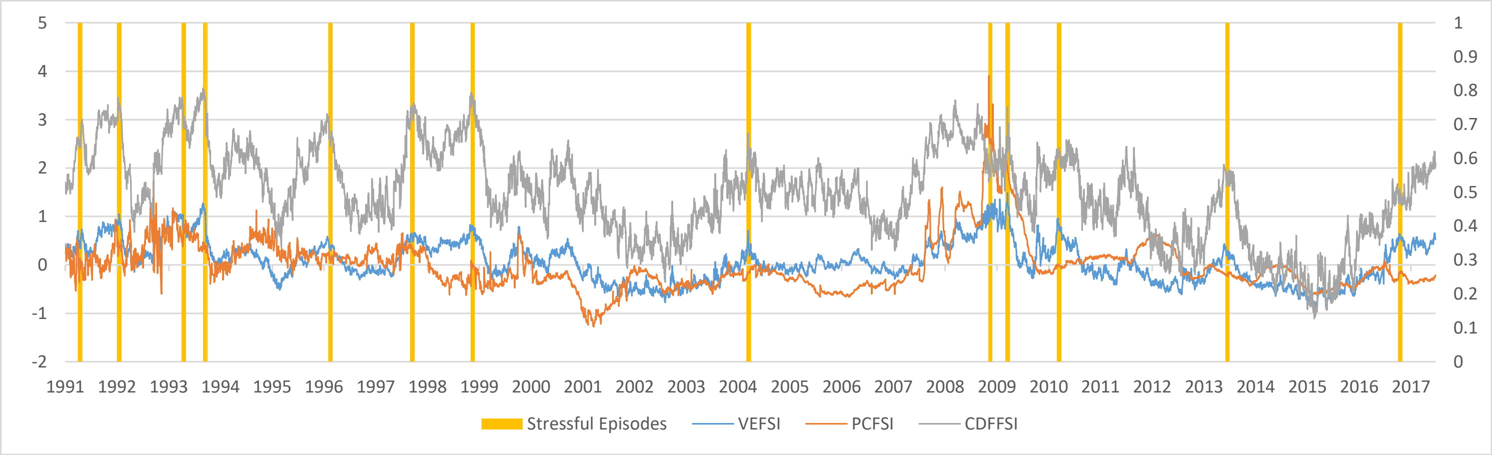


Figure 3.7 FSI Comparisons (Re-balanced)

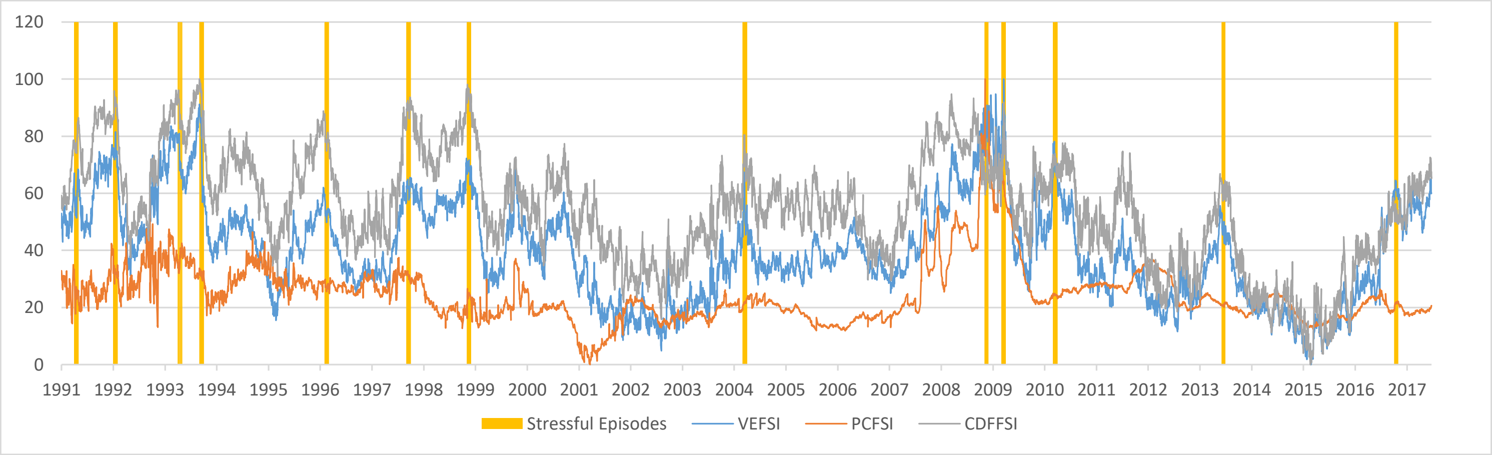


Table 3.4 Index Correlations

Correlation	**VEFSI Short**	**PCFSI Short**	**CDFFSI Short**	**VEFSI Long**	**PCFSI Long**	**CDFFSI Long**
VEFSI Short	1.00					
PCFSI Short	0.75	1.00				
CDFFSI Short	0.90	0.66	1.00			
VEFSI Long	0.83	0.30	0.77	1.00		
PCFSI Long	0.86	0.84	0.72	0.62	1.00	
CDFFSI Long	0.89	0.62	0.99	0.77	0.67	1.00

Correlation	**VEFSI**	**PCFSI**	**CDFFSI**
VEFSI	1.00		
PCFSI	0.55	1.00	
CDFFSI	0.90	0.40	1.00

Table 3.4 above shows the correlations between the different weighting methods and the FSIs which do or do not include the corporate spreads and VIX measures, over the 2002 to 2017 sample period. The lower panel shows the correlations over the entire 1991 to 2017 period. In both panels the strongest correlations are between the VE and CDF weighting FSIs, while the lowest correlation is between the PC weighted FSI and the VE method. These results are largely in line with those found in Illing and Liu (2006) who also find lower correlation between VE and factor analysis weighting methods. Figures 3.6 and 3.7 above plot the stress levels calculated by the three aggregation methods. As the CDF can only take values between zero and one, it is plotted on a secondary axis. This may make it appear like the CDF calculation gives substantially different results, however by looking at Figure 3.7 where the indexes are all re-balanced to give the highest observation the value of 100, and the smallest the value of zero, it can be seen that the VE and CDF aggregation methods are closely linked. Comparatively, the PC aggregation method produces the most different results. In general, the PC method values financial stress as lower than the other two measures, however it increases to comparable levels during episodes of extreme stress, for example the final quarter of 2008. Illing and Liu (2006) note that in their analysis the factor analysis under-estimates the frequency and severity of stressful events using Canadian data. They find factor analysis weighting creates the highest type I error percentage, with type I errors being failure to report a high-stress event. This suggests that factor analysis may also being under-reporting financial stress in this case also. The VE FSI appears to be a middle ground between the PC and CDF weighted FSIs, producing

estimates that follow the same pattern as the CDF, but with lower values. As many studies remark the relatively good performance of VE weighting for correctly reporting financial stress, this chapter views VE as the most likely candidate for capturing UK financial stress.

3.4. Performance of FSIs

This chapter has already stated it has not attempted to empirically prove the accuracy of the FSI, however it may still be useful to compare high points of the index to the findings of other FSIs that have been empirically tested. As can be seen in Figures 3.6 and 3.7, there are several peaks where the FSIs report high stress, in Figure 3.7 there are several periods that are higher than 80. Given that the UK has no expert data to compare the FSI results with, this chapter looks to the literature to establish whether these events match with known periods of financial stress. This approach is similar to the one taken by Hakkio and Keeton (2009) where they compare their FSI with financial stress periods defined by consensus in the literature. For UK data, the findings of Cardarelli et al. (2011) and Balakrishnan et al (2009) are particularly helpful as they include UK FSIs in their studies. Cardarelli et al (2011) also take a similar approach in consulting the literature to compare with their FSIs

The first high point for this chapter's FSIs, primarily for the VE and CDF weightings, is around April 1991. This high point is credited to the Nikkei/junk bond collapse in early 1991 and is characterised by a sudden spike with a rapid drop-off in both the Cardarelli study and this chapter's FSI (Cardarelli et al, (2011) The second period of high stress is in January 1992, which may be associated with the bursting of the Japanese stock bubble in early 1992. Illing and Liu (2006) note high stress later on in 1992 associated with credit losses for Canadian banks due to a real estate price collapse, but this is likely to be a localised event for Canada only. The ERM crisis occurred towards September 1992, but this chapter's FSI reports low financial stress during the early part of this year, which may indicate a failure of the FSIs to capture the high interest rate and exchange rate stress prevalent at this time. The FSI does report stress above 75 for both the VE and CDF around this time, and the PC weighted measure is at its highest point pre-2007. It appears therefore that the FSI captures Black Wednesday but does not attribute it relatively high stress.

Both April and September 1993 report very high stress levels, which are not easy to interpret. April's high point could be attributed to the ongoing aftermath of the ERM and Scandinavian banking crises, which are cited as the reason in Cardarelli et al (2011), however the high-point in September is difficult to attribute to anything. By looking at the individual variables, indicators related to equity values are the cause of the high stress. Another potential false positive from the CDF FSI is the high point in February 1996. Both the PC and VE weightings do not report the period to particularly stressful, suggesting that this may be an issue with the CDF aggregation method. During the highlighted period in late 1997, both the CDF and VE methods report above average stress, which corresponds to the timings of the Asian financial crisis, however once again Carderelli et al (2011) do not report high stress during this period. Illing and Liu (2006) however remark this period as being comparably stressful according to both their FSIs and their expert survey.

The next high point is captured as a local high point by several different studies including Cardarelli et al (2011), Hollo et al (2012), Hakkio and Keeton (2009) and Illing and Liu (2006). Reasons for this high pointed are cited as the bailout of LTCM (Hakkio and Keeton, 2009) and the Russian Ruble crisis in August. Both the CDF and VE FSIs capture this high-point, however the PC weighted FSI does not. This may an example of the high failure rates of PC FSIs reported by Illing and Liu (2006) and Oet et al (2011). Unlike several of the other studies mentioned above, none of the FSI aggregation methods report significantly high stress during the 2000 to 2002 period, which is frequently attributed to the dot com bubble. The highest points appear to be at the end of 1999 and the end of 2000, but neither are ranked much higher than 60 in the re-balanced results.

March 2004 exhibits another potential false positive for the CDF weighted FSI. The high stress value appears to come from a high interest rate disparity between the UK and US, but only the CDF measure is valued higher than 65. This period is not reported as stressful in any of the literature, including Cardarelli et al. (2011). After this period the performance of all FSIs broadly correspond with results of the literature that use financial crisis data. In most cases financial stress increases steadily from 2007 onwards, culminating between November 2008 and March 2009. The VE and PC measures have global high points during this time period, while the CDF has a local peak earlier in 2008. The March 2010 local high-point corresponds to a US announcement about a large increase of supplementary financing account and reporting of large net losses from Freddy Mac and Fannie Mae.[4]

As less of the literature uses post-financial crisis data, sources to compare this chapter's FSIs with are more limited, however the results of all the FSIs are largely in keeping with available stress measures. The final FSI high points correspond to events that are not potentially related to the financial crisis in the UK, but spill-overs from the European debt crisis after 2012.

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[4] Taken from the St-Louis Fed's timeline of the Financial Crisis https://www.stlouisfed.org/financial-crisis/full-timeline

The June 2013 high-point occurs when bailouts for Greece and Ireland were at their highest. June 2013 saw Greece being downgraded to an emerging market, while Ireland was receiving bailouts until late 2013. The final upward trend occurs after the UK's 2015 general election, after which the UK submitted the European Union Referendum Act, which formalised the procedure for holding the Brexit referendum. Financial stress was relatively high at the start of August for all of the measures, corresponding to the results of the referendum, and has trended upwards for the VE and CDF indexes, whereas the PC has stayed relatively constant. The CMAX exchange rate variable is the key variable behind these large stress levels, commensurate with the nature of the financial news in the referendum results. This can also be seen in the GARCH EFFEX measure discussed in earlier sections and recorded in Figure 3.1.

Overall, each FSI in this chapter performs satisfactorily compared to the results found in the literature, however there are several remarks to be made about the potential efficacy of the CDF and PC weighting systems. The CDF aggregation appears to exaggerate the frequency and severity of financial stress episodes compared to the literature, with a number of periods designated as high stress that aren't found in comparable FSIs. On the contrary the PC method appears to fail to capture many consensus stressful episodes. For the purposes of this chapter, these shortcomings do not necessarily rule out the use of these aggregation methods to measure financial stress. Noting that the CDF and PC weightings tend to exaggerate or underestimate financial stress respectively, these measures can be used as more relaxed or stringent measures of financial stress, which is useful for the purposes of robustness. As for the VE-weighted measure, the fact that it is the middle-ground between the other two aggregation methods does not ensure accuracy, however given that it has a noted good performance in other FSI studies, and corroborates well with the literature, it is viewed by this chapter as the most accurate measure of UK financial stress.

3.4.1 Identifying periods of financial stress

A primary purpose of an FSI is to be a snapshot of financial stress at certain point of time. By construction, the FSIs created in this chapter, and many of those cited in the literature compare observations of stress to a historical high in order to ascertain the relative level of stress in a financial system. Most chapters calculate particularly stressful periods as observations that are significantly higher than the mean level of stress over a time-period, usually using sample standard deviations as the measuring stick for this purpose. The most frequently used calculation for stressful periods is one-tailed one standard deviation away from the mean level of stress. Balakrishnan et al (2011) use one and one-point-five standard deviations away from the mean, while Illing and Liu (2006) use two standard deviations. The number of deviations depend on the desired stringency of the measure, as noted by Hakkio and Keeton (2009), as well as a theory-based interpretation as to what level financial stress becomes binding. Hakkio and Keeton (2009) also consider the percentile technique, where they view anything above the 90th percentile to be considered stressful. A final approach they consider is the comparison of the current stress episode with a historical benchmark, i.e. choosing an appropriate date which is widely considered to be stressful period, and then choosing all periods with FSIs levels equal-to or greater than this date as stressful periods. A more computationally intensive method is used by Hollo et al (2012) where they use a non-linear Markov-switching model to determine the thresholds for stressful periods.

For the purposes of this chapter, the simple standard deviation method is considered the simplest and most appropriate. Because of its computational simplicity, the standard deviation method can be used on all of the FSI weighting methods, as well as calculated using different levels of stringency. This makes robustness checks easier and more effective. For this reason, this chapter takes the benchmark definition of a stressful period as an observation that is one standard deviation above the mean, but also tests to see if the results stand when using 1.5 or two standard deviations.

3.4.2 The links between Financial stress and Quantitative Easing

A final area of importance for this chapter is outlining the potential links between financial stress and the Quantitative Easing strategy. While not often discussed separately from other types of monetary policy in the literature, QE can affect several commonly used financial stress measures in particular. To begin, a primary example is the effect QE is likely to have on long term government gilts and thereby the yield curve measure. While typically a flattened yield curve measure indicates higher financial stress, a successful QE policy will simultaneously flatten the yield curve while reducing financial stress through the corresponding injection of liquidity (Joyce et al (2011). However, if the depression in gilt yields are not commensurate with a reduction on yields of private debt, it can be expected that the corporate spread indicators will report higher stress. In effect, the combination of a flattened yield curve indicator but widening debt spread indicators presents evidence that QE is successful in reducing gilt yields, but the effects are limited in scope to the government debt markets.

In addition to this, it can be expected that the measures that approximate liquidity risk will report lower stress in response to the introduction of reserves associated with QE (Shleifer and Vishny, 2011) It can be expected therefore that the interbank lending rates should narrow, as well as the spread on commercial bank debt. This increase in liquidity should have the most noticeable effect on these assets given that interbank lending and bank yields come with relatively few other types of risk beyond liquidity. For the other assets such as the equity and debt market indicators the liquidity effects are more difficult to separate from other channels, but the effects of QE on liquidity should still be incorporated. This leads on to the final main channel through which QE will operate to reduce financial stress. By conducting purchases, the Bank of England announced itself to be a last-resort lender and supporter of financial markets. If taken as a serious commitment by financial investors this should signal that the UK economy was to be supported, reducing the likelihood of downturns, bankruptcy and default, and therefore reducing the risk premiums on the riskier assets (Kapetanios et al., 2012). This effect will be strongest for the riskiest of the financial assets included in this chapter, i.e. the low-rated debt spreads and the CMAX indicator for equities, which have higher premiums to compensate for higher default risk. As such, reduced debt spreads and higher equity prices as a reaction to QE policies indicate a successfully translated signalling effect. Furthermore, the VIX option-implied pricing of volatility and the GARCH indicators could potentially be reduced by QE reducing market uncertainty in the same way.

Finally, Joyce et al (2011) amongst others note that QE should cause a small devaluation of sterling due to the injection of reserves into the economy. This should have an impact on the CMAX exchange rate and interest parity indicators given that they both include trade-weighted sterling value. This effect should however occur over the longer-term and therefore not be captured in these measures which focus on the shorter-term. It could be expected that QE announcements would cause sudden drops in the value of sterling, which would be registered in the CMAX indicator. In these circumstances, this should not be interpreted as increased financial stress apart from for participants in currency markets.

Overall, QE could potentially have a dramatic impact on financial stress in the UK. In terms of intentions, the overall desirable effect of the policy, while not being specifically cited as an ultimate objective, is the reduction of financial stress. This would allow financial markets to translate QE effects to the wider economy effectively, so the inflation and growth targets could be achieved. However, this outcome is not necessarily the most probable. Almost all the financial indicators included in the index described above could in some way be affected by the policy, albeit not in a uniform manner for a financial stress index. The overall stress index value could, for example, report high stress from the yield curve and exchange rate indicators, while simultaneously reporting lowered stress in terms of default risk and counterparty risk. Such contradictions in outcome are difficult to avoid, but nevertheless make the impact of QE harder to predict.

3.5 Conclusions

The purpose of this chapter was to create a workhorse model of financial stress in the United Kingdom, by utilising the existing approaches as a basis. By examining the contributions of key studies like Illing and Liu (2006), Cardarelli et al (2011) and Oet et al (2011) this chapter has used data spanning from 1991 to 2017, and formulated a measure using three of the most high-performing aggregation methods. This measure captures financial stress in the UK's equity, foreign exchange, debt and banking sector, and can be used as a general snapshot of duress in the UK's financial system over the course of the 2008 financial crisis and beyond. In further chapters of this dissertation this index (henceforth FSI) will be used analysed in greater detail to examine the interaction between financial stress, QE and asset pricing. As it has been discussed in this chapter that the aggregated index could have many potential responses from QE, the individual components of the index are also useful when examining these key interactions and will therefore also be examined in further detail.

Chapter.4

The Effect of Quantitative Easing on UK financial stress and the volatility of Gilts, Bonds and Equities

4.1 Introduction

The Bank of England’s Quantitative Easing (QE) policy, enacted in three distinct periods between 2009 and 2015, saw the large-scale purchase of long-term UK government gilts through a process of reverse-auctions. These purchases, which total more than £375 billion, were of gilts with at least 3 years to redemption, and extended across the entire maturity spectrum. The intention of the Bank was to improve the stability and function of the UK’s financial markets, while achieving the macroeconomic targets of stimulating growth and reaching the year’s 2% inflation target. While only an intermediate objective, Quantitative Easing was also intended to raise the prices and restore stability of other financial assets than UK gilts, namely UK corporate bonds and equities. The examination of the wider economic effect of QE has been covered by several studies, while the literature on the financial market impact is less extensive but has still produced evidence for the success of QE in achieving its objectives.

This chapter however discusses a gap in the literature surrounding quantitative easing by examining the effects of the policy on the volatility of gilts, bonds and equities, additionally analysing the spill-over effects between the three asset types. This is important because the stable functioning of financial markets, while not traditionally of concern to central banks, was an objective given the strained circumstances that existed in the UK in the aftermath of the 2007 financial crisis. Additionally, as the portfolio-balance and confidence channels rely on reduced risk premia on increasing asset prices to transmit the quantitative effects of the policy to the wider economy, the volatility of UK asset markets is relevant to the effectiveness of QE (Joyce, Tong, & Woods, 2011). Specifically, the Bank of England’s intervention was intended to restore market performance to pre-crisis levels through the manipulation of gilt markets, and this chapter establishes the efficacy of QE in this regard. A systematic decrease in volatility across asset types could be considered a success for QE as a policy tool in that high and stable asset prices increase investor confidence, lower equity and corporate bond risk premia and lower cost of finance. On the other hand, distortions to relative volatilities of competing assets, whether intentional or not, alters the risk characteristics of these assets and therefore the purchasing behaviour of financial market participants, resulting in portfolio rebalancing. Given that the BoE QE strategy involves the diversification of portfolios away from gilts into equities and corporate bonds, distortionary effects to return volatilities could have helped or hindered the policy.

In a less direct manner, asset volatilities play a key role in the valuation of financial assets, being important aspects of popular pricing methods such as Black-Scholes equations and the Value at Risk (VaR) calculation method. Any impact of QE on relative asset volatilities will therefore have a large impact on the pricing of many financial assets that would otherwise be unrelated to QE. Furthermore, capital requirement regulations such as Basel II and later Basel III often consider pricing volatility as a measure of market risk, again utilising VaR. This means that any policy action that impacts asset volatilities will have a tangible impact on optimal bank behaviour. It could be argued therefore that a QE policy that reduced asset volatility would also reduce constraints on bank-lending in terms of both regulation as well as improving risk to reward ratios. Reduced risk would also increase the incentive of banks and other institutions to increase investment, supporting the economic stimulation that QE was intended to address. The potential for widespread effects from a monetary policy shock to asset volatility is therefore a topic worthy of study, especially when focussing on a time-period of financial stress and economic downturn, where large shocks to asset pricing and volatility could have potentially led to deepening financial crisis. As a final consideration, this chapter adds to this examination of QE’s effect on risk valuations by interpreting the effect of QE auctions and announcements on a variety of financial stress indicators, as well as an aggregated financial stress index for the UK. By analysing asset price volatilities and measures of financial stress in such a framework, this chapter establishes the effect of QE on UK financial market risk. Many of these indicators are also popular metrics used in predicting the future economic outlook. Any impact of QE that improves the state of these measures may also encourage a more positive economic outlook and thereby provide an economic stimulus.

The majority of quantitative easing in the UK occurred between March 2009 and October 2012, which can be divided into three distinct phases. The first phase, which was labelled QE1, took place between 2009 and early 2010 and saw over £200 billion spent on mostly UK gilts, with relatively small amounts spent on commercial paper and corporate bonds. QE2 occurred more than a year and a half later after an announcement by the MPC in October 2011. This phase lasted until May 2012 and saw the purchase of an extra £75 million worth of gilts. The final phase, QE3, took place in July 2012 with the majority of the £50 million purchases taking place before the end of October 2012. After this point, relatively small scale and isolated purchases occurred at the discretion of the MPC, mostly encompassed within a week in the case of each intervention. The interventions themselves occurred in the format of reverse auctions, where private investors would allocate the quantity of gilts they were willing to sell at their chosen price level, and the Asset purchase facility would purchase at the most competitive prices. In terms of the maturity structure of the gilt purchases, £168 billion would be spent on assets with maturities between 3 and 10 years, £124 billion on gilts with 10-25 years to maturity, and finally £68 billion on assets with 25 plus years to maturity.

The rest of this chapter proceeds as follows. Section 2 contains a brief literature review of the theoretical and empirical studies that contribute to the methodology of this chapter, as well as a brief outline of previous studies that have discussed relevant aspects of QE with respect to asset volatility. This section will be concluded with a brief explanation of the gap in this literature and therefore the contribution this chapter makes to the analysis of QE as a policy tool. Sections 3 and 4 describe the data sources, structure and sample periods, and outlines the empirical methods and model specifications that will be used. Section 5 presents the key results of the analysis, along with interpretation and analysis. Finally, section 6 concludes the chapter with an overall summary of the findings, with some brief discussion of the importance of these findings in the context of the study of asset volatility and QE theory.

4.2 Literature Review

As introduced above, quantitative easing was conducted through a series of announced auctions when the Bank of England decided it was necessary to intervene to stabilise the UK economy. Resultantly, the announcements of gilt purchases contained a large amount of macroeconomic news that investors could use to change their portfolio holdings, providing a link between information flow and return or price volatility. There are numerous investigations of this link in terms of macroeconomic news for a variety of different assets. For example, Jones, Lamont and Lumsdaine (1998) empirically analyse the effect of macroeconomic data announcements on Treasury bond returns, finding that the return volatility is significantly higher on the announcement days, albeit with a rapid decay of the effect. De Goeij and Marquering (2006) employ a similar study but allow for the effects of negative and positive news to be different using a threshold variable. Their findings reinforce the findings of Jones et al. (1998) but add that negative news has a greater impact on the volatility of US treasury bonds.

For equities, Bomfim (2003) similarly uses a Generalised Autoregressive Conditional Heteroskedasticity (GARCH) model to analyse the effects of macroeconomic news on stock market volatility, specifically looking at pre-announcement ‘calm before the storm effects’. He finds that US stock prices do respond reliably to macroeconomic news, and that return volatility is significantly reduced the day before scheduled monetary policy announcements. Flannery & Protopapadakis (2002) uses the release of macroeconomic data including CPI, PPI, M1 and M2 as indicators for equity volatility, finding that volatility exhibit strong responses to at least 6 of 17 macroeconomic indicators, with more having significant relationships with the returns only. Their results reinforce Bomfim’s (2003) in that US stock prices do respond to macroeconomic announcements and data releases. Rigobon & Sack (2004) also studies the effects of monetary policy on stock prices, finding that the correlation between policy rate and other assets shifts significantly on monetary policy dates.

As quantitative easing is such an unconventional monetary policy tool, there is relatively little literature on the volatility effects of the gilt purchase programme. For the US, Tan and Kohli (2011) examine the volatility of US stock prices during the US QE programme between 2008 and 2011. Using both AR and GARCH models, they find that price volatility reduced as a result of the programme. The lack of literature is especially apparent for the UK’s experience of QE, where only two major studies cover volatility effects. As mentioned in the previous chapters Joyce et al. (2011) examine option-implied volatility of the FTSE100 and find that it reduced significantly during the duration of the QE1 phase. ~~there exists little discussion of the UK’s QE programme and its effect on volatility, especially of other assets to UK gilts.~~

Secondly, Steeley and Matyushkin (2015), provides the most extensive study, which analyses the effects of QE1, QE2 and QE3 on a panel of UK gilts of varying maturities. As this chapter builds upon this paper, it is important to elaborate on the methods this paper uses. In terms of methods, Steeley and Matyushkin (2015)~~U~~ use~~ing~~ a GARCH model, ~~they use~~using dummy variables for QE auctions and announcements, ~~and find~~finding that there is a significant volatility reduction as a result of the programme, almost down to the levels that were prevalent before the collapse of Northern Rock. They also find that QE1’s effect was the most pronounced and that longer maturity government gilts reacted the most to the intervention. Rather than solely time-series analysis, they also conduct a cross-sectional model to determine the characteristics of bonds that make them reactive to QE. They find that bonds with longer time to maturity and more QE purchase activity tend to have higher volatility. Finally, they also conduct Granger causality tests between money supply and gilt volatility to determine whether the monetary transmission mechanism itself drives bond volatility. They find that only 9 of the 24 gilts they examine produce a significant causal link between the two at the 5% significance level. They conclude that the QE had a strong reducing effect on gilt volatility, with the effect being most pronounced at the far end of the maturity spectrum. They also found that bonds that had the highest purchase activity had smaller reductions in volatility of the QE periods. The final conclusions is that QE was effective in reducing gilt volatility, with the liquidity and signalling channels producing the most effect, with a relatively modest effect apportioned to the portfolio balance channel.- Apart from these two studies, there exists little discussion of the UK's QE programme and its effect on volatility, especially of other assets to UK gilts.

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There is however significant literature unrelated to QE, which discuss the relationships in both returns and volatility between bonds, gilts and equities. Campbell and Taksler (2003) using standard OLS analysis find that equity volatility varies inversely with treasury spread yields, and additionally finds that equity volatility is a significant indicator for corporate bond spreads. Fleming, Kirby and Ostdiek (1998) use both Generalised Method of Moments (GMM) and Autoregressive (AR) models to link information flows between different asset markets. They find strong volatility linkages between bond, equity and bill markets in the US. Gebhardt, Hvidkjaer and Swaminathan (2005) discuss stock and bond market interaction when analysing the relationships between stocks and bonds issued from the same company. They find significant spill-over effects where high-performing equities cause bonds from the same company to out-perform others.

In terms of QE's effect on financial markets, the purchase of gilts was intended to have spill-over effects onto asset types that were not directly intervened with. Through the 'portfolio balance' channel, equity and corporate bond prices were expected to increase when government gilts were purchased. The Portfolio Balance channel was first proposed by Tobin and is loosely based on Keynes' Liquidity Preference model (Tobin, 1958). It is a popular theoretical concept in Keynesian monetary economics, and is recurrent discussion point in articles that analyse central banking policy (Andrés, Lopez-Salido and Nelson, 2004). Theoretically the Portfolio Balance channel reflects the impact of changing asset quantities in a market on its' relative expected return. A change in quantity of one asset, ceteris paribus, will alter its relative expected return in comparison to competing assets. For example, decreased quantity in one type of asset increases its price and will induce portfolio operators to switch out the affected asset for other relatively more profitable assets. In terms of asset volatility, this channel should translate in a spill-over effect from gilts into the returns and volatility of other comparable assets.

The second potential channel that QE has been expressed to work through is the so called 'Signalling channel' and the similar ‘Expectations channel’ the latter of which has also been referred to as the ‘macro/policy news channel’ and ‘policy signalling effects’ in a Bank of England publication (Joyce et al., 2011). The Signalling Channel reflects the impact on expectations that occurs when a monetary authority makes a statement of intent about a certain macro policy. In these circumstances, individuals can be reassured or worried by the news, and alter their expectations of future asset values and yields accordingly (Kapetanios et al., 2012). This channel uses the assumption that investors are rational and forward looking, and will therefore make inferences from central bank announcements, and using this information to make market-based decisions. In this way, investors will not only react to a policy made by the central bank when it is actually carried out, but also when it is initially announced. This leads to important implication that a large part of the quantitative easing effect will be recorded in the first few days around and announcement. A further implication, relevant to this chapter, is that gilt purchase announcements should not only affect gilt volatility but give information for the future prices and values of equities and corporate bonds. Many of the articles published in the last few years have argued that the expectations effect QE creates is just as important as the portfolio balance effect; and as such this theory is discussed to a great extent by the articles discussing optimal monetary policy (Bernanke et al, (2004) Adam and Billi (2004), etc.).

This chapter contributes to these literatures in several ways, while tying together many of the different strands touched upon in these earlier studies. First of all, it offers an entirely new contribution to the volatility and monetary policy literature by examining the effect of monetary policy announcements on UK gilts, stocks and equities, providing new analysis on calm-before-the-storm effects in the context of unconventional monetary policy announcements. Secondly it contributes to the literature on spill-over effects between the volatility of different asset types, a subject area that is relatively uncovered especially for data from UK financial markets. Finally, this chapter extends the literature discussing the effect of QE on the UK, specifically its financial markets and the stress levels therein. It builds upon the findings of Steeley & Matyushkin (2015) in its gilt market analysis, extending the effects of QE announcements on gilt volatility while observing the secondary effects this volatility effects have on other financial assets. In this way, this chapter also provides analysis for the efficacy of QE as monetary policy, offering some evidence for the degree to which QE announcements and intervention propagated through the UK’s financial markets.

4.3 Methodology

4.3.1 Univariate GARCH models

In the initial examination of asset returns, this chapter uses a univariate Generalised AutoRegressive Conditional Heteroskedasticity model (GARCH) to model both the conditional mean and variance of bond, gilt and equity returns. The ARCH and GARCH family of processes were proposed by Engle (1982) and Bollerslev (1986) respectively. In these univariate models the conditional variance of an asset's return is a linear function of previous conditional variances, squared previous errors as well as in this case a series of dummy indicator variables. Resultantly the univariate model looks like this:

$$r_{j,t} = c_j + \phi_j r_{j,t-1} + \sum_{i=1}^{11} \gamma_{i,j} D_{j,t} + \varepsilon_{j,t} \qquad j = 1,2,\dots,48 \tag{1}$$

$$\varepsilon_{j,t} \left| r_{jt-1}, r_{jt-2}, \dots \sim N\left(0, h_{j,t}\right)\right. \tag{2}$$

$$h_{j,t} = \omega_j + \alpha_j \varepsilon_{j,t-1}^2 + \beta_j h_{j,t-1} + \sum_{i=1}^{11} \kappa_{i,j} D_{i,t} \tag{3}$$

Where $r_{j,t}$ is the log return of asset *j* at time *t* and D is a selection of dummy variables. As (1) shows the mean equation follows a standard ARMA process while the $\beta_j h_{j,t-1}$ term in the variance specification shows it to be a GARCH(1,1) specification. As will be discussed in more detail later, ARMA(1,1) is not the only specification for the mean equation, some variables, especially longer term bonds and gilts, contain ARMA(2,2) processes or others. The equation above is the general specification that most of this chapter's analysis uses as a basis.

For each return variable, this chapter determined the most appropriate ARMA designation for use in the mean equation of the GARCH equation. The appropriate lag order for the AR and MA terms were selected using the most negative Akaike, Schwarz and Hannan-Quinn information criterion statistics, as well as the models that maximised the log-likelihood function. For the vast majority, ARMA (1,1) specifications were the most appropriate, with a small amount of the corporate bonds requiring ARMA(2,2) specifications. These models are largely in line with the models used in the literature for estimating GARCH equations. ARCH tests were then performed on each model to determine the presence of conditional heteroskedastic effects. All tests found these ARCH effects, which provides further evidence for the appropriateness of a GARCH model.

Similar to the underlying AR model specification, information criterion and hypothesis testing were used to judge between the various specifications of well-performing ARCH and GARCH models. Hypothesis tests for GARCH terms for every variable found that there are significant effects from the variance of the error term, however in almost all cases a GARCH-M specification yielded insignificant GARCH effects in the mean equation. Asset returns that did show significant GARCH effects in the mean equation still yielded poorer statistics on the information criteria than standard GARCH specifications, so the GARCH term was dropped. EGARCH and TGARCH models were also experimented with but did not significantly improve the model for any of the assets. Finally, various lag orders for the ARCH and GARCH terms for each asset, however the standard GARCH(1,1) specification was found to be the most appropriate in all cases.

Similar to Steeley and Matyushkin (2015) and using concepts originally discussed in Glosten, Jagannathan and Runkle (1993), this chapter determined if negative news has a different effect to positive on return volatility. To do this, this chapter included an indicator variable labelled I_t which was valued 1 when $\varepsilon_{j,t-1} < 0$ and zero otherwise. Including this variable makes the GARCH specification the following:

$$r_{j,t} = c_j + \phi_j r_{j,t-1} + \sum_{i=1}^{11} \gamma_{i,j} D_{j,t} + \varepsilon_{j,t} + \theta \varepsilon_{j,t-1} \qquad j = 1,2,\ldots,48 \quad (4)$$

$$\varepsilon_{j,t} \big| r_{jt-1}, r_{jt-2}, \ldots \sim N\left(0, h_{j,t}\right) \quad (5)$$

$$h_{j,t} = \omega_j + \alpha_j \varepsilon_{j,t-1}^2 + \beta_j h_{j,t-1} + \lambda_j I_t \varepsilon_{t-1}^2 + \sum_{i=1}^{11} \kappa_{i,j} D_{i,t} \quad (6)$$

When I_t equals zero, that element of the equation disappears and the model returns to a standard GARCH specification. Empirically this is established, as Glosten, Jagannathan and Runkle (1993) discusses, by the significance of the standard t-test on the coefficient for I_t which is λ. When this is not significantly different from zero, the term is dropped from the equation and the standard GARCH (1, 1) is used.

4.3.2 Dummy Variables

For the univariate analysis, this chapter selected to include dummies for important QE events as well as others controlling for individual market forces. The first set of dummies cover the effects of QE-related announcements, with the value of the variable being 1 on days on which news was released from the Bank of England on the subject of QE and valued zero otherwise. This chapter also includes dummies for the day before and after these announcements, similar to Bomfim's analysis (2003), to examine for the existence of calm-before-the-storm effects and post announcement volatility respectively. The choice for these announcements were mainly taken from Joyce et al.'s (2011) event study but extended along the same criteria for announcements that took place after the sample period of that study.

A similar approach was also taken for the actual auction days for the gilts is the asset purchase programme: The dummy variable Auction is given the value of 1 on days on which reverse-auctions are held, and 0 otherwise. Like the announcement dummies, this chapter also includes dummies for the day before and after auction days. Finally, this chapter includes three dummy variables, where the QE intervention periods are split into three separate dummies, each being value 1 during certain phases of QE, and 0 otherwise. These are designated QE1, QE2 and QE3.[5] QE1 occurs between 2009 and 2010, QE2 between 2011 and early summer 2012, and finally QE3 is valued 1 between late summer 2012 and January 2013. The inclusion of these dummies to determine the mean and volatility effects of the entire intervention periods by the Bank of England, analysing significant systematic rather than event effects.

In all univariate specifications this chapter includes dummy variables that account for day of the week effects. For example, the dummy for Tuesday is valued at 1 on all Tuesdays over the sample, and 0 otherwise. The inclusion of these variables was intended to separate the effects of the different weekdays on returns and volatility, from the effects of the QE auctions that sometimes occurred on those days. Finally, this chapter includes a dummy variable indicating the presence of the financial crisis. Like Steeley and Matyushkin (2015) this chapter specifies the financial crisis to have begun at the collapse of Northern Rock on the 14th of September, 2007. This dummy is valued at 1 for all days between this date and the start of the asset purchase programme and is included in the equations for assets with samples that run before this date to control for the significant general increase in volatility that the financial crisis entailed.

4.3.3 Financial Stress Indicators

In addition to the volatility of returns, this chapter examines alternate measures of financial risk and stress, and determines the effect of QE announcements, auctions, and overall intervention periods upon them. This chapter examines the individual stress indicators as well as the aggregated stress indices discussed in the previous chapter, using the same univariate GARCH methodology to model these financial stress indicators and following the same steps in model specification and testing. The same QE dummy variables are also used, with the

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[5] This chapter splits the purchases between 2011 and 2013 into QE1 and QE2, whereas chapter 1 kept all purchases after 2011 designated QE2. This choice was made in order to facilitate comparison with Steeley and Matyushkin's (2015) results, who include the QE2 and QE3 distinction.

omission of the day-of-the-week and financial crisis effects. The financial stress indicators replace $r_{j,t}$ in equations 1 and 2 but in all other ways are treated with the same procedure.

4.3.4 Multivariate GARCH models

The univariate GARCH specification by nature does not allow for spill-over effects from the variance of UK gilts onto equities or corporate bonds. To determine the existence of such spill-over effects, this chapter conducts a multivariate GARCH analysis using Engle and Kroner's (1995) Multivariate Simultaneous Generalized ARCH model (henceforth BEKK), and Engle's (2002) Dynamic Conditional Correlation model (DCC) specifications, in both cases using a VAR to model the mean spill-over effects between the assets. Given the complication of unrestricted multivariate GARCH estimation, this chapter restricts the analysis to a tri-variate specification, in each case with a corporate bond or equity return modelled against an individual UK gilt as well as UK gilt index. The use of more additional variables was decided against as it would dramatically increase the complication of the estimation, while offering little further evidence or interpretation in addition to the variables used, which are described in the next section. This chapter also does not include the dummy variables from the univariate analysis in the multivariate estimation for the same reason. While the inclusion of the dummy variables would not be problematic in the DCC specification, inclusion in the BEKK framework would require a prohibitively large amount of parameters to be estimated. A tri-variate VAR(1) was selected after using model specification tests and the use of information criterion. In the cases where more than 1 lag was selected by the criteria, the mean equations followed a VAR with 2 or 3 lags, with the majority of assets following the VAR(1) specification. The general specification of a VAR(k) is as follows:

$$Y_t = \alpha + \emptyset_1 Y_{t-1} + \emptyset_2 Y_{t-2} + \emptyset_p Y_{t-k} + \varepsilon_t \tag{7}$$

Where the $\emptyset_i$ are (n*n) coefficient matrices. As this chapter is examining daily data with attention paid towards the variance effects of QE, the results of this VAR are estimated simply for use in the multivariate models and will not be discussed. The BEKK(1,1) model, which is the most common version of the model, was used after further model specification tests determined it to be the most appropriate. This BEKK specification is defined as follows:

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1} \tag{8}$$

Where C is a lower triangular matrix $(n \times n)$ for constants and A and B $(n \times n)$ parameter matrices. In the tables below the elements of A and B are shown. a_{11}, a_{22} and a_{33} are the diagonal elements of the A parameter matrix and demonstrate the effect of an assets innovations on its own volatility, while the off-diagonal elements a_{ij} represent the effect of asset *i's* shock on asset *j*'s volatility. For the B matrix the diagonal elements represent the assets own past volatility effect on its conditional variance, while the off-diagonal elements again exhibit the volatility effects of one asset on another's conditional variance.

The DCC model is estimated using the two-step method following the same VAR(1) mean equation estimation. The first step is estimated using univariate GARCH parameters, then in the second step the correlations between these parameters are then estimated. For the purposes of this chapter, The DCC framework is briefly described as follows.[6]

$$H_t = D_t R_t D_t \tag{9}$$

Where H_t is the 3x3 conditional covariance matrix, R_t is the conditional correlation matrix and D_t is a diagonal matrix with standard deviations on the diagonal elements. D_t and R_t is described as follows:

$$D_t = diag\left(h_{11t}^{\frac{1}{2}}, \dots, h_{33t}^{\frac{1}{2}}\right) \tag{10}$$

$$R_t = diag(q_{11t}^{-\frac{1}{2}}, \dots q_{33t}^{-\frac{1}{2}})Q_t diag(q_{11t}^{-\frac{1}{2}}, \dots q_{33t}^{-\frac{1}{2}}) \tag{11}$$

Q_t is a symmetric positive definite matrix.

$$Q_t = (1 - \theta_1 - \theta_2)\overline{Q} + \theta_1 \xi_{t-1} \xi'_{t-1} + \theta_2 Q_{t-1} \tag{12}$$

$\overline{Q}$ is the 3x3 unconditional correlation matrix of the standardised residuals ξ_{it}. θ_1 and θ_2 are non-negative parameters which sum to less than one. The conditional correlation is given by

$$\rho_{i,j,t} = \frac{q_{i,j,t}}{\sqrt{q_{i,i,t} q_{j,j,t}}} \tag{13}$$

And shows the conditional correlation between assets i and j at time t, which is one of the key elements of interest for this chapter. For all of the assets, comparison of log-likelihood values showed that the standard lag order DCC(1,1) framework was the most effective, with standard univariate GARCH (1,1) models capturing the conditional variances. Furthermore, inclusion of asymmetric GARCH terms did not improve the models so were omitted in the final analysis.

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[6] For a more extensive description of the model, see the original Engle (2002) article.

4.3.5 Data Selection

This chapter uses daily data for a selection of UK gilts, bonds and equities that are traded on London exchanges. Indexes were selected where possible to give a proxy for the aggregate reaction to QE announcements and intervention. For all of the data, Bloomberg and DataStream were used to collect closing/last prices. These prices were then used to calculate returns as the log daily change in price. For sample size this chapter selected the period between January 1st 2000, and March 16th 2016, with a resulting sample size of 4091 observations. The 2000 sample start date was chosen for several reasons. Apart from the obvious intention to have a sufficient sample size from which to draw satisfactory inference, the intention was to capture the entire duration of the long-term government gilts that were involved in QE. Second, the sample range chosen facilitates the comparison of results with Steely and Matyushkin (2015) who use a similar sample range in their analysis of UK gilt volatility. However, many of the assets analysed did not exist, or did not have price data for the entire sample period. This is especially true for many of the corporate bond indexes, some of which are available only from 2010 onwards, in which case the sample includes the most observations possible. Tables 4.1 and 4.2 below summarise the sample sizes for the gilts and corporate bond indexes used in this chapter.

For the multivariate analysis both the BEKK and DCC models were estimated between 26/09/2007 and 04/09/2015, which is the longest sample period where data was available for all of the assets involved. However, in both BEKK and DCC frameworks, the Bloomberg bonds use a shorter sample of between 05/01/2010 and 04/09/2015 due to these bonds only being sold after January 2010. The sample size for the equities and the non-Bloomberg bonds come to 2008 observations, while the Bloomberg bond analysis contains 1433 observations. this chapter does not believe that the shorter sample will dramatically alter the results found, however it should be noted that the Bloomberg indexes assets were not sold during QE1, but many of their underlying corporate bonds were, meaning that high volatility for these indexes is expected at the start of the sample.

Gilts

For gilts, this chapter chose the individual assets that were directly intervened with, as well as three UK gilt indexes. This selection was made for two reasons, first of all these gilts should exhibit the greatest volatility reactions to QE announcements and auctions compared to gilts that were not purchased. Secondly, the market condition of these gilts should have provided the most information for investors of equities and corporate bonds about the QE, so the volatility relationships between these gilts and other assets are of particular importance. As an additional reason, the study conducted by Steeley and Matyushkin (2015) already provides a robust and comprehensive analysis of the gilt market effects of QE, the intention of this chapter is to observe the volatility linkages as a result of QE, and the assets purchased by the QE programme are the most relevant to achieving this objective. As mentioned above, not all gilts existed or had price data over the entire sample. Table 4.1 below summarises the different sample sizes. Several of the gilts were only purchased in the latter stages of the programme, i.e. in QE3, these have been omitted from the table but were included in the univariate analysis.

The gilt chosen for the tri-variate estimations was the asset denominated GB0033280339, which was one of the most purchased assets with over £15,000 million worth being bought by the BoE and having being purchased in both QE1 and QE2 phases. This chapter therefore views this asset a useful proxy for volatility transmission from individual gilts to other assets. The FTSE Actuaries All Stocks index was also selected as it the best proxy for the overall purchases effect, as the index contains a weighted portfolio of UK gilts of various maturities.

Table 4.1 Gilt Returns Summary

Gilt ISIN/Name	Sample Start	Sample Finish		Gilt ISIN/Name	Sample Start	Sample Finish
GB00B29WRG55	28/02/2008	07/03/2013		**GB00B16NNR78**	30/08/2006	14/03/2016
GB0008921883	05/01/2000	27/09/2013		**GB0002404191**	05/01/2000	14/03/2016
GB00B3KJDW09	11/03/2009	06/03/2014		**GB00B24FF097**	26/09/2007	14/03/2016
GB0031829509	18/07/2002	08/09/2014		**GB0004893086**	17/05/2000	14/03/2016
GB00B4LFZR36	28/10/2009	22/01/2015		**GB00B52WS153**	17/06/2009	14/03/2016
GB0033280339	17/09/2003	04/09/2015		**GB0032452392**	20/02/2003	14/03/2016
GB0008881541	05/01/2000	07/12/2015		**GB00B00NY175**	15/04/2004	14/03/2016
GB00B0V3WX43	22/02/2006	14/03/2016		**GB00B3KJDS62**	25/02/2009	14/03/2016
GB0008931148	05/01/2000	14/03/2016		**GB00B1VWPJ53**	30/05/2007	14/03/2016
GB00B1VWPC84	17/05/2007	14/03/2016		**GB00B128DP45**	03/05/2006	14/03/2016
GB00B39R3F84	18/09/2008	14/03/2016		**GB00B39R3707**	28/08/2008	14/03/2016
GB00B4YRFP41	01/07/2009	14/03/2016		**GB00B06YGN05**	18/05/2005	14/03/2016
GB00B058DQ55	16/03/2005	14/03/2016		**GB00B54QLM75**	22/10/2009	14/03/2016
GB0009997999	05/01/2000	14/03/2016		**Gilt 5-15-year Index**	05/01/2000	14/03/2016
GB00B3KJDQ49	18/02/2009	14/03/2016		**Gilt All Stocks Index**	05/01/2000	14/03/2016
GB0030880693	19/09/2001	14/03/2016		**Gilt Over 15 years Index**	05/01/2000	14/03/2016

Corporate Bonds

This chapter uses corporate bond indexes as a proxy for corporate bond markets rather than using individual bonds. The reason for this decision was an attempt to avoid capturing industry-specific problems or shocks in the analysis, which would have potentially occurred if this chapter had selected an array of individual bonds from different UK companies. Bond indexes containing underlying assets from a variety of companies should not suffer from this issue. The indexes used for this chapter were selected based on several criteria. First of all, this chapter attempted to find bond funds that contained assets from mainly UK-based companies, rather than international indexes or those that contained some European company securities. Indexes where 80% or above of the underlying securities were from UK based companies were selected for this reason. This decision was made to limit the effect that international shocks had on the analysis. This is especially important given that the Fed and the ECB were both conducting their own QE programmes over the sample period, and that indexes that contained large amounts of non-UK assets would be likely to be influenced by non-UK QE announcements. As a large a sample size as possible was another concern, as well as the selection of bond funds that traded frequently enough that QE announcements would be reflected in prices on a daily basis. Table 4.2 below summarises the sample sizes for the UK corporate bond indexes used in this chapter.

Table 4.2 Corporate Bond Returns Summary

Bond Name	**Sample Start**	**Sample Finish**		**Bond Name**	**Sample Start**	**Sample Finish**
SPDR Barclays Capital Sterling Corporate Bond ETF	05/01/2000	14/03/2016		**Bloomberg GBP Investment Grade Corporate Bond Index**	05/01/2010	14/03/2016
Barclays Sterling Corporate Bond Fund	02/06/2006	14/03/2016		**Bloomberg GBP Investment Grade European Corporate Bond Index 1 to 5 Year**	05/01/2010	14/03/2016
iShares Core GBP Corporate Bond	30/03/2004	14/03/2016		**Bloomberg Investment Grade Corporate 10+ Bond Index**	05/01/2010	14/03/2016
CF Bentley Investment Funds	06/01/2005	14/03/2016		**Bloomberg Investment Grade Corporate 5-10 years Bond Index**	05/01/2010	14/03/2016
JPMorgan Fund	03/12/2001	14/03/2016		**Bloomberg Investment Grade Corporate 1-10 years Bond Index**	05/01/2010	14/03/2016
Bloomberg GBP High Yield Corporate Bond Index	05/01/2010	14/03/2016		**Bloomberg Investment Grade Corporate 1-3 years Bond Index**	05/01/2010	14/03/2016

Equities

For Equities, the selection process was much simpler compared to corporate bond indexes. There is a comparatively large literature that uses the FTSE stock indexes for proxies of UK financial markets. this chapter uses the same rationale, and therefore includes the FTSE100, 250, 350 and ALLSHARE indexes, with particular attention paid to the FTSE250, which has been argued to contain the most information of a UK-specific effect. As the FTSE indexes have been traded continuously since before 2000, data is available over the entire sample period. Also, as these indexes have the largest amount of trading days in a year, these trading days are the basis for the dating in the time series analysis. Where return data was unavailable for the other assets, but equity trading occurred, missing values were replaced by zeroes, to signify that no changes in prices occurred. There are less than ten missing values over the sample period for corporate bonds and gilts, so there should not be any distorting effects from this data manipulation.

Financial Stress Variables

Table 4.3 below shows the financial stress indicators used in this chapter. These variables were selected because of their frequent use in literature that discusses daily indicators of financial stress, principally elements of the literature that create financial stress indexes from such variables. In addition, stress indicators were selected that have links to the key areas of financial markets that QE was intended to affect. Stress indicators with links to equity, corporate bonds and gilt markets were selected, as well as an indicator capturing effects on sterling exchange rates. By examining these indicators, this chapter links the effects on the mean and variance of UK financial asset returns to UK financial stress. UK specific data is considered rather than international financial stress indicators, given this chapter's purpose in examining the UK's QE programme. The majority of the variables are discussed at length in Illing and Liu (2006), Oet et al (2011), Hakkio and Keeton (2009) and Hollo et al (2012), but a brief summary of the type of financial stress is included in the table. As column two of the table shows the measures capture several different types of stress, including some measures that relate to the equities, gilts and corporate bond returns discussed above. For example, the AAA, AA, BBB and BBB-AAA spreads all capture risk in corporate debt markets, while the commercial bank bond spread captures the same but isolated to bank debt markets. In addition, the CMAX100, CMAXALL and FTSE100VIX measures capture the return volatility in UK equity markets. Finally, the yield curve measure captures the slope of the government gilt yield curve, which is strongly related to gilt market returns. Given the nature of these variables, most of them have data available as far back as the early 1980s, however corporate spread data of all credit qualities is only available from April 2002, the sample for the GARCH analysis of all these variables is therefore using the balanced sample period of 12/4/2002 to 14/3/2016.

Table 4.3a Financial Stress Indicator Summary

Variable	Aspect of Financial Stress represented	Calculation	Data
Bank Beta (BETAFTAS)	Strain on bank profitability and stability	$\beta = \frac{\mathrm{cov}(r, m)}{\mathrm{var}(m)}$ r=ALLSHARE financials return index m=ALLSHARE return index	Datastream,
Commercial Bank Bond Spread (BNKBDSPR)	Risk in bank debt markets	10-year Commercial bank yields minus 10-year government bond yields	Datastream, Bank of England Interactive Database
Interbank Liquidity Spread (LIBORTBILL)	Liquidity and counterparty risk in interbank lending	3-month LIBOR minus 3-month UK Treasury Bill rate	Datastream, Bank of England Interactive Database
Interbank Cost of Borrowing (LIBORBANK)	Risk premium in interbank borrowing	3-month LIBOR minus BoE Bank rate	Datastream, Bank of England Interactive Database
Interbank Liquidity Spread (LIBORGOVT)	Liquidity and counterparty risk in interbank lending	3-month LIBOR minus 3-month UK government bond rate	Datastream, Bank of England Interactive Database
Weighted Sterling Crashes (CMAXEFFEX)	Flight from sterling towards foreign currencies	$\frac{x_t}{\max\left[x \in x_{t-j} \middle\vert j = 0,1,\dots,365\right]}$ x_t=Sterling trade-weighted effective exchange rate	Datastream, Bank of England Interactive Database
Covered Interest Spread (CIPUKUS)	Limited arbitrage and uncertainty in government bond markets	$(1 + r_t^*) - (\frac{F_t}{S_t^*})(1 + r_t)$ r_t^*=US govt 3-month Treasury yield F_t=US to UK 3-month forward exchange rate S_t^*= US to UK 3-month spot exchange rate r_t= UK govt 3-month Treasury yield	Datastream, Bank of England Interactive Database

Table 4.3b Financial Stress Indicator Summary (continued)

Variable	**Aspect of Financial Stress represented**	**Calculation**	**Data**
AAA-Corporate Bond Spread (AAACPSPR)	Risk in corporate sector debt markets	10-year AAA-rated Corporate bond yields minus 10-year government bond yields	Datastream
AA-Corporate Bond Spread (AACPSPR)	Risk in corporate sector debt markets	10-year AA-rated Corporate bond yields minus 10-year government bond yields	Datastream
BBB-AAA Corporate Bond Spread (BBB-AAACPSPR)	Risk in corporate sector debt markets	10-year BBB-rated Corporate bond yields minus 10-year AAA-rated corporate bond yields	Datastream
BBB Corporate Bond Spread (BBBCPSPR)	Risk in corporate sector debt markets	10-year BBB-rated Corporate bond yields minus 10-year government bond yields	Datastream
Yield Curve Spread (YLDCURVE10-3)	Long-term uncertainty and cost of short-term borrowing.	10-year government bond yield minus 3-month government bond yield	Bank of England Interactive Database
Stock Market Crash Index (CMAX100) (CMAXALL)	Uncertainty in equity valuation and expectations of future bank profitability	$\frac{x_t}{\max[x \in x_{t-j} \vert j = 0,1,\ldots,365]}$ x_t=FTSE100 price index $\frac{x_t}{\max[x \in x_{t-j} \vert j = 0,1,\ldots,365]}$ x_t=FTSEALLSHARE price index	Datastream
Equity Option-Implied Volatility (FTSE100VIX)	Uncertainty in equity valuation and fundamentals	Daily price level of FTSE100 VIX index	Datastream

Dummy Variables

Table 4.4 below summarises the announcement dates and offers a brief summary of the nature of the announcement. In general, announcements were included if they offered some information to investors about the current and future nature of QE purchases. Many of the announcement dates are included even though they turned out to contain no new information, they are included because there was still considerable uncertainty as to the course of future QE purchases before each of these announcements.

Table 4.4 Announcement Dates Summary

Announcement Date(s)	**Relevance to QE**
08/01/09	Bank of England reduces Bank rate by 0.5 percentage points to 1.5%
05/02/09	Bank of England reduces Bank rate by 0.5 percentage points to 1.0%
05/03/09, 09/04/09	Bank of England reduces Bank rate by 0.5 percentage points to 0.5% and announces £75 billion of gilt purchases.
07/05/09, 04/06/09, 09/07/09	Bank of England announces further £50 billion of gilt purchases. Total at £125 billion
06/08/09, 10/09/09, 08/10/09	Bank of England announces further £50 billion of gilt purchases. Total at £175 billion
05/11/09, 10/12/09, 07/01/10, 04/02/10, 04/03/10, 08/04/10, 10/05/10, 10/06/10, 08/07/10, 05/08/10, 09/09/10, 07/10/10, 04/11/10, 09/12/10, 13/01/11, 10/02/11, 10/03/11, 07/04/11, 05/05/11, 09/06/11, 07/07/11, 04/06/11, 08/09/11	Bank of England announces further £25 billion of gilt purchases. Total at £200 billion
06/10/11, 10/11/11, 08/12/11, 12/01/12	Bank of England announces further £75 billion of gilt purchases. Total at £275 billion
09/02/12, 08/03/12, 05/04/12, 10/05/12, 07/06/12	Bank of England announces further £50 billion of gilt purchases. Total at £325 billion
05/07/12, 02/08/12, 06/09/12, 04/10/12, 08/11/12, 06/12/12, 10/01/13, 07/02/13, 07/03/13, 04/04/13, 09/05/13, 06/06/13, 04/07/13, 01/08/13, 05/09/13, 10/10/13, 07/11/13, 05/12/13, 09/01/14, 06/02/14, 06/03/14, 10/04/14, 08/05/14, 05/06/14, 10/07/14, 07/08/14, 04/09/14, 06/11/14, 04/12/14, 08/01/15, 05/02/15, 05/03/15, 09/04/15, 11/05/15, 04/06/15, 09/07/15, 06/08/15, 10/09/15, 05/11/15, 10/12/15, 14/01/16, 04/02/16, 17/03/16	Bank of England announces further £50 billion of gilt purchases. Total at £375 billion[7]

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[7] Announcement dates taken from Bank of England news releases database. http://www.bankofengland.co.uk/archive/Pages/digitalcontent/historicpubs/newsreleases.aspx

Summary Statistics

All of the returns were tested for the presence of unit roots using ADF, PP and DFGLS tests. All of the assets were found to be stationary, with a rejection of the null hypothesis of non-stationarity at the 1% significance level in all cases. As can be seen in the tables’ 4.5-8 below, all variables suffer from non-normality in the residuals, with excess kurtosis being most significant factor in the Jarque-Bera statistic. This result is to be expected given the nature of financial market data and provides evidence for time-varying variance structures. Further evidence is provided by tables’ 4.9-11 which show the autocorrelations of each variable up to six lags. The respective portmanteau Q-statistic p-values are also included in these tables. The significance of the autocorrelations of the equity and government gilt returns provide evidence for a conditional variance structure. As table 4.10 shows, corporate bonds seem to exhibit the least significant autocorrelations, however these assets exhibited autocorrelations at much higher lag orders which are not shown here. Because of this, these corporate bond returns are also considered to exhibit a time-varying variance structure.

Table 4.5a Gilts Summary Statistics

Gilt (Govt ISIN)	Mean	Median	Max.	Min.	Std. Dev.	Skew.	Kurt.	Jarque-Bera	Prob.	Obs.
GB0002404191	5.30E-05	0.000117	0.057799	-0.030185	0.005669	0.249427	7.562656	3590.991	0	4091
GB0004893086	6.49E-05	0.000122	0.066164	-0.035012	0.006424	0.23972	7.614404	3587.994	0	4001
GB0008881541	-6.53E-05	-0.000186	0.017761	-0.013164	0.002854	-0.053698	5.715838	1238.606	0	4024
GB0008921883	-6.39E-05	-0.000181	0.01161	-0.012145	0.002547	-0.126668	5.42159	856.883	0	3469
GB0008931148	-6.06E-05	-8.40E-05	0.022743	-0.016368	0.003221	-0.003776	5.653102	1199.858	0	4091
GB0009997999	-8.35E-06	4.23E-05	0.023283	-0.019572	0.004057	-0.047935	4.514578	392.589	0	4091
GB0030880693	6.79E-05	0.000167	0.051407	-0.026747	0.00514	0.273734	8.025438	3898.164	0	3661
GB0031829509	-3.94E-08	-9.93E-05	0.011335	-0.013085	0.002543	-0.153538	5.959343	1131.95	0	3069
GB0032452392	7.76E-05	0.000195	0.053985	-0.036675	0.006743	-0.010265	5.315299	737.5887	0	3302
GB0033280339	-5.71E-07	-9.90E-05	0.016046	-0.013457	0.002542	0.023691	6.763037	1785.089	0	3025
GB00B00NY175	0.000117	0.000245	0.050441	-0.035636	0.006888	-0.00662	5.152973	581.7511	0	3012
GB00B058DQ55	5.20E-05	6.94E-05	0.023101	-0.019705	0.003745	0.051017	5.457147	700.3061	0	2779
GB00B06YGN05	0.00015	0.000119	0.058503	-0.039606	0.009024	0.009717	4.765182	355.3817	0	2737
GB00B128DP45	0.000125	0.000106	0.05512	-0.03674	0.008277	-0.000775	4.788367	332.4856	0	2495
GB00B0V3WX43	9.70E-06	-9.65E-05	0.019561	-0.014079	0.002718	0.183351	8.444669	3154.081	0	2542
GB00B16NNR78	9.99E-05	0.000121	0.061799	-0.031324	0.005933	0.541849	10.85968	6326.366	0	2412

Table 4.5b Gilt Summary Statistics (continued)

Gilt (Govt ISIN)	Mean	Median	Max.	Min.	Std. Dev.	Skew.	Kurt.	Jarque-Bera	Prob.	Obs.
GB00B1VWPC84	4.21E-05	0	0.022427	-0.018982	0.003258	0.118099	7.800721	2148.552	0	2232
GB00B1VWPJ53	0.000151	0.000179	0.052285	-0.03463	0.007954	-0.016619	4.736666	279.5859	0	2224
GB00B24FF097	0.000145	0.000183	0.063122	-0.032975	0.006468	0.435032	9.774603	4159.826	0	2140
GB00B29WRG55	2.38E-07	-9.97E-05	0.011535	-0.011565	0.001831	0.029005	10.58335	3040.867	0	1269
GB00B39R3F84	5.93E-05	6.79E-05	0.023795	-0.019531	0.003487	0.24401	8.014713	2001.225	0	1892
GB00B39R3707	0.000198	0.000177	0.05561	-0.036972	0.009157	0.001299	4.529177	185.8044	0	1907
GB00B3KJDQ49	7.98E-05	0.000139	0.02513	-0.023146	0.00429	0.046439	5.427105	439.0186	0	1786
GB00B3KJDS62	0.000162	0.000233	0.049784	-0.035489	0.007514	0.136015	5.165038	353.3348	0	1781
GB00B3KJDW09	-1.68E-06	-4.98E-05	0.008073	-0.010513	0.001421	-0.30968	9.312387	2112.066	0	1260
GB00B4LFZR36	4.48E-06	-5.00E-05	0.007128	-0.005976	0.001286	0.138387	6.27476	594.9363	0	1322
GB00B4YRFP41	6.18E-05	8.77E-05	0.016406	-0.013782	0.003114	-0.01177	4.744549	214.983	0	1695
GB00B54QLM75	0.000276	0.00027	0.031795	-0.039555	0.009621	-0.022088	3.744235	37.40317	0	1615
GB00B52WS153	0.000188	0.00027	0.02436	-0.023893	0.006401	0.007269	3.642228	29.31661	0	1705
GILTS_5_15_YEAR_INDEX	4.29E-05	0.000168	0.025964	-0.033701	0.003766	-0.599255	9.764879	8045.635	0	4091
GILTS_ALL_STOCKS_INDEX	3.29E-05	0.000133	0.027146	-0.020589	0.003819	-0.277012	5.76487	1355.391	0	4091
UK_GILTS_INDEX_OVER_15_Y	8.74E-05	0.000188	0.056778	-0.032824	0.006689	0.00346	6.070093	1606.658	0	4091

Table 4.6 Corporate Bond Summary Statistics

Corporate Bond	**Mean**	**Median**	**Max.**	**Min.**	**Std. Dev.**	**Skew.**	**Kurt.**	**Jarque-Bera**	**Prob.**	**Obs.**
CB_BARCLAYS_STERLING	-4.36E-05	0.000522	0.014389	-0.017061	0.003385	-0.563462	5.175908	618.9672	0	2474
CB_BENTLEY_INVESTMENT	0.000169	0.000546	0.02709	-0.033281	0.005003	-0.716583	7.445053	2570.235	0	2828
CB_BLOOMBERG10PLUS	0.000314	0.000391	0.018613	-0.01955	0.004959	-0.147722	3.748294	42.20492	0	1565
CB_BLOOMBERG110	0.000221	0.000203	0.007642	-0.009239	0.001939	-0.24613	4.037235	85.95605	0	1565
CB_BLOOMBERG13	0.000111	0.000108	0.002747	-0.003063	0.000591	-0.307051	4.983623	281.1707	0	1565
CB_BLOOMBERG510	0.000276	0.000223	0.010975	-0.013269	0.002776	-0.254287	3.970064	78.22861	0	1565
CB_BLOOMBERG_EUROPEAN	0.000155	0.000166	0.003744	-0.004788	0.001009	-0.326877	4.374936	151.1428	0	1565
CB_BLOOMBERG_HIGH_YIELD	0.000369	0.000532	0.016552	-0.023374	0.00259	-1.363377	14.51639	9133.235	0	1565
CB_BLOOMBERG_INVESTMENT	0.000273	0.000312	0.013121	-0.014813	0.003559	-0.174975	3.780993	47.75959	0	1565
CB_ISHARES_CORE_CORPORA	-7.62E-06	0.000287	0.077156	-0.075115	0.005085	-0.350503	42.56613	197181.7	0	3022
CB_JPMORGAN_FUND_	0.000119	0.000167	0.028896	-0.017507	0.003277	-0.094947	5.949662	1313.397	0	3608
CB_SPDR_BARCLAYS_CAPITAL	0.000233	0.000283	0.040378	-0.038994	0.003281	-0.232565	14.78374	23706.12	0	4091

Table 4.7 Equities Summary Statistics

Equity	**Mean**	**Median**	**Max.**	**Min.**	**Std. Dev.**	**Skew.**	**Kurt.**	**Jarque-Bera**	**Prob.**	**Obs.**
FTSE100	-2.21E-05	0.000337	0.093843	-0.092656	0.01233	-0.149836	8.911069	5971.248	0	4091
FTSE250	0.000229	0.000843	0.074621	-0.067348	0.010732	-0.333561	6.862563	2618.998	0	4091
FTSE350	1.26E-05	0.000477	0.089529	-0.088193	0.011897	-0.187793	8.773777	5706.531	0	4091
FTSEALLSHARE	1.49E-05	0.000476	0.088107	-0.087099	0.011706	-0.204955	8.814981	5792.519	0	4091

Table 4.8 Stress Indicator Summary Statistics

Stress Indicator	Mean	Median	Max.	Min.	Std. Dev.	Skew.	Kurt.	Jarque-Bera	Prob.	Obs.
AAACORPSPREAD	0.5238	0.4620	1.6430	0.0960	0.2241	1.8266	7.4399	5002.9500	0	3632
AACORPSPREAD	1.0577	0.8190	2.6940	0.2480	0.5224	0.7668	2.3550	418.8440	0	3632
BBB_AAACORPSPREAD	1.3424	1.2810	3.5440	0.5260	0.5088	0.9966	4.3545	878.8581	0	3632
BBBCORPSPREAD	1.8662	1.7420	4.5360	0.8650	0.6670	0.9723	3.7275	652.3845	0	3632
BANKBDYIELDSPREAD	0.2468	0.2618	0.6904	-0.1689	0.1340	-0.0705	2.7711	10.9372	0.004217	3632
BETAFTAS	1.2740	1.2231	2.1631	0.6240	0.3253	0.7433	3.3107	349.0880	0	3632
CMAX100	0.9039	0.9139	1.0000	0.6280	0.0664	-0.8586	3.7993	542.9556	0	3632
CMAXALL	0.8965	0.9054	1.0000	0.6217	0.0700	-0.7155	3.3883	332.7162	0	3632
LCMAXEFFEX	-0.0444	-0.0292	0.0000	-0.2857	0.0479	-2.0515	7.5645	5700.5680	0	3632
FTSE_100VIX	19.9275	17.3030	75.5400	9.0990	9.0294	1.8855	7.8328	5686.5390	0	3632
DCIPUKUS	0.0000	0.0001	0.0319	-0.0243	0.0037	0.0482	9.4904	6376.2720	0	3632
LIBORBANK3	0.2590	0.1700	2.5613	-0.1595	0.3000	1.8165	7.1899	4653.9860	0	3632
LIBOR3GOVT	-0.8943	-0.9799	2.1030	-3.6356	1.2797	0.0262	2.2242	91.4922	0	3632
LIBORTBILLSPREAD	0.2661	0.1464	2.2533	-0.0475	0.3270	3.0433	13.9581	23778.7300	0	3632
DUKGOVTBUSGOVTB	-0.0001	0.0000	0.5170	-0.3160	0.0551	0.1383	7.1505	2618.5750	0	3632
DYIELDCURVE103	0.0000	-0.0010	0.5480	-0.3360	0.0530	0.4402	8.3427	4437.0370	0	3632
VEFSISHORT	0.0357	-0.0824	2.0851	-0.8612	0.4945	1.5880	5.8410	2747.9880	0	3632
PCFSISHORT	0.0625	-0.1399	3.0761	-1.1214	0.8452	0.9930	3.7030	671.7059	0	3632
CDFFSISHORT	0.5002	0.4841	0.8510	0.1526	0.1390	0.2857	2.6139	71.9833	0	3632

Table 4.9a Gilt Autocorrelation Table

Gilt (Govt ISIN)	AC(1)	AC(2)	AC(3)	AC(4)	AC(5)	AC(6)	Q-Stat(1)	Q-Stat(2)	Q-Stat(3)	Q-Stat(4)	Q-Stat(5)	Q-Stat(6)
GB0002404191	0.044	-0.048	-0.044	0.015	-0.017	-0.031	7.892	17.363	25.43	26.303	27.538	31.509
GB0004893086	0.051	-0.055	-0.04	0.015	-0.017	-0.024	10.372	22.506	28.964	29.84	30.984	33.313
GB0008881541	0.046	-0.005	-0.036	0.019	-0.029	-0.035	8.3628	8.4516	13.752	15.236	18.738	23.567
GB0008921883	0.043	0.006	-0.045	0.014	-0.03	-0.031	6.2959	6.4319	13.453	14.173	17.282	20.549
GB0008931148	0.047	-0.02	-0.034	0.017	-0.026	-0.04	8.9167	10.52	15.313	16.484	19.349	25.749
GB0009997999	0.031	-0.028	-0.041	0.012	-0.024	-0.032	3.9027	7.1199	14.036	14.635	17.02	21.093
GB0030880693	-0.034	0.046	0.036	-0.02	0.017	0.022	4.1672	11.951	16.611	18.03	19.06	20.908
GB0031829509	0.02	0.008	-0.024	0.031	-0.018	-0.038	1.2334	1.4476	3.1825	6.1834	7.1364	11.663
GB0032452392	0.024	-0.058	-0.052	0.025	-0.006	-0.021	1.9568	13.082	22.03	24.105	24.234	25.737
GB0033280339	0.043	-0.033	0.008	0.03	-0.025	-0.017	5.4759	8.6846	8.8843	11.531	13.433	14.298
GB00B00NY175	0.04	-0.071	-0.063	0.029	-0.012	-0.019	4.9	19.929	32.03	34.564	34.969	36.048
GB00B058DQ55	0.04	-0.037	-0.022	0.034	-0.022	-0.016	4.4803	8.3228	9.7157	12.898	14.203	14.913
GB00B06YGN05	0.034	-0.08	-0.066	0.026	-0.018	-0.021	3.186	20.945	33.057	34.952	35.866	37.056
GB00B128DP45	0.03	-0.069	-0.059	0.022	-0.02	-0.024	2.2462	14.231	22.989	24.244	25.243	26.702
GB00B0V3WX43	0.05	-0.017	0.007	0.045	-0.024	-0.036	6.3391	7.0745	7.1849	12.251	13.663	17.036

Notes. Q-stats were all found to be significant to at least the 5% level

Table 4.9b Gilt Autocorrelation Table (continued)

Gilt (Govt ISIN)	AC(1)	AC(2)	AC(3)	AC(4)	AC(5)	AC(6)	Q-Stat(1)	Q-Stat(2)	Q-Stat(3)	Q-Stat(4)	Q-Stat(5)	Q-Stat(6)
GB00B16NNR78	0.054	-0.067	-0.029	0.039	-0.013	-0.028	7.0018	17.928	19.926	23.628	24.053	25.961
GB00B1VWPC84	0.053	-0.035	-0.007	0.041	-0.028	-0.042	6.3072	9.069	9.1673	12.969	14.786	18.827
GB00B1VWPJ53	0.032	-0.073	-0.057	0.028	-0.018	-0.025	2.3331	14.18	21.311	23	23.711	25.105
GB00B24FF097	0.062	-0.082	-0.031	0.043	-0.008	-0.033	8.277	22.573	24.697	28.649	28.804	31.186
GB00B29WRG55	0.091	0.009	-0.007	0.005	-0.044	-0.053	10.45	10.558	10.613	10.646	13.095	16.736
GB00B39R3F84	0.075	-0.066	0.011	0.048	-0.037	-0.061	10.553	18.813	19.034	23.476	26.123	33.21
GB00B39R3707	0.046	-0.094	-0.05	0.035	-0.02	-0.032	3.9664	20.713	25.589	27.977	28.754	30.711
GB00B3KJDQ49	0.011	-0.076	-0.022	0.027	-0.035	-0.019	0.645	0.005	0.009	0.012	0.01	0.016
GB00B3KJDS62	0.02	-0.121	-0.043	0.039	-0.022	-0.021	0.6854	26.68	29.932	32.663	33.541	34.305
GB00B3KJDW09	-0.023	-0.031	0.069	0.038	-0.091	-0.018	0.6969	1.914	7.8882	9.7265	20.172	20.58
GB00B4LFZR36	0.031	-0.045	0.007	0.066	-0.08	-0.002	1.2336	3.9785	4.0429	9.7853	18.338	18.345
GB00B4YRFP41	0.007	-0.06	-0.015	0.037	-0.043	0.016	0.0742	6.2552	6.6267	9.0063	12.172	12.585
GB00B54QLM75	0.02	-0.099	-0.047	0.021	-0.027	-0.009	0.6209	16.479	20.066	20.787	22.005	22.145
GB00B52WS153	0.019	-0.081	-0.03	0.023	-0.016	0.013	0.6442	11.928	13.494	14.397	14.85	15.161
GILTS_5_15_ YEAR_INDEX	-0.035	-0.069	0.004	0.004	-0.025	-0.017	4.9887	24.713	24.787	24.838	27.334	28.482
GILTS_ALL_ STOCKS_INDEX	0.01	-0.07	-0.042	0.019	-0.01	-0.025	0.3839	20.193	27.322	28.755	29.178	31.662
UK_GILTS_INDEX _OVER_15_Y	0.033	-0.079	-0.053	0.019	-0.006	-0.025	4.5185	30.13	41.684	43.175	43.34	45.997

Notes. Q-stats were all found to be significant to at least the 5% level

Table 4.10 Corporate Bond Autocorrelation Table

Corporate Bond	**AC(1)**	**AC(2)**	**AC(3)**	**AC(4)**	**AC(5)**	**AC(6)**	**Q-Stat(1)**	**Q-Stat(2)**	**Q-Stat(3)**	**Q-Stat(4)**	**Q-Stat(5)**	**Q-Stat(6)**
CB_BARCLAYS _STERLING	-0.012	-0.015	0.007	0.033	-0.015	-0.001	0.3598	0.8961	1.0034	3.6814	4.2546	4.2566
CB_BENTLEY _INVESTMENT	0.147	-0.016	0	0.024	0.035	-0.034	61.591	62.357	62.357	63.956	67.491	70.675
CB_BLOOMBERG10PLUS	0.007	-0.073	-0.006	0.014	-0.027	0.025	0.0829	8.3752	8.4385	8.7395	9.8657	10.884
CB_BLOOMBERG110	0.011	-0.021	0.03	0.012	-0.037	0.024	0.1766	0.8781	2.263	2.4931	4.6035	5.5012
CB_BLOOMBERG13	-0.011	-0.039	0.036	0.045	-0.012	-0.012	0.1975	2.582	4.6567	7.8871	8.1057	8.3304
CB_BLOOMBERG510	0.012	-0.028	0.031	0.008	-0.04	0.031	0.2364	1.5084	2.9895	3.0834	5.5762	7.0989
CB_BLOOMBERG _EUROPEAN	0.012	-0.006	0.033	0.024	-0.041	0.005	0.2246	0.2875	1.9861	2.9219	5.5532	5.6004
CB_BLOOMBERG _HIGH_YIELD	0.385	0.295	0.128	0.088	0.107	0.106	232.87	369.56	395.18	407.25	425.2	442.95
CB_BLOOMBERG _INVESTMENT	-0.001	-0.066	0.002	0.013	-0.03	0.026	0.0023	6.7387	6.7431	7.0055	8.3831	9.4511
CB_ISHARES_CORE _CORPORA	-0.137	0.047	0	0.042	-0.016	0.02	57.134	63.755	63.755	68.972	69.775	70.977
CB_JPMORGAN_FUND_	-0.017	-0.021	0.033	-0.001	0.009	0.016	1.0734	2.6505	6.6737	6.6812	6.9722	7.8445
CB_SPDR_BARCLAYS _CAPITAL	0.021	-0.01	-0.007	0.048	0.007	0.022	1.7695	2.2183	2.4279	11.973	12.147	14.194

Notes. Q-stats were all found to be significant to at least the 5% level

Table 4.11 Equity Autocorrelation Table

Equity	**AC(1)**	**AC(2)**	**AC(3)**	**AC(4)**	**AC(5)**	**AC(6)**	**Q-Stat(1)**	**Q-Stat(2)**	**Q-Stat(3)**	**Q-Stat(4)**	**Q-Stat(5)**	**Q-Stat(6)**
FTSE100	-0.048	-0.047	-0.057	0.052	-0.046	-0.035	9.3507	18.586	31.835	42.998	51.806	56.754
FTSE250	0.094	0.006	-0.013	0.021	-0.014	-0.032	35.982	36.13	36.821	38.56	39.413	43.627
FTSE350	-0.033	-0.043	-0.053	0.049	-0.045	-0.036	4.3563	11.809	23.164	32.964	41.118	46.295
FTSEALLSHARE	-0.028	-0.041	-0.052	0.049	-0.044	-0.035	3.2905	10.107	21.007	31.014	38.856	43.982

Notes. Q-stats were all found to be significant to at least the 5% level

4.4 Results

Using either the GARCH model described above or the one described in Section 3.1, this chapter estimates the conditional variance for a selection of gilts, bonds and equities over the period between 2000 and 2016. The results of these models are outlined in the tables below, with gilts, bonds and equities given their own tables for easy comparison. This chapter will now discuss the results of each asset type individually before comparing the results between them.

4.4.1 Univariate Results

Mean Equation

The estimated coefficients for the mean equation are summarised below in tables 4.12, 4.13 and 4.14 where either *, **, *** demonstrate that the coefficient is significant at the 10%, 5% and 1% levels respectively. For example, the value in row five, column twelve denotes the coefficient of the effect of the financial crisis dummy on the log daily return of Gilt GB0031829509, which was found to be significant at the 5% level. In this case the interpretation is that over the period between the collapse of Northern Rock and the start of QE, this gilt's returns were higher than that found over the rest of the sample. In general, we can see that the QE announcements did not cause significant price reactions from the gilts over the entire sample period, with only one gilt showing a response significant at the 5% level. The strongest effect on the gilts and gilt indexes come from the dummy variable for auction days and likewise for the day after auction days. Most of the 32 assets examined showed significant return responses to auction days at the 5% level, with the vast majority of the responses being positive. In addition, QE1 and QE3 show several significant results, with the effects being negative on gilt returns. These results are largely in line with the results found by Steeley and Matyushkin (2015) and other results in the literature, where insignificant announcement effects and positive auctions effects are found. Steeley & Matyushkin (2015) find QE1 caused negative return effects, however their results are different in that they find more of the gilts to be significantly affected and also find QE3 to have insignificant (but similarly negative) effects. The insignificant announcement effects can somewhat be explained by fact that many of the announcements for which the dummy is valued 1 ~~are~~ convey relatively little new information, as can be seen by Table 4.4 in section 4.3 where many of the announcements are simply statements by the MPC that QE will continue in the same manner as previous announcements. Omitting these announcements from the dummy variable improves the significance of the coefficient, however not be enough to offer any different conclusions.

It seems that for most of the gilts there are no significant day-of-the-week effects, apart from in the cases of the gilt indexes, which exhibit significantly different returns on Thursdays and Fridays in comparison to Mondays. The Financial crisis variable is the final variable with a significant effect, albeit for only 8 of the gilts. In all of these cases, the financial crisis period caused daily returns to be higher, which is conducive with periods of high financial uncertainty.

Corporate Bonds

For corporate bonds the results are comparable but far less uniform. For example, QE announcements did not cause any kind of response for corporate bond returns except for in one case, and QE auctions appear to have caused higher returns in a manner similar to UK gilts. The coefficients for the auction variable seem to be smaller and less significant for corporate bonds. These results provide evidence that either the QE macro-news or portfolio-balance channels were in effect, where investors who purchased corporate bond indexes either took macroeconomic information from the situation in gilt markets when choosing their corporate bond portfolios, or that the changing quantity of available gilts caused investors to re-adjust their portfolios towards corporate bonds. The QE period dummies show insignificant results for the majority of the corporate bond indexes, with only two showing results significant to the 5% level. These effects are positive, unlike the results for the gilt returns, and seem to be limited to the high yield corporate bonds as captured by the Bloomberg high yield index. Taken together, the positive auction results suggest that QE did have positive influence on corporate bond prices, however this effect appears to be short term in nature, with the overall period dummies showing mean prices were insignificantly different from the rest of the sample.

In terms of the other results, it is apparent that corporate bond indexes exhibit day-of-the-week effects like the UK gilt indexes, but there does not seem to be any interpretable pattern to these effects for the mean equation. Finally, the financial crisis variable was not included for many of the models given the sample restrictions, however it seems to have not caused any significant effects apart from in the case of the JPMorgan ETF and Bentley index, both having significant and negative returns during that period when compared to the rest of the sample.

Equities

Unlike corporate bonds and gilts, FTSE returns exhibit no significant reaction to any of the announcements or QE auction days. Although insignificant in size, it seems that returns were higher after QE announcements, whereas they were lower when the auctions occurred. This suggests that the portfolio balance and macro-news channels were not significant causes for equity prices over the short term. This result mirrors the event-study findings of Joyce et al. (2011) where they find equity returns were demonstrated little reaction to MPC announcements.

The other results suggest a significant day-of-the-week effect for the more prominent of the FTSE indexes, and the expected negative and significant effect of the financial crisis on equity returns. The QE1 period shows a significant positive effect on two of the four equity indexes, specifically the FTSE350 and ALLSHARE, which may suggest that equities related to smaller businesses were more strongly affected by QE, similar to the case of the high yield corporate bonds. Despite this, equities appear to be the least affected asset type by QE, with none of the QE events having a significant impact and only one of the three QE periods exhibiting higher returns.

In summary of the conditional mean results, the strongest responses to QE come from the UK gilts, while the weakest are from the various FTSE indexes. This result is logical given that all of the UK gilts included in this analysis were directly intervened with at one point of the QE purchases, and largely reflects the findings in the rest of the literature. The failure of QE to illicit any significant price response from equities is of concern when judging the efficacy of the portfolio balance channel, especially when auctions caused large price increases for UK gilts. The suggestion by portfolio balance channel theory would be that falling gilt yields/rising gilt prices would cause or at least coincide with increasing equity prices (Joyce et al. 2011). According to the results shown below, if anything the reverse of this is actually the case, with QE auction days coinciding with small negative price reactions. The expected relationship can be observed for corporate bonds in most cases, with the indexes that contain the shortest-term bonds having the smallest price reactions. This result is again logical given that it can be expected that investors might trade out UK gilts for corporate bonds of a similar term, and that UK gilts of less than three years were not purchased at all by the Bank of England.

Table 4.12a Gilt Mean Equation

Gilt (Govt ISIN)	ANN-1	ANN	ANN+1	AUC-1	AUC	AUC+1	TUES	WED	THURS	FRI	Fin Crisis	QE1	QE2	QE3
GB00B29WRG55	-0.1500	0.4900	-0.0599	0.0808	0.1850	-0.2840	0.1760	0.2300	0.1290	-0.0643	0.3920	-0.0218	-0.0692	-0.0951
GB0008921883	-0.1590	0.5370	-0.3890	-0.0054	0.3050	-0.0990	-0.0806	0.0223	-0.0991	0.0596	0.2900	-0.1720	-0.2400	-0.3190
GB00B3KJDW09	0.1280	-0.0148	-0.2100	0.0340	0.3090	-0.3740	-0.0079	-0.0576	0.1620	0.0689		-0.0557	-0.0255	-0.1070
GB0031829509	0.0761	0.1960	-0.3080*	-0.0815	0.1710	0.0020	0.0558	-0.1220	-0.0167	0.1870	0.4360**	-0.2750	-0.0649	-0.2570
GB00B4LFZR36	0.0171	-0.1040	-0.0749	0.0982	0.0741	-0.0888	-0.0741	-0.0274	0.0831	-0.0881		0.0686	-0.0289	-0.1510
GB0033280339	0.1290	0.0977	-0.0471	-0.1600	0.3410*	-0.3510*	-0.0005	-0.1390	-0.0062	0.0271	0.4760**	-0.1070	0.2030	0.0133
GB0008881541	0.0344	0.5570	-0.0947	0.0734	0.3830	-0.3280	-0.1390	-0.0618	-0.1540	-0.0133	0.3910	-0.3000	-0.0775	-0.2830
GB00B0V3WX43	-0.0285	0.1530	-0.0384	-0.0388	0.4610**	-0.4110*	-0.0393	-0.0664	-0.0928	-0.0785	0.4960**	-0.2420	0.0663	-0.0117
GB0008931148	0.0068	0.2090	-0.2210	0.0300	0.8690***	-0.3900	-0.1280	-0.0319	-0.0576	0.0956	0.4110*	-0.4650	-0.0914	-0.4860
GB00B1VWPC84	0.0169	0.0691	-0.0482	0.0494	0.7480***	-0.3140	-0.1160	-0.2300	-0.0357	-0.0556	0.4370	-0.4920	-0.1520	-0.2680
GB00B39R3F84	-0.3010	0.0229	0.0232	0.1060	0.7670***	-0.1840	-0.1960	-0.2330	0.0182	-0.0016		-0.4470	-0.1760	-0.5440
GB00B4YRFP41	-0.3550	-0.1530	-0.1990	0.2680	0.6230*	0.0462	-0.2580	-0.3380	0.0439	0.0621		-0.5340	-0.2600	-0.6800*
GB00B058DQ55	-0.4420	-0.0334	-0.0632	0.1950	0.9350***	-0.1800	-0.1600	-0.2160	0.0254	0.0435	0.2590	-0.5500	-0.2400	-0.7190
GB0009997999	-0.4730	0.0287	-0.2180	0.1470	1.1390***	-0.2300	-0.1400	-0.1700	-0.0682	0.1880	0.2530	-0.6200*	-0.3190	-0.8160*
GB00B3KJDQ49	-0.4930	-0.3150	-0.3430	0.1040	1.4310***	-0.1060	-0.2600	-0.4740	0.0971	0.3390		-0.7520*	-0.5170	-1.0250**
GB0030880693	-0.7250	0.0166	-0.1680	0.6300	1.3400***	-0.3170	-0.2620	-0.3030	-0.0907	0.2920	0.0912	-0.8560*	-0.6920	-1.2720**

*Notes. *, ** and *** denote the level of significance of each term. ANN and AUC refer to QE announcement and auctions days, respectively.*

-1 or +1 refer to the days preceding or following auctions or announcements.

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Table 4.12b Gilt Mean Equation (continued)

Gilt (Govt ISIN)	**ANN-1**	**ANN**	**ANN+1**	**AUC-1**	**AUC**	**AUC+1**	**TUES**	**WED**	**THURS**	**FRI**	**Fin Crisis**	**QE1**	**QE2**	**QE3**
GB00B16NNR78	-0.3450	-0.1190	0.0307	0.7110	1.8950***	-0.6230	-0.5420	-0.4860	0.0008	0.3120	0.2730	-1.1090**	-0.9530	-1.2590*
GB0002404191	-0.6600	0.0167	-0.2020	0.7380	1.6250***	-0.3230	-0.2480	-0.2660	-0.0604	0.4620*	0.0825	-0.9130*	-0.8660	-1.5290**
GB00B24FF097	-0.2980	-0.8180	-0.2140	0.6630	1.9650***	-0.5680	-0.4240	-0.6600	0.5260	0.6260	0.0713	-1.0290*	-1.0330	-1.5440*
GB0004893086	-0.7310	-0.1840	-0.1460	0.7940	1.8970***	-0.5490	-0.2470	-0.2110	0.0844	0.6730**	-0.0064	-0.9750	-0.9720	-1.5550*
GB00B52WS153	-0.2670	-1.2350	-0.7290	0.4750	2.0460***	-0.2680	-0.5870	-0.9990*	0.5440	0.8730		-0.9720	-1.1430	-1.7420**
GB0032452392	-0.4310	-0.5490	-0.2310	0.7800	2.2380***	-0.8270	-0.0455	-0.4350	0.3550	0.7910**	-0.0592	-0.9990*	-1.0780	-1.6680**
GB00B00NY175	-0.5130	-0.7170	-0.1910	0.8550	2.0640***	-0.8390	-0.2240	-0.6050	0.2160	0.5200	-0.0594	-0.9580	-1.0720	-1.5710
GB00B3KJDS62	-0.4710	-1.3380	-0.5640	0.4910	2.2560***	-0.8530	-0.5110	-0.9210	0.6310	1.0360*		-0.8450	-0.9140	-1.5020*
GB00B1VWPJ53	-0.4980	-1.2880	-0.4790	0.9130	2.4740***	-0.9210	-0.5030	-0.9100	0.6700	0.9050*	-0.2590	-1.1980**	-1.3780*	-2.0060**
GB00B128DP45	-0.4240	-0.7060	-0.1970	1.0860	2.4170***	-0.9290	-0.4860	-0.8640	0.3190	0.8570*	-0.0872	-1.0750*	-1.3200	-1.9300**
GB00B39R3707	-0.5670	-1.6530*	-0.3480	1.0550	2.4990***	-1.0920	-0.5600	-0.8880	0.8360	1.0560		-1.0490	-1.2700	-1.9290
GB00B06YGN05	-0.7720	-0.7180	-0.2490	1.1640	2.3710***	-1.1010	-0.2400	-0.6500	0.3370	0.8340	-0.1100	-1.0060	-1.2970	-1.8080*
GB00B54QLM75	-1.1510	-2.6340**	-1.0240	0.0487	2.9210***	0.3530	-0.3990	-1.0000	1.2210	1.7630**		-0.9410	-1.8500	-2.3880*
GILTS_5_15 _YEAR_INDEX	-0.2890	0.5910	-0.1460	0.5210	0.9910***	-0.1200	-0.2610	-0.2140	-0.5150***	0.4530**	0.2990	-0.7030**	-0.5610	-0.9710**
GILTS_ALL _STOCKS_INDEX	-0.2810	0.3890	-0.2650	0.7810**	1.0340***	-0.1190	-0.2670	-0.2400	-0.3970**	0.4580***	0.1780	-0.7140**	-0.7620*	-1.2280***
UK_GILTS_INDEX _OVER_15_Y	-0.6100	0.3310	-0.0173	1.3920**	1.8730***	-0.6830	-0.3270	-0.2840	-0.3660	0.7980***	0.0408	-1.0840*	-1.2280	-1.7740*

*Notes. *, ** and *** denote the level of significance of each term. ANN and AUC refer to QE announcement and auctions days, respectively. -1 or +1 refer to the days preceding or following auctions or announcements.*

Table 4.13 Corporate Bond Mean Equation

Corporate Bond	**ANN-1**	**ANN**	**ANN+1**	**AUC-1**	**AUC**	**AUC+1**	**TUES**	**WED**	**THURS**	**FRI**	**Fin Crisis**	**QE1**	**QE2**	**QE3**
SPDR Barclays Capital Sterling Corporate Bond ETF	-0.5760	0.1310	0.0012	0.5360*	0.7170**	-0.0229	-0.5170***	-0.4040***	-0.2940*	0.0007	-0.3410	0.3520	-0.2150	-0.2280
Barclays Sterling Corporate Bond Fund	-0.1330	-0.3160	0.2160	-0.2690	0.8480**	-0.0743	0.3230	0.0448	0.0296	0.1620	-0.3530	0.4370	-0.0603	0.2360
iShares Core GBP Corporate Bond UCITS ETF	0.3760	-0.2140	-0.5360	0.5950	1.0580**	-0.0646	-0.1470	-0.9850***	0.2660	0.5730**	-0.2580	0.1420	-0.5490	-0.5020
CF Bentley Investment Funds	-0.0265	-0.2030	0.1990	-0.2610	0.7420	-1.1810**	0.1560	-0.2140	0.3360	0.1960	-0.9680**	0.9950*	0.6500	0.3150
JPMorgan Fund ICVC	-0.2320	0.1560	0.4130	-0.5100*	0.9730***	-0.1680	-0.2370	-0.0473	-0.2870*	0.1900	-0.4390**	0.4240	0.1220	0.2780
Bloomberg GBP High Yield Corporate Bond Index	-0.0704	0.5650***	-0.1580	-0.1730	0.1670	-0.0722	-0.3700***	-0.3560***	-0.3320***	-0.1480			0.9630**	0.9280***
Bloomberg GBP Investment Grade Corporate Bond Index	-0.5670	-0.4250	-0.0278	0.1210	1.1110***	0.1210	-0.5900**	-0.7360**	-0.2410	0.0376			-0.2920	-0.4260
Bloomberg GBP Investment Grade European Corporate Bond Index 1 to 5 Year	-0.1170	0.0311	0.0040	0.0270	0.0930	-0.0020	-0.4070***	-0.4670***	-0.3150***	-0.2630***			0.1290	0.0804
Bloomberg Investment Grade Corporate 10+ Bond Index	-0.7200	-0.6930	-0.0371	-0.0186	1.7050***	0.0506	-0.6510*	-0.8790**	-0.1880	0.2150			-0.6550	-0.6620
Bloomberg Investment Grade Corporate 5-10 years Bond Index	-0.5470	-0.1110	-0.0496	-0.0757	0.7940**	0.0378	-0.5810***	-0.6670***	-0.4180*	-0.1180			-0.0718	-0.0642
Bloomberg Investment Grade Corporate 1-10 years Bond Index	-0.3680	-0.0287	-0.0087	-0.0342	0.4880**	0.0133	-0.5000***	-0.5680***	-0.3730**	-0.1830			0.0390	0.0104
Bloomberg Investment Grade Corporate 1-3 years Bond Index	-0.0447	0.0043	0.0213	0.0158	-0.0143	-0.0185	-0.3020***	-0.3980***	-0.2660***	-0.2470***			0.1470**	0.0847

*Notes. *, ** and *** denote the level of significance of each term. ANN and AUC refer to QE announcement and auctions days, respectively.*

-1 or +1 refer to the days preceding or following auctions or announcements.

Table 4.14 Equity Mean Equation

Equity	**ANN-1**	**ANN**	**ANN+1**	**AUC-1**	**AUC**	**AUC+1**	**TUES**	**WED**	**THURS**	**FRI**	**Fin Crisis**	**QE1**	**QE2**	**QE3**
FTSE100	0.2440	1.2540	-0.6780	-0.5790	-0.9530	-1.2010	0.0407	-0.6890	-0.3780	0.3000	-0.9720	1.8710*	1.7180*	0.4870
FTSE250	0.2810	1.6980	-0.6870	-0.3780	-1.7210*	-0.8400	0.0110	0.1010	0.3830	1.5560***	-1.4620	1.6610	2.1340	1.6330
FTSE350	-0.0978	1.2180	-0.9100	-0.9670	-0.7710	-0.9220	0.0345	-0.1770	0.0322	0.7780*	-1.0220**	2.1550***	1.6980*	1.6250*
FTSEALLSHARE	-0.0992	1.2160	-0.9120	-0.9590	-0.7710	-0.9180	0.0386	-0.1600	0.0442	0.7950*	-1.0410**	2.1470***	1.6960*	1.6200*

*Notes. *, ** and *** denote the level of significance of each term. ANN and AUC refer to QE announcement and auctions days, respectively. -1 or +1 refer to the days preceding or following auctions or announcements.*

Table 4.15a Gilt Conditional Variance Terms

Gilt (Govt ISIN)	Constant	$Resid^2_{t-1}$	$GARCH_{t-1}$	Negative News
GB00B29WRG55	2.98E-06~~2.98E-06~~	0.149999~~0.149999~~	0.599982~~0.599982~~	
GB0008921883	5.77E-06~~5.77E-06~~	0.149947~~0.149947~~	0.599803~~0.599803~~	
GB00B3KJDW09	9.51E-07~~9.51E-07~~	0.153456~~0.153456~~	0.601974~~0.601974~~	
GB0031829509	3.22E-06~~3.22E-06~~	0.159787~~0.159787~~	0.606414~~0.606414~~	
GB00B4LFZR36	6.14E-08~~6.14E-08~~	0.186552~~0.186552~~	0.624313~~0.624313~~	
GB0033280339	3.00E-06~~3.00E-06~~	0.155759~~0.155759~~	0.603177~~0.603177~~	
GB0008881541	2.38E-06~~2.38E-06~~	0.176185~~0.176185~~	6.20E-01~~6.20E-01~~	
GB00B0V3WX43	4.91E-06~~4.91E-06~~	0.176313~~0.176313~~	0.613043~~0.613043~~	
GB0008931148	7.06E-06~~-1.09E-07~~	0.152327~~0.081564~~	0.601157~~0.937704~~	-0.036004
GB00B1VWPC84	5.43E-06~~-5.96E-07~~	0.155287~~0.072577~~	0.60262~~0.931735~~	-0.024447
GB00B39R3F84	8.33E-06~~-6.48E-07~~	0.266974~~0.022929~~	0.605945~~0.980289~~	-0.012792
GB00B4YRFP41	5.93E-06~~-8.76E-07~~	0.183411~~0.014117~~	0.569872~~1.001226~~	
GB00B058DQ55	4.24E-06~~-1.03E-06~~	0.128029~~0.019781~~	0.668939~~0.984111~~	-0.013709
GB0009997999	1.22E-05~~-1.39E-06~~	0.113663~~0.024036~~	0.579873~~0.979641~~	-0.013977

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GB00B3KJDQ49	6.03E-08~~-1.62E-06~~	0.019640~~0.052623~~	0.975655~~1.000362~~	-0.013363
GB0030880693	1.86E-06~~-2.02E-06~~	0.025375~~0.033243~~	0.968186~~0.966048~~	-0.013571

Table 4.15b Gilt Conditional Variance Terms (continued)

Gilt (Govt ISIN)	Constant	$Resid_{t-1}^{2}$	$GARCH_{t-1}$	Negative News
GB00B16NNR78	1.68E-05~~-2.49E-06~~	0.09974~~0.043999~~	0.76903~~0.930565~~	
GB0002404191	2.57E-07~~-3.37E-06~~	0.031632~~0.034707~~	0.960236~~0.964686~~	-0.016626
GB00B24FF097	1.90E-06~~-2.82E-06~~	0.041957~~0.055828~~	0.942988~~0.920173~~	
GB0004893086	3.51E-06~~-3.82E-06~~	0.028871~~0.037475~~	0.964428~~0.965588~~	-0.019331
GB00B52WS153	1.59E-06~~-5.83E-07~~	0.028034~~0.011609~~	0.962945~~1.001283~~	-0.028401
GB0032452392	3.52E-06~~-4.04E-06~~	0.027959~~0.033775~~	0.964941~~0.970546~~	-0.02115
GB00B00NY175	3.26E-07~~-5.53E-06~~	0.032102~~0.049848~~	0.960315~~0.955842~~	-0.032709
GB00B3KJDS62	8.98E-08~~-1.52E-06~~	0.04834~~0.029467~~	0.928235~~0.984091~~	-0.030619
GB00B1VWPJ53	2.21E-06~~-2.14E-06~~	0.037757~~0.047699~~	0.954754~~0.964908~~	-0.033866
GB00B128DP45	2.98E-06~~-4.30E-06~~	0.042205~~0.054356~~	0.950189~~0.95333~~	-0.030552
GB00B39R3707	1.38E-06~~-9.61E-07~~	0.067284~~0.049235~~	0.912996~~0.96093~~	-0.035285
GB00B06YGN05	5.60E-06~~-5.49E-06~~	0.04138~~0.058955~~	0.951645~~0.950413~~	-0.035167
GB00B54QLM75	1.11E-06~~-1.90E-06~~	0.039151~~0.076984~~	0.955511~~0.941091~~	-0.055263
GILTS_5_15_YEAR_INDEX	2.71E-06~~-2.92E-06~~	0.059841~~0.084285~~	0.850376~~0.883997~~	-0.058158

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GILTS_ALL_STOCKS_INDEX	7.56E-07~~-1.19E-06~~	0.010095~~0.035593~~	0.986068~~0.979511~~	-0.03874
UK_GILTS_INDEX_OVER_15_Y	4.41E-06~~-4.61E-06~~	0.031282~~0.045983~~	0.956302~~0.966362~~	-0.039201

Table 4.16 Corporate Bond Conditional Variance Terms

Corporate Bond	**Constant**	$Resid^2_{t-1}$	$GARCH_{t-1}$	**Negative News**
SPDR Barclays Capital Sterling Corporate Bond ETF	-2.51E-06	0.07664	0.815628	
Barclays Sterling Corporate Bond Fund	2.93E-06	0.032396	0.96677	-0.023362
iShares Core GBP Corporate Bond UCITS ETF	-8.07E-07	0.109922	0.713917	-0.036357
CF Bentley Investment Funds	5.93E-07	0.136639	0.832507	
JPMorgan Fund ICVC	-4.73E-07	0.037327	0.941891	
Bloomberg GBP High Yield Corporate Bond Index	-3.33E-07	0.121322	0.881099	
Bloomberg GBP Investment Grade Corporate Bond Index	-2.16E-06	0.073088	0.849226	
Bloomberg GBP Investment Grade European Corporate Bond Index 1 to 5 Year	-1.10E-07	0.077447	0.769015	
Bloomberg Investment Grade Corporate 10+ Bond Index	-4.05E-06	0.068972	0.875831	
Bloomberg Investment Grade Corporate 5-10 years Bond Index	-1.41E-06	0.074004	0.755349	
Bloomberg Investment Grade Corporate 1-10 years Bond Index	-6.25E-07	0.072925	0.772931	
Bloomberg Investment Grade Corporate 1-3 years Bond Index	-3.57E-08	0.049814	0.899767	

Table 4.17 Equity Conditional Variance Terms

Equity	**Constant**	$Resid^2_{t-1}$	$GARCH_{t-1}$
FTSE100	2.07E-06	0.112177	0.87052
FTSE250	1.98E-06	0.116682	0.846246
FTSE350	1.69E-06	0.11377	0.866255
FTSEALLSHARE	1.75E-06	0.114524	0.865197

Table 4.18a Gilt Variance Equation

Gilt (Gilt ISIN)	ANN-1	ANN	ANN+1	AUC-1	AUC	AUC+1	TUES	WED	THURS	FRI	Fin Crisis	QE1	QE2	QE3
GB00B29WRG55	-0.0008	-0.0003	-0.0013	-0.0006	-0.0005	-0.0005	-0.0010	-0.0008	-0.0009	-0.0011	0.0000	-0.0002	-0.0004	-0.0004
GB0008921883	-0.0019	-0.0013	-0.0024**	-0.0010	-0.0010	-0.0009	-0.0019	-0.0018	-0.0018	-0.0025*	-0.0005	-0.0006	-0.0006	-0.0010
GB00B3KJDW09	-0.0006	-0.0003	-0.0008	-0.0003	-0.0002	-0.0002	-0.0007	-0.0005	-0.0005	-0.0007		0.0000	-0.0003	-0.0003
GB0031829509	-0.0008***	0.0010	-0.0005	-0.0005	-0.0007**	-0.0004	-0.0036***	-0.0039***	-0.0033***	-0.0049***	0.0017***	0.0010***	-0.0005	-0.0004
GB00B4LFZR36	-0.0001*	0.0001	-0.0001	-0.0001	-0.0002	0.0000	-0.0010***	-0.0013***	-0.0012***	-0.0011***		0.0010**	0.0001**	0.0001
GB0033280339	-0.0013***	-0.0002	0.0003	-0.0001	-0.0004	-0.0004	-0.0048***	-0.0037***	-0.0040***	-0.0042***	0.0036***	0.0024***	0.0002	0.0000
GB0008881541	-0.0023	-0.0013	-0.0031**	-0.0012	-0.0012	-0.0011	-0.0025	-0.0023	-0.0021	-0.0036**	-0.0003	-0.0004	-0.0009*	-0.0012***
GB00B0V3WX43	-0.0008***	0.0008	-0.0009**	-0.0002	-0.0004	0.0000	-0.0053***	-0.0052***	-0.0045***	-0.0052***	0.0051***	0.0034***	0.0003	0.0002
GB0008931148	-0.0039***	-0.0007	-0.0012**	-0.0007	-0.0002	-0.0003	-0.0076***	-0.0049***	-0.0047***	-0.0057***	0.0039***	0.0032***	0.0012***	0.0003
GB00B1VWPC84	-0.0017***	0.0011*	0.0004	-0.0014***	-0.0011	0.0009	-0.0059***	-0.0036***	-0.0056***	-0.0047***	0.0059***	0.0047***	0.0021***	0.0009***
GB00B39R3F84	-0.0016***	0.0008	0.0011*	-0.0003	-0.0012	0.0015*	0.0009**	0.0022***	0.0000	0.0012**			0.0000	0.0000
GB00B4YRFP41	-0.0021***	0.0013	0.0008	-0.0001	-0.0011	0.0013	0.0006*	0.0016***	0.0003	0.0000		-0.0001***	-0.0001***	-0.0001**
GB00B058DQ55	-0.0025***	0.0012	0.0015**	-0.0005	-0.0004	0.0009	0.0008	0.0020***	0.0004	0.0003	0.0001***	-0.0002***	-0.0001***	-0.0001
GB0009997999	-0.0039***	0.0030*	0.0009	-0.0011	-0.0005	0.0015	0.0017**	0.0032***	0.0003	0.0017**	0.0002***	-0.0001	-0.0001	0.0000
GB00B3KJDQ49	-0.0054***	0.0051**	0.0018	-0.0015	-0.0001	0.0018	0.0014	0.0039***	-0.0005	0.0000*		-0.0003***	-0.0001*	-0.0001
GB0030880693	-0.0085***	0.0117***	-0.0025	-0.0042	0.0005	0.0035	0.0020	0.0058***	-0.0011	0.0030*	0.0003***	-0.0001	0.0001	0.0001

*Notes. *, ** and *** denote the level of significance of each term. ANN and AUC refer to QE announcement and auctions days, respectively.*

-1 or +1 refer to the days preceding or following auctions or announcements.

Table 4.18b Gilt Variance Equation (continued)

Gilt (Govt ISIN)	**ANN-1**	**ANN**	**ANN+1**	**AUC-1**	**AUC**	**AUC+1**	**TUES**	**WED**	**THURS**	**FRI**	**Fin Crisis**	**QE1**	**QE2**	**QE3**
GB00B16NNR78	-0.0124***	0.0120**	0.0015	-0.0098***	-0.0018	0.0083**	-0.0229***	-0.0076**	-0.0185***	-0.0145***	0.0039***	0.0035**	0.0049***	0.0028**
GB0002404191	-0.0095***	0.0157***	-0.0047	-0.0055	0.0007	0.0046	0.0042***	0.0071***	0.0000	0.0054***	0.0004***	-0.0002	0.0000	0.0001
GB00B24FF097	-0.0114***	0.0197***	-0.0064	-0.0048	-0.0025	0.0072	0.0023	0.0090***	-0.0050*	0.0051	0.0007**	-0.0001	0.0001	0.0002
GB0004893086	-0.0091***	0.0172**	-0.0067	-0.0051	-0.0014	0.0066	0.0038*	0.0083***	-0.0003	0.0066**	0.0004***	-0.0003	-0.0002	-0.0001
GB00B52WS153	-0.0160***	0.0218***	-0.0068	-0.0043	-0.0043	0.0084	0.0004	0.0132***	-0.0096**	0.0059		0.0000	0.0001	0.0001
GB0032452392	-0.0098***	0.0170**	-0.0049	-0.0073	0.0009	0.0065	0.0033	0.0095***	-0.0018	0.0073**	0.0005**	-0.0003	-0.0002	-0.0001
GB00B00NY175	-0.0096**	0.0177**	-0.0053	-0.0073	0.0001	0.0074	0.0053**	0.0102***	-0.0009	0.0087***	0.0005**	-0.0003	-0.0002	-0.0001
GB00B3KJDS62	-0.0164***	0.0202**	-0.0055	-0.0106	-0.0017	0.0124*	-0.0015	0.0126**	-0.0092**	0.0066		0.0000	0.0004	0.0004
GB00B1VWPJ53	-0.0132**	0.0258**	-0.0107	-0.0080	-0.0013	0.0095	0.0022	0.0112**	-0.0089*	0.0083*	0.0004	-0.0004	-0.0003	-0.0002
GB00B128DP45	-0.0073	0.0221*	-0.0106	-0.0130	0.0024	0.0114	0.0034	0.0056	-0.0012	0.0086*	0.0005*	-0.0007	-0.0006	-0.0005
GB00B39R3707	-0.0199***	0.0247*	-0.0132	-0.0151***	-0.0037	0.0191***	-0.0010	0.0120*	-0.0072	0.0128*		0.0000	0.0006	0.0006
GB00B06YGN05	-0.0088	0.0306**	-0.0169	-0.0144	0.0024	0.0131	0.0075	0.0097*	0.0002	0.0121**	0.0005*	-0.0010	-0.0008	-0.0007
GB00B54QLM75	-0.0191**	0.0299*	-0.0187	-0.0004	-0.0278	0.0292***	-0.0027	0.0191**	-0.0161***	0.0098		-0.0002	-0.0006	-0.0008
GILTS_5_15 _YEAR_INDEX	-0.0031*	0.0013	0.0035	-0.0053***	0.0063**	-0.0018	0.0047***	0.0060***	0.0058***	0.0027***	0.0014***	0.0007*	0.0012***	0.0006
GILTS_ALL _STOCKS _INDEX	-0.0052***	0.0067**	-0.0010	-0.0029	0.0010	0.0018	0.0024***	0.0011**	0.0014***	-0.0011*	0.0002***	-0.0002*	0.0000	-0.0001
UK_GILTS_INDEX _OVER_15_Y	-0.0101**	0.0245**	-0.0092	-0.0094*	0.0023	0.0071	0.0069***	0.0073***	0.0044**	0.0050**	0.0007***	-0.0005	-0.0001	0.0000

*Notes. *, ** and *** denote the level of significance of each term. ANN and AUC refer to QE announcement and auctions days, respectively.*

-1 or +1 refer to the days preceding or following auctions or announcements.

Table 4.19 Corporate Bond Variance Equation

Corporate Bond	**ANN-1**	**ANN**	**ANN+1**	**AUC-1**	**AUC**	**AUC+1**	**TUES**	**WED**	**THURS**	**FRI**	**Fin Crisis**	**QE1**	**QE2**	**QE3**
SPDR Barclays Capital Sterling Corporate Bond ETF	0.0020	-0.0013	0.0018	-0.0029**	0.0037**	-0.0019	0.0038***	0.0042***	0.0055***	0.0037***	0.0007***	0.0006*	0.0010**	0.0007
Barclays Sterling Corporate Bond Fund	0.0025	-0.0011	-0.0006	-0.0011	0.0020	-0.0004	-0.0067***	-0.0015**	-0.0022***	-0.0038***	0.0001***	-0.0002***	-0.0003**	-0.0004***
iShares Core GBP Corporate Bond UCITS ETF	-0.0014	0.0023	0.0045	-0.0017	0.0000	-0.0046**	0.0039***	0.0157***	0.0034***	0.0035***	0.0408***	0.0150***	0.0120***	0.0026
CF Bentley Investment Funds	-0.0087**	-0.0089*	-0.0075*	-0.0034	-0.0030	-0.0032	-0.0090*	-0.0091*	-0.0093*	-0.0087	-0.0014	-0.0020	-0.0015	-0.0028
JPMorgan Fund ICVC	0.0021*	-0.0036**	0.0026**	0.0001	-0.0037**	0.0035***	-0.0005	0.0018***	-0.0001	0.0018**	0.0003***	0.0000	0.0001	0.0003
Bloomberg GBP High Yield Corporate Bond Index	0.0013**	-0.0006	-0.0003	0.0005*	-0.0008**	0.0000	0.0000	0.0001	0.0003**	-0.0001			0.0003**	0.0001**
Bloomberg GBP Investment Grade Corporate Bond Index	-0.0036**	0.0001	0.0035**	0.0008	-0.0056**	0.0049***	0.0049***	0.0051***	0.0020	0.0035**			0.0001	0.0000
Bloomberg GBP Investment Grade European Corporate Bond Index 1 to 5 Year	-0.0002	0.0003	0.0002	-0.0001	-0.0001	0.0001	0.0005***	0.0004***	0.0002*	0.0003*			0.0001	0.0000
Bloomberg Investment Grade Corporate 10+ Bond Index	-0.0084***	0.0017	0.0050	-0.0005	-0.0083	0.0089**	0.0084***	0.0085***	0.0037	0.0070**			0.0002	0.0003
Bloomberg Investment Grade Corporate 5-10 years Bond Index	-0.0017	0.0004	0.0018	-0.0003	-0.0016	0.0003	0.0045***	0.0047***	0.0021**	0.0035***			0.0010**	0.0003
Bloomberg Investment Grade Corporate 1-10 years Bond Index	-0.0008	0.0004	0.0009	-0.0002	-0.0007	0.0003	0.0021***	0.0021***	0.0009**	0.0015***			0.0005**	0.0001
Bloomberg Investment Grade Corporate 1-3 years Bond Index	-0.0001*	0.0000	0.0001**	0.0000	0.0000	0.0000	0.0001***	0.0001	0.0001	0.0000			0.0000	0.0000

*Notes. *, ** and *** denote the level of significance of each term. ANN and AUC refer to QE announcement and auctions days, respectively.*

-1 or +1 refer to the days preceding or following auctions or announcements.

Table 4.20 Equity Variance Equation

Equity	**ANN-1**	**ANN**	**ANN+1**	**AUC-1**	**AUC**	**AUC+1**	**TUES**	**WED**	**THURS**	**FRI**	**Fin Crisis**	**QE1**	**QE2**	**QE3**
FTSE100	0.0165	0.0035	-0.0133	-0.0212***	-0.0006	0.0127*	-0.0591***	-0.0494***	-0.0454***	-0.0532***	0.0194***	0.0110**	0.0025	0.0013
FTSE250	0.0152**	0.0129	-0.0153	-0.0143	0.0111	-0.0013	0.0036	0.0030	0.0037	-0.0084**	0.0131***	0.0070**	0.0076**	0.0034
FTSE350	0.0011	0.0168	-0.0165	-0.0211***	0.0205	-0.0047	0.0031	-0.0004	0.0006	-0.0024	0.0078***	0.0047**	0.0042*	0.0038*
FTSEALLSHARE	0.0014	0.0163	-0.0159	-0.0207***	0.0199	-0.0046	0.0027	-0.0005	0.0008	-0.0027	0.0077***	0.0047**	0.0042*	0.0039*

*Notes. *, ** and *** denote the level of significance of each term. ANN and AUC refer to QE announcement and auctions days, respectively.*

-1 or +1 refer to the days preceding or following auctions or announcements.

Variance Equation

Table 4.15-17 summarise the results of the ARCH and GARCH terms from the variance equation of each respective GARCH equation, as well as the negative news variable where appropriate, while Tables 4.18-20 show the results of the dummy variables in the equation. All terms in Tables 4.15-17 are significant to at least the 5% level. As before this chapter will go through the asset types individually before drawing comparisons between the volatilities of gilts, bond and equities. The innovation and conditional volatility terms for gilts are discussed in table 4.15, bonds in table 4.16 and equities in 4.17.

Gilts

The estimated parameters for the lagged residuals and the past conditional variances indicate that the variance processes are mostly stable, with 21 of the models being improved by allowing negative volatility shocks to differ in value to positive. Using Zivot's formula (p.8, 2009) to calculate, this chapter found that the half-life of volatility shocks for short term gilts were around 2/3 days while for longer term gilts the shocks took 30+ days to decay. It appears that there is a link between the time to maturity of the gilt in question, and the degree of persistence in the ARCH and GARCH terms. The longer time-to-maturity gilts tend to have a higher persistence of volatility shocks than the shorter term gilts. A good example of this is with the gilt indexes, where the index containing shorter maturity assets has weaker persistence in volatility shocks than those of the longer index. The final 3 columns of table 4.15b shows these results. This link between time to maturity and volatility persistence is not much discussed in the literature, however similar results are found in Steeley and Matyushkin (2015). In addition, this link is not determined statistically, but only through observation of the results and should therefore not be considered binding. As can be seen in Table 4.15, positive news denoted by the coefficient standard lagged residual term has a larger effect on gilt volatility than negative news in almost all cases.

Table 4.18 shows the coefficients for the rest of the parameters in the model. Comparing these to the results of the mean equation, in general the parameters were much more significant in affecting the volatility of returns rather than the mean. Of particular interest is the results for the announcement indicators, which are shown to be significant for most of the gilts included in the analysis. For almost all of the gilts, the day before announcements are observed to be much calmer than the standard sample volatility, which can be observed in the significant and negative coefficient on the indicator variable. This provides evidence for significant 'Calm-before-the-storm' effects, where gilt investors held off on transactions until they received new information from MPC meeting announcements. Further evidence for this effect is given by the fact that the coefficient on the actual announcement is significant and positive, i.e. that volatility increased for most gilt returns on days where the MPC announced its decisions and therefore new economic information was given to market participants. Fewer gilts saw significant reactions to the day after announcement days than the before or during, however the majority of the gilts saw reduced volatility the day after announcements, whether significant or not. This suggests a slight calming effect on gilt markets from QE announcements, which is evidence for QE intervention being viewed as positive economic news. Given that one of QE's objectives was to restore pre-crisis financial market conditions, QE announcements causing reduced volatility could be considered a successful outcome. However, the overall combined volatility effect of the announcements is positive for many of the gilts, meaning that QE announcements made these markets more volatile overall. The auction variable coefficients appear to be far less significant for the variance equations in comparison to the results of the corresponding mean equations. For the vast majority of the gilts, volatility on auction days was positively affected but not significantly different to the rest of the sample, with a similar result being found for the days preceding and following.

Almost all of the gilts show significant and positive coefficients for the financial crisis dummy variable, which shows that the financial crisis period saw a significant increase in general gilt volatility up to the onset of QE. Examining the scale of the coefficients, it is clear that the QE2 and QE3 periods following the financial crisis period however show gilt volatility to be insignificantly different from the pre-crisis levels for the majority of gilts. It can be inferred from this that these periods saw a general decline in volatility after the financial crisis period. The QE1 period shows significantly higher volatility than over the rest of the sample, however when comparing the variance to the financial crisis indicator, the QE1 period exhibited lower gilt volatility than the financial crisis period preceding it. Coupling these results with the findings for the QE events, it can be reasonably asserted that QE periods oversaw reduced gilt volatility, but that these effects were over the longer term and not as a reaction specifically to auctions.

Aside from these results almost all of the gilts exhibit different levels of volatility depending on the weekday, however these follow no observable pattern. As can be seen in table 4.18 the first several gilts exhibit stronger volatility on Mondays, with almost all of the other day indicators showing negative coefficients. However, the remaining gilts largely exhibit positive coefficients for these indicators, including the gilt indexes, demonstrating that Mondays were exhibited less volatility than the other weekdays.

Corporate Bonds

Like with the gilts, the estimated lagged residuals and GARCH terms are all stable, but only two of the models were improved by allowing for asymmetrical news shocks. Using the same formula, shock half-lives are between 2 and 33 days depending on the index, however unlike the gilts there is no observed pattern between the half-life of the shocks and the maturities of the bonds included in each index. For most of the indexes, volatility shocks will have decayed within half a month. For the two indexes that included the negative news indicator, it seems that positive news has a stronger effect on volatility than negative, this is similar to the findings for gilts.

Table 4.19 shows the effects of the other variables included in the model. Only 4 of the 12 indexes showed any change in volatility in days preceding QE announcements, and the effects are not uniform in sign. Therefore, there is little evidence of the 'calm-before-the-storm' effects that are apparent in the gilt results. Bond volatility on announcements days and the day following is not significantly different from the rest of the sample, suggesting that QE announcements contained relatively little information for bond investors to trade by. Those indexes that were affected by the announcements reacted in a non-uniform way, with indexes showing increased volatility, while others the opposite. Therefore, if any information was taken from QE announcements, it was not a consistent message amongst corporate bond investors. In this way, there is little evidence to suggest that QE announcements reduced volatility in these markets.

For the APF auction variables the results are similarly inconsistent. The day before auctions saw volatility levels consistent with the rest of the sample for all but two of the indexes, which saw slightly reduced volatility. On the actual auction days, four of the indexes had significantly different volatility when compared to the rest of the sample, however once again the signs on the respective coefficients do not show an observable pattern. For the majority of the bond indexes, auction day's coefficients were negative, however they are also insignificant. The day after auction days caused increased volatility in 8 of the 12 indexes, however only 4 of these results are significant to the 5% level. This does suggest a possible time lagged effect from QE auctions on corporate bonds, where information taken by investors from QE intervention caused changes to trading patterns for corporate bonds the next day.

All but one of the corporate bond indexes which had samples long enough to include the financial crisis dummy variable show highly significant and positive coefficients, suggesting that the period between the fall of Northern Rock and QE1 caused general volatility to increase by a large degree. However, unlike the gilt variance results, corporate bond volatility did not reduce over the following QE periods. This is shown by the significant and positive coefficients on several of the QE period dummies, showing that corporate bond volatility was still distinctly different from pre-crisis levels after the onset of QE. While the coefficient values are lower for the QE periods than the financial crisis indicator, the most evidenced interpretation is that corporate bonds were not as significantly affected by QE than UK gilts. Overall, there is insufficient evidence to conclude that QE auctions or announcements significantly affected corporate bond volatility, with the results showing no pattern in terms of the sign of coefficients or indeed the significance levels of results.

As for day of the week effects, most of the corporate bond indexes exhibited higher volatility on other weekdays when compared to Monday, especially on Tuesdays and Fridays. These results are consistent to those found in the literature and are comparable to the results found for some of the gilts, especially the gilt indexes.

Equities

Table 4.17 shows that the 4 equity indexes have stable and significant ARCH and GARCH processes, with comparatively stronger ARCH effects than is the case for gilts and corporate bonds. None of the equity models were improved by allowing for asymmetrical news effects so in all 4 cases these items were dropped from the model. The half-life of past volatility shocks appears to be longer for equities than for corporate bonds and gilts, with all but the FTSE250 taking around 30+ days to decay. The FTSE250 index shocks decayed at a quicker rate of about 18 days. The FTSE100 shocks had the longest decay time at 39 days.

As can be seen by Table 4.20 QE announcements did not significantly alter the volatility of any of the equity indexes. There are no observable calm-before-the-storm effects, with the day before QE announcements having no significant decrease in equity volatility. The FTSE250, which is the only asset to respond to any aspect of the announcements, saw a small but significant increase in volatility on days before QE announcements, however as this effect is not captured in any of the other indexes it is unlikely to be an interpretable result. Given that QE announcements were intended to support equity returns and reduce equity volatility, these results provide evidence that these effects did not take place. These results are in line with the results in the literature, like Joyce et al (2011) where QE announcements were met with mixed and small reactions from equity markets. QE auction days exhibit much stronger effects on equity volatility however. It seems that the day before QE auctions equity volatility was reduced, possibly due to investors holding off on trades until new market information arrives the next day. Higher volatility is often connected to higher information flow in the literature and these results suggest that QE auctions provided significant market information for equity investors.

The QE period results suggest some QE effects over the longer-term for equities. All of the index volatilities were significantly increased by the period after the fall of Northern Rock, as can be seen by the positive coefficients that are significant at the 1% level. QE1 and QE2 also show volatility significantly higher than the pre-crisis sample, albeit slightly lower than the financial crisis period. QE1 in particular appears to have had little impact on reducing equity volatility. By QE2 and QE3 the FTSE100 and 250 are back to pre-crisis levels, however the 350 and ALLSHARE, which contain riskier assets, still shows volatility greater than pre-crisis levels. It seems that after the financial crisis period, over the ensuing QE periods the higher volatility than sample reduces to insignificance as intervention continued but took a relatively long time when compared to the results for gilts. While it could be argued that over the longer-term QE oversaw reduced equity volatility, these results give little direct evidence that it was QE itself that caused this effect, especially when considering the non-effect of the auctions and announcements. What is more likely is that it was simply time and reduced uncertainty that lowered equity variance back to its pre-crisis levels.

Comparisons

Comparing the results of the other two asset types to those found for gilts, it can be seen that corporate bond index and equity volatility had much smaller reactions to QE announcements and intervention. Whereas there were significant volatility effects on days preceding and during MPC announcements for gilts, these effects can only be observed in a couple of the corporate bond indexes, and none of the equity indexes. This is evidence towards the conclusion that equity investors did not use QE announcements either as information for the general outlook of the UK economy, or more specifically as information for future relative rates of return between these asset classes. Corporate bond investors appear to have taken more information from QE announcements, however this information does not appear to be uniform in nature, especially when the mean equation shows that there wasn't significant positive or negative return changes during announcement days. For the auctions indicators, there appears to be little to compare between the asset types except the general comparison that most assets were unaffected by the auctions in terms of volatility.

Table 4.21a BEKK Model Results

Variance Term	FTSE100	FTSE250	FTSE350	FTSEALLSHARE	CFBentley	iShares	JPMorgan	SPDR
$\boldsymbol{a_{1,1}}$	0.1763***	0.0253	-0.0610***	0.0373***	0.1314***	0.1153***	-0.0176	-0.0088***
$\boldsymbol{a_{1,2}}$	-0.0682***	-0.1133***	0.1704***	0.0619***	-0.0310*	0.0515***	0.0695***	0.0858***
$\boldsymbol{a_{1,3}}$	0.0777***	-0.2216***	0.1409***	-0.0727***	-0.1567***	-0.0155***	-0.0607***	-0.0890***
$\boldsymbol{a_{2,1}}$	-0.0668**	-0.1936	-0.0587	-0.1587	0.0921	-0.0622***	0.0166	-0.0642**
$\boldsymbol{a_{2,2}}$	-0.2841***	0.0754**	0.0233	-0.0672***	0.0746**	-0.0410***	0.0239	0.0297***
$\boldsymbol{a_{2,3}}$	0.0204	0.1192*	0.0788	0.0304	-0.0402	0.0096***	-0.0006	-0.0882***
$\boldsymbol{a_{3,1}}$	-0.0255	0.0232	-0.0972	-0.0604	0.0089	0.0265***	0.0831***	0.0329***
$\boldsymbol{a_{3,2}}$	-0.0099	-0.0199*	0.1282***	-0.1088***	0.0319**	0.0339***	-0.0490**	0.0801***
$\boldsymbol{a_{3,3}}$	0.0286	0.0227	0.0547	0.0750***	0.1999***	-0.0443***	0.0048	0.0022***
$\boldsymbol{b_{1,1}}$	0.8422***	0.9809***	0.9177***	0.9364***	0.9388***	0.9391***	0.9820***	0.9793***
$\boldsymbol{b_{1,2}}$	-0.0928***	-0.0054***	-0.0018**	-0.0171***	-0.0117***	-0.0273***	-0.0518***	-0.0162***
$\boldsymbol{b_{1,3}}$	-0.1026***	-0.0094***	-0.0012	0.0368***	-0.0245***	-0.0601***	0.0380***	-0.0172***
$\boldsymbol{b_{2,1}}$	0.0218***	0.0439	-0.0431*	-0.0007	0.0662***	-0.0180***	0.0311***	-0.0012***
$\boldsymbol{b_{2,2}}$	0.9518***	0.8935***	0.9459***	0.9838***	0.9716***	0.9055***	0.9006***	0.9723***
$\boldsymbol{b_{2,3}}$	0.0074***	0.1531***	0.0003	-0.0513***	0.0038**	0.0249***	0.0524***	0.0055***
$\boldsymbol{b_{3,1}}$	0.0775***	0.0121**	0.0321***	0.0632***	-0.0668***	-0.0903***	0.0226***	0.0086***
$\boldsymbol{b_{3,2}}$	0.0439***	-0.0299***	-0.0016	0.0529***	0.0307***	-0.2620***	-0.0471***	-0.0152***
$\boldsymbol{b_{3,3}}$	0.9890***	0.9963***	0.9456***	0.9452***	0.9813***	0.9297***	0.9999***	0.9616***

*Notes. *, ** and *** denote the level of significance of each term*

Table 4.21b BEKK Model Results (continued)

Variance Term	**10plus**	**1-10 years**	**1-3 years**	**5-10 years**	**European**	**High Yield**	**Investment**
$\boldsymbol{a_{1,1}}$	0.0414*	0.0100*	0.0627***	0.2384***	0.0558	0.0187	-0.0234***
$\boldsymbol{a_{1,2}}$	0.0235***	-0.0697***	0.1494***	-0.0014	0.0670	0.0831	-0.1871***
$\boldsymbol{a_{1,3}}$	-0.0214***	0.0778***	0.0132	0.1543***	0.1206	-0.0226	0.2505***
$\boldsymbol{a_{2,1}}$	-0.0422	0.0540***	-0.0589	0.1308***	-0.0330	0.0290	0.0747***
$\boldsymbol{a_{2,2}}$	-0.0110	0.0594***	0.0226	0.1121***	-0.0701	-0.0697	-0.0367***
$\boldsymbol{a_{2,3}}$	-0.0163	0.0453**	0.0582	-0.0750***	-0.0539	-0.0212	-0.1801***
$\boldsymbol{a_{3,1}}$	0.0634***	0.2285***	0.0545	-0.1240***	-0.1463***	0.1003*	-0.0752***
$\boldsymbol{a_{3,2}}$	0.1528***	0.0839***	-0.1244	-0.0094***	-0.1264***	0.0883	-0.0408***
$\boldsymbol{a_{3,3}}$	-0.0128***	-0.0413***	-0.0506	0.0126**	0.0079	0.0301	-0.1111***
$\boldsymbol{b_{1,1}}$	0.9286***	0.8667***	0.8840***	0.9720***	0.8799***	1.0000***	0.9518***
$\boldsymbol{b_{1,2}}$	-0.0380***	-0.0360***	-0.0688***	0.0153***	-0.0781***	-0.1054***	0.0513***
$\boldsymbol{b_{1,3}}$	-0.0268***	-0.0854***	0.0166***	0.1248***	-0.0554	-0.0052**	-0.0493***
$\boldsymbol{b_{2,1}}$	0.0216***	-0.0060	0.0455**	-0.2304***	0.0460***	0.0284***	0.0710***
$\boldsymbol{b_{2,2}}$	0.9872***	0.9824***	0.9999***	0.9679***	0.9999***	0.9211***	0.9534***
$\boldsymbol{b_{2,3}}$	0.0173***	0.0693***	-0.0018	0.0115***	0.0415	-0.0032**	-0.0593***
$\boldsymbol{b_{3,1}}$	0.0224***	0.1099***	-0.1093***	0.0179***	0.0801***	-0.0098***	0.1393***
$\boldsymbol{b_{3,2}}$	0.0072***	0.0180***	-0.0756***	0.0023***	0.0554***	-0.0305***	-0.0496***
$\boldsymbol{b_{3,3}}$	0.9878***	0.9996***	0.9848***	0.9672***	0.9309***	0.9632***	0.9702***

*Notes. *, ** and *** denote the level of significance of each term*

4.4.2 Multivariate Results

BEKK

Having found results suggesting that gilt volatility was the strongest effected by QE of all the asset types, this chapter will now discuss the results from the full BEKK estimation, followed by a comparison from the DCC model. These multivariate results presenting evidence on how these QE effects spill-over from gilt to bond and equity volatility. Table 4.21 above shows the conditional variance coefficients, for example element a_{12} in the second column represents the effect of the FTSE100's innovations on GB0033280339's volatility. *, ** and *** show the significance levels of Wald tests at 10, 5 and 1 percent levels respectively. For the purposes of this chapter, the most interesting elements of the above table are a_{21} and b_{21}, as well as a_{31} and b_{31} as these show the volatility spill-over effects from both individual gilt and the gilt index respectively onto the assets denoted in the first row of the table. Of secondary interest is the elements a_{23} and b_{23} which demonstrate the effect of the individual gilts volatility upon the larger index. As can be seen, most of these terms are found to be significant to at least the 5% level, however element a_{21} is found to be insignificantly different to zero for all but three of the assets. In all but two of the models, the effect of innovations from the individual gilt to the index is also insignificant suggesting negligible ARCH spill-over effects. However almost all of the equivalent GARCH spill-over effects are significant to the 1% level and Wald tests with the restriction that $a_{21} = b_{21} = 0$ and $a_{23} = b_{23} = 0$ reject the null hypothesis at the 5% level, suggesting there is overall a spill-over effect from the gilt to the other assets over the entire sample period. The a elements denoting the spill-over effect from the gilt index to the other assets are found to be insignificant in five out of eight cases, with all of the equity indexes not exhibiting a spill-over effect. Once again, the GARCH spill-over, element b_{31} in this case, is significant however and the overall results of Wald tests found the cumulative effect of both terms to be significantly different from zero in all cases.

The results of the Bloomberg bonds, found in table 4.21b largely reflect those found for the other equities and corporate bonds. These results have been compiled separately because the sample size is different, with data on the Bloomberg assets only being available from January 2010. Once again, the a_{21} and a_{23} parameters are found to be insignificant for most of the bonds, further suggesting that individual gilt shocks had little effect on the other assets own variances. Volatility spill-overs from both the individual gilt and the index seem to have occurred however, as both the b_{21} and b_{31} parameters are found to be significant, with most of the coefficients having a positive sign, suggesting that gilt volatility increased the conditional variance of Bloomberg bonds over the entire sample period

Overall these results suggest that over the entirety of the sample there were significant volatility spill-over effects from UK gilts and gilt indexes towards corporate bonds and equities. The shock elements i.e. the elements in the **A** matrix, appear to be much weaker and less significant, suggesting that shocks to gilts had smaller spill-over effects than changes in their respective volatilities. Given that the results of the univariate equations show that gilts reacted the strongest to the QE dummies, with most of the gilts seeing reduced volatility on days before announcements and auctions, these QE effects may well have had significant spill-over effects onto equities and corporate bonds through the volatility linkages that are exhibited in the multivariate BEKK results.

However, while these significant relationships may hold over the sample in its entirety, this chapter conducts a sub-sample analysis to determine whether during the two major QE periods, QE1 and QE2, these significant spill-over effects still held. Using the start and end dates of the QE periods, the two samples were estimated using the same BEKK specification. As can be seen by tables 4.22 the results of the QE1 and QE2 periods largely reflect those found over the entire sample. For equities however, both QE periods exhibited much weaker spill-over effects, with the FTSE100, 250 and ALLSHARE showing insignificant spill-overs during QE1, and the FTSE100, 350 and ALLSHARE index showing insignificant spill-overs during QE2. Corporate bonds show results consistent with the full sample estimation, with the exception of the SPDR Barclays and Barclays Sterling indexes. The implication of these results is that the spill-over effects, while still significant for corporate bonds, appears to be much weaker during the period of ongoing QE auctions.

Table 4.22a BEKK Wald Test Results

Test Specification	FTSE100	FTSE250	FTSE350	FTSEALLSHARE	CFBentley	iShares	JPMorgan	SPDR	Barclays Sterling
$a_{2,1}=b_{2,1}=0$	0.0000	0.2881	0.0008	0.3470	0.0000	0.0000	0.0000	0.0000	N/a
$a_{3,1}=b_{3,1}=0$	0.0000	0.0376	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	N/a
$a_{2,3}=b_{2,3}=0$	0.0000	0.0000	0.4041	0.0000	0.0000	0.0000	0.0000	0.0000	N/a
QE1	**FTSE100**	**FTSE250**	**FTSE350**	**FTSEALLSHARE**	**CFBentley**	**iShares**	**JPMorgan**	**SPDR**	**Barclays Sterling**
$a_{2,1}=b_{2,1}=0$	0.0000	0.7489	0.0000	0.9043	0.0000	0.0000	0.0000	0.9678	0.0000
$a_{3,1}=b_{3,1}=0$	0.3267	0.8620	0.0000	0.6943	0.0000	0.0137	0.0000	0.9891	0.0000
$a_{2,3}=b_{2,3}=0$	0.0000	0.4649	0.0921	0.9923	0.0000	0.0000	0.0000	0.9475	0.0000
QE2	**FTSE100**	**FTSE250**	**FTSE350**	**FTSEALLSHARE**	**CFBentley**	**iShares**	**JPMorgan**	**SPDR**	**Barclays Sterling**
$a_{2,1}=b_{2,1}=0$	0.2370	0.0000	0.9160	0.8466	0.0489	0.0000	0.0000	0.9892	0.9990
$a_{3,1}=b_{3,1}=0$	0.9158	0.0000	0.7138	0.0446	0.0000	0.0000	0.0000	0.9966	0.9997
$a_{2,3}=b_{2,3}=0$	0.0000	0.0000	0.9171	0.0575	0.0000	0.0000	0.0000	0.7947	0.9920

Table 4.22b BEKK Wald Test Results (continued)

Test Specification	10plus	1-10 years	1-3 years	5-10 years	European	High Yield	Investment
$a_{2,1}=b_{2,1}=0$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$a_{3,1}=b_{3,1}=0$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$a_{2,3}=b_{2,3}=0$	0.0000	0.0000	0.0171	0.0032	0.0003	0.0000	0.0000
QE2	**10plus**	**1-10 years**	**1-3 years**	**5-10 years**	**European**	**High Yield**	**Investment**
$a_{2,1}=b_{2,1}=0$	0.0021	0.0000	0.0000	0.8656	0.0000	0.0000	1.0000
$a_{3,1}=b_{3,1}=0$	0.0000	0.0000	0.0000	0.1323	0.0000	0.4421	1.0000
$a_{2,3}=b_{2,3}=0$	0.0006	0.0000	0.0000	0.9987	0.0000	0.0000	1.0000

DCC Results

Table 4.23 shows the estimation results from the DCC model. Elements with sub-script 1 denote the asset labelled in the first row of the tables, while those with sub-scripts 2 and 3 show the results of the gilt and gilt index respectively. R_{12}, R_{13} and R_{23} respectively refer to the constant correlation coefficient between the three assets, while a and b are adjustment coefficients. As expected, we can see that the significance of the α_i and β_i are for the most part the same as those found in the results of the univariate specifications. This is no surprise given that the DCC models estimate these terms in the same univariate specification. As in most cases these values sum closely to 1, we can see that there is high persistence in the conditional variances. In all but two cases in the first table we can see that the correlation between the asset in question and the gilt is significantly different from zero, as denoted by the *, ** and *** in the same manner as earlier sections. All of the equity indexes exhibit a negative correlation with both the individual gilt and the gilt indexes, with periods of high volatility for the gilts corresponding with low volatility for equities. This result matches well with the findings in the univariate analysis, where it was found that gilts tended to have significant negative volatility reactions to QE announcements, while equities responded with weak and positive variance responses. Overall the results of the DCC specification corroborate with the BEKK model in finding strong spill-overs between gilt variance and equity variance.

Corporate bonds shown in table 4.23 exhibited significant positive correlations of between 35 and 80 percent, providing evidence that there was significant spill-over in volatility from gilts to bonds over the sample period. The correlation between the gilt index and the corporate bonds is found to be significant in seven of the models, however significant correlation between the corporate bonds and the individual gilt is only found in four of the twelve cases, wherein all but one of the Bloomberg indexes found the correlation to insignificantly different to zero. A possible explanation for this weak correlation between the bonds and the individual gilt is the pull-to-par effects GB0033280339 experienced towards the end of the sample as it approached maturity. As the gilt approached redemption, its pricing and therefore for its volatility of returns may have become more disconnected from the returns of other bonds and equities and more correlated with its underlying fundamentals. This may offer an explanation as to why the insignificance is particularly apparent for the Bloomberg bonds, as this sample begins only in 2010 rather than 2007. Further evidence can be seen in figure 4.1 where the conditional correlation between the gilt and the gilt index, equities and corporate bonds all begins to move towards zero after around 2013. A sub-sample analysis ending in 2013 showed that the correlation between the individual gilt and the other assets was much more significant when compared to the entire sample.

As a and b are significant and sum to almost 1, this presents strong evidence that the correlation between these asset variances was not constant over time. This chapter therefore looks at the conditional correlations plotted over time to discuss spill-over effects and possible connections to QE. Figures 4.1 through 4.33 show these correlations, with the vertical lines representing the beginning and ends of distinct QE periods. The orange and yellow lines denote the start and end of QE1 respectively, while the purple, green, blue and red represent the QE2 and QE3 periods in the same manner. The first figure shows the conditional correlation between the asset and the individual gilt GB0033280339, while the second figure shows the correlations between the asset and the gilt index. As the correlations between the gilt and gilt index are roughly of the same nature in each model, only one figure, figure 4.3 shows the correlation between the individual gilt and the index it is part of. As we can see, the correlation between the gilt and the index are largely stable over time, with decreases in the correlation coefficient during the QE1 and QE2 periods and a significant decrease in correlation towards the end of the sample.

For the equities, the shape and nature of the correlations are largely similar, and so it is easier to discuss them all collectively. Figures 4.1-9 show that the start of the QE1 period is characterised by a strengthening of correlation between the gilt variance and the equity indexes, which then reverts over the course of the QE1 period. This lends some evidence that the initial QE purchases of the gilt had strong spill-over effects, which became less significant over the following months. This behaviour also exists in the correlation between the equities and the gilt index, suggesting that it was not just the individual gilt GB0033280339 which had a strengthening spill-over effect at the start of QE1. For the most part however during QE1 and QE2 periods the correlation gets weaker between the equities and both the individual gilt and gilt indexes. This is especially apparent during QE2, where the correlation drops from around -0.6 to -0.25. When compared to the decrease in correlation between the individual gilt and the gilt index, during QE1 and QE2 there was weaker correlations in general for both gilts and equities.

For corporate bonds the conditional correlations are a lot less uniform in nature. Figures 4.10-19 show that the QE1 period saw an initial reduction in the correlation between most of the bond indices and the both the individual gilt and the index, followed by an upwards trend over the rest of the QE1 period to close to its original level. Intuitively, the onset of QE1 saw weaker correlation between the gilts and these bonds, which steadily increased in the following months, a result which is in line with the conditional correlations of the equities, albeit without the initial strengthening of correlations which occurred for equities at the start of QE1. However, while the conditional correlations of equities continued to decrease over the QE1 period, for most of the corporate bonds the trends tend upwards again, strengthening over the period.

The QE2 period also caused non-uniform reactions from the bonds, however it seems the effects were less pronounced when compared to QE1. For most of the bonds, the conditional correlations for both gilt and the index seem to change relatively little over the QE2 period, however for the Bloomberg assets five of the seven conditional correlation plots show drops in correlation in the weeks before QE2 began, which is then restored over QE2 and QE3. This may suggest that this QE period restored more normal market function after a negative shock to correlation. For the Barclays Sterling corporate bond index, the results are different as Fig. 4.19 shows. The correlation between both the individual gilt and the index drop dramatically from the onset of QE1 from around 0.7 to around 0 by the end of QE1. After this point the correlation does not recover, and Barclays Sterling shows little relationship to either the gilt or the gilt index after this point. The CF Bentley fund also exhibits little correlation with either the gilt or the gilt index, and this lack of correlation does not seem to be dramatically altered during any of the QE periods. This chapter can offer little explanation for this sharp decline in correlation, as the Barclays sterling index especially contains many of the same individual corporate bonds as other indexes analysed in this chapter, however the behaviour of its conditional correlation with the gilt index and the individual gilt is unique.

Taken in summary, the results suggest once more that equities had relatively weak and negative volatility links to UK gilts during the periods of QE purchases, supporting the findings of the univariate analysis where gilt volatility was swiftly reduced over QE1, while equities showed significant volatility for a much longer time. Corporate bond volatility shows a much stronger and consistent correlation with gilt volatility; however, it appears once again to be at its weakest during QE periods. Apart from this, there are no patterns common for all of the corporate bond indexes, suggesting that the transferral of volatility to corporate bonds had mixed effects.

Table 4.23a DCC Results

Variance Term	**FTSE100**	**FTSE250**	**FTSE350**	**FTSE ALLSHARE**	**CF Bentley**	**iShares**	**JP Morgan**	**SPDR**	**Barclays Sterling**
$\boldsymbol{Constant_1}$	0.0186**	0.0164**	0.0182**	0.0178**	0.0042***	0.0031*	0.0043*	0.0069*	0.0002
$\boldsymbol{\alpha_{1,1}}$	0.1049***	0.0816***	0.1016***	0.1016***	0.1195***	0.0499***	0.1065***	0.0845***	0.0129***
$\boldsymbol{\beta_{1,1}}$	0.8866***	0.9076***	0.8890***	0.8890***	0.8676***	0.9448***	0.8569***	0.8555***	0.9841***
$\boldsymbol{Constant_2}$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\boldsymbol{\alpha_{2,2}}$	0.0308***	0.0310***	0.0308***	0.0308***	0.0299***	0.0317***	0.0308***	0.0315***	0.0329***
$\boldsymbol{\beta_{2,2}}$	0.9676***	0.9674***	0.9677***	0.9676***	0.9685***	0.9668***	0.9676***	0.9670***	0.9656***
$\boldsymbol{Constant_3}$	0.0026	0.0026	0.0026	0.0026	0.0026	0.0028	0.0027	0.0027	0.0026
$\boldsymbol{\alpha_{3,3}}$	0.0408***	0.0410***	0.0408***	0.0408***	0.0399***	0.0427***	0.0416***	0.0417***	0.0405***
$\boldsymbol{\beta_{3,3}}$	0.9459***	0.9455***	0.9459***	0.9459***	0.9469***	0.9431***	0.9445***	0.9443***	0.9462***
$\boldsymbol{R_{12}}$	-0.3188***	-0.2934***	-0.3198***	-0.3200***	0.0361	0.6687***	0.3749***	0.7551***	0.0483
$\boldsymbol{R_{13}}$	-0.3015***	-0.2949***	-0.3038***	-0.3038***	0.0491	0.7049***	0.4127***	0.8214***	0.0082
$\boldsymbol{R_{23}}$	0.7371***	0.7331***	0.7370***	0.7369***	0.7077***	0.6149***	0.7306***	0.7563***	0.6772***
$\boldsymbol{a_1}$	0.0279**	0.0321***	0.0288**	0.0287**	0.0140	0.0127	0.0166	0.0643***	0.0137**
$\boldsymbol{b_1}$	0.9611***	0.9554***	0.9599***	0.9600***	0.9814***	0.9847***	0.9770***	0.9022***	0.9825***

*Notes. *, ** and *** denote the level of significance of each term*

Table 4.23b DCC Results (continued)

Variance Term	**High-Yield**	**Investment**	**European**	**10 plus**	**5-10 years**	**1-10 years**	**1-3 years**
$Constant_1$	0.0072	0.0088	0.0066*	0.0115*	0.0178	0.0135	0.0013
$\alpha_{1,1}$	0.1524***	0.0422***	0.0578***	0.0457***	0.0493**	0.0535**	0.0499***
$\beta_{1,1}$	0.8474***	0.9418***	0.8874***	0.9409***	0.8960***	0.8875***	0.9383***
$Constant_2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\alpha_{2,2}$	0.0254	0.0267	0.0269	0.0266	0.0267	0.0269	0.0266
$\beta_{2,2}$	0.9744***	0.9731***	0.9729**	0.9732***	0.9731***	0.9729***	0.9732***
$Constant_3$	0.0001	0.0001	0.0001	0.0001*	0.0001	0.0001	0.0001
$\alpha_{3,3}$	0.0408**	0.0423***	0.0413***	0.0433***	0.0404***	0.0405***	0.0419***
$\beta_{3,3}$	0.9511***	0.9485***	0.9504***	0.9468***	0.9513***	0.9514***	0.9496***
R_{12}	0.1839	0.3933	0.7319	-0.7207**	0.6800	0.7152*	0.6536
R_{13}	0.1595	0.8755***	0.6587	0.9073***	0.8015***	0.7834***	0.5346
R_{23}	0.5207	0.3134	0.5181	-0.8654**	0.5455	0.5528	0.4973
a_1	0.0213	0.0072	0.0332	0.0049***	0.0219**	0.0269***	0.0263*
b_1	0.9707***	0.9914***	0.9552***	0.9947***	0.9706***	0.9632***	0.9647***

*Notes. *, ** and *** denote the level of significance of each term*

Figure 4.1, 4.2 and 4.3 FTSE100 Correlation Time Plots

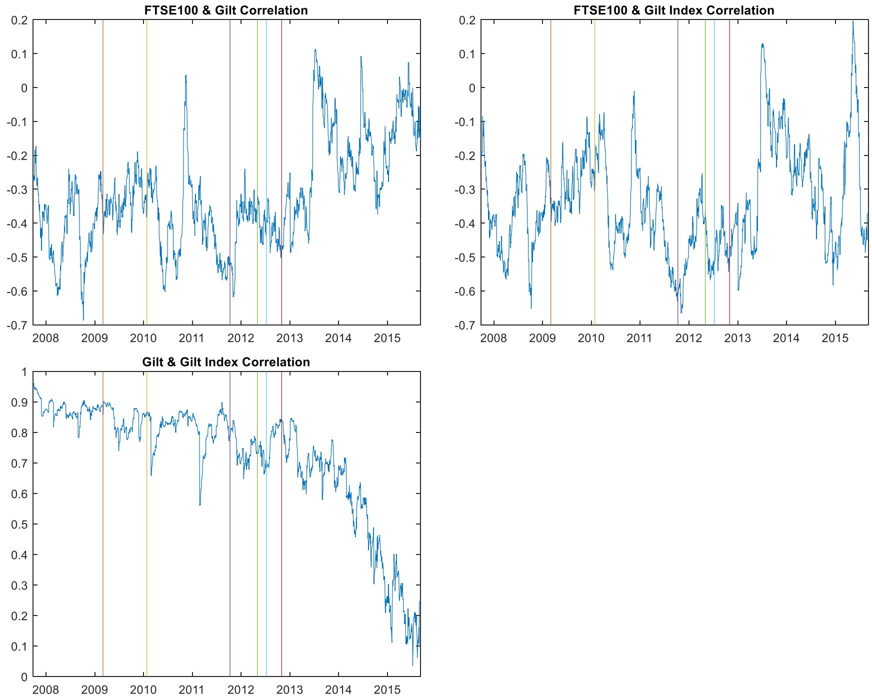


Figure 4.4 and 4.5 FTSE250 Correlation Time Plots

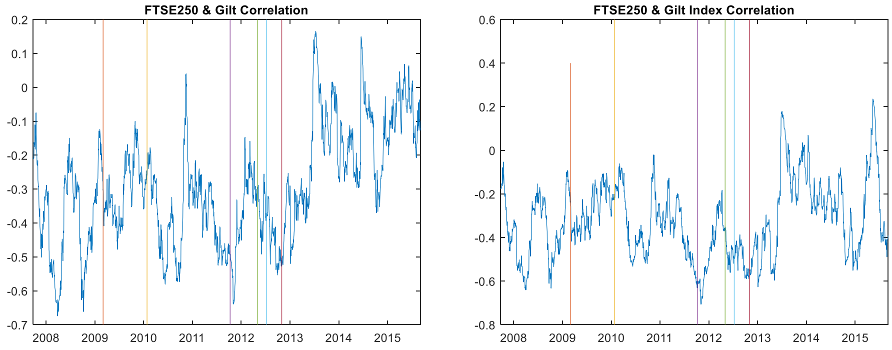


Figure 4.6 and 4.7 FTSE350 Correlation Time Plots

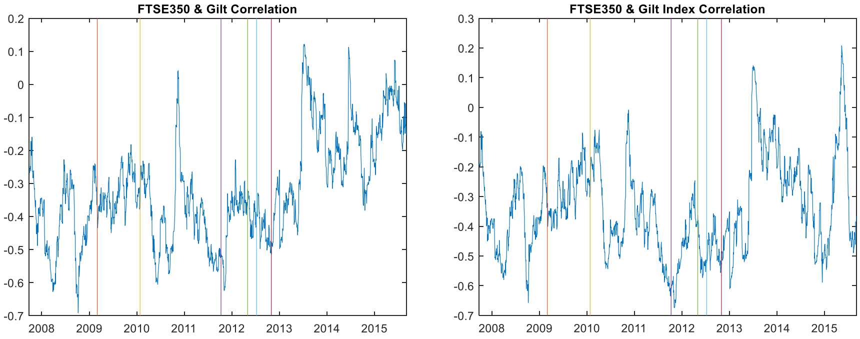


Figure 4.8 and 4.9 FTSEALLSHARE Correlation Time Plots

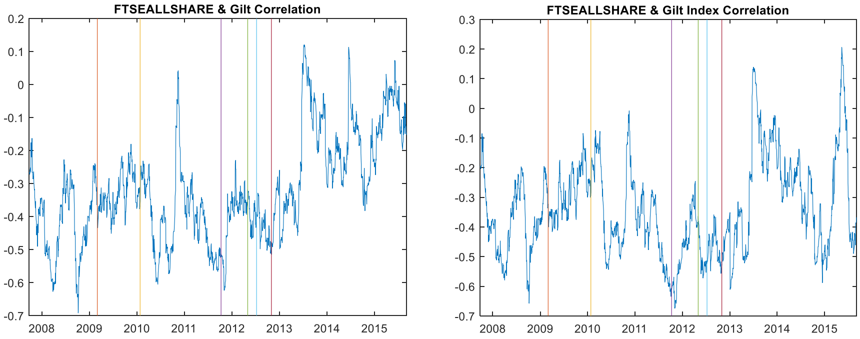


Figure 4.10 and 4.11 SPDR Barclays Correlation Time Plots

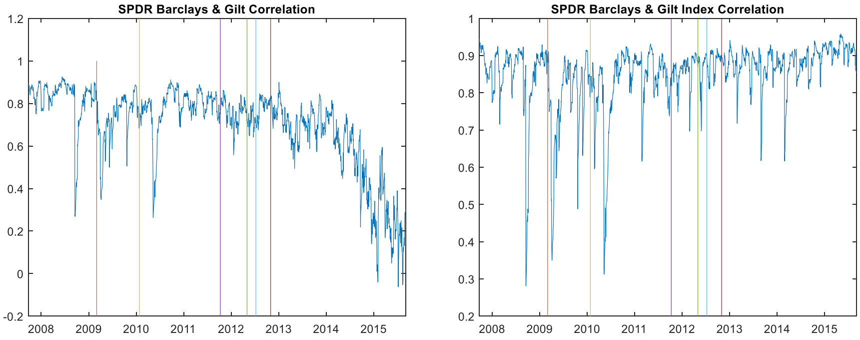


Figure 4.12 and 4.13 JP Morgan Correlation Time Plots

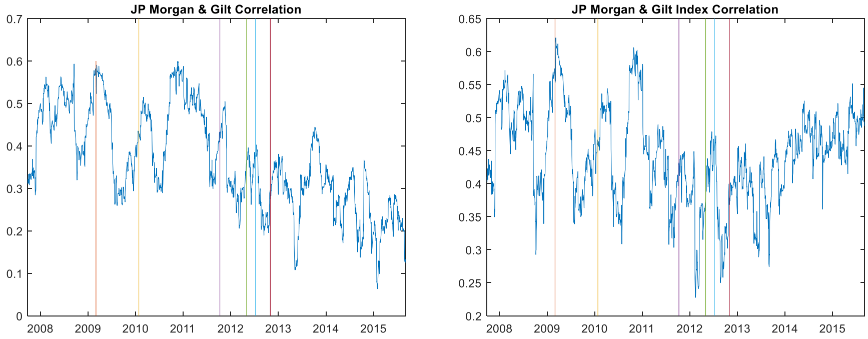


Figure 4.14 and 4.15 iShares Correlation Time Plots

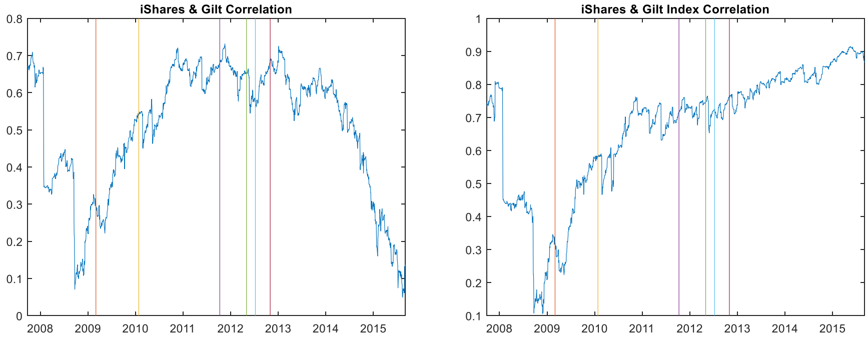


Figure 4.16 and 4.17 CF Bentley Correlation Time Plots

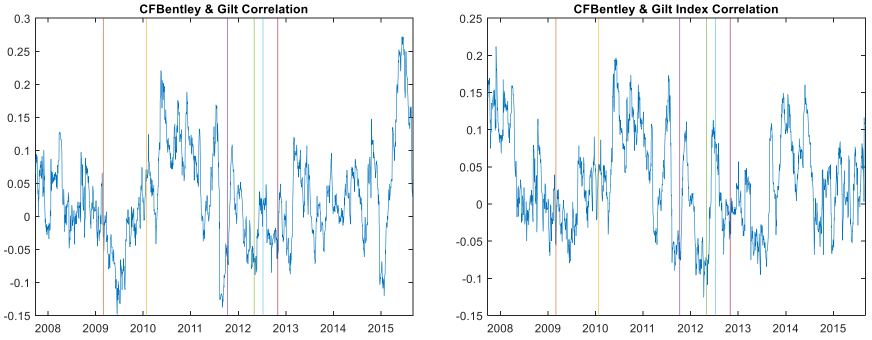


Figure 4.18 and 4.19 Barclays Sterling Correlation Time Plots

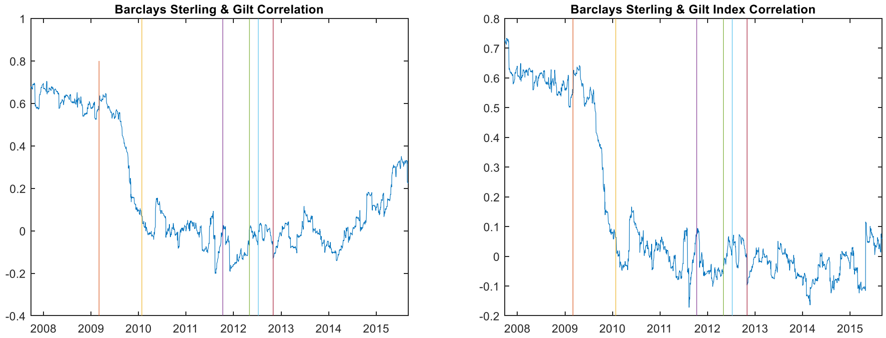


Figure 4.20 and 4.21 Bloomberg High Yield Correlation Time Plots

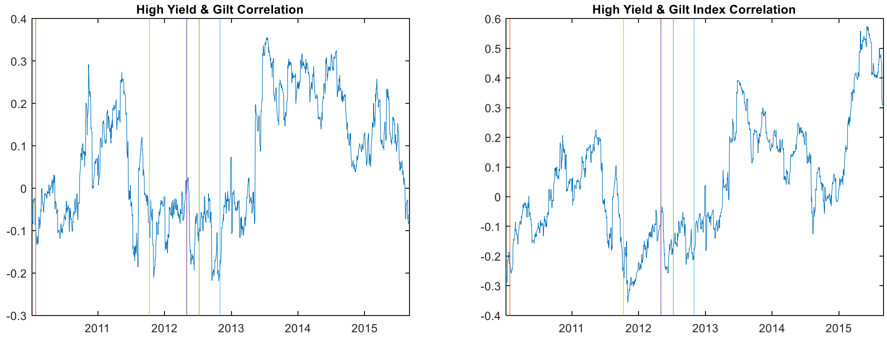


Figure 4.22 and 4.231 Bloomberg Investment Correlation Time Plots

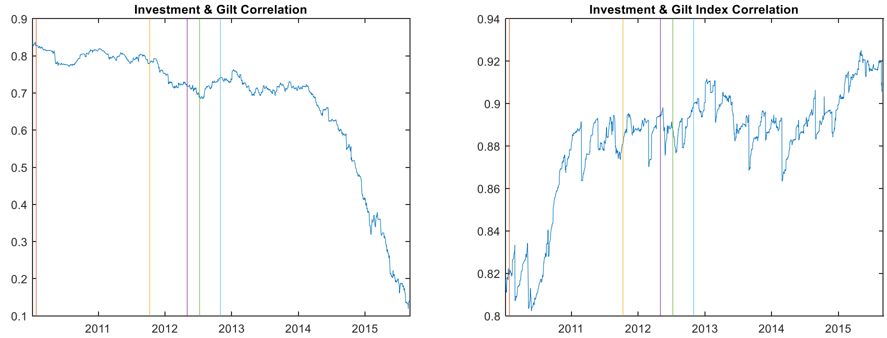


Figure 4.24 and 4.25 Bloomberg European Correlation Time Plots

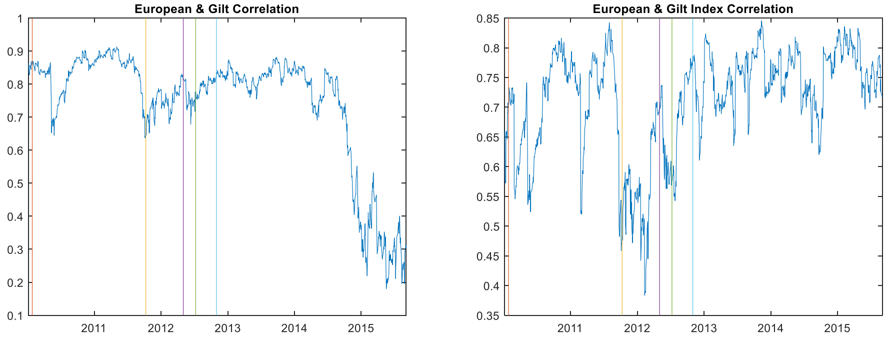


Figure 4.26 and 4.27 Bloomberg 5-10 years Correlation Time Plots

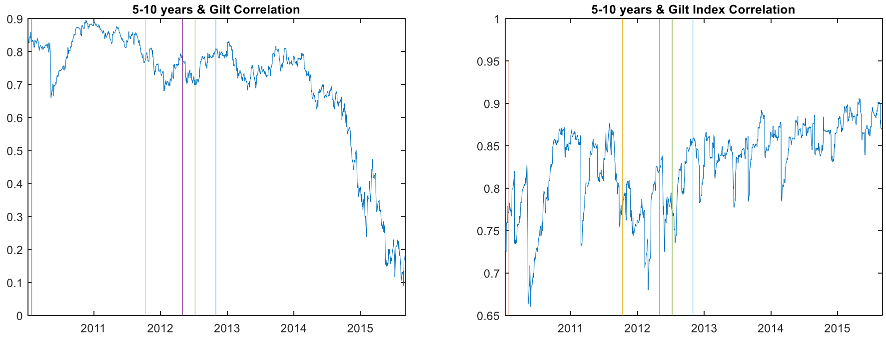


Figure 4.28 and 4.292 Bloomberg 1-10 years Correlation Time Plots

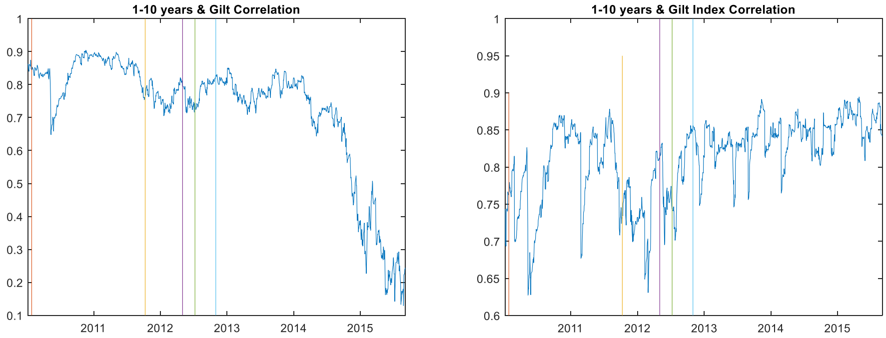


Figure 4.30 and 4.31 Bloomberg 1-3 years Correlation Time Plots

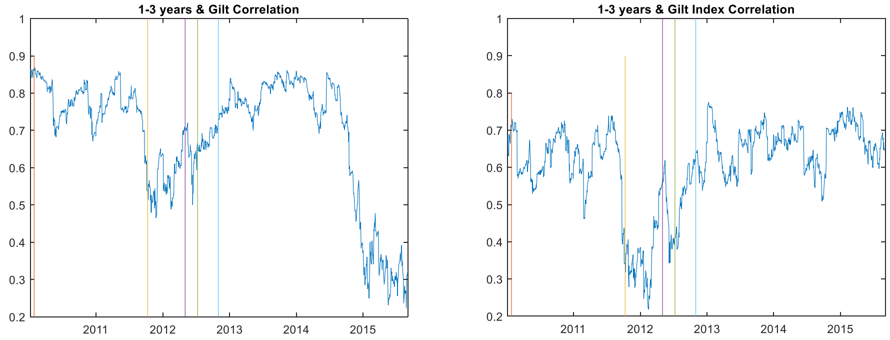
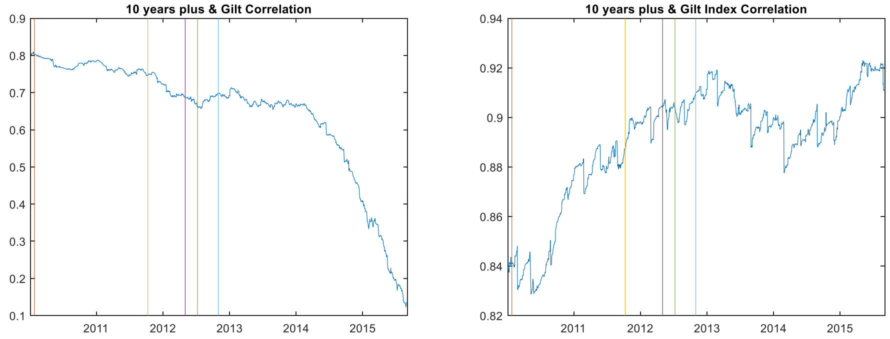


Figure 4.32 and 4.33 Bloomberg 10+ years Correlation Time Plots



4.4.3 Financial Stress measures and QE

The results so far suggest a limited impact of QE on financial asset volatility, focused mainly on UK gilts, weaker effects on corporate bonds, and unsubstantial effects on equities. If asset volatility is interpreted as an indication of market risk, stress and uncertainty, many of the results suggest that QE did not universally restore individual market's function to pre-crisis levels. As discussed before, this chapter examines a variety of alternative measures of financial stress and risk to complement the findings of the previous sections. This chapter uses individual indicators as well as an overall stress index to provide these alternative measures of financial stress. Tables 4.24 and 4.25 show the effects of the same QE dummies on the alternative financial risk/stress measures discussed earlier. The first table displays the results from the mean equation. The values in this table can be interpreted as the effect of the QE events on the level of financial stress as captured by these indicators, compared to their respective sample means. The second table contains the results from the conditional variance equations, with the significant values being interpreted as the QE events causing higher/lower variance than the sample unconditional variance.

Mean Equations

For most of the variables, positive coefficients are interpreted as increased stress, while for the CMAX variables, the FTSE VIX and the Yield curve measure positive values correspond to reduced stress. Looking at the overall FSIs, all three aggregation methods show significant impacts from QE announcement days. Announcements appear to have a negative effect on the level of the FSIs, indicating that market stress was lower on these days. By looking at the individual indicators it can be seen that this effect is driven by the CMAXEFFEX, FTSE100 VIX and the BBB yield spread, all of which show coefficients that indicate reduced stress. The BBB spread also shows reduced stress on days following announcements, suggesting a potentially slower incorporation of information in lower-quality debt markets. The same is true for the UK-US bond spread indicator, where both announcement days and the days following show reduced stress compared to the overall mean stress level. The other individual measures do not show significantly effects from the announcement variables. These results suggest that market perceptions of risk were reduced by QE announcements, especially when considering that the FTSE100 VIX measure is often considered a measure of expected volatility (Hakkio and Keeton, 2009). In addition, the fact that this effect seems to be partly driven by the exchange rate and interest-parity measures suggest that the QE announcement had effects on an international investor outlooks.

Auction days, on the other hand, indicate significantly higher stress for the overall FSI, and many of the individual indicators mentioned above. The result for the yield curve measure is consistent with the mean equation results for the longer-term gilts i.e. that gilt prices were increased on auction days, lowering long-term yields and flattening the yield curve, as shown by the negative coefficient on the yield curve measure. In this case the yield curve measure is here not capturing market stress, but rather the sought-after effects of the asset purchases. Several of the corporate spreads show large risk spreads on auction days, however this again matches with the intended QE effects, so cannot be considered in this case to be capturing financial stress alone. Finally, the LIBOR-gilt spread indicates higher financial stress, but this is again mostly likely driven by the effect of the auctions on the 3-month gilt yield rather than any effect on the LIBOR, as evidenced by the small and insignificant effect on the other LIBOR related measures. The effects of the auctions on the FTSEVIX, however, indicates greater financial stress in terms of the market perceptions of equity risk, where the price of FTSE100 options were significantly higher when auctions were on-going. Given the results of the equity GARCH models in section 4.4.1.1 and 4.4.1.2., where QE auctions and announcements had very little effect on actual equity pricing or volatility, this effect on the FTSEVIX could be interpreted as an effect purely on market-risk perceptions. For both the announcements and auctions, there appears to be no calm-before-the-storm effects on the overall FSIs, as the days prior to announcements and auctions are insignificantly different from the unconditional mean.

None of the QE-period dummies show significant effects on the overall FSI, suggesting that QE periods of asset purchases did little to change the level of financial stress in the UK financial system. Looking at the individual components of the FSI, none of the indicators that capture equity or exchange rate effects show significant results for these periods. For the individual components QE3 appears to have the largest effects, mainly on the corporate risk spread indicators. Corporate risk spreads were significantly smaller during the QE3 purchase period, but not significantly different from their mean levels during the other two intervention periods. The largest effects on the CMAX100, CMAXALL and FTSE100VIX occur during QE1, however none of these are significant at even the 10% level. In addition, the exchange rate measure, CMAXEFFEX was insignificantly different from its mean level during the three QE periods. Two of the LIBOR measures show significantly reduced stress because of the one or more of the QE periods, however these results do not corroborate with one another. Finally, the yield curve measure indicates a widening of the yield curve during the first and third phases of QE, significant to the 10% level. These results match with those found in Steeley & Matyushkin (2015) amongst others, who find that the QE1 phase lowered yields on short and medium-term bonds, widening the yield spread between the 3-month and 10-year gilt yields. The effects on the yield curve and LIBOR indicators are only marginally significant, and not strong enough for the overall FSI to register a significant response. The overall conclusion from the mean equation results is that QE events caused significant temporary impacts on financial stress in UK financial markets, however the periods of QE intervention had little impact on the long-term level of financial stress. These results have negative implications on QE, suggesting that QE did not systematically reduce financial stress over the course of the intervention phases. Peaks and troughs of financial stress appear only to relate to QE events, rather than a systematic process.

Variance Equation

Table 4.24 shows the conditional volatility equation for the individual indicators and the overall FSI. Looking at the overall FSI results, the conditional variance was not significantly different on any of the QE periods, or indeed on most of the QE events. Only the days preceding QE announcements show significantly greater volatility than the standard variance. The only other QE event that shows a result significant at the 5% level is the days following QE auctions, where volatility was lower. While there are several individual indicators that show significant results, there is no clear discernible pattern, meaning that these results are likely to result from idiosyncrasies in the individual indicator data. The overall result is therefore that QE did little to affect the variance of financial stress during the period.

Table 4.24 Financial Stress Indicators Mean Equation

Indicator	**ANN-1**	**ANN**	**ANN+1**	**AUC-1**	**AUC**	**AUC+1**	**QE1**	**QE2**	**QE3**
AAACPSPR	-0.0036**	-0.0009	0.0017	-0.0030**	0.0012	-0.0011	0.0280	0.0036	-0.0435***
AACPSPR	-0.0058***	-0.0005	-0.0008	-0.0040	0.0080***	-0.0002	0.0037	-0.0254	-0.0814***
BBB-AAACPSPR	-0.0016	-0.0034	-0.0010	0.0010	0.0029	0.0011	-0.0074	-0.0462*	-0.0286
BBBCPSPR	-0.0055**	-0.0071**	0.0016	-0.0003	0.0087***	0.0058**	0.0290	-0.0233	-0.0774***
BNKBDSPR	-0.0078*	-0.0035	-0.0036	0.0024	0.0048	0.0002	0.0574**	-0.0388	-0.0110
BETAFTAS	0.0716	-0.0170	0.0150	0.0311	-0.0143	0.0305	0.3570	-0.1640	-1.5480*
CMAX100	-0.2150	0.3370	-0.9470	0.6630	0.2690	-0.1800	-19.7160	-3.4410	8.7650
CMAXALL	-0.3760	0.1020	-1.0410	0.6410	0.2330	-0.0685	-19.4200	-3.5880	7.3640
CMAXEFFEX	0.5630	0.9100**	0.0708	0.0967	-0.0895	0.3670	-3.7210	-0.6600	-1.9570
FTSE100VIX	0.0832	-0.2825***	-0.3074***	0.0301	0.2621***	0.1014	-0.9150	-0.5038	0.3048
CIPUKUS	-0.0003	0.0002	0.0000	0.0001	-0.0001	-0.0001	0.0000	0.0001	0.0001
LIBORBNK	0.0000	0.0001	0.0000	0.0002	0.0001	0.0001	0.0004	-0.0063**	0.0001
LIBORGOVT	-0.0083	0.0058	0.0001	0.0068	0.0149***	-0.0072	-0.0152**	-0.0049	-0.0164**
LIBORTBILL	-0.0002	0.0007	0.0030***	0.0002	0.0002	0.0003	-0.0007	-0.0006	0.0000
UKB-USB	0.0074*	-0.0096*	-0.0106**	-0.0015	-0.0051	0.0006	0.0026	0.0027	0.0032
YLDCURVE10-3	0.0081	-0.0014	0.0038	-0.0060	-0.0130***	0.0056	0.0079*	0.0058	0.0108*
VEFSI	-0.0049	-0.0085*	-0.0049	-0.0004	0.0124***	0.0032	0.0360	-0.0385	-0.0498
PCFSI	-0.0053	-0.0083**	-0.0070**	0.0020	0.0094***	0.0018	-0.0360	-0.0323	-0.0151
CDFFSI	-0.0005	-0.0051**	-0.0005	-0.0027*	0.0010	-0.0011	0.0221	0.0032	0.0027

*Notes. *, ** and *** denote the level of significance of each term. ANN and AUC refer to QE announcement and auctions days, respectively.*

-1 or +1 refer to the days preceding or following auctions or announcements.

Table 4.25 Financial Stress Indicator Variance Equation

Indicator	**ANN-1**	**ANN**	**ANN+1**	**AUC-1**	**AUC**	**AUC+1**	**QE1**	**QE2**	**QE3**
AAACPSPR	-0.2990	0.8770***	-0.2749	0.1809	-0.0459	-0.0201	-0.0297	-0.0455	-0.1424*
AACPSPR	-0.3581*	0.2444	0.6623***	0.0871	0.0126	-0.1081	0.0951*	0.0784	0.0139
BBB-AAACPSPR	0.1835	-0.1606	0.1233	0.0499	-0.0408	-0.0462	0.0579**	0.0590*	0.0173
BBBCPSPR	-0.1702	0.0273	0.3451	-0.0610	0.2569	-0.1801	0.0466	0.0236	0.0038
BNKBDSPR	0.0187	0.5095*	-0.4678**	-0.1288	0.1812	-0.0439	-0.0055	-0.0144	-0.0094
BETAFTAS	0.3814**	-0.3341	-0.0175	0.0049	0.2374	-0.0563	-0.0823*	-0.1212**	-0.0881
CMAX100	0.1019	0.0962	-0.2633	-0.0288	0.1209	-0.0860	0.0384	0.0115	0.0495
CMAXALL	0.0003	0.0005	-0.0008	0.0000	-0.0001	0.0000	0.0002	0.0001	0.0003
CMAXEFFEX	0.5081***	-0.2698	-0.1552	-0.1168	0.2152	-0.1462	0.0212	0.0151	0.0050
FTSE100VIX	-0.2030	0.5773**	-0.2595	-0.3481**	0.5526**	-0.2056	-0.0243	0.0048	-0.0020
CIPUKUS	0.0000	0.0001	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LIBORBANK	-0.6718***	0.6180***	-0.6402***	-0.2036*	0.3922**	-0.2398**	0.0338***	0.0117	0.0219
LIBORGOVT									
LIBORTBILL	-0.7428***	0.6064***	0.1925**	0.2077**	0.0884	-0.2346*	-0.0839***	-0.2096***	-0.1390***
UKB-USB	-0.0149	0.2064	-0.2368	-0.0798	0.1141	-0.0403	0.0022	-0.0031	-0.0033
YLDCURVE10-3	-0.0476	0.2005	-0.1133	-0.2462*	0.2154	0.0314	-0.0073	-0.0061	-0.0072
VEFSI	0.3496*	-0.0952	-0.1993	-0.1849	0.3881*	-0.2121	0.0080	0.0036	-0.0031
PCFSI	-0.0235	0.0937	0.0012	-0.0825	0.3213	-0.3009**	0.0207	0.0277	0.0340
CDFFSI	0.4570***	-0.2183	0.1951	-0.1191	0.1649	0.0129	-0.0355*	-0.0239	-0.0366

*Notes. *, ** and *** denote the level of significance of each term. ANN and AUC refer to QE announcement and auctions days, respectively.*

-1 or +1 refer to the days preceding or following auctions or announcements.

4.5 Conclusions

This chapter discusses the volatility of gilts, bond and equities during the timeframe of the UK financial crisis and the Bank of England's Quantitative Easing policy. It also examines alternative measures of financial stress, risk and uncertainty and analyses QE's impact upon these indicators. Using both univariate and multivariate GARCH analyses, this chapter examines these impacts, as well as observing the relationships between the different assets themselves. The purpose of this is to see which assets were the most strongly affected by the Bank of England's monetary policy strategy, and whether the effects were as widespread as anticipated by the theory surrounding Quantitative Easing, the ultimate objective being to ascertain the implication of QE on the UK's financial markets and thenceforth onto the wider economy. As stated before, asset volatility plays a key role in financial regulation, bank lending behaviour and derivatives pricing, meaning that any impact from QE will likely have a widespread economic effect, both over the short and long-term.

Using univariate GARCH modelling, this chapter finds there is indeed a strong positive reaction from QE gilt auctions, albeit only on UK gilts, whereas sterling-based corporate bond indexes had mixed reactions and UK equities were almost entirely unaffected. For asset volatility, which was the main emphasis of this chapter, this chapter finds that days preceding QE announcements and auctions significantly reduced gilt volatility, however for equities volatility spiked on auction days while for bonds the effects were mixed and weak. The overall conclusion to draw from these results was that QE announcements and auctions had only a very narrow effect on UK financial markets, with only gilt markets being consistently and systematically affected.

Finding that only gilts were shown to have been significantly affected by QE, this chapter examines the volatility relationships between gilts, equities and bonds in order to determine whether QE could have had an effect on these assets through a consistent and significant spill-over between these asset types. This chapter's results point towards significant spill-over effects over the entire sample, however the results of the sub-sample analyses focussing on the QE1 and QE2 periods were far less consistent. For equities in particular these results show insignificant variance relationships between gilts and the FTSE indices during both QE1 and QE2. While corporate bonds in general exhibited stronger spill-overs, these effects were again less significant during QE2 in particular.

Finally, this chapter examines alternative measures of financial stress, risk and uncertainty using indicators that are related to equity, bond and gilt markets. Using a Financial stress index composed of these indicators, this chapter establishes that QE events had significant impacts on financial stress, however the evidence suggests that the effects of the announcements and auctions were contradictory in effect. This chapter also finds that over the longer-term QE intervention appears to not have systematically reduced financial stress in any significant manner.

The overall conclusions of this chapter are that QE had its strongest effects on the volatility of gilt markets, a result that is reflected frequently in the literature. However, for bonds and equities the results are far less convincing, with bonds showing erratic and inconsistent reactions to QE announcements and auctions while exhibiting weakened variance relationships during QE periods. For equities the conclusion of this chapter is that QE did not significantly reduce return volatility, and there may be have instead caused volatility in equity markets to increase by purchasing UK gilts. The lack of effect on volatility, coupled with the limited effect on price levels, is fairly damning of QE. For financial markets a successful QE policy would have decreased volatility across a range of assets and reduced financial stress in general, allowing more relaxed trading conditions and improving lending channels. The negative conclusions of this chapter have strong implications for the holders of equities in particular, especially banks, as it suggests that banks would be required to hold ever-greater amounts in reserve due the increased volatility impact of QE. At the very least, QE cannot be considered an overwhelming success in improving financial conditions and may in fact have contributed to the constrained bank-lending behaviour that has been recorded since the financial crisis (Ivashina & Scharfstein, 2010), (De Haas & Van Horen, 2012). The wider economy is also likely to have been negatively affected by this failure to calm financial markets, with the limited bank-lending stifling real investment.

However, it is important not to over-estimate the impact of these results. The analysis in this chapter conducts does not prove that QE had no effect on financial market conditions, only that the effect was not immediately captured on auction days and announcements, and that any long-term effects took place beyond the three phases of QE. Furthermore, this chapters modelling of volatility spill-overs is simplistic by necessity, and future analysis could provide stronger conclusions on how gilt volatility reductions translated into other financial markets. Further research could also explore the negative relationship between equities and gilt volatilities to determine whether it is a UK specific effect or indeed connected to Quantitative Easing rather than conventional monetary policy intervention. It could also be useful in future research to analyse whether weakening variance relationships were a result of QE, or merely a symptom of the financial market duress that QE was attempting to remedy, a question that is unfortunately beyond the scope of this chapter. As it stands, the conclusions of this chapter are that QE unfortunately did not consistently reduce asset volatility, and so did not substantially improve financial conditions in terms of market risk, bank lending and through these, economic growth.

Chapter.5

Financial Stress and Forecasting UK Equity Risk Premiums

5.1 Introduction

The issue of US equity premium prediction using both economic and technical indicators is the subject of extensive study and has been since the early 1970s. Recent studies have found that for the US stock predictability has not existed during the last 30 years, and that the ability of investors to exploit information from predictive economic variables has been almost entirely crowded-out. It has also been established by articles like Guidolin & Timmermann's (2005) and Lee & Kim (1993) that financial and economic uncertainty have a significant impact on market efficiency and therefore the predictability of equity returns. With the upheaval of the 2008 financial crisis, an examination of the impact of financial and economic stress on return prediction is particularly relevant, especially in connection to the unconventional monetary policy strategies used by the FED, ECB and BoE. This chapter asks and answers the question whether for the UK, financial and economic cycles have a significant impact on stock predictability and thereby UK market efficiency, examining in addition whether UK equity premiums follow the same patterns and characteristics as their US counterparts. The focus of the study is the examination of spreads, valuation ratios and other economic variables and if they can be used to predict the equity premium on the two largest UK equity indexes. Following the recent addition to US literature by Neely et al (2014), which finds that equity premiums can be predicted as successfully with technical trading rules as economic variables, this chapter also analyses technical indicators in UK financial markets.

This chapter produces results that are commensurate with much of the recent literature on US equity premium forecasting using economic variables, however results are found that are at odds with the favourable use of technical indicators exhibited in Neely et al. (2014). For economic variables this chapter find that only a select few predictors can provide consistent forecasting ability both in and out of sample, these variables being the most frequently cited in the US literature. For technical indicators the majority of trend-following trading rules cannot predict equity premium, with only the indicators that utilise both trade volumes and pricing trends having any success, and even these results are borderline economically insignificant. Furthermore, unlike Neely et al (2014) this chapter finds that the combination of the information from these indicators into principal components does not consistently yield superior predictive performance, with the in and out-of-sample performance resting heavily on the model selection used in the principal component procedure. There is a strong degree in variability in the performance of forecasting variables over time, with the variability having strong links to both the business and financial cycles. This chapter finds that there is substantial component of predictability related to the business cycle, however that the business cycle alone is insufficient in explaining the time-varying nature of equity prediction. This chapter finds results showing that periods of high financial stress, such as the recent 2007-2009 financial crisis, significantly increase the predictive performance of both types of indicators when compared to periods of relaxed financial circumstances, an effect that is even more pronounced than the results found for the business cycle.

To investigate these predictors individually, this chapter employs the standard predictive regression frameworks, as well as using principal component analysis to incorporate information from all of the indicators combined. Monthly data spanning 1975 to 2017 is used, maximising the sample size to compensate for the relatively short period of data availability for the UK compared to the US. A battery of tests and statistics are used to compare the performance of these predictors against benchmarks popular in the literature, including the use of out-of-sample analysis to ensure robustness.

The remainder of the chapter proceeds as follows. Section 2 describes the existing literature on equity premium predictability, briefly discussing the methods and results used as well as the changing consensus of the literature. Section 3 then discusses the empirical approach and data used in the chapter. Section 4 discusses the empirical findings of both in-sample and out-of-sample predictability, before discussing the use of financial stress indicators to analyse time-varying predictability. Section 5 then offers some concluding remarks opportunities for expansion.

5.2 Literature Review

For the purposes of this chapter, the important elements of this extensive literature are the articles that discuss stock return predictability with regards to financial conditions, policy regimes and the business cycle, as well as stability of prediction over time, and breakpoints in the predictability of returns. The following section of this chapter will therefore summarise these distinct areas relevant to stock return prediction, starting with articles that examine the relationship between financial variables and macroeconomic indicators such as GDP and inflation. Next, the direct issue of the predictability of stock returns, and the significance of individual indicators will be discussed.

The academic study of stock return predictability has been ongoing for over a century, with new methods and innovations in statistical analysis allowing for the revision of initially favourable results on equity premium prediction. The 1970s and 80s saw the publication of several articles cynical of whether stock returns could be predicted at all, with the conventional view being that a simple random walk process was the most effective for the prediction of stock returns. This, some have argued, was because stock markets were subject to the market efficiency elements of the efficient market hypothesis (EMH) in that readily available economic information could not be used systematically for the prediction of excess returns. More recently however, several studies have debated this issue, finding that stock returns could indeed be systematically predicted, and additional theoretical articles have argued that these findings are still consistent with EMH. Once stock return predictability had been established, recent studies have focussed on which variables provide the most explanatory power, and whether these relationships are stable over time and monetary regime changes.

For a substantial period of time stock returns were thought to be best characterised by a simple random-walk process. More recently however, several articles have been produced that find evidence that stock returns can be predicted by other financial variables, macroeconomic indicators, and as will be discussed later in this section, by monetary policy indicators. The most frequently used variables for predicting stock returns include proxies that relate to equity risk premium. Rozeff (1984) for example, uses stock dividend yields as a proxy, while Campbell (1987) use the default premium on bonds as a proxy and Fama & French (1989) use past volatility in stock returns. Industrial output is also used in the aforementioned Pesaran & Timmermann (1995) article, Chen et al (1986) and Balvers et al (1990). In Pesaran & Timmermann (1995) they use a variety of financial indicators including dividend yield, earnings/price ratio, the 1 and 12-month T-bill rates, the inflation rate, growth in narrow money stock and the rate of industrial growth. In all of these cases the growth of industrial output is found to contain predictive power for future stock returns. There are several studies like Fama and French (1989) that link bond market factors and the term structure of interest rates to the predictability of stock returns. Campbell (1987) finds that the risk premia on stock tends to move closely with risk premia of 20-years to maturity bonds, using a model that captures both conditional means and variances. Pesaran and Timmermann (1994), who focus on stock return predictability at varying time horizons, also use a variety of interest rates of different maturities, finding most of them to have strong predictive power for S&P 500 stock return. Technical indicators and market trading rules have also been used to predict the stock return, with varying results. Neely et al (2014) and Baetje and Menkhoff (2016) examine the success of technical indicators in predicting US equity premiums, with Neely et al (2014) finding that technical indicators outperform economic predictors.

In terms of empirical techniques, the majority of earlier studies use linear models. As Granger (1992) comments, during the early seventies the consensus existed that stock returns could not be predicted by the simplest linear models. However, after this time ARIMA models and Vector Autoregressive models (VAR) have been used in several articles to demonstrate stock return predictability, such as Campbell's variance decomposition for stock returns (1990) and Thorbecke (1997). More recently many commentators have discussed how forecasting over long time horizons potentially causes large errors and have pointed out regime changes break down the forecast ability of many predictors. For the forecasting of GDP Giacomini & Rossi (2006) find that there is a breakdown in the usefulness of financial variables including yield curves over the 1970s and 80s. Inoue & Rossi (2011) find that changing monetary policy regimes are a reason for breakdowns in forecasting of economic variables and note that structural break tests are often ineffective for determining when parameters have changed. Because of this literature many articles on stock predictability have attempted to incorporate regime-switching models to accommodate for this variability. Granger (1992) surveys this literature and compares the predictions of a random-walk process, ARIMA processes as wells as regime changing models such as Switching Threshold Auto Regressive (STAR) models. They also consider cointegration models for use in stock return prediction. After this survey they recommend the continued use of models that incorporate causal variables but also include regime switching features. Pesaran and Timmermann (1995, 2000) present one of the most frequently used models for predicting stock returns in an economically exploitable way. In a series of publications, they develop a system of recursive modelling to represent an invented investor who only holds ex-ante information and attempts to earn excess returns. In Pesaran & Timmermann (2000) they account for the changing usefulness of indicators by allowing variables to be incorporated only when they add significant predictive power to the model, rather than being continuously included. Furthermore, the points at which new potentially relevant variables are included is designated within the model rather than being imposed by the authors, avoiding potential issues associated with choosing breakpoints using hindsight rather than ex-ante information. Multiple techniques are often employed in the more recent studies of equity premium forecasting. For example, Rapach et al. (2010) use the standard OLS predictive framework, but then create a combined forecast approach from using a weighted average of multiple individual economics indicators.

Since the early 2000s, where there has been a revival of studies questioning stock return predictability, empirical focus has been on in improving the accuracy of the linear and recursive modelling. Goyal and Welch (2008) uses the standard bivariate analysis, however they use bootstrapping in order to improve the accuracy of t-statistics used in significance testing. This approach is also used in Neely et al (2014), Amihud and Hurvich (2004) and Lewellen (2004) amongst others. Others have sought to improve the accuracy of stock prediction analysis by imposing economic constraints on stock returns, such as Phan and Sharma (2015), where they use non-negative parameter restrictions, and Pettenuzzo et al (2014) where they constrain the equity premium to be non-negative and enforce limitations on the Sharpe ratio. These modifications, they argue, increase the performance of stock return predictors, while maintaining realistic restrictions.

The overall consensus in results of the earlier literature on stock returns is that they can be forecasted, albeit with varying degrees of success based on the time-periods and countries in question. However since 2004 there has been a re-visiting of these results, most famously by Goyal & Welch (2008) where they question whether predictability ever existed. Using historical average equity premiums as benchmarks, they analyse predictability both in-sample and out-of-sample and find that most economic indicators cannot outperform this simple benchmark over the long run consistently. Since publication this paper is arguably considered one of the benchmarks for methodology and data selection, and much of the predictability literature produced after 2008 utilises the data or methodology of this paper. Rapach et al. (2010) for example revisit Goyal & Welch's paper, and argue the case for the combination of multiple economic indicators as significantly outperforming historical averages as a means of equity premium prediction, meaning that combined economic indicators have forecasting success where the examination of individual indicators show less optimistic results. They also argue that these findings are robust to the impact of economic cycles, and in fact that equity premium prediction is at its most effective during periods of economic uncertainty.

With the more recent consensus being that long-term stock predictability is non-existent, there has been a shift in focus from the traditional study of economic variables to the analysis of other aspects of stock predictability. As an example, Neely et al.'s (2014) examination of technical indicators uses elements of Goyal and Welch's (2008) economic predictor dataset in their comparative study, seeking to determine whether technical trading rules suffer from the same lack of long-run forecasting ability as economic predictors. They find that economic variables contain complementary information to technical indicators, and that these technical indicators often outperform economic predictors both in and out of sample.

In a recent paper, Baetje and Menkhoff (2016) examines both economic and technical indicators, drawing methodology and data from both aforementioned papers, but focusses on the instability of these predictors since the 1970s. They find several breakpoints in terms of predictive relationships, presenting evidence that economic variables in particular suffer from structural breaks in terms of predictability. They also argue that technical indicators are much more consistent, containing economically exploitable relationships with stock returns over the long term.

Other studies have noted the strong time-varying nature of stock predictability. There is a sizeable literature that discusses how monetary policy regimes and business cycles affect forecasting. In terms of stock volatility Hamilton & Lin (1996) and Schwert (1989, 1999) find identifying economic turning points are highly important to forecasting and find that 60% of the variance of stock returns are accounted for by economic recessions. Additionally, Clare and Psaradakis (1995) find evidence of a January and September effect robust across stock sizes in UK stock markets. The usage of macroeconomic variables to observe patterns in stock market characteristics is also to be found in Schwert (1989) as well as Fama and French (1989). The latter of these two articles uses business cycle indicators and find that excess stock returns vary inversely with business conditions, i.e. that the greatest stock returns are found in periods of recession. They also find that there are strong linkages between bond and stock markets, especially during recessions. Using a variety of tests, they show that factors that track bond returns also work effectively in predicting stock returns, and to some extent vice-versa. In a more recent paper, Henkel et al. (2011) find a strong counter-cyclical factor to stock return predictability in most of the G7 countries, arguing that many of the frequently cited economic indicators, such as term spreads and dividend yields, only give important information during economic downturns.

While the relationship between the economic cycle and stock predictability has been frequently discussed, there exists less studies that relate financial circumstances to stock predictability. A few examples include Guidolin & Timmermann's (2005) study of the importance of different 'regime states' for UK stock returns. They characterise 'Bear' states as having high volatility and negative returns, while 'Bull' states contain periods of high returns and low volatility. They argue that different business cycle conditions have implications for the optimal portfolio of stocks, bonds and bills through effects on financial conditions. Lee and Kim (1993) find that the October 1987 crash in the US strengthened the co-movements amongst stock markets, and that higher volatility periods coincide with stronger price co-movements. Their key finding is that stock returns are economically predictable and exploitable however note that there is very variable indicator effectiveness over time, some of which is accounted for by periods of financial stress. Monetary policy is also linked to stock return prediction through its interaction with the business cycle and financial conditions. Patelis (1997), finds that monetary policy indicators such as the yield spread predict initially lower expected returns and then higher thereafter. They find evidence that expected real returns are unaffected by monetary policy, however expected dividend growth and expected excess returns are strongly affected. Ewing (2001) also finds that monetary policy is a significant indicator for stock returns using a similar VAR model. Thorbecke (1997) finds a relationship between negative shocks to the Federal Funds rate and stock returns and positive shocks to unborrowed reserves and stock returns. In this way Thorbecke finds a link between monetary policy similar in nature to Quantitative Easing and the level of stock returns. These findings are corroborated in Jensen & Johnson (1995) who find in the period 1962-1991 expected stock returns are significantly higher in expansive monetary policy periods. In a further paper they examine whether business conditions alone account for this effect, or whether the monetary sector has a separate and distinguishable effect. In this chapter they use the Federal Reserve's discount rate as a proxy for monetary policy stance and find that dividend yields and default spreads have significantly different effects on stock returns depending on the Fed's monetary stance. They find that only in expansive periods do these variables player a significant part in explaining expected stock returns, while during restrictive periods the effects are far less significant (Jensen & Johnson, 1996).

The overall extent of the relevant literature for this chapter covers three distinct subject areas, firstly whether stock returns can be predicted by economic or financial indicators. As has been shown above, the majority of the evidence for this revolves around US stock returns, however the Pesaran and Timmermann (2000) articles have focussed on UK stock returns in their extensive studies. The second area focusses on the stability of the predictions across time, sampling horizons and altering business cycles/economic conditions, where the general consensus is that predictability alters by large amounts across different sample horizons and is strongly impacted by the business cycle and economic crises. Finally, the literature above debates whether financial conditions and monetary policy has a significant impact on asset prices, especially the prediction of future returns, and finds for the most part that monetary policy regimes do indeed alter forecasting. This chapter aims to tie these strands of literature together by questioning whether UK stock returns can be predicted by financial and economic indicators, whether further predictive ability can occur during periods of financial stress as well as during the business cycle and different monetary policy regimes.

5.3 Methodology

As initial analysis, this chapter follows the conventional framework for analysing equity risk premium forecasting, which is a simple bivariate regression model:

$$r_{t+1} = a_i + \beta_i x_{i,t} + \varepsilon_{i,t+1} \quad (1)$$

Where r_{t+1} is the equity risk premium i.e. the return on a stock index minus of the risk-free rate between periods t and $t+1$. $x_{i,t}$ is a economic variable as a predictor variable and ε_{t+1} is a zero-mean disturbance term. Economic variables/indicators are defined in this chapter as time series variables that contain economic information relevant to the present and future levels of stock returns. As an example, credit spreads contain information about the relative riskiness of UK financial markets, which contains information relevant to UK equities through its measure of default probabilities and risk at during that time period. While there exists a great body of literature linking stock returns to a spectrum of different variables, this chapter limits the analysis to the most frequently cited and successful indicators. Technical indicators are defined in this chapter as trend-following measures that capture price movements and trading activity associated with the equity indexes in question. In this case, the technical indicators in all cases capture recent price movements and trading volumes, both of which theoretically yield important information for future FTSE price levels and therefore returns. In this case the equity risk premium is the difference between the continuously compounded return on the FTSE100 and ALLSHARE indexes including dividends, and the log return on a risk-free bill. To examine whether stock returns are predictable via other economic or technical indicators, the value of β_i must be determined to be significantly greater than zero.

Data Selection

This chapter approximates the data used in Goyal and Welch (2008) in order to keep results comparable with previous studies. Given that the focus of this chapter is UK stock return predictability however, some of the variables used in Goyal and Welch have been omitted because they have no UK equivalents, or that the UK equivalent has been recorded for a much shorter time period and if it were to be included it would a prohibitively short sample period. As it stands, this chapter estimates predictive regressions using monthly data starting in January 1975 for the FTSE ALLSHARE index and December 1983 for the FTSE100. For the economic variables, this chapter used the following to predict equity risk premium:

1) Dividend yield (DY) of the equity index, the total dividend amount for the index, expressed as a percentage of the total market value for the constituents of that index.

$$DY_t = \frac{\sum_1^n (D_t * N_t)}{\sum_n^n (P_t * N_t)} * 100 \tag{2}$$

2) Price/Earnings Ratio (PE) of the equity index, derived by dividing the total market value of an index by the total earnings.

$$PE_t = \frac{\sum_1^n (P_t * N_t)}{\sum_1^n (E_t * N_t)} * 100 \tag{3}$$

Where:

DY_t = aggregate dividend yield on day t

PE_t = price earnings ratio at day t

D_t = dividend per share on day t

N_t = number of shares in issue on day t

E_t = earnings per share on day t (Negative earnings per share are treated as zero)

P_t = unadjusted share price on day t

n = number of constituents in index

3) Treasury Bill rate (TBL): interest rate on a three-month Treasury bill.
4) Long-term yield (LTY): long-term government bond yield. (Included maturities are 5, 10, 15 and 20 years).
5) Term spread (TMS): the long-term yield minus the Treasury bill rate. (Included are the spreads between the 3-month rate and the 5, 10 and 15 years to maturity yields).
6) Default Yield Spread (DYS): The difference between the yields of Moody's Baa rated bonds and Moody's Aaa rated bonds.
7) Default return spread (DRS): the difference between the yields of corporate bonds and government gilts of the same maturity.
8) Inflation (INF): calculated as a percentage change in the RPI index for all products. Following Neely (2014) an extra lag is included to account for delays in RPI releases.
9) Industrial Production (PROD) (MAN): the percentage change in the Index of Industrial production for production and manufacturing respectively.
10) Stock Variance (SVAR): Measured as the sum of squared daily returns on the FTSE100 and FTSEALLSHARE.

Table 5.1 reports the summary statistics for these economic variables used, including the number of observations for each individual. Note that the sample sizes of most of the regressions are constrained by the FTSE100 data, which only begins in 1984. It can be seen that the average monthly equity premium for the FTSE100 is 1.09E-03, which is smaller than the FTSEALLSHARE mean of 1.30E-03. Additionally, almost all of the economic variables are non-normal barring the longer-term term spreads and the FTSE100 dividend yield.

In addition to these macroeconomic variables, this chapter follows the methodology of Neely et al (2014) in including 14 technical price indicators following three popular technical strategies. These indicators are calculated in the exact same method as seen in Neely et al (2014). The first moving-average (MA) rule generates a buy or sell signal ($S_{i,t}$ = 1 for buy, $S_{i,t}$= 0 for sell) by comparing two pricing moving averages. These are shown below:

$$S_{i,t} = \begin{cases} 1 \; if \; MA_{s,t} \; \geq MA_{l,t} \\ 0 \; if \; MA_{s,t} \; < \; MA_{l,t} \end{cases} \tag{4}$$

Where

$$MA_{j,t} = \left(\frac{1}{j}\right) \sum_{i=0}^{j-1} P_{t-i} \; for \; j = s, l; \tag{5}$$

P_t is the level of the FTSE100 or the FTSEALLSHARE, and s and l is the length of the short and long moving-average. This chapter values s at either 1, 2 or 3 periods while l is valued at either 9 or 12 periods. As described in Neely et al (2014) the MA rule generates a buy signal when the short moving average is greater than the long moving average. The intuition behind this is that when prices are trending upward the short MA tends to increase faster than the long MA, generating a buy signal. The reverse is also true for the sell signal.

Table 5.1 Summary Statistics Economic Variables

Economic Indicators	Mean	Median	Max.	Min.	Std. Dev.	Skew.	Kurt.	Jarque-Bera	Prob.	Sum	Sum Sq. Dev.	Obs.
FTSE100	1.09E-03	2.88E-03	5.41E-02	-0.13	0.02	-1.24	8.60	622.36	0.00	0.44	0.15	398
FTSE100DY	3.65	3.59	5.76	1.98	0.78	-0.01	2.74	1.05	0.59	1367.74	224.71	375
FTSE100PE	17.21	15.77	39.63	7.70	6.01	1.23	4.44	96.02	0.00	4905.82	10246.00	285
FTSEALLSHARE	1.30E-03	3.63E-03	8.92E-02	-0.14	0.02	-0.79	7.78	533.71	0.00	0.66	0.22	505
FTSEALLDY	4.07	3.83	8.03	2.06	1.15	0.60	2.81	30.99	0.00	2058.15	673.62	506
FTSEALLPE	17.58	16.90	33.68	8.03	5.01	0.70	3.28	24.71	0.00	5079.82	7227.15	289
TBL	6.70	5.86	16.18	0.05	4.38	0.15	2.08	19.52	0.00	3390.26	9670.07	506
LTY(5)	7.15	7.04	15.54	0.22	3.89	-0.03	1.87	26.86	0.00	3620.12	7659.92	506
LTY(10)	7.50	7.59	15.44	0.66	3.79	0.11	1.77	33.09	0.00	3794.41	7236.08	506
LTY(15)	7.57	7.77	15.69	1.04	3.73	0.32	1.95	31.60	0.00	3830.64	7036.20	506
TMS(3-5)	0.45	0.55	4.80	-3.94	1.42	-0.26	3.53	11.38	0.00	229.85	1023.17	506
TMS(3-10)	0.80	0.99	5.98	-4.55	1.83	-0.19	3.07	3.23	0.20	404.15	1699.17	506
TMS(3-15)	0.87	0.94	7.13	-5.20	2.21	-0.01	3.08	0.16	0.92	440.38	2463.15	506
DRS(5)	0.36	0.32	1.02	-0.10	0.23	0.81	3.09	34.29	0.00	112.94	15.98	316
DRS(10)	0.30	0.29	1.31	-0.28	0.29	0.92	4.07	59.55	0.00	95.27	26.89	316
DRS(15)	0.24	0.26	1.59	-0.42	0.42	0.91	3.62	36.30	0.00	56.88	42.25	236
INF	5.64	3.70	26.90	-1.60	5.28	1.94	6.56	581.42	0.00	2849.70	14062.72	505
PROD	0.06	0.10	7.50	-7.00	1.20	-0.07	9.72	951.51	0.00	31.00	731.28	505
MAN	0.04	0.10	9.50	-9.60	1.34	-0.32	14.05	2578.62	0.00	19.40	901.71	505
DYS	1.11	0.97	3.38	0.55	0.46	1.71	6.73	540.49	0.00	561.21	108.31	506

The second strategy used is based on pricing momentum and is a relatively simple calculation. The buy signal is generated when

$$S_{i,t} = \begin{cases} 1 \; if \; P_t \geq P_{t-m} \\ 0 \; if \; P_t < P_{t-m} \end{cases} \tag{6}$$

I.e. when the current stock price is higher than its level m periods ago, where in this case m takes the value of either 9 or 12 periods. The interpretation of this momentum rule is that if prices are higher/lower than they were several months ago, this indicates a positive/negative momentum which may continue into the future, generating capital gains/loss should the investor purchase the stock now.

Finally, this chapter uses the 'on-balance' volume used by Neely et al (2014) but originally from Granville (1963). This is defined as follows:

$$OBV_t = \sum_{k=1}^{t} VOL_k D_k \tag{7}$$

Where VOL_k is a measure of the trading volume during period k and D_k is a binary variable that is valued 1 if $P_k - P_{k-1} \geq 0$ and -1 otherwise. The same buying signal is then generated from OBV_t

$$S_{i,t} = \begin{cases} 1 \; if \; MA_{s,t}^{OBV} \geq MA_{l,t}^{OBV} \\ 0 \; if \; MA_{s,t}^{OBV} < MA_{l,t}^{OBV} \end{cases} \tag{8}$$

Where

$$MA_{j,t}^{OBV} = \left(\frac{1}{j}\right) \sum_{i=0}^{j-1} OBV_{t-i} \; for \; j = s, l; \tag{9}$$

This technical indicator combines the information from the MA signal with information from relatively high recent trade volumes, generating a buy signal when there is a strong positive upward price trend coupled with high trading activity. Once again s is valued at 1,2 and 3 and l 9 and 12. The buy signals from these three indicator types discussed above are denoted MA, MOM and OBV respectively. For more information on the rationale of such indicators, see Neely et al (2014) however they are designed to capture trends in equity prices. Tables 2 and 3 contain the summary statistics of these technical indicators for both the FTSE100 and ALLSHARE. As can be seen in both tables, the indicators show buy signals between 60% and 72% of the time for the FTSE100 and between 63% and 74% of the time for the ALL SHARE index. These statistics resemble the same trends as found in the American data of Neely et al (2014). However it should be noted that this chapter achieves a much smaller sample range, with 228 observations being the smallest sample size. This is due to the limited data set for trade volumes for both the FTSE indices, which only become available on DATASTREAM from 1993 onwards.

For these technical indicators the variables take the place of $x_{i,t}$ in Equation (1) changing it to

$$r_{t+1} = a_i + \beta_i S_{i,t} + \varepsilon_{i,t+1} \tag{10}$$

Where $S_{i.t}$ denotes technical indicator i at time t. The main hypothesis to test is that β_i = 0 in both the economic and technical indicator regressions. Table 5.2 summarises all the included technical indicators.

Table 5.2 Summary Statistics Technical Indicators FTSE100

FTSE100	Mean	Median	Max.	Min.	Std. Dev.	Skew.	Kurtosis	Jarque-Bera	Prob.	Sum	Sum Sq. Dev.	Obs.
MA Buy (1>9)	0.68	1.00	1.00	0.00	0.47	-0.76	1.58	70.62	0.00	265.00	85.40	391
MA Buy (1>12)	0.68	1.00	1.00	0.00	0.47	-0.79	1.62	70.85	0.00	265.00	84.01	388
MA Buy (2>9)	0.68	1.00	1.00	0.00	0.47	-0.76	1.58	70.62	0.00	265.00	85.40	391
MA Buy (2>12)	0.70	1.00	1.00	0.00	0.46	-0.85	1.73	73.17	0.00	270.00	82.11	388
MA Buy (3>9)	0.69	1.00	1.00	0.00	0.46	-0.80	1.64	71.79	0.00	268.00	84.31	391
MA Buy (3>12)	0.71	1.00	1.00	0.00	0.46	-0.91	1.82	75.53	0.00	274.00	80.51	388
MOM (9)	0.71	1.00	1.00	0.00	0.45	-0.94	1.89	77.73	0.00	278.00	79.84	390
MOM (12)	0.72	1.00	1.00	0.00	0.45	-0.97	1.94	78.83	0.00	278.00	78.30	387
OBV Buy (1>9)	0.63	1.00	1.00	0.00	0.48	-0.54	1.30	48.03	0.00	178.00	65.65	282
OBV Buy (1>12)	0.62	1.00	1.00	0.00	0.49	-0.51	1.26	47.29	0.00	174.00	65.48	279
OBV Buy (2>9)	0.61	1.00	1.00	0.00	0.49	-0.47	1.22	47.55	0.00	173.00	66.87	282
OBV Buy (2>12)	0.59	1.00	1.00	0.00	0.49	-0.36	1.13	46.69	0.00	164.00	67.60	279
OBV Buy (3>9)	0.62	1.00	1.00	0.00	0.49	-0.48	1.23	47.63	0.00	174.00	66.64	282
OBV Buy (3>12)	0.60	1.00	1.00	0.00	0.49	-0.40	1.16	46.80	0.00	167.00	67.04	279

Table 5.3 Summary Statistic Technical Indicators FTSEALLSHARE

FTSEALL	**Mean**	**Median**	**Max.**	**Min.**	**Std. Dev.**	**Skew.**	**Kurtosis**	**Jarque-Bera**	**Prob.**	**Sum**	**Sum Sq. Dev.**	**Obs.**
MA Buy (1>9)	0.71	1.00	1.00	0.00	0.45	-0.93	1.86	98.13	0.00	353.00	102.28	497
MA Buy (1>12)	0.74	1.00	1.00	0.00	0.44	-1.09	2.18	111.13	0.00	365.00	95.31	494
MA Buy (2>9)	0.70	1.00	1.00	0.00	0.46	-0.88	1.78	95.50	0.00	349.00	103.93	497
MA Buy (2>12)	0.74	1.00	1.00	0.00	0.44	-1.11	2.24	113.77	0.00	367.00	94.35	494
MA Buy (3>9)	0.72	1.00	1.00	0.00	0.45	-0.98	1.96	102.07	0.00	358.00	100.12	497
MA Buy (3>12)	0.73	1.00	1.00	0.00	0.44	-1.04	2.08	106.46	0.00	361.00	97.19	494
MOM (9)	0.74	1.00	1.00	0.00	0.44	-1.12	2.26	115.53	0.00	370.00	94.55	497
MOM (12)	0.76	1.00	1.00	0.00	0.43	-1.20	2.44	124.87	0.00	374.00	90.85	494
OBV Buy (1>9)	0.66	1.00	1.00	0.00	0.48	-0.67	1.44	40.40	0.00	152.00	51.98	231
OBV Buy (1>12)	0.64	1.00	1.00	0.00	0.48	-0.60	1.37	39.27	0.00	147.00	52.22	228
OBV Buy (2>9)	0.63	1.00	1.00	0.00	0.48	-0.55	1.30	39.37	0.00	146.00	53.72	231
OBV Buy (2>12)	0.64	1.00	1.00	0.00	0.48	-0.57	1.32	38.97	0.00	145.00	52.79	228
OBV Buy (3>9)	0.65	1.00	1.00	0.00	0.48	-0.63	1.39	39.98	0.00	150.00	52.60	231
OBV Buy (3>12)	0.63	1.00	1.00	0.00	0.48	-0.53	1.28	38.73	0.00	143.00	53.31	228

5.4. Results

5.4.1 In-sample results

Tables 5.4 and 5.5 show the results of the bi-variate least squares regressions using Equations 1 and 10 for both the FTSE100 and FTSEALLSHARE. The coefficient on the economic and technical indicators is reported in the third column of each table, with the significance levels of 10%, 5% and 1% the coefficient reported by *, ** and *** respectively. Additionally, the fourth column of each table reports the R^2 statistic for each regression using the entire sample. For the FTSE100 it can be seen that only two of the regressors are found to be significant using data from their respective entire samples, with the longest term spread only being significant at the 10% level. The results of the FTSE ALLSHARE largely reflect those found for the FTSE100, however term spreads are found to have even less of an effect, and stock variance is a more significant factor for the ALLSHARE, which is likely due to the index containing relatively smaller and more risky stocks than the 100. Another point of interest is that none of the technical indicators are found to have significant predictive effects on either equity premium, even at the 10% significance level. This is in sharp contrast to the Neely et al. paper (2014), where almost all the technical indicators were found to have significant relationships with the equity premium on the S&P 500. Like Neely et al. (2014) buy signals predict mostly positive equity premiums for the FTSE100 but the MA indicators predict negative premiums for FTSEALLSHARE, all of which are insignificantly different from zero.

P-value insignificance is not the only factor when considering economically significant predictive relationships. Although the R^2 statistics are found to be very small for all of the predictors, economic and technical alike, this is to be expected due to the inherently unpredictable and volatile nature of stock returns, especially in a sample that includes financial crisis periods. Previous commentators have argued that an R^2 statistic of 0.005 (0.5%) and above represents an economically significant degree of predictability (Kandel and Stambaugh 1996, Xu 2004, Campbell and Thompson 2008, Neely et al. 2014) with Xu (2004) especially finding that profitable trading strategies can be generated from indicators that have low predictability. This chapter therefore uses 0.5% as a baseline to show economically important predictive relationships. As can be seen from Table 5.4, four of the indicators have R^2's that approach or surpass this level for the FTSE100, including one of the on-balance technical indicators. While the coefficients were found to be insignificant, the 5-year default return spread and the longest term-spread are shown to contain economically important information. For the FTSE ALLSHARE, five indicators of which two are technical indicators have also reported R^2

above this threshold. None of the term-spreads are significant by this measure, while the default return spread does not quite reach the 0.005 threshold. For both equity indices it is only the on-balance volume buy signal that seems to have a significant relationship with equity premiums. Apart from this, technical indicators perform very poorly over the entire sample.

In addition to the standard R^2 statistic this chapter is also interested in the performance of technical and economic indicators in periods of expansion or recession. Following the Neely et al. (2014) procedure, this chapter creates a pseudo R^2 statistic for both the economic and technical variables during expansion and recession periods, with these periods being denoted by the OECD UK recession indicator from the St Louis Fed. When this dummy is valued 1 the UK was considered to be in recession by OECD indicators, and in expansion when the dummy was valued 0. The R^2 was computed in the following manner:

$$R_c^2 = 1 - \frac{\sum_{t=1}^{T} I_t^c \hat{\varepsilon}_{i,t}^2}{\sum_{t=1}^{T} I_t^c (r_t - \bar{r})^2} \text{ for } c = \text{ EXP, REC}; \tag{11}$$

Where I_t^{EXP} and I_t^{REC} represent the aforementioned recession indicator dummy variables in period t. $\hat{\varepsilon}_{i,t}^2$ is the fitted residual based on the full-sample estimates of each of the regression models for both technical and economic indicators. $\bar{r}$ is the sample mean of r_t and T is the number of usable observations. One important caveat to note is that the above equation can yield negative statistics, in such cases the interpretation is that the variable in question does not provide significant economic information during the denoted period.

Starting with the FTSE100 R_{REC}^2 it can be seen that almost all of the economic indicators perform worse in recession periods compared to the entire sample R^2 statistic, with the short default return spread and the default yield spreads being the exceptions. Both of these exhibit the economically significant R^2 of above 0.005 during recession periods, most likely due to these indicators capturing corporate risk, which is of particular importance during periods of economic downturn. In comparison the technical indicators exhibit slightly larger statistics during recession periods, but still only on-balance volume indicators are found to be economically significant. For the FTSEALLSHARE, the results are somewhat different. While a few of the economic exhibit larger statistics for recession periods, most notably the short default return spread and the dividend yield, the technical indicators uniformly perform worse, with the on-balance volume signals losing their significance during these periods.

The R_{EXP}^2 statistics for the FTSE100 show that almost all the economic predictors perform better in UK expansion periods than over the entire sample or indeed in recession periods. The exception to this is the technical indicators, which perform marginally better in recessions than expansions but not to an economically significant degree. In expansions periods, seven of the economic predictors show improved predictability over the 0.5% threshold, while none of the technical indicators achieve this. For the FTSEALLSHARE the results are mostly similar in nature. However, in contrast to the FTSE100 equity premium, the technical indicators almost uniformly perform better in expansion periods than over the entire sample or recession periods. In addition, only four of the economic indicators show economically significant statistics, while two of the technical indicators do so. Term spreads also perform much better in recession periods for the FTSEALLSHARE while performing worse for the FTSE100. If the conclusions of commentators like Bekaert et al (2009) and Henkel et al. (2011) are to be considered, where there is a predictable counter-cyclical factor to equity premiums, then it should be observed that the economic indicators with ties to the business cycle such as the term and default spreads should have stronger R^2 statistics during these recession periods. As discussed above, this chapter's results do not reflect this, however altering the sample to not include the financial crisis period, the R^2 statistics are a lot more consistent with the conclusions of these other commentators, which suggests the financial crisis period has a significant effect on the outcomes of the sample predictive regressions.

Table 5.4 Bivariate Results FTSE100

FTSE100					
Predictor	**Start Date**	**Coefficient**	R^2	R^2_{REC}	R^2_{EXP}
TBL	1983M12	-0.0002	0.0022	-0.0001	0.0039
LTY(5)	1983M12	-0.0002	0.0013	-0.0005	0.0026
LTY(10)	1983M12	-0.0002	0.0007	-0.0008	0.0019
LTY(15)	1983M12	-0.0001	0.0004	-0.0008	0.0012
TMS(3-5)	1983M12	0.0007	0.0026	0.0011	0.0037
TMS(3-10)	1983M12	0.0007	0.0039	0.0024	0.0049
TMS(3-15)	1983M12	0.0007*	0.0047	0.0030	0.0059
DRS(5)	1990M12	-0.0059	0.0059	0.0103	0.0020
DRS(10)	1990M12	-0.0031	0.0027	-0.0009	0.0060
DRS(15)	1997M08	-0.0022	0.0027	-0.0019	0.0066
INF(-1)	1983M12	-0.0005	0.0025	-0.0004	0.0045
INF(-2)	1983M12	-0.0005	0.0028	0.0010	0.0041
INDMAN	1983M12	0.0001	0.0000	0.0000	0.0001
INDPROD	1983M12	0.0001	0.0000	0.0002	-0.0001
DY	1986M01	0.0026**	0.0108	-0.0008	0.0191
PE	1993M07	-0.0001	0.0014	-0.0029	0.0051
MA(1,9)	1984M09	0.0003	0.0001	-0.0002	0.0002
MA(1,12)	1984M12	0.0005	0.0001	0.0003	0.0000
MA(2,9)	1984M09	0.0002	0.0000	0.0002	-0.0001
MA(2,12)	1984M12	-0.0006	0.0002	-0.0013	0.0013
MA(3,9)	1984M09	-0.0013	0.0010	-0.0011	0.0025
MA(3,12)	1984M12	0.0002	0.0000	0.0004	-0.0002
MOM(9)	1984M09	0.0022	0.0026	0.0038	0.0017
MOM(12)	1984M12	0.0002	0.0000	0.0003	-0.0002
OBV(1,9)	1993M10	-0.0004	0.0001	0.0008	-0.0004
OBV(1,12)	1994M01	-0.0011	0.0010	0.0014	0.0006
OBV(2,9)	1993M10	0.0022	0.0038	0.0073	0.0009
OBV(2,12)	1994M01	-0.0011	0.0010	0.0014	0.0006
OBV(3,9)	1993M10	0.0018	0.0027	0.0043	0.0013
OBV(3,12)	1994M01	0.0028	0.0063	0.0142	-0.0004
DYS	1983M12	-0.0015	0.0010	0.0060	-0.0027
SVAR	1984M02	0.0000	0.0021	-0.0043	0.0067

Table 5.5 Bivariate Results FTSEALLSHARE

FTSEALLSHARE					
Predictor	**Start Date**	**Coefficient**	R^2	R^2_{REC}	R^2_{EXP}
TBL	1975M02	-0.0001	0.0005	-0.0001	0.0009
LTY(5)	1975M02	-0.0001	0.0002	-0.0005	0.0007
LTY(10)	1975M02	0.0000	0.0000	-0.0003	0.0003
LTY(15)	1975M02	0.0000	0.0000	0.0004	-0.0003
TMS(3-5)	1975M02	0.0004	0.0007	0.0020	-0.0002
TMS(3-10)	1975M02	0.0005	0.0017	0.0042	-0.0001
TMS(3-15)	1975M02	0.0005	0.0028	0.0061	0.0005
DRS(5)	1990M12	-0.0052	0.0046	0.0078	0.0016
DRS(10)	1990M12	-0.0030	0.0025	-0.0016	0.0063
DRS(15)	1997M08	-0.0021	0.0024	-0.0018	0.0062
INF(-1)	1975M02	0.0001	0.0004	0.0008	0.0002
INF(-2)	1975M02	0.0000	0.0000	0.0020	-0.0012
INDMAN	1975M02	0.0005	0.0009	-0.0002	0.0018
INDPROD	1975M02	0.0007	0.0017	0.0012	0.0021
DY	1975M02	0.0019***	0.0113	0.0130	0.0101
PE	1993M03	-0.0002	0.0023	-0.0037	0.0074
MA(1,9)	1975M11	-0.0011	0.0006	-0.0010	0.0015
MA(1,12)	1976M02	-0.0001	0.0000	-0.0002	0.0001
MA(2,9)	1975M11	-0.0004	0.0001	-0.0013	0.0009
MA(2,12)	1976M02	-0.0009	0.0004	-0.0031	0.0024
MA(3,9)	1975M11	-0.0014	0.0010	-0.0041	0.0040
MA(3,12)	1976M02	-0.0011	0.0005	-0.0025	0.0023
MOM(9)	1975M11	-0.0005	0.0001	0.0005	-0.0001
MOM(12)	1976M02	-0.0018	0.0016	-0.0033	0.0044
OBV(1,9)	1998M01	0.0015	0.0016	0.0000	0.0032
OBV(1,12)	1998M04	0.0010	0.0007	0.0005	0.0009
OBV(2,9)	1998M01	0.0039	0.0114	0.0064	0.0161
OBV(2,12)	1998M04	0.0010	0.0007	0.0005	0.0009
OBV(3,9)	1998M01	0.0015	0.0016	-0.0003	0.0034
OBV(3,12)	1998M04	0.0031	0.0074	0.0011	0.0132
DYS	1975M02	0.0012	0.0007	-0.0015	0.0022
SVAR	1985M02	-0.0001***	0.0174	0.0038	0.0269

5.4.2 Principal Component Analysis

This chapter next uses principal component analysis to estimate the combined information from these economic and technical indicators. This method has the advantage over standard multivariate analysis as it incorporates information from these variables parsimoniously whilst filtering out noise or outliers from individual predictors and lessening the effects of sample overfitting. The principal component predictive regression for the economic variables is given by the following equation (PC^{ECON}):

$$r_{t+1} = a + \sum_{k=1}^{K} \beta_k \hat{F}_{k,t}^{ECON} + \varepsilon_{t+1} \tag{12}$$

Where the economic indicators $x_t = (x_{1,t}, \dots, x_{N,t})'$ are included in a N-vector (N = 18) These are then incorporated to create a set of K principal components. let $\hat{F}_t^{ECON} = (\hat{F}_{1,t}^{ECON}, \dots, \hat{F}_{K,t}^{ECON})'$ denote the vector containing the principal components from the economic variables. These principal components are then regressed in the above equation in the same OLS manner as the previous regressions.

The same treatment was given to all the technical indicators with $\hat{F}_t^{TECH}$ replacing $\hat{F}_t^{ECON}$ to create the PC^{TECH} model:

$$r_{t+1} = a + \sum_{k=1}^{K} \beta_k \hat{F}_{k,t}^{TECH} + \varepsilon_{t+1} \tag{13}$$

Where $\hat{F}_t^{TECH} = (\hat{F}_{1,t}^{TECH}, \dots, \hat{F}_{K,t}^{TECH})'$ is the vector containing the first K principal components extracted from $S_t = (S_{1,t}, \dots, S_{N,t})'$, the N-Vector of the technical indicators. Finally, this chapter also parsimoniously includes information from the entire set of macroeconomic and technical indicators by estimating the following predictive regression, the PC^{ALL} model.

$$r_{t+1} = a + \sum_{k=1}^{K} \beta_k \hat{F}_{k,t}^{ALL} + \varepsilon_{t+1} \tag{14}$$

Here, all of the above variables are consolidated into a few principal components from the two vectors containing the macroeconomic and technical variables. Where $\hat{F}_t^{ALL} = (\hat{F}_{1,t}^{ALL}, \dots, \hat{F}_{K,t}^{ALL})'$ is the K-vector containing the first K principal components.

The selection method of the number of principal components to include follow Neely et al (2014). This chapter allowed $K = N$ initially, creating the same number of principal components as there were variables. After this, only the principal components that added at least 5% proportion explanatory power were taken. After this AIC and SIC criterion as well as adjusted R^2 were used to select the appropriate value of K to include in the regression. Tables 5.6 and 5.7 show these statistics for the FTSE100 and FTSEALLSHARE indexes. For the FTSE100, three principal components were selected from amongst the technical indicators, four from the economic indicators, and two from a combination of these two variable sets, as shown by the highlighted areas of Table 5.6. For the ALLSHARE, one technical principal component was chosen, two economic principal components and model containing three principal components taken from both economic and technical indicators.

Table 5.6 PC Model Statistics FTSE100

FTSE100	**AIC**	**SIC**	**Adj-R^2**
PC1 Tech	5.6159	5.6420	0.0000
PC1 +PC2	5.6202	5.6593	-0.0007
PC1 +PC2 +PC3**	**5.6188**	**5.6710**	**0.0042**
PC1 +PC2 +PC3 +PC4	5.6256	5.6908	0.0009
PC1 Econ	5.6645	5.6940	0.0268
PC1 +PC2	5.6691	5.7133	0.0264
PC1 +PC2 +PC3	5.6759	5.7348	0.0239
PC1 +PC2 +PC3 +PC4**	**5.6765**	**5.7501**	**0.0273**
PC1 +PC2 +PC3 +PC4 +PC5	5.6799	5.7682	0.0281
PC1 +PC2 +PC3 +PC4 +PC5 +PC6	5.6857	5.7888	0.0264
PC1 All	5.6919	5.7213	-0.0002
PC1+PC2**	**5.6679**	**5.7121**	**0.0276**
PC1+PC2+PC3	5.6748	5.7337	0.0249
PC1+PC2+PC3+PC4	5.6833	5.7569	0.0207
PC1 +PC2 +PC3 +PC4 +PC5	5.6851	5.7734	0.0230
PC1 +PC2 +PC3 +PC4 +PC5 +PC6	5.6915	5.7945	0.0208

Table 5.7 PC Model Statistics FTSEALLSHARE

FTSEALL	**AIC**	**SIC**	**Adj-R^2**
PC1 Tech**	**5.6746**	**5.7048**	**0.0003**
PC1+PC2	5.6833	5.7286	-0.0040
PC1+PC2+PC3	5.6920	5.7524	-0.0084
PC1 Econ	5.6558	5.6853	0.0292
PC1 +PC2**	**5.6539**	**5.6980**	**0.0352**
PC1 +PC2 +PC3	5.6584	5.7173	0.0349
PC1 +PC2 +PC3 +PC4	5.6623	5.7360	0.0351
PC1+PC2+PC3+PC4+PC5	5.6692	5.7575	0.0325
PC1 +PC2 +PC3 +PC4 +PC5 +PC6	5.6768	5.7798	0.0291
PC1 All	5.6784	5.7086	-0.0035
PC1+PC2	5.6336	5.6788	0.0447
PC1+PC2+PC3**	**5.6317**	**5.6921**	**0.0506**
PC1+PC2+PC3+PC4	5.6402	5.7156	0.0467
PC1+PC2+PC3+PC4+PC5	5.6402	5.7307	0.0507

Figures 5.1-5.11 show the principal component loadings as well as the plots of each principal component over the sample period. It can be seen by looking at Fig.5.1 and 5.7 that the first and second components of both the FTSE100 and ALLSHARE models are very similar in nature. The first component for both appears to switch from positive to negative during the financial crisis period, potentially indicating the movement of the UK economy from growth to recession in terms of economic cycles. ~~t~~The~~is~~ second components of both models spike~~s~~ during periods that surround the financial crises in 2002 and 2007/8. This may explain why these~~is~~ components ~~is~~are weighted heavily with the SVAR volatility measure and default yield spreads, as these are indicators are dramatically more variable during periods of financial instability. The third and fourth economic principal components of FTSE100, which are not present in the ALLSHARE model, show largely the same pattern as the second component, but with weightings that are more difficult to explain. In addition, observing Fig.5.1 it can be seen that the third component is valued mostly around zero, except during the interim period between QE1 and QE2, as well as the during the aforementioned 2002 financial crisis. It seems that the second, third and fourth components capture periods of economic instability where normal predictive relationships do not hold.

Figures 5.2 and 5.7 show the time plots for the technical indicators. Due to the binary nature of the technical indicators, the component plots mainly take on two values, a positive or negative value depending on the time period. A positive value can be interpreted as a consensus buy-period for most of the technical indicators while negative values show consensus sell-periods. It can be seen that sell signals occur at times corresponding once again to the 2002 and 2008 financial crisis periods, as well as during most of the QE1 and QE2 periods. It seems that the second and third principal components for the FTSE100, which are once again not found in the ALLSHARE model, only become active during periods when the first ‘consensus’ component is in transition from buy to sell signals. These could therefore be interpreted as capturing periods where pricing conditions do not point to a clear trading strategy, i.e. ‘non-consensus’ indicators. This could also represent a period of uncertainty and financial stress, similar to the second components of the economic indicators mentioned above. Figures 5.3 and 5.8 show the time plots for the combined model PC^{ALL}. Unsurprisingly, they appear to closely match the patterns show in figures 5.1, 5.2, 5.7 and 5.9, i.e. the economic and technical components.

Looking at figures 5.4 and 5.9 ~~F~~for both of the indices it can be seen that the first economic principal component is loaded heavily with the spreads and interest rate elements of the economic variables, while macroeconomic indicators like industrial production and RPI rates are given very little weight. The second principal component conversely incorporates these factors heavily, while also giving large weights to SVAR and DYS. The loadings of these components again suggest that both long-term business cycle elements as well as short term financial stress elements are captured in the components.~~It can be seen by looking at Fig.5.1 that this component spikes during periods that surround the financial crises in 2002 and 2007/8. This may explain why this component is weighted heavily with the SVAR volatility measure and default yield spreads, as these are indicators are dramatically more variable during periods of financial instability. The third and fourth economic principal components of FTSE100, which are not present in the ALLSHARE model, show largely the same pattern as the second component, but with weightings that are more difficult to explain. In addition, observing Fig.5.1 it can be seen that the third component is valued mostly around zero, except during the interim period between QE1 and QE2, as well as the during the aforementioned 2002 financial crisis. It seems that the second, third and fourth components capture periods of economic instability where normal predictive relationships do not hold.~~

The first Technical principal component is largely similar for both indexes as shown by Figures 5.5 and 5.9 Similar to the proposition made by Neely et al. (2014), this component seems to be a consensus indicator amongst the buy signals generated from the technical strategies. It can be seen that the technical indicators are loaded almost equally into the component for both indexes, and the component is value positively when the buy signals are generated, and negatively when sell signals are generated. ~~Figures 5.2 and 5.7 shows that sell signals occur at times corresponding once again to the 2002 and 2008 financial crisis periods, as well as during most of the QE1 and QE2 periods. It seems that the second and third principal components for the FTSE100, which are once again not found in the ALLSHARE model, only become active during periods when the first 'consensus' component is in transition from buy to sell signals. These could therefore be interpreted as capturing periods where pricing conditions do not point to a clear trading strategy, i.e. 'non-consensus' indicators.~~ Finally, it can be seen in Figures 5.6 and 5.10 that for both of the PC^{ALL} models the first two principal components are split neatly into technical and economic indicators respectively. As Neely et al. (2014) argues, this indicates that the economic and technical indicators provide separate yet complementary information.

As a final note, this chapter finds that both the in-sample and out-of-sample principal component regression results are significantly affected by the number of components included in each respective predictive regression. For example, including only one technical principal component in the FTSE100 regression negatively impacts in-sample significance while slightly improving out-of-sample performance in comparison to the three components model. With no clear correct methodology on what information to include from the principal components, this chapter follows Neely et al (2014) in choosing models that perform the best according to information criterion and adjusted- R^2 statistics, as this methodology is the most viable without using ex-post information.

Table 5.8 shows the results of the PC^{TECH}, PC^{ECON} and PC^{ALL} models, including as before their respective performances during recessions/expansions. The R^2 statistics for all models are greater than the 0.005 or 0.5% threshold. The technical models are found to be the least significant in predictive power, with only the third technical principal component for the FTSE100 being significant at the 10% level. The economic indicators perform better for both indexes, with significant coefficients and R^2 statistics between 1 and 3%. The FTSEALLSHARE's PC^{ALL} model understandably performs the best out of the three, as it parsimoniously incorporates relevant information from both the technical and economic indicators and is equal to more than the sum of the R^2 statistics of the economic and technical models. This however is not the case for the FTSE100 where the model selection rule chose two principal components for PC^{ALL} for a parsimonious model, but these seems to have inhibited the explanatory power compared to the four principal-component economic model. The R^2 statistic is still well over the 0.5% threshold however.

The recession and expansion R^2 statistics largely reflect the results found in the bi-variate models discussed earlier. The PC^{TECH} models for both indexes show that predictability is higher in recession than both the sample and the expansion periods and are greater than the 0.5% economic significance threshold. For the PC^{ECON} and PC^{ALL} models, predictability for the most part is stronger in expansion periods rather than recessions, however the FTSE100 PC^{ALL} equation exhibits stronger predictability during recessions, though not by a large degree.

These results are found to be robust to the sample size. To check that R^2 statistics were not affected by the relatively short samples of around 240 observations, this chapter re-did the principal component analysis, creating PC^{ECON}, PC^{TECH} and PC^{ALL} models after removing the predictors that significantly shortened the sample size. The variables removed include all of the On-balance Volume buy signals, the 15-year default spread and the price-to-earnings ratio. Conducting the same regressions again yield results that are largely similar, with PC^{ECON} exhibiting much larger R^2 statistics during expansions and the financial crisis period.

Table 5.8 PC In-Sample Results

FTSE100					
Predictor	**Start Date**	**Coefficient**	$\boldsymbol{R^2}$	$\boldsymbol{R^2_{REC}}$	$\boldsymbol{R^2_{EXP}}$
PC1tech	1994M01	0.0004	0.0155	0.0418	-0.0072
PC2tech		-0.0007			
PC3tech		-0.0019*			
PC1econ	1997M08	-0.0007**	0.0237	0.0140	0.0321
PC2econ		-0.0011			
PC3econ		-0.0001			
PC4econ		0.0009			
PC1all	1997M08	0.0004	0.0172	0.0208	0.0147
PC2all		-0.0007*			
FTSEALLSHARE					
Predictor					
PC1tech	1998M04	0.0004	0.0055	0.0077	0.0035
PC1econ	1997M08	-0.0007**	0.0310	0.0288	0.0331
PC2econ		-0.0015**			
PC1all	1998M04	0.0002	0.0405	0.0366	0.0440
PC2all		-0.0010**			
PC3all		-0.0012*			

Figure 5.1 Time-plots of FTSE100 Economic Principal Components

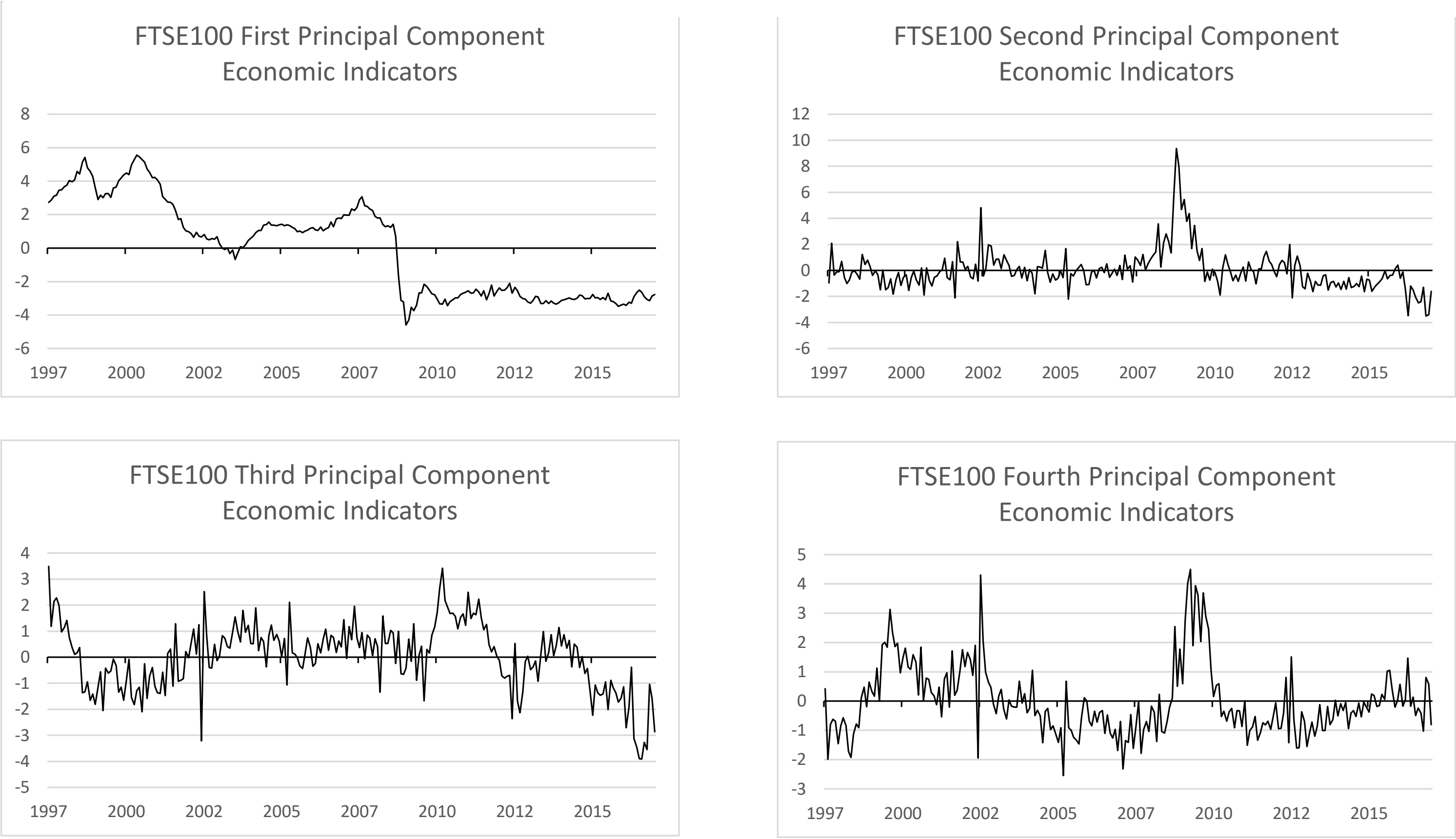


Figure 5.2 Time-plots of FTSE100 Technical Principal Components

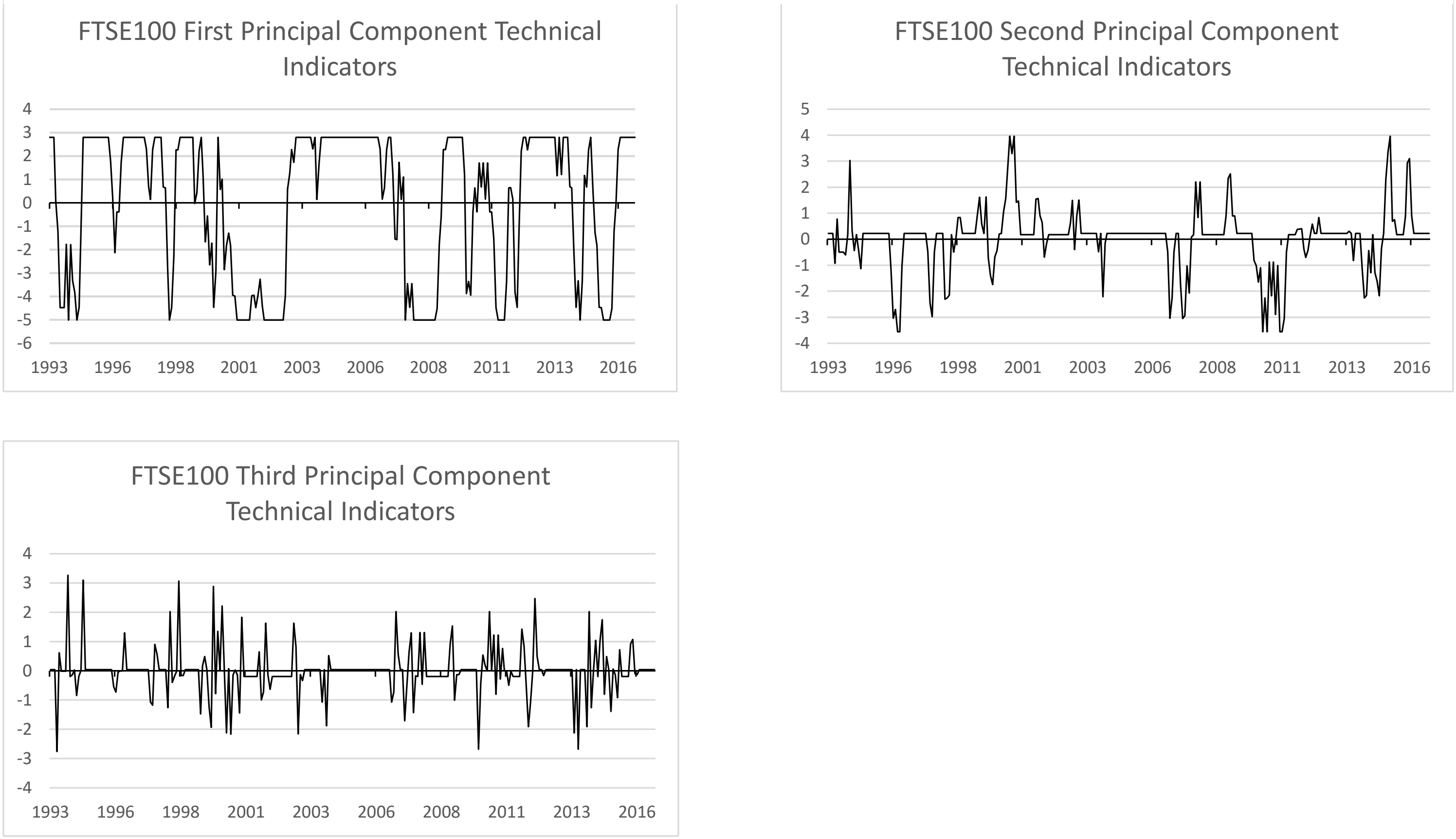


Figure 5.3 Time-plots of FTSE100 All Principal Components

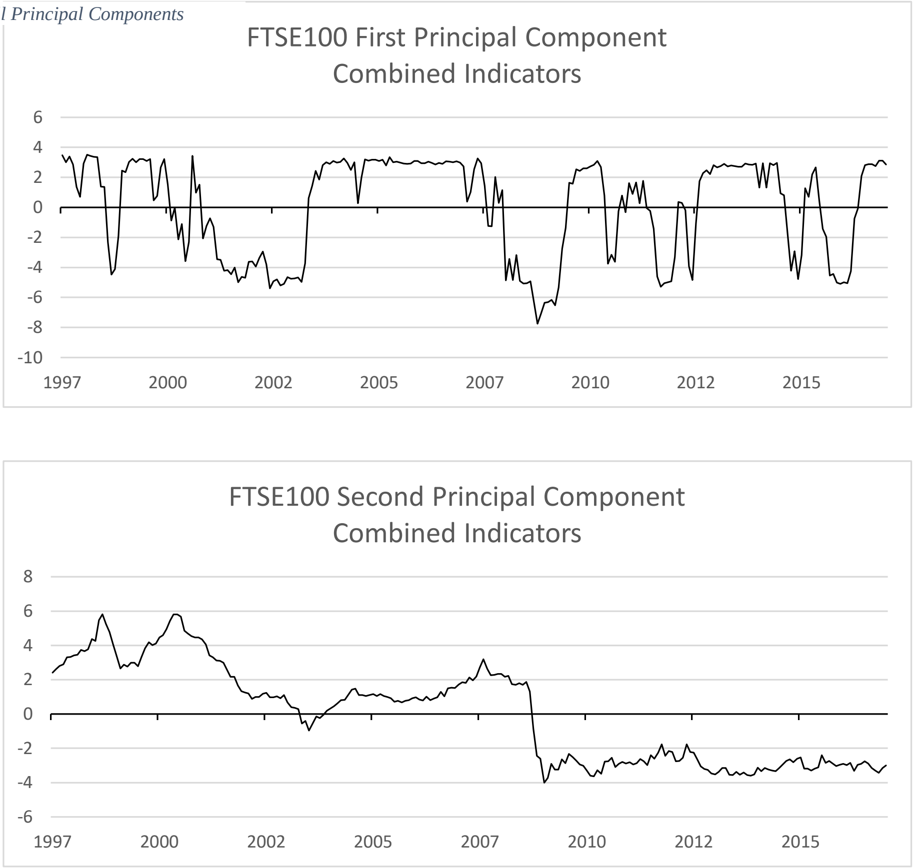


Figure 5.4 FTSE100 Economic Principal Components Loadings

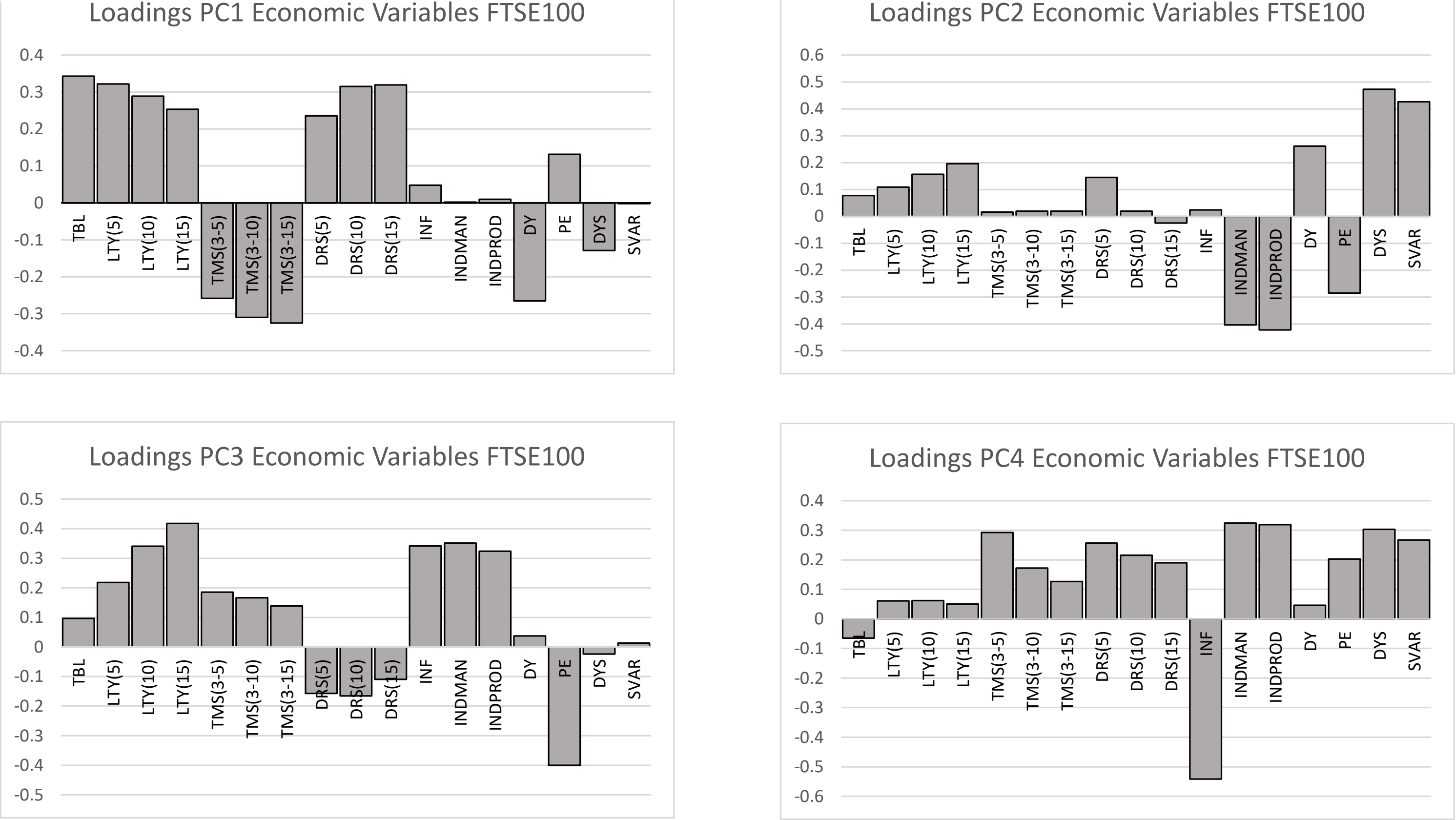
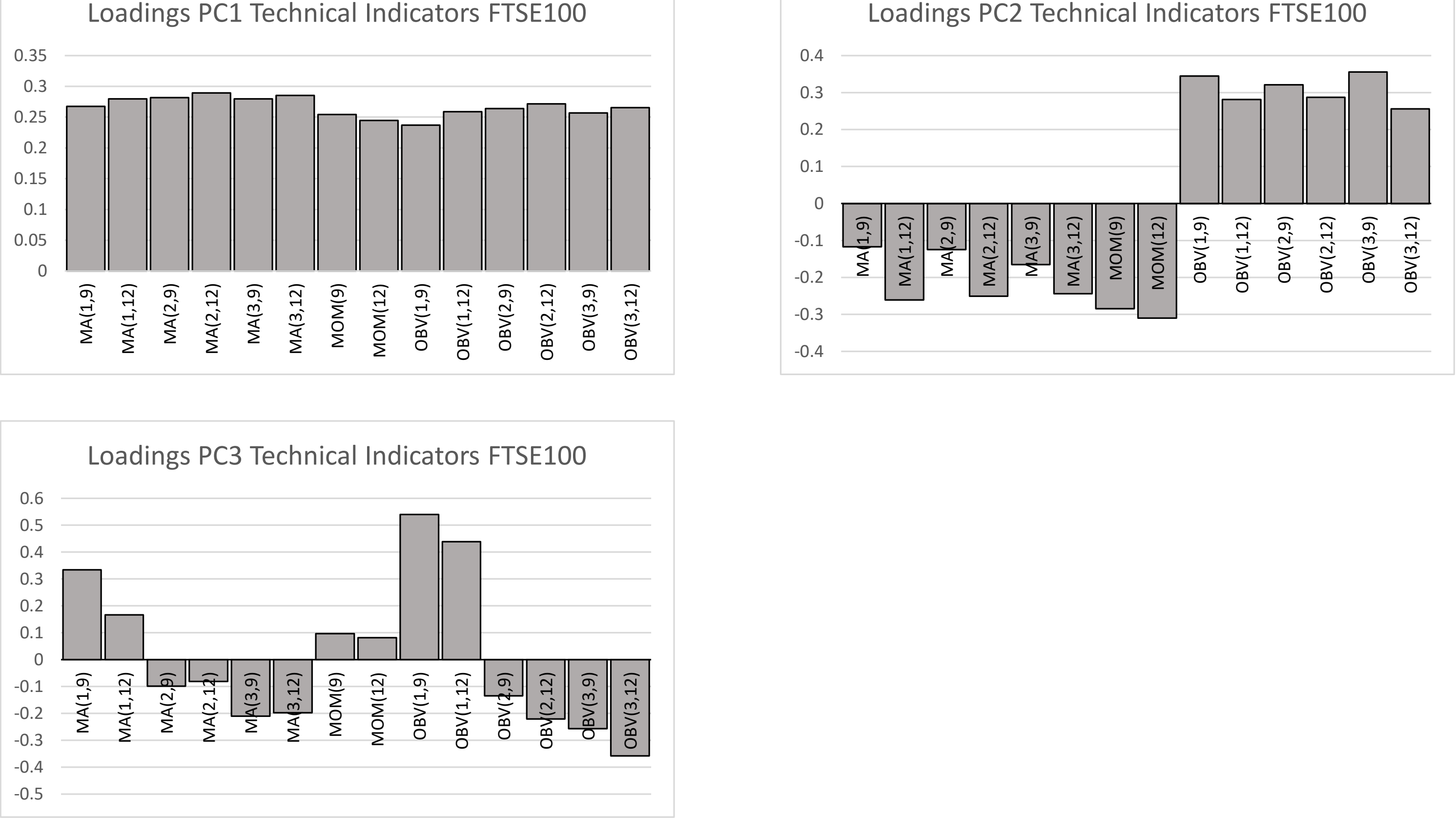


Figure 5.5 FTSE100 Technical Principal Component Loadings



Loadings PC1 Technical Indicators FTSE100

Loadings PC2 Technical Indicators FTSE100

Loadings PC3 Technical Indicators FTSE100

Figure 5.6 FTSE100 All Principal Component Loadings

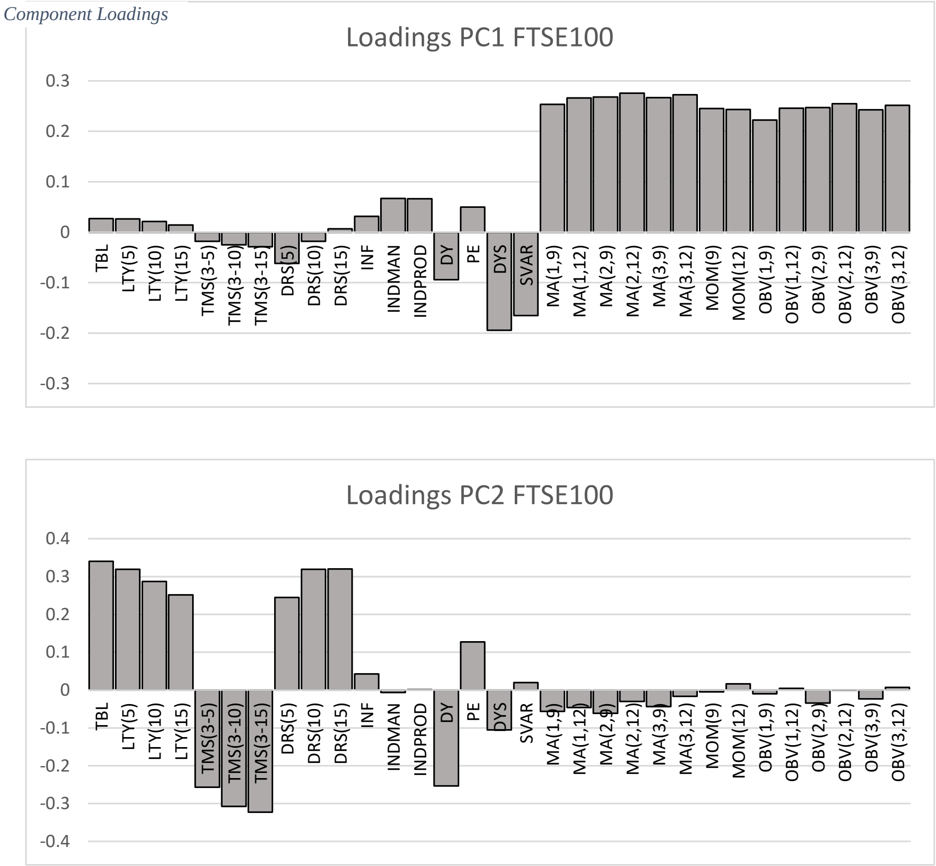
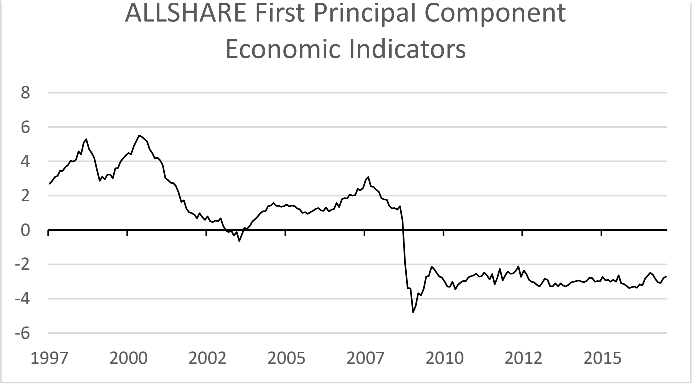
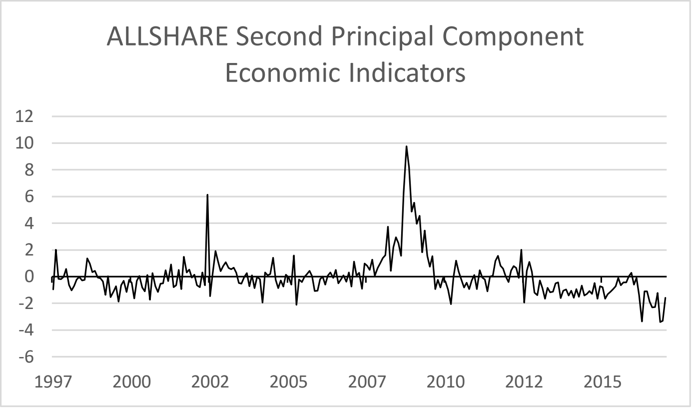


Figure 5.7 Time-plots of FTSEALLSHARE Economic & Technical Principal Components





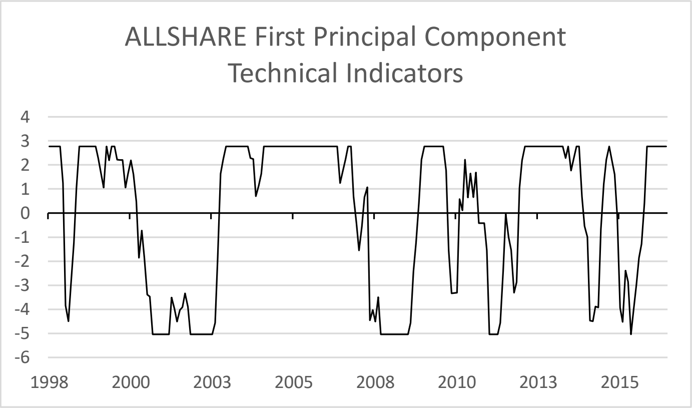


Figure 5.8 Time-plots of FTSEALLSHARE All Principal Components

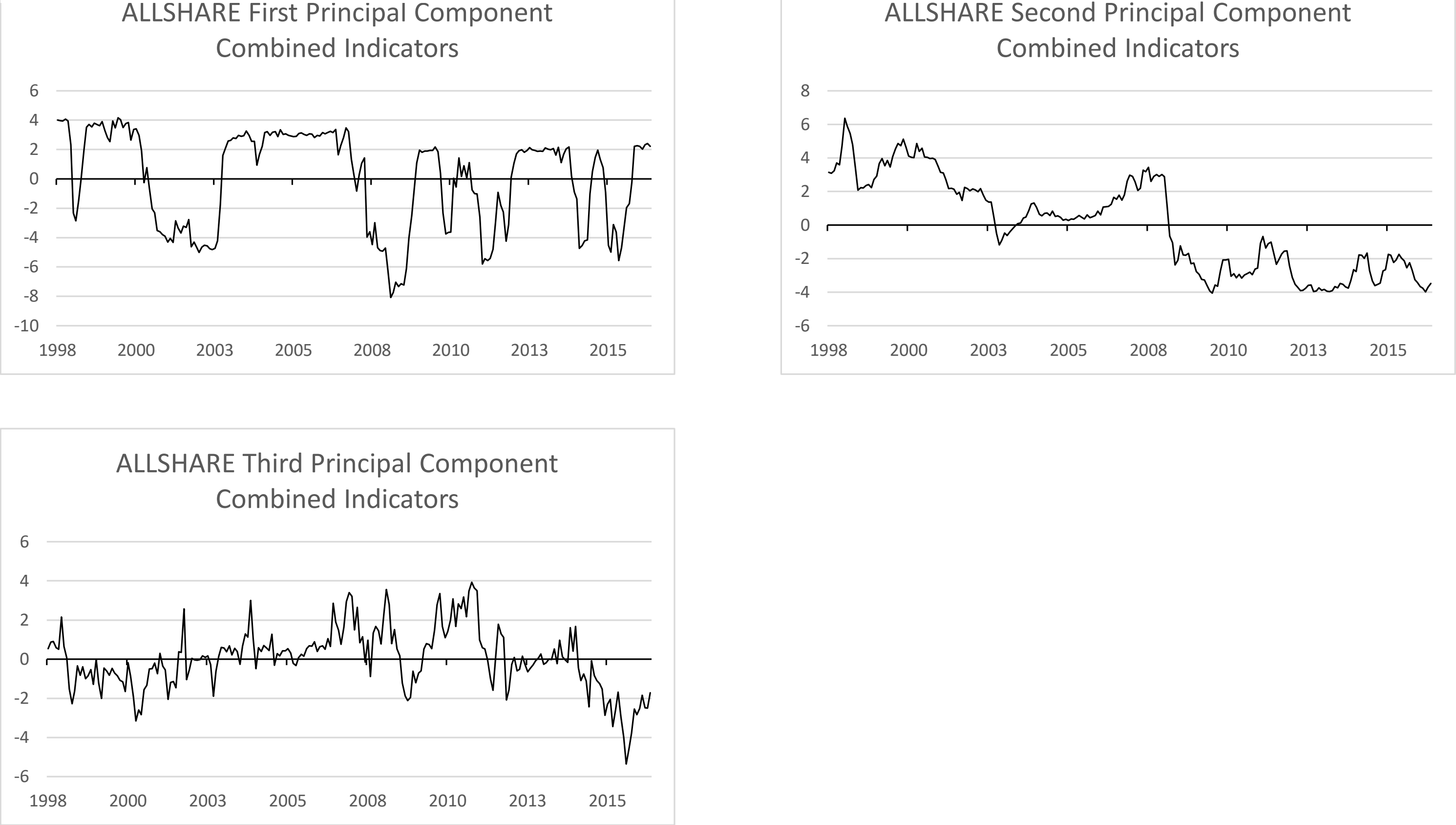


Figure 5.9 FTSEALLSHARE Economic & Technical Principal Component Loadings

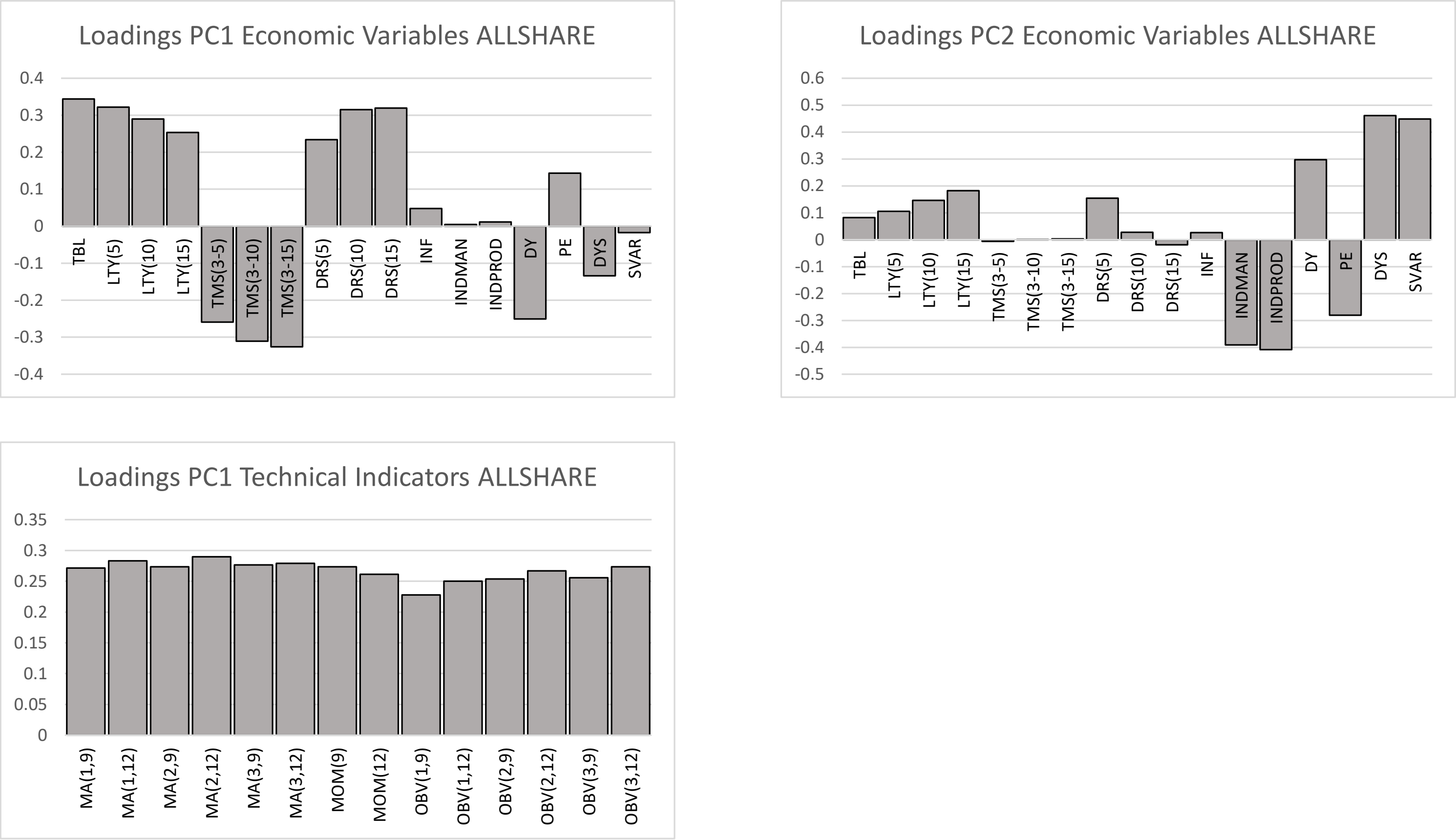


Figure 5.10 FTSEALLSHARE Technical All Component Loadings

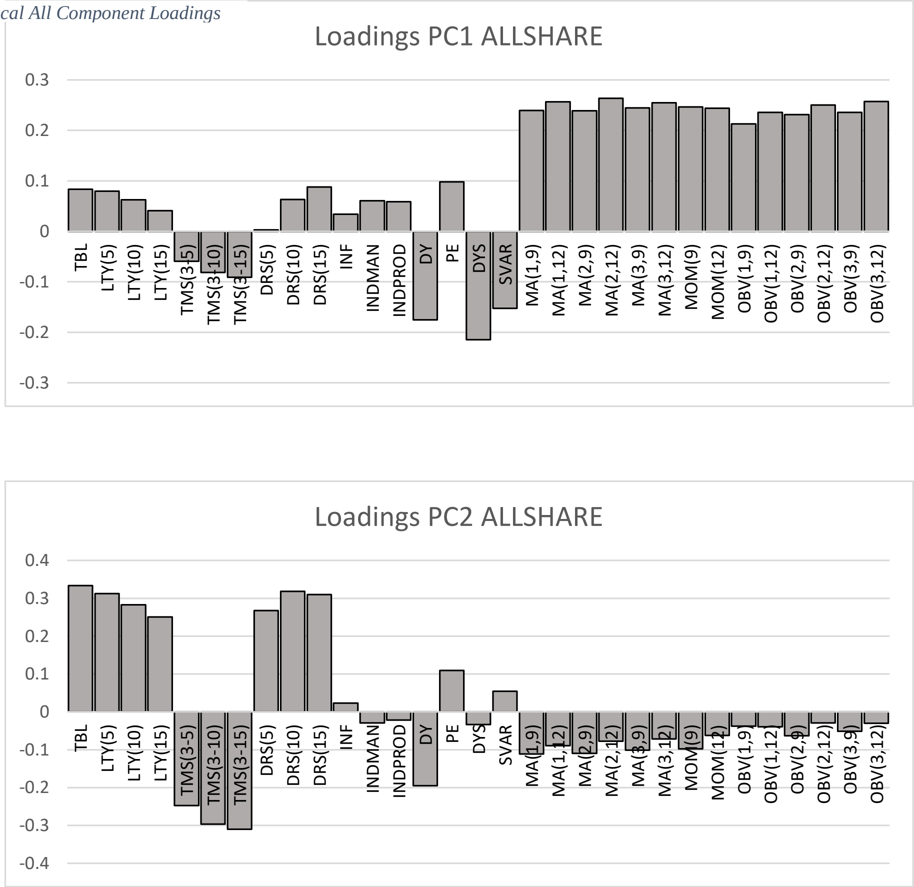
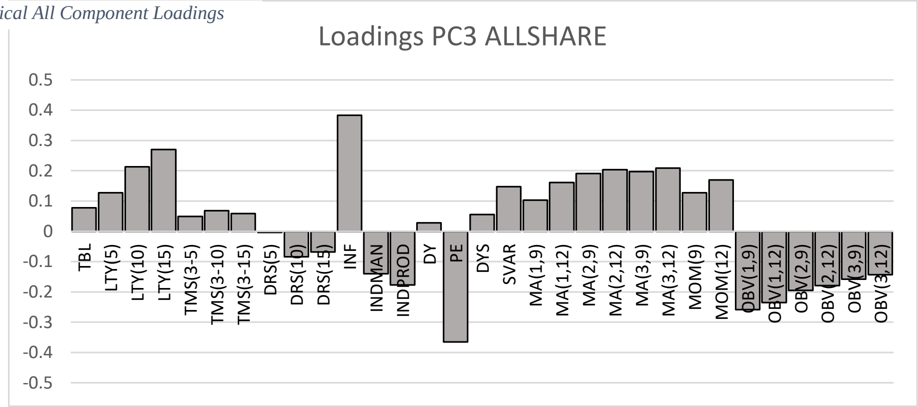


Figure 5.11 FTSEALLSHARE Technical All Component Loadings



5.4.3 Out of Sample Analysis

To check the validity of the previous sections' results this chapter examines the out-of-sample performance of these economic and technical predictors. The one step ahead equity premium forecast is given by the following equation.

$$\hat{r}_{t+1} = \hat{\alpha}_{t,i} + \hat{\beta}_{t,i} x_{i,t} \tag{15}$$

Where $\hat{\alpha}_{t,i}$ and $\hat{\beta}_{t,i}$ are the OLS estimates from an initial estimation period. These models were estimated using a 10-year sample to establish a reasonable in-sample period that accurately estimates the parameters. While this is a smaller initial estimation period than some commentators use, with Neely et al. (2014) using a 15-year initial sample and Goyal and Welch (2008) using 20 years, 10-years is used by Xu (2004) amongst others and is suitable for UK data as data availability precludes the use of longer estimation periods. Tables 5.9 and 5.10 below show the start of the out-of-sample (OOS) start date in the second column for each predictor. In addition, this chapter like before also conducted an auxiliary regression which dropped several of the indicators where data is only available from relatively recently in order to lengthen the forecasting period. Furthermore, these forecasting models are all generated using the same time period, in order to improve comparison between the predictors. This chapter also generates out-of-sample forecasts based on the same principal component analysis as before.

$$\hat{r}^{j}_{t+1} = \hat{\alpha}_t + \textstyle\sum_{k=1}^{K} \hat{\beta}_{t,k}\, \hat{F}^{j}_{1:t,k,t} \text{ for } j = \text{ECON, TECH, or ALL} \tag{16}$$

Where $\hat{F}^{j}_{1:t,k,t}$is the kth principal component extracted from the macroeconomic, technical and a combination of the two, models. Once again, these predictors were estimated using OLS using a 10-year sample period. All of these forecasts are compared to the forecast given by an historical forecast of the equity premium, using the same respective initial estimation samples as each predictor. This historical average forecast is given by the simple equation:

$$\hat{r}^{HA}_{t+1} \textstyle\sum_{s=1}^{t} r_s \tag{17}$$

Which is a benchmark used repeatedly in the literature surrounding out-of-sample forecasting, used most famously by Goyal and Welch (2008) and Campbell and Thompson (2008). This equation assumes a constant expected equity risk premium i.e. $r_{t+1} = \alpha + \varepsilon_{t+1}$. Goyal and Welch (2008) find that most macroeconomic variables fail to outperform the historical average for S&P 500 equity premium forecasting, with only the term spread and inflation being significantly superior in out-of-sample forecasting.

Tables 5.9 and 5.10 below show the results of these OOS forecasts, which have been summarised by a variety of means. First of all, this chapter uses the Campbell and Thompson (2008) out-of-sample R^2 statistic (R^2_{OS}) as measure of predictor performance. This statistic measures the reduction in Mean Squared Forecast Error (MSFE) for the predictive regression forecast relative to the historical average discussed above. A positive value indicates that the predictor outperforms the historical average while a negative value indicates the opposite. The features of the R^2 statistics mentioned above, where values over 0.005 are considered to be economically significant, still hold for this statistic. In addition to the overall R^2_{OS} statistic, this chapter also includes $R^2_{OS}Rec$, $R^2_{OS}Exp$ statistics which measure the same MSFE, but only during periods denoted as recessions and expansions like the in-sample counterparts. The fourth column shows the MSFE-Adjusted statistic, taken from Clark and West (2007). Which is given by regressing the value from the following equation on a constant and testing the resulting t-statistic for a zero coefficient.

$$\hat{f}_{t+1} = (r_{t+1} - \hat{r}_{1t,t+1})^2 - [\left(r_{t+1} - \hat{r}_{2t,t+1}\right)^2 - \left(\hat{r}_{1t,t+1} - \hat{r}_{2t,t+1}\right)^2] \qquad (18)$$

Where r_{t+1} is the equity premium, $\hat{r}_{1t,t+1}$ is the returns forecasted from the historical average and $\hat{r}_{2t,t+1}$ is the returns forecasted from the predictive regressions. Regressing $\hat{f}_{t+1}$ on a constant and using the ensuing t-statistic for a zero coefficient. Clark and West (2007) state that this hypothesis should be rejected if the t-stat is valued greater than +1.282 and +1.645 (for one sided 0.1 and 0.05 tests respectively). The MSFE-adjusted statistic tests the null hypothesis that the historical average MSFE is less than or equal to the predictive regression value. Table 5.9 and 5.10 show the t-statistics from these regressions, accompanied by * and ** to denote rejection of the null hypothesis at corresponding significance levels.

Columns four and five of the table show the Root Mean Squared Error (RMSE) and the Mean Absolute Error (MAE) respectively for the predictive regressions, with values closer to zero showing better predictive performance. $RMSE^{HA}$ and MAE^{HA} show the errors of the corresponding historical average forecast. RMSE is used by Goyal and Welch (2008) amongst other commentators.

Looking at Table 5.9 it can be seen that for the economic indicators only the term and default return spreads outperform the historical average over the entire OOS period, with only the default return R^2_{OS} stats being both positive and over the 0.005 threshold. The MSFE-adjusted statistic also shows that these predictors outperform the historical average forecast, with significance at least the 10% level. However, apart from these variables and four of the on-balance volume indicators, none of the other predictors outperform the historical average to a significant degree with respect to the R^2_{OS} and MSFE-adjusted statistics. Only the OBV(2,12) and OBV(3,12) technical indicators significantly outperforms the historical average, surpassing the 0.005 threshold. These two variables are however outperformed by the historical average according to the MSFE, RMSE and MAE statistics, meaning that these variables cannot be considered to have economically exploitable out of sample performance. All of the principal components regressions are outperformed by the historical average over the entire sample, with the technical indicator principal component performing the best, with marginally significant MSFE statistics, and smaller RMSE and MAE statistics than the historical average.

The results of the FTSE100 are however very different to those found in Table 5.10 for the ALLSHARE, where several more of the predictors outperform the historical average over the entire sample. Of the economic variables, the long-term yields, default return spreads, the inflation indexes and the industrial output indexes outperform the historical average in one or more of the measures, though the LTY(5) and the industrial output indexes do not outperform the historical to an economically significant degree according to the R^2_{OS}. Statistic. An interesting point is that the out-of-sample R-squared statistic is negative for the 15-year default return spread yet the MSFE-adjusted statistic is statistically significant. These two statistics appear to be in contradiction to one another, which is a result of the MSFE-adjusted statistic accounting for additional estimation error in the alternative (historical average) model. In any case, all the other statistical results for DRS(15) show worse or the same performance as the HA, suggesting that DRS(15) provides little effective forecasting ability out-of-sample. The inflation measures perform well according to most of the measures, except the MAE. Of the technical indicators, once again the on-balance volume buy signals outperform the historical average in more than one measure, but none of the other buy signals show better performance. The principal components also outperform the historical average, contrary to the case for the FTSE100, according to all of the statistical measures.

As can be seen in the two tables, there is a significant difference between the two indexes in terms of predictability, specifically with regards to economic indicators. One potential reason for this could be that the FTSE ALLSHARE covers stocks from smaller companies, whose markets may not be as efficient. Weaker market efficiency might come from less frequent trades, less well understand asset fundamentals or more constrained arbitrage. This may allow trading rules involving technical indicators or relying on economic predictors to be more effective than in the relatively more efficient FTSE100 markets. Another reason for this discrepancy may be down to time-varying factors in return predictability. As can be seen in the second column of each table, the ALLSHARE uses longer OOS periods, many starting in the 1980s. This may explain the differences in performance of the predictors. To test this, this chapter dropped several of the variables in the same manner as discussed above for the principal component technique, and then forecasted using the same estimation window and out-of-sample period. These results, which are found in the appendix, show the degree of predictability is more consistent between the two equity indexes. In both cases only the longest-term yield spread is significant, along with the T-bill rate. The inflation predictor also marginally outperforms the historical average for both indexes, however none of these variables surpass the 0.005 benchmark.

The out-of-sample results corroborate with the literature in that they find the majority of economic indicators cannot outperform the historical average benchmark. Goyal and Welch (2008) find that inflation and the term spread are the only significant economic predictors out of sample, finding the default return spread is strongly outperformed by the benchmark. Neely et al. (2014) find the long-term government yield is a significant indicator, as well as the dividend yield and their equivalent of this chapters SVAR variable. The long-term yield and SVAR measures are both found to be significant for the FTSE ALLSHARE, albeit not consistently.

Moving on to the other R^2_{OS} statistics, tables 5.9 shows that recession periods show stronger predictability for almost all of the interest rate spreads for the FTSE100, but none of the other indicators. Of the technical indicators, only one of the on-balance volume buy signals has both a positive R^2_{OS}Rec statistic and shows greater predictability in recession than in the overall sample. The other technical indicators are not only strongly outperformed by the historical benchmark, they also perform worse during recession than over the entire sample or during expansion periods. The FTSE ALLSHARE technical indicators also exhibit this performance, almost of the indicators are outperformed by the historical average, with the weakest performance during recession periods, and the relative strongest predictability occurring in periods of expansion. The economic indicators tend to perform best during recessions, compared to both expansions and the overall sample. The T-bill rate and the long-term yields being the exception to this for the FTSE 100 but not the ALLSHARE. These results are at odds to those found by Neely et al (2014) who find that technical indicators perform better in recessions than expansions, behaving in the same manner as the economic predictors. This suggests either two conclusions, either that equity premium prediction using technical indicators is more viable during economic expansion; a result at odds with theory that states market efficiency is greater during boom periods compared to downturns, or alternatively there is a factor not captured by the business cycle that explains the variability in premium forecasting accuracy.

Overall, these results present little evidence that equity premium prediction is economically viable out-of-sample, and there appears to be little difference between the performance of economic or technical indicators. Only four types of indicators show any degree of out-of-sample performance, three of which are economic and one technical. Using combined information from the individual indicators in the form of principal components improves performance for predicting the ALLSHARE equity premium, but not the FTSE100, a fact which suggests that there is a high-degree of differences in predictability between individual stock indexes, even within the same country.

Table 5.9 FTSE100 Out-of-Sample Results

FTSE100	OOS Start	R^2_{OS}	MSFE -Adjusted	RMSE	MAE	$RMSE^{HA}$	MAE^{HA}	R^2_{OS}Rec	R^2_{OS}Exp
TBL	1994m01	-0.0369	-0.3840	0.0175	0.0131	0.0172	0.0130	-0.0576	-0.0186
LTY(5)	1994m01	-0.0306	-0.3978	0.0175	0.0130	0.0172	0.0130	-0.0509	-0.0126
LTY(10)	1994m01	-0.0371	-0.5516	0.0175	0.0131	0.0172	0.0130	-0.0619	-0.0152
LTY(15)	1994m01	-0.0409	-0.6752	0.0175	0.0131	0.0172	0.0130	-0.0678	-0.0171
TMS(3-5)	1994m01	-0.0012	0.1262	0.0172	0.0131	0.0172	0.0130	0.0051	-0.0068
TMS(3-10)	1994m01	0.0011	0.5445	0.0172	0.0131	0.0172	0.0130	0.0071	-0.0042
TMS(3-15)	1994m01	0.0014	0.6565	0.0172	0.0130	0.0172	0.0130	0.0050	-0.0018
DRS(5)	2001m01	0.0210	1.8202**	0.0175	0.0132	0.0177	0.0132	0.0561	-0.0099
DRS(10)	2001m01	0.0110	1.3146*	0.0176	0.0132	0.0177	0.0132	0.0344	-0.0096
DRS(15)	2007m09	-0.0016	0.5080	0.0182	0.0142	0.0182	0.0143	-0.0126	0.0097
INF(-1)	1994m01	-0.0017	0.1085	0.0172	0.0130	0.0172	0.0130	-0.0014	-0.0020
INF(-2)	1994m01	-0.0058	-0.1022	0.0172	0.0130	0.0172	0.0130	-0.0094	-0.0026
INDMAN	1994m01	-0.1052	-0.5039	0.0181	0.0137	0.0172	0.0130	-0.0805	-0.1271
INDPROD	1994m01	-0.0084	-0.2446	0.0173	0.0132	0.0172	0.0130	0.0108	-0.0254
DY	1996m02	-0.3054	0.6975	0.0199	0.0163	0.0174	0.0133	-0.2843	-0.3237
PE	2003m08	-0.1770	-0.4869	0.0174	0.0130	0.0160	0.0123	-0.2299	-0.1298
DYS	1994m01	-0.0528	-0.7601	0.0176	0.0135	0.0172	0.0130	-0.0817	-0.0273
SVAR	1994M03	-0.0443	-0.0334	0.0175	0.0135	0.0172	0.0131	-0.0557	-0.0344
MA(1,9)	1994m10	-0.0863	-1.6897	0.0177	0.0135	0.0170	0.0129	-0.1019	-0.0722
MA(1,12)	1995m01	-0.0373	-1.4903	0.0174	0.0134	0.0171	0.0131	-0.0543	-0.0221
MA(2,9)	1994m10	-0.0753	-1.5843	0.0176	0.0133	0.0170	0.0129	-0.0956	-0.0570
MA(2,12)	1995m01	-0.0851	-1.1711	0.0178	0.0137	0.0171	0.0131	-0.1288	-0.0460
MA(3,9)	1994m10	-0.0786	-0.8909	0.0177	0.0134	0.0170	0.0129	-0.1055	-0.0543
MA(3,12)	1995m01	-0.0964	-1.6335	0.0179	0.0137	0.0171	0.0131	-0.1289	-0.0674
MOM(9)	1994m11	-0.0301	-2.7443	0.0173	0.0132	0.0170	0.0129	-0.0246	-0.0351
MOM(12)	1995m02	-0.0592	-1.0120	0.0177	0.0135	0.0171	0.0131	-0.0957	-0.0273
OBV(1,9)	2003m11	-0.0106	-0.8176	0.0162	0.0126	0.0161	0.0125	0.0004	-0.0205
OBV(1,12)	2004m02	0.0001	0.2667	0.0163	0.0127	0.0163	0.0127	-0.0001	0.0003
OBV(2,9)	2003m11	0.0013	0.4280	0.0161	0.0125	0.0161	0.0125	0.0157	-0.0115
OBV(2,12)	2004m02	0.0062	0.9955	0.0163	0.0126	0.0163	0.0127	-0.0001	0.0116
OBV(3,9)	2003m11	-0.0096	0.0377	0.0162	0.0125	0.0161	0.0125	-0.0016	-0.0167
OBV(3,12)	2004m02	0.0068	1.0088	0.0163	0.0125	0.0163	0.0127	0.0066	0.0069
PC Tech	2004M02	-0.0021	1.2752	0.0163	0.0126	0.0163	0.0127	0.0165	-0.0179
PC Econ	2007M09	-0.0253	-0.8410	0.0184	0.0143	0.0182	0.0143	-0.0552	0.0051
PC All	2007M09	-0.0681	-1.7806	0.0188	0.0150	0.0182	0.0143	-0.0312	-0.1056

Table 5.10 FTSEALLSHARE Out-of-Sample Results

FTSE ALLSHARE	**OOS Start**	R_{OS}^2	**MSFE -Adjusted**	**RMSE**	**MAE**	$RMSE^{HA}$	MAE^{HA}	R_{OS}^2**Rec**	R_{OS}^2**Exp**
TBL	1985m03	-0.0048	1.3222*	0.0196	0.0144	0.0195	0.0141	0.0270	-0.0280
LTY(5)	1985m03	0.0024	1.6470**	0.0195	0.0143	0.0195	0.0141	0.0324	-0.0194
LTY(10)	1985m03	0.0052	1.8003**	0.0195	0.0143	0.0195	0.0141	0.0336	-0.0156
LTY(15)	1985m03	-0.0101	1.9103**	0.0196	0.0146	0.0195	0.0141	0.0423	-0.0482
TMS(3-5)	1985m03	-0.0076	-0.8881	0.0196	0.0141	0.0195	0.0141	-0.0105	-0.0055
TMS(3-10)	1985m03	-0.0091	-1.2742	0.0196	0.0141	0.0195	0.0141	-0.0123	-0.0067
TMS(3-15)	1985m03	-0.0013	-0.1319	0.0195	0.0141	0.0195	0.0141	0.0023	-0.0039
DRS(5)	2001m01	0.0065	0.9883	0.0176	0.0133	0.0177	0.0131	0.0332	-0.0167
DRS(10)	2001m01	0.0075	0.9994	0.0176	0.0133	0.0177	0.0131	0.0306	-0.0128
DRS(15)	2007m09	-0.0025	3.3730**	0.0182	0.0140	0.0182	0.0141	-0.0145	0.0100
INF(-1)	1985m03	0.0078	1.9049**	0.0194	0.0143	0.0195	0.0141	0.0342	-0.0115
INF(-2)	1985m03	0.0095	2.0097**	0.0194	0.0142	0.0195	0.0141	0.0329	-0.0076
INDMAN	1985m03	0.0037	1.1170	0.0195	0.0141	0.0195	0.0141	0.0118	-0.0022
INDPROD	1985m03	0.0038	1.0875	0.0195	0.0141	0.0195	0.0141	0.0125	-0.0026
DY	1985m03	-0.7183	-0.2681	0.0256	0.0218	0.0195	0.0141	-0.5611	-0.8328
PE	2003m08	-0.0745	-0.1800	0.0167	0.0126	0.0162	0.0125	-0.1245	-0.0313
DYS	1985m03	-0.0011	1.6415*	0.0195	0.0143	0.0195	0.0141	0.0113	-0.0102
SVAR	1995M03	0.0142	1.3945*	0.0170	0.0132	0.0171	0.0131	0.0092	0.0187
MA(1,9)	1985m12	-0.0124	-0.3869	0.0196	0.0142	0.0194	0.0141	-0.0273	-0.0015
MA(1,12)	1986m03	-0.0292	0.1944	0.0198	0.0144	0.0195	0.0142	-0.0766	0.0056
MA(2,9)	1985m12	-0.0055	-0.7444	0.0195	0.0142	0.0194	0.0141	0.0036	-0.0122
MA(2,12)	1986m03	-0.0459	0.3089	0.0199	0.0145	0.0195	0.0142	-0.1147	0.0045
MA(3,9)	1985m12	-0.0034	-0.5436	0.0195	0.0142	0.0194	0.0141	-0.0058	-0.0017
MA(3,12)	1986m03	-0.0026	1.5138*	0.0195	0.0142	0.0195	0.0142	-0.0178	0.0086
MOM(9)	1985m12	-0.0986	-0.9442	0.0204	0.0149	0.0194	0.0141	-0.1438	-0.0654
MOM(12)	1986m03	-0.1140	0.2817	0.0206	0.0148	0.0195	0.0142	-0.2167	-0.0387
OBV(1,9)	2008m02	0.0018	0.4076	0.0181	0.0142	0.0181	0.0141	0.0025	0.0011
OBV(1,12)	2008m05	0.0160	1.8184**	0.0182	0.0143	0.0184	0.0144	0.0002	0.0291
OBV(2,9)	2008m02	0.0116	1.1895	0.0180	0.0141	0.0181	0.0141	0.0057	0.0170
OBV(2,12)	2008m05	0.0124	1.1410	0.0182	0.0143	0.0184	0.0144	-0.0074	0.0289
OBV(3,9)	2008m02	0.0017	0.2832	0.0181	0.0141	0.0181	0.0141	0.0024	0.0010
OBV(3,12)	2008m05	0.0204	1.5667*	0.0182	0.0142	0.0184	0.0144	0.0067	0.0319
PC Tech	2008M05	0.0188	1.4557*	0.0182	0.0143	0.0184	0.0144	0.0107	0.0256
PC Econ	2007M09	0.0400	2.2440**	0.0179	0.0137	0.0182	0.0141	0.0563	0.0231
PC All	2008M05	0.0635	3.7476**	0.0178	0.0136	0.0184	0.0144	0.0120	0.1065

5.4.4 Financial Stress and predictability

Both the in-sample and out-of-sample R^2 statistics suggest there is a high degree of variability in predictability dependent on sample period and economic circumstances, which corroborates with much of the findings in the literature. However, the results of the previous section for technical indicators are in contradiction to the findings of the studies that have examined them, finding that expansion periods exhibit higher predictability than recession. Henkel et al (2011) found that recession periods are unambiguously better for stock predictability, and both Neely et al (2014) and Baetje and Menkhoff (2016) confirm this is the case for technical indicators. Either this contradiction in results could be from the differences between the US and UK economies, or alternatively there are other factors that affect predictability. Noting that the data sample in this chapter includes several periods of financial duress, most noticeably the 2007-2009 financial crisis, an explanation for these results may be that the business cycle is not the only factor that affects predictability, and that financial market stress is a significant contributor to equity premium predictability.

Figures 5.12 and 5.13 below exhibit the time-varying nature of premium predictability. Using rolling regression windows of ten years, PC^{ECON} and PC^{TECH} models were estimated using OLS, recording the R^2 statistic for each sample period which are plotted below. For example, the FTSE100 PC^{TECH} model was estimated with a sample period between 1994 month one and 1994 month two, and the R^2 statistic was saved. Then the same model was estimated between 1994 month one and 1994 month three, again saving the R^2 statistic. This process was repeated until 2004 month 1, after which rolling windows of 120 observations were used until the end of sample period at 2017m02. The OECD recession and expansion indicators are overlaid across these plots for ease of interpretation. As an additional note, the initial R^2 estimates are likely to be over-estimated until around 5 years or 60 observations when there are enough estimates to establish a realistic estimate. The PC^{ALL}model was also estimated, however the results are, as can be expected, a middle-ground between the PC^{ECON} and PC^{TECH}models so are not shown here.

Looking at Fig. 5.12 and Fig. 5.13 it can be seen that the technical indicators are fairly consistent in R^2 values up until the financial crisis period. Of the two, the FTSE100 exhibits the most variability: the FTSE100 R^2 statistic stays largely between 0.02 and 0.04 between 1997 and 2007 but appears to increase to around 0.07 during recession periods. The 2000 to 2002 recession in particular is characterised by higher R^2 statistics. The ALLSHARE is largely consistent between 2001 and 2008, staying between 0.005 and 0.02 over this period, however there is a noticeable increase in the R^2 stats towards 2007. The PC^{ECON}also exhibit higher R^2 statistics during the 2000-2002 recession, followed by a similar period of low predictability between 2002 and 2008. The relationship between recessions and predictability during this period appears to be consistent with the both the findings of Neely et al. (2014), however the 2003-2004 recession appears to solicit no significant change in R^2 statistics, with little effect on either the PC^{ECON} and PC^{TECH} models. Furthermore, while the 2007-2009 recession does capture a period of high predictability for all of the PC models, an expansion period rather than recession between 2009 and 2012 is characterised by relatively high and volatile predictability. During this time period the UK was close to suffering from a ‘double-dip’ recession, which may explain this high predictability, however it remains as evidence that the business cycle alone does not account for variability in predictability.

Figure 5.12 FTSE100 Technical and Economic PC model performance over time

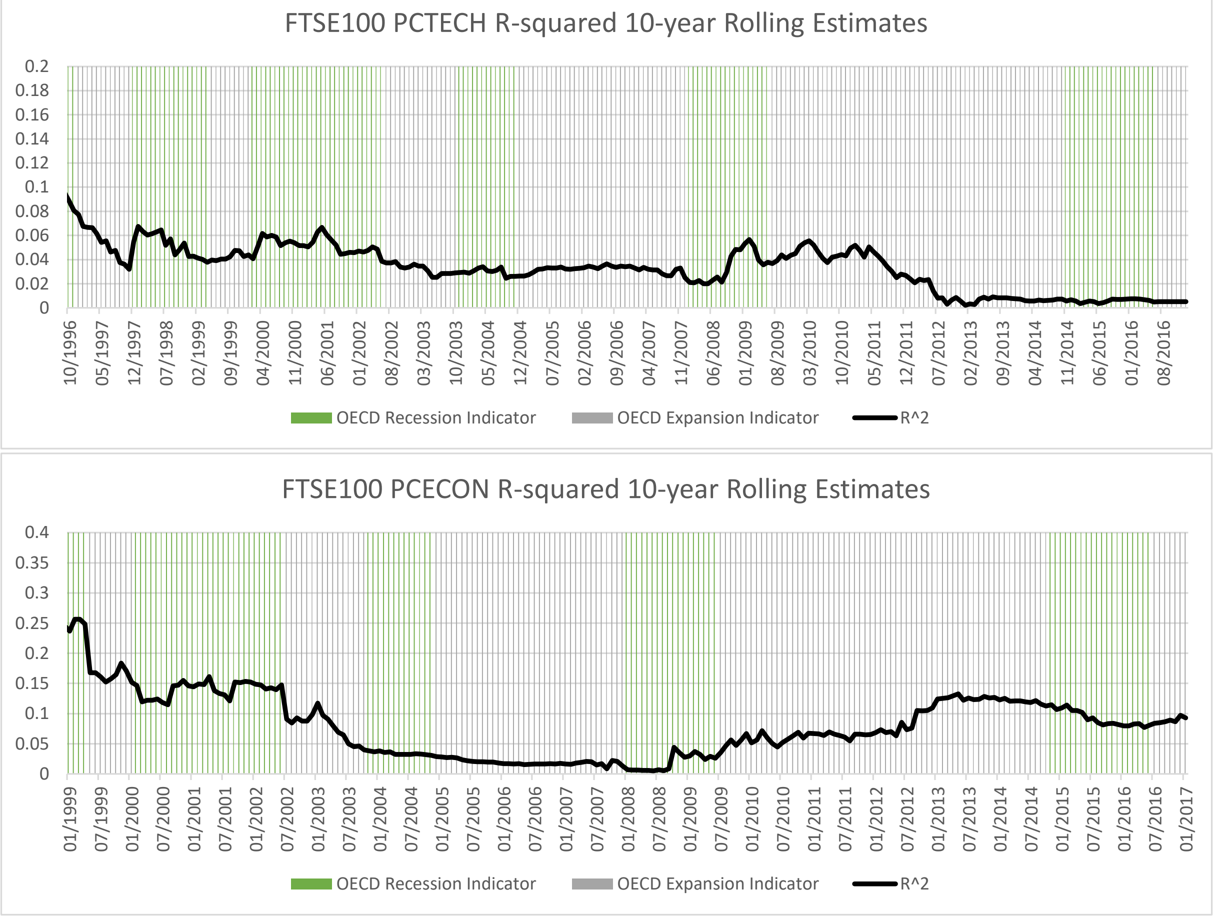
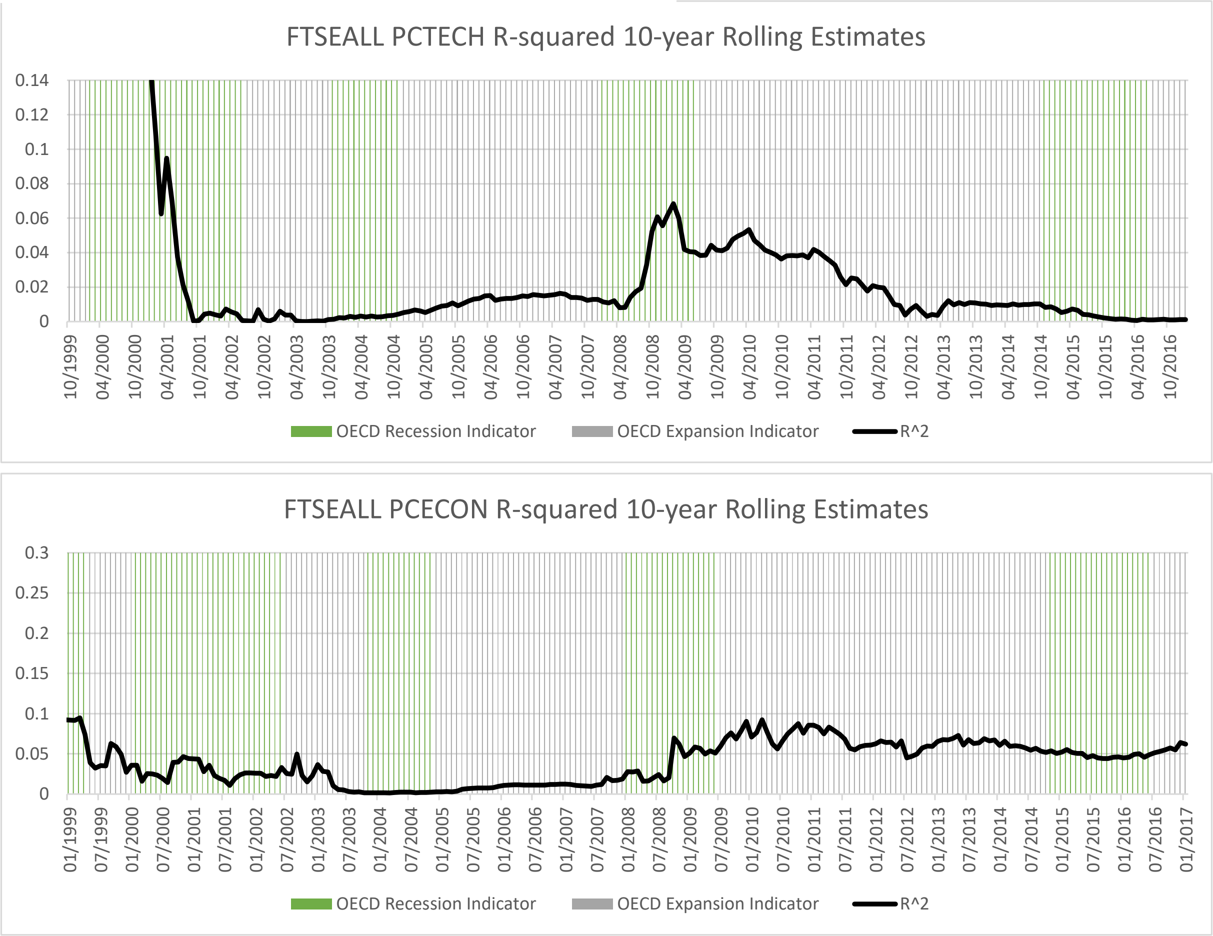


Figure 5.13 FTSEALLSHARE Technical and Economic PC model performance over time



With the previous results suggesting that the business cycle alone is insufficient for capturing the variability of predictability for the UK, and given the sample includes one of the larger financial crises in the last century, this chapter explores financial stress as a factor for predictability. As discussed before, the connection between financial stress, risk, and volatility has been frequently discussed, such as in Guidolin & Timmermann (2005). Building upon this, this chapter uses the previously created measure of the UK's financial stress to examine the relationship between predictability and economic conditions.

Table 5.11 FSI Components

Market	Variable	Aspect of Financial Stress represented	Calculation	Source
Interbank	Bank Beta (BETAFTAS)	Strain on bank profitability and stability	$\beta = \frac{\text{cov}(r,m)}{\text{var}(m)}$	Datastream
	Commercial Bank Bond Spread (BNKBDSPR)	Risk in bank debt markets	10-year Commercial bank yields minus 10-year government bond yields	Datastream, Bank of England Interactive Database
	Interbank Liquidity Spread (LIBORTBILL)	Liquidity and counterparty risk in interbank lending	3-month LIBOR minus 3-month UK Treasury Bill rate	Datastream, Bank of England Interactive Database
	Interbank Cost of Borrowing (LIBORBANK)	Risk premium in interbank borrowing	3-month LIBOR minus BoE Bank rate	Datastream, Bank of England Interactive Database
Foreign Exchange	Weighted Sterling Crashes (CMAXEFFEX)	Flight from sterling towards foreign currencies	$\frac{x_t}{\max\left[x \in x_{t-j} \middle\| j = 0,1,\ldots,365\right]}$	Datastream, Bank of England Interactive Database
Debt	Covered Interest Spread (CIPUKUS)	Limited arbitrage and uncertainty in government bond markets	$(1 + r_t^*) - (\frac{F_t}{S_t^*})(1 + r_t)$	Datastream, Bank of England Interactive Database
	UK-US Government Bond Spread (UKGOVTBUSGOVTB)	Limited arbitrage and uncertainty in government bond markets	10-year UK Government Bond Yield minus 10-year US Government Bond Yield	Datastream, Bank of England Interactive Database
	Yield Curve Spread (YLDCURVE10-3)	Long-term uncertainty and cost of short-term borrowing.	10-year government bond yield minus 3-month government bond yield	Bank of England Interactive Database
Equity	Stock Market Crash Index (CMAXALL)	Uncertainty in equity valuation and expectations of future bank profitability	$\frac{x_t}{\max\left[x \in x_{t-j} \middle\| j = 0,1,\ldots,365\right]}$ x_t=FTSEALLSHARE price index	Datastream

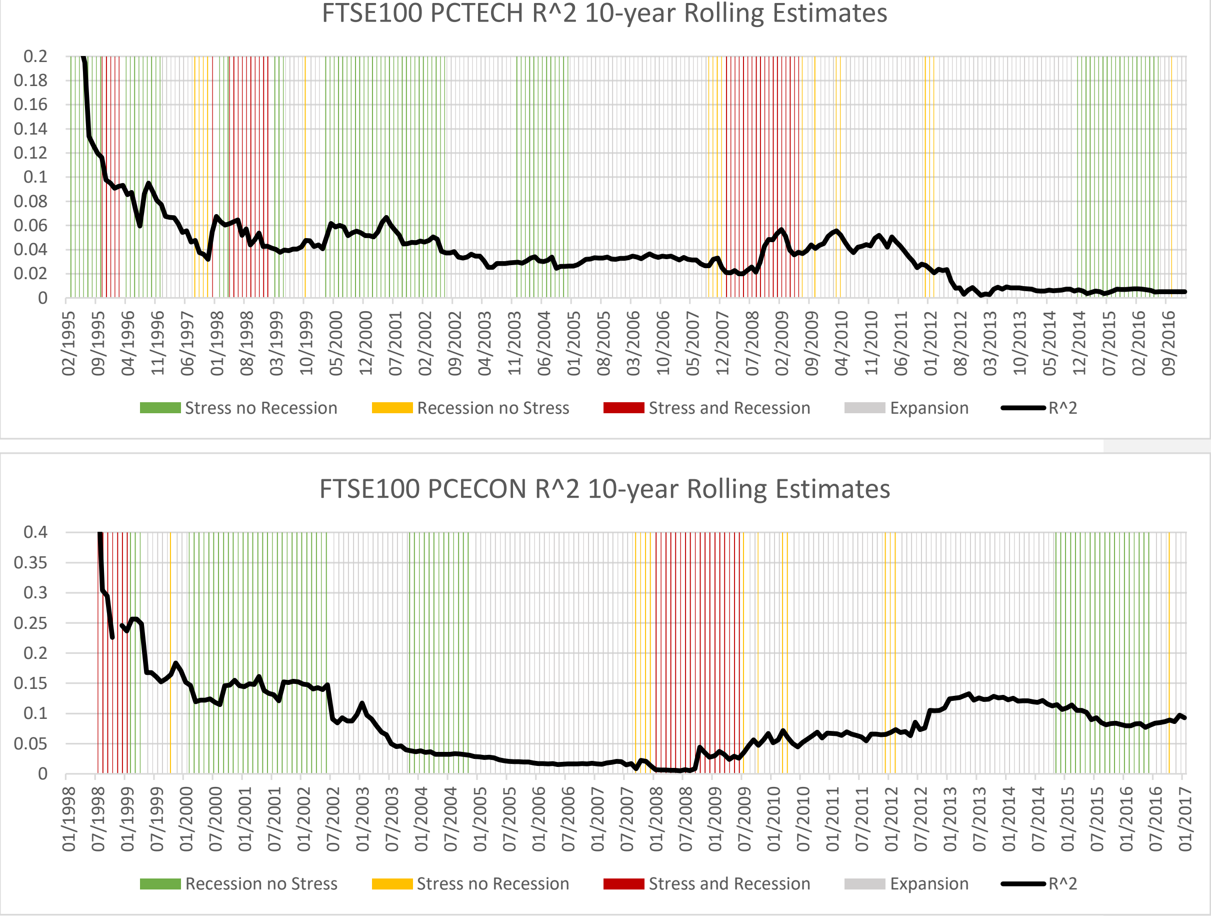
For the purposes of this chapter, the long sample FSI is used, as shown by table 5.11. As discussed in chapter 2, the simple standard deviation method is considered the simplest and most appropriate threshold mark for financial crises. Because of its computational simplicity, the standard deviation method can be used on all of the FSI weighting methods, as well as calculated using different levels of stringency. This makes robustness checks easier and more effective. For this reason, this chapter takes the benchmark definition of a stressful period as an observation that is one standard deviation above the mean. The following results are robust to this measure, as testing found the results qualitatively consistent when using 1.5 or two standard deviations. At the most stringent benchmark of two standard deviations, the effects described below are stronger in most cases.

Treating the FSIs in the same manner as the business cycle indicators, I_t^{FS} and I_t^{NonFS} represent periods of financial stress and periods of relaxed financial conditions, respectively. Stressful periods are defined as periods when the FSIs indicate stress levels more than one standard deviation above the sample mean with I_t^{FS} being valued at one during these periods. $I_t^{NonFS}$is the simple inverse of this, indicating periods of relatively normal financial conditions The Financial stress measure shown in Figures 5.14 and 5.15 are from the VE, CDF and PC aggregations of the index, where the periods highlighted in the figures are months when any of the FSIs indicate average stress values above one standard deviation from the sample mean. This could be considered a relaxed interpretation of financial stress, however all three of the measures mostly corroborate the timings of financial stress episodes, with differences being solely in the start and finish of such periods. For example, all of the FSIs indicate stress between 2011 and 2012, however the PC FSI only indicates one-month of high stress, while the CDF aggregation finds three. In any case, using more stringent benchmarks yield qualitatively similar results. When measuring predictability, the I_t^{FS} and I_t^{NonFS} indicators are calculated from the stressful or non-stressful periods found in the VE calculation.

Looking at Figures 5.14 and 5.15 periods highlighted in green are the same periods of recession as shown earlier, however now in addition periods of red denote months when both the business cycle was in recession and the financial system was in a period of financial stress. Amber periods denote times when the financial system was stressed, but the overall economy was in expansion. For all of the plots, the highest R^2 statistics occur when the economy is both in recession and suffering from financial stress, during the financial crisis period. While it is impossible to say with certainty which of the two factors if either are the driving force, it is clear that recession and financial stress together correlate with high predictability.

The amber periods are of particular interest as they seem to correspond to periods of rising or high predictability, especially after the recession period between 2008 and 2009. Local periods of high R^2 statistics during expansion correspond to periods of financial stress, best shown by the 2010 high-point. However, there are several periods of high R^2 statistics that are not denoted as either stressful periods or recession, such as the time-period between 2002 and 2003. A possible explanation for this period of high predictability is the 2002 US stock market downturn, which did not cause an economic recession in the UK, but significant financial stress in the US (Hakkio and Keeton, 2009). A spill-over effect from US financial stress may be the root of the higher predictability, however it is beyond the scope of this chapter to determine this by including a US financial stress measure. Another period of relatively large R^2 statistics is during the middle of 2011, which are apparent in Figures 5.14 in 5.15 to not be captured by the financial stress indicator. Looking at the monthly average values of the FSIs during this period, they are all close to but below the one standard deviation threshold, meaning that financial stress was above average during this period but not sufficiently so compared to other stressful episodes. Whether these issues are down to the FSIs failing to capture stressful periods, or more likely an indication of more factors at play than the business and financial cycles, is unclear. However overall, the R^2 statistics appear to demonstrate a link between financial stress and predictability that explains some of the increased predictability since the financial crisis, and the unexpected relationship between economic expansion and the forecasting ability of the technical indicators.

Figure 5.14 FTSE100 Technical and Economic PC model performance over time



Using the same in-sample and out-of-sample R^2 statistics as before but using financial stress periods rather than recession or expansion yields the results found in tables 5.12 and 5.13. For the sake of conciseness, these tables only include the variables that were found to have performed both in-sample and out-of-sample, specifically the term spreads, credit spreads, inflation and the on-balance volume indicators. The PC regression results are also included, even though the PC models for the FTSE100 were all found to perform poorly out-of-sample. The results of the other variables are contained in the appendix and follow largely the same patterns. The in-sample Table 5.12 reports the R^2 statistics for the overall sample, recessions, expansions, financial stress periods and non-stressful periods.

For both equity premiums and almost all of the indicators, predictability is noticeably higher during financially stressful periods. Almost all of the R^2FS statistics are positive and above the 0.005 level. In addition, periods of low financial stress show R^2 statistics lower than the sample predictability, with almost all of the predictors exhibiting predictability lower than the 0.005 threshold to be considered economically exploitable. The only exception to this pattern is from the longer-term credit spreads, which appear to yield the most predictability during expansion periods and perform poorly during periods of high financial stress. Of interest here is that this is at odds with the shortest (5-years) credit spread that has the largest R^2 statistics during financial stress. This may indicate the different information the respective credit spreads contain, the shortest maturity spread may indicate upcoming debt-market risk in the short-term, containing relevant trading information for investors trading with shorter-term profits in mind, while the longer spreads contain more information about long-term risk premia. The fact that the longer default return spreads are have smaller R^2 statistics lends credence to this explanation.

The out-of-sample performance of these variables also show that predictability is highly concentrated around financial stress periods, especially in the case of the on-balance technical indicators. During these periods the on-balance indicators strongly outperform the historical

Overall these results suggest a strong relationship between periods of financial stress and predictability for both the economic and technical indicators. While these results do not refute the relationship between the business cycle and predictability in any way, it is clear that the financial cycle contributes a significant element to this predictability, particularly in the case of the technical indicators.

Table 5.12 In-Sample predictive comparisons

FTSE100	R^2	R^2Rec	R^2Exp	R^2FS	R^2NFS		**FTSEALLSHARE**	R^2	R^2Rec	R^2Exp	R^2FS	R^2NFS
TMS(3-5)	0.0014	0.0000	0.0027	0.0068	-0.0001		**TMS(3-5)**	0.0007	-0.0004	0.0017	0.0066	-0.0010
TMS(3-10)	0.0039	0.0017	0.0059	0.0099	0.0022		**TMS(3-10)**	0.0032	0.0007	0.0056	0.0130	0.0004
TMS(3-15)	0.0056	0.0029	0.0080	0.0109	0.0041		**TMS(3-15)**	0.0051	0.0018	0.0082	0.0155	0.0021
DRS(5)	0.0059	0.0103	0.0019	0.0146	0.0034		**DRS(5)**	0.0046	0.0078	0.0016	0.0209	0.0000
DRS(10)	0.0026	-0.0010	0.0058	-0.0073	0.0054		**DRS(10)**	0.0024	-0.0016	0.0062	-0.0037	0.0041
DRS(15)	0.0027	-0.0019	0.0066	-0.0176	0.0084		**DRS(15)**	0.0024	-0.0018	0.0062	-0.0140	0.0077
INF(-1)	0.0012	-0.0027	0.0049	0.0108	-0.0015		**INF(-1)**	0.0019	-0.0022	0.0057	0.0145	-0.0017
INF(-2)	0.0011	-0.0017	0.0037	0.0125	-0.0021		**INF(-2)**	0.0016	-0.0013	0.0043	0.0155	-0.0024
OBV(1,9)	0.0001	0.0008	-0.0004	-0.0026	0.0021		**SVAR**	0.0171	0.0102	0.0236	-0.0049	0.0233
OBV(1,12)	0.0010	0.0014	0.0006	-0.0080	0.0039		**OBV(1,9)**	0.0016	0.0000	0.0032	0.0114	-0.0012
OBV(2,9)	0.0038	0.0073	0.0009	0.0207	0.0003		**OBV(1,12)**	0.0007	0.0005	0.0009	0.0158	-0.0020
OBV(2,12)	0.0038	0.0064	0.0016	0.0132	0.0015		**OBV(2,9)**	0.0114	0.0064	0.0161	0.0437	0.0020
OBV(3,9)	0.0027	0.0043	0.0013	0.0092	0.0020		**OBV(2,12)**	0.0007	0.0005	0.0009	0.0158	-0.0020
OBV(3,12)	0.0063	0.0142	-0.0004	0.0168	0.0037		**OBV(3,9)**	0.0016	-0.0003	0.0034	0.0083	-0.0003
							OBV(3,12)	0.0074	0.0011	0.0132	0.0248	0.0040
PC Tech	0.0155	0.0418	-0.0072	0.0078	0.0177		**PC Tech**	0.0055	0.0077	0.0035	0.0248	-0.0002
PC Econ	0.0237	0.0140	0.0321	0.031121	0.021317		**PC Econ**	0.0310	0.0288	0.0331	0.0365	0.0293
PC All	0.0172	0.0208	0.0147	0.0114	0.0190		**PC All**	0.0405	0.0366	0.0440	0.0503	0.0377

Table 5.13a Out-of-Sample Predictive Comparisons

FTSE100 OOS	**OOS Start**	R^2_{OS}	R^2_{OS}**Rec**	R^2_{OS}**Exp**	$R^2_{OS}FS$	$R^2_{OS}NFS$
TMS(3-5)	1994m01	-0.0012	0.0051	-0.0068	0.0170	-0.0065
TMS(3-10)	1994m01	0.0011	0.0071	-0.0042	0.0148	-0.0029
TMS(3-15)	1994m01	0.0014	0.0050	-0.0018	0.0105	-0.0013
DRS(5)	2001m01	0.0210	0.0561	-0.0099	0.0655	0.0068
DRS(10)	2001m01	0.0110	0.0344	-0.0096	0.0303	0.0049
DRS(15)	2007m09	-0.0016	-0.0126	0.0097	-0.0112	0.0039
INF(-1)	1994m01	-0.0017	-0.0014	-0.0020	0.0179	-0.0074
INF(-2)	1994m01	-0.0058	-0.0094	-0.0026	0.0191	-0.0130
OBV(1,9)	2003m11	-0.0106	0.0004	-0.0205	-0.0142	-0.0090
OBV(1,12)	2004m02	0.0001	-0.0001	0.0003	-0.0190	0.0090
OBV(2,9)	2003m11	0.0013	0.0157	-0.0115	0.0371	-0.0157
OBV(2,12)	2004m02	0.0062	-0.0001	0.0116	0.0221	-0.0012
OBV(3,9)	2003m11	-0.0096	-0.0016	-0.0167	0.0381	-0.0323
OBV(3,12)	2004m02	0.0068	0.0066	0.0069	0.0348	-0.0062
PC Tech	2004M02	-0.0021	0.0165	-0.0179	0.0251	-0.0148
PC Econ	2007M09	-0.0253	-0.0552	0.0051	-0.0646	-0.0032
PC All	2007M09	-0.0681	-0.0312	-0.1056	0.0179	-0.1165

Table 5.13b Out-of-Sample Predictive Comparisons

FTSEALLSHARE OOS	**OOS Start**	R_{OS}^2	R_{OS}^2**Rec**	R_{OS}^2**Exp**	R_{OS}^2FS	R_{OS}^2NFS
TMS(3-5)	1985m03	-0.0076	-0.0105	-0.0055	-0.0086	-0.0075
TMS(3-10)	1985m03	-0.0091	-0.0123	-0.0067	-0.0092	-0.0091
TMS(3-15)	1985m03	-0.0013	0.0023	-0.0039	0.0027	-0.0020
DRS(5)	2001m01	0.0065	0.0332	-0.0167	0.0365	-0.0036
DRS(10)	2001m01	0.0075	0.0306	-0.0128	0.0298	-0.0001
DRS(15)	2007m09	-0.0025	-0.0145	0.0100	-0.0121	0.0036
INF(-1)	1985m03	0.0078	0.0342	-0.0115	0.0229	0.0052
INF(-2)	1985m03	0.0095	0.0329	-0.0076	0.0236	0.0071
SVAR	1995M03	0.0142	0.0092	0.0187	-0.0192	0.0243
OBV(1,9)	2008m02	0.0018	0.0025	0.0011	0.0180	-0.0091
OBV(1,12)	2008m05	0.0160	0.0002	0.0291	0.0125	0.0180
OBV(2,9)	2008m02	0.0116	0.0057	0.0170	0.0562	-0.0183
OBV(2,12)	2008m05	0.0124	-0.0074	0.0289	0.0479	-0.0089
OBV(3,9)	2008m02	0.0017	0.0024	0.0010	0.0180	-0.0093
OBV(3,12)	2008m05	0.0204	0.0067	0.0319	0.0372	0.0105
PC Tech	2008M05	0.0188	0.0107	0.0256	0.0413	0.0054
PC Econ	2007M09	0.0400	0.0563	0.0231	0.0813	0.0137
PC All	2008M05	0.0635	0.0120	0.1065	0.0704	0.0594

Figure 5.14 FTSE100 Technical and Economic PC model performance over time

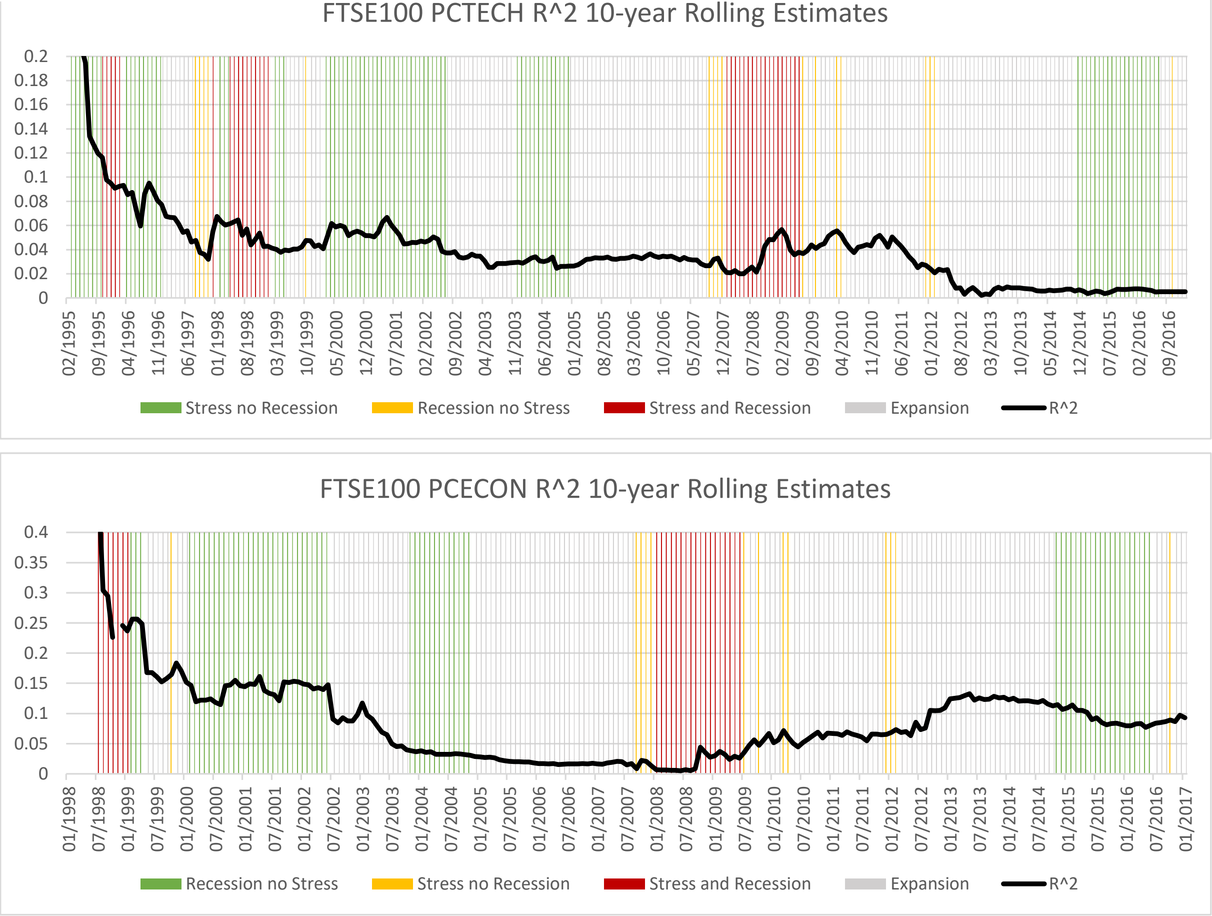
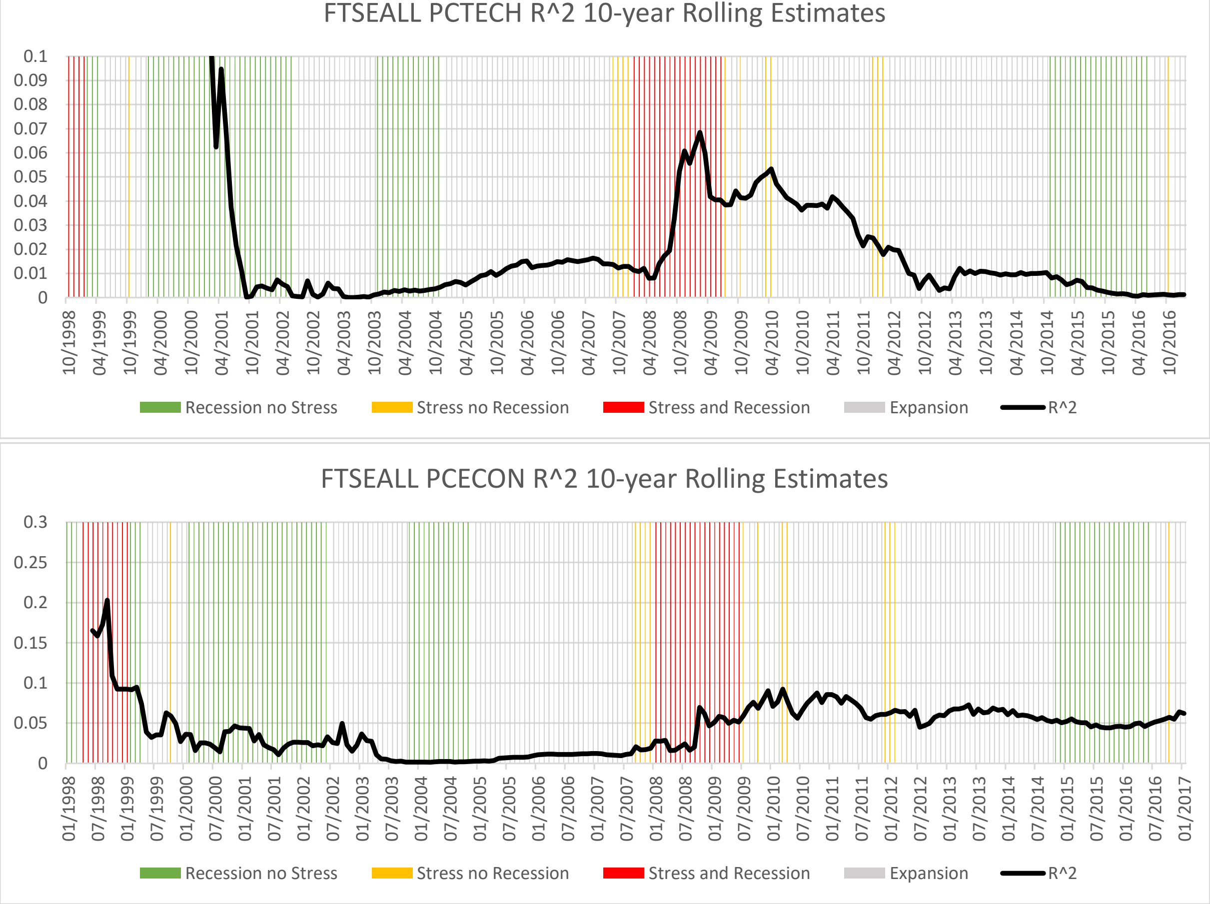


Figure 5.15 FTSEALLSHARE Technical and Economic PC model performance over time



5.5 Conclusions

This chapter has examined equity premium prediction for the UK using the most popular and successful economic and technical indicators over the longest sample that reliable UK financial data can provide, comparing the performance of these indicators with one another and the results found in the literature, especially the recent work conducted by Neely et al (2014). For economic indicators results are found that are commensurate with much of the recent literature on US equity premium forecasting; only a select few predictors can provide consistent forecasting ability both in and out of sample. On the other hand, this chapter establishes that the success of these indicators is not a statistical fluke or an idiosyncrasy of US financial markets, rather that term and credit spreads contain relevant and stable information for equity traders. Furthermore, if market efficiency can be connected to the failure of return predictability, then the results found for economic indicators suggest UK financial markets are of a comparable market efficiency to the US in this regard. For technical indicators similar results are found to the economic variables, that the majority of trend-following trading rules cannot predict equity premium, with only the indicators that utilise both trade volumes and pricing trends having any success. Unlike Neely et al (2014) the combination of the information from these indicators into principal components does not consistently yield superior predictive performance, with the in and out-of-sample performance resting heavily on the model selection used in the principal component procedure. These results suggest two potential conclusions, firstly that the UK financial markets are more efficient than their US counterparts in that trading rules are not economically exploitable. The second conclusion is that the later sample used in this chapter is the key factor in the non-performance of technical indicators, with Neely et al (2014) using data from as early as the 1950s, where trading rules may have been more successful. This conclusion supports the argument that market efficiency has improved since the 1980s.

On the other hand, this chapter also finds evidence of strong variability in the performance of forecasting variables, variability that can successfully explained by with respect to both the economic and financial conditions of the United Kingdom. This chapter tests to see whether the business cycle, a factor that is well-established in the literature as cause of time-varying predictability in the US, is relevant for equity premium prediction in the UK. This chapter finds that there is substantial component of predictability related to the business cycle, however that the business cycle alone is insufficient in explaining the time-varying nature of equity prediction. The final novel contribution of this chapter is therefore to explicitly display the effect of financial stress on the predictive ability of both economic and technical indicators as an addition to the business cycle. This chapter finds results showing that periods of high financial stress, such as the recent 2007-2009 financial crisis, significantly increase the predictive performance of both types of indicators when compared to periods of relaxed financial circumstances, an effect that is even more pronounced than the results found for the business cycle. These results open the way for future examination as to whether it is the business cycle or rather financial conditions that impacts changing predictive performance, an analysis that is beyond the scope of this chapter but of interest to any study that examines economic forecasting or the effects of financial stress on market efficiency.

6. Thesis Conclusion

Judging the effects of monetary policy during a financial crisis is a difficult task. The unprecedented use of QE in such an unstable economic climate makes differentiating the outcomes of the policy from the general volatility of the period problematic. This thesis has attempted to isolate any potential effects of QE on asset pricing through a range of econometric methods, simultaneously modelling financial stress and its own impact on pricing. Previous research into QE has been constrained heavily by theoretical assumptions on portfolio balance theory, signalling theory and other asset pricing channels, this thesis has used these channels as a basis for possible impact but has not modelled such channels explicitly. Instead this thesis has followed an empirically rigorous but theoretically agnostic approach, judging QE through quantifiable effects without attempting to characterise these effects through a theoretical framework. Throughout this thesis, the empirical analyses have shown that QE had much narrower effect on financial markets than previously understood. While much of the results echo other studies in finding significant effects on gilt yields, at least in the short term, this thesis has presented evidence that depress gilt yields did not transmit to rising asset prices or reduced financial stress. Chapters 2 and 4 shows that gilt yields possess the necessary links with other UK assets to be a vector for monetary policy transmission, and that QE auctions, announcements and purchase periods significantly impacted gilt pricing and volatility. However, these same analyses show that corporate bonds were not systematically affected in the same way by QE and that UK equities are shown to be largely unaffected by the policy. The final chapter of the thesis has shown that equity market efficiency was significantly affected by financial stress and the business cycle after the onset of QE, indicating that QE did little to restore pre-financial crisis market efficiency. The conclusion drawn from the results of all the chapters of this thesis is that UK equities markets were largely unaffected by QE.

These findings have a range of implications for economic study. First and foremost, this thesis presents evidence that portfolio-balance and signalling channels are not as determinate in asset pricing as previously understood. Although there is evidence found throughout this thesis that shows government bonds were significantly impacted by the QE announcements and purchases, the evidence that these effects were transmitted through to other financial instruments is sadly more lacking. The portfolio balance channel in particular has been shown to be less extensive than anticipated, with equity prices and corporate bonds showing mixed and limited responses to the QE purchases. This thesis also provides evidence that not all Bank of England announcements had their intended effects on supporting asset prices through the signalling and macro news channels, as many announcements and QE periods were characterised by higher volatility and market uncertainty. Furthermore, although QE was not a policy aimed at improving financial conditions, at least over the long term, the failure of the policy to reduce the symptoms of financial stress and general asset volatility has implications on the policy and its usage in future. Upon review of these conclusions, proponents of QE could consider that QE seemingly is not a solution to adverse financial conditions or liquidity problems in the short term. This interpretation is also of potential interest to policy-makers, monetary policy theorists and researchers studying asset pricing. The weak responses of the other assets to gilt price changes also suggest that in times of financial or economic duress, the links between asset markets are much weaker, presenting a potential obstacle for the efficient pricing of financial assets. Another important implication of this thesis is that financial stress has a significant impact on market efficiency, at least with regards to equity markets. The financial cycle has been proven to be a significant contributor to financial market inefficiency, alongside the business cycle. This creates an avenue for future study or revision into market efficiency, arbitrage pricing and preferred habitat theories during times of economic duress.

It is important note to overstate the implications of these conclusions for there are several limitations of this thesis to consider. In terms of focus this thesis has not attempted to judge QE in terms of its declared objectives. These have always been macroeconomic in scale, with relatively little consideration of the effect on asset pricing apart from as a transitory objective. Furthermore, this thesis offers no implications about whether QE prevented economic or financial downturn, or whether the policy was cost effective with regards to the potential cost of future inflationary effects. The scale of this thesis' critique of QE can therefore be limited to the argument that QE required stable financial market function to transmit its intended effects to the wider economy, a factor the policy did not achieve. This leads on to the second limitation of the thesis, the focus on the short term. The empirical studies have focused on capturing QE effects at short periodicities, with time-windows of a few months at maximum. For this reason, this thesis cannot conclude that QE had no effects on asset pricing over the longer-term. This was not a stated objective of the thesis, as any examination of QE's macroeconomic effects both in the short and long-term would be prohibitively extensive for an individual thesis. However, it should be noted that none of the conclusions drawn from this thesis can be considered the full picture when quantifying the effects of QE. In addition, while the focus of this chapter has been on UK markets, and efforts were made to ensure that the assets studied were primarily affected by UK QE only, this thesis has not and could not isolate a UK specific effect from spill-over effects of foreign financial circumstances. The ECB and FEDs use of QE in particular will have undoubtedly had an effect on UK asset pricing, a fact which has not been compensated for due to the inherent complexity of such a task. The final key limitation of this thesis is the lack of theoretical modelling in terms of the potential effects of QE and financial crisis on asset pricing. While the focus on empirical examination was a stylistic choice with its own strengths, it cannot be ignored that the lack of theoretical structures in the empirical examinations might have led to the over/under-estimation of the effects of QE. The mixed results found for corporate bonds and equities may have gained some additional interpretation if their pricing had been modelled more explicitly within a theoretical framework.

These limitations leave avenues for potential future research. First and foremost, the financials stress index created in this thesis could be expanded upon to further examine the interaction between QE and financial conditions. Chapter 3 discusses the effect of QE events on the level of the index, however further research could examine how monetary policy or QE affected the likelihood of Financial stress reaching a crisis threshold. Alternatively, the stress index could be adapted to focus more on indicators that capture the liquidity, bank-lending and channels of QE, and therefore be used to analyse the policy more thoroughly. Further to this, the index itself could be investigated in more detail. At the time of writing, this index is the most comprehensive measure of financial stress that exists for the United Kingdom, with other indexes being either narrower in scope or shorter in sample. However currently the index is untested in terms of success rates for capturing crisis events, merely using the same methodology as studies who have tested their respective indices. Further research into testing and improving this index could therefore produce a measure that is valuable for academic and policy-making purposes.

Apart from the financial stress index, there remains many unanswered questions from this thesis that could be explored in future research. One interesting potential area could be the links between QE, market efficiency and constrained arbitrage because of the financial crisis. The results of chapter 4 in particular find that financial stress is associated with greater success in return predictability and thereby to reduced market efficiency. The model in chapter 4 however does not analyse the interaction between stress and stock forecasting, merely linking the two informally. Future research could model the interaction between stress and predictability more explicitly and thereby provide a stronger contribution to forecasting literature.

7. Appendix

7.1 Appendix to Chapter 1

7.1.1 VEC Coefficient Tables

The coefficient estimates of the endogenous variables in the system were estimated by OLS with Newey-West standard errors and are reported in the appendix for each VAR model. Each column refers to the dependent variable and the value in each cell is the estimated lagged coefficient. T-stats are reported in the second row of each cell. Significant coefficients are denoted with *, ** and *** for 10, 5 and 1 percent levels of significance, respectively. As an example, the first column twelfth row denotes the effect of 5 years to maturity commercial bank bond yields lagged 2-periods on the FTSE100.

A-Table 1.1a Coefficient Table Commercial Yield Model

	FTSE 100	**Comm 5**	**Comm 15**	**Comm 25**	**Dollar**	**Euro**	**Govt 5**	**Govt 15**	**Govt 25**
FTSE100 (-1)	0.117	-0.437	-0.023	0.093	-0.031	0.032	-0.275	0.095	0.086
	1.939	*-1.649*	*-0.101*	*0.471*	*-0.582*	*0.984*	*-0.956*	*0.352*	*0.348*
FTSE100 (-2)	0.002	0.343	0.010	-0.019	0.115***	0.032	0.596	0.210	0.143
	0.029	*1.256*	*0.043*	*-0.091*	*2.092*	*0.963*	*2.017*	*0.753*	*0.564*
FTSE100 (-3)	-0.081***	-0.332**	-0.191	-0.022	0.031	-0.031	-0.574***	-0.504**	-0.253
	-1.347	*-1.257*	*-0.855*	*-0.113*	*0.580*	*-0.977*	*-2.009*	*-1.866*	*-1.034*
FTSE100 (-4)	-0.077**	0.321	-0.118	-0.422***	0.051	0.092**	0.130	0.091	-0.272
	-1.315	*1.249*	*-0.540*	*-2.213*	*0.976*	*2.938*	*0.469*	*0.345*	*-1.142*
Comm5 (-1)	0.030	0.096	-0.145***	-0.164*	-0.008	-0.011	-0.105	-0.317*	-0.291*
	0.874	*0.630*	*-1.119*	*-1.449*	*-0.266*	*-0.585*	*-0.636*	*-2.030*	*-2.055*
Comm5 (-2)	-0.136***	-0.110	-0.126	-0.145*	-0.021	0.006	-0.158	-0.176	-0.155
	-3.980	*-0.736*	*-0.987*	*-1.305*	*-0.699*	*0.340*	*-0.974*	*-1.144*	*-1.117*
Comm5 (-3)	0.000	-0.222	-0.053	-0.016	-0.007	-0.023	0.080	-0.040	-0.043
	-0.013	*-1.475*	*-0.415*	*-0.143*	*-0.221*	*-1.233*	*0.491*	*-0.259*	*-0.309*
Comm5 (-4)	0.042	0.334***	0.242***	0.108	0.043*	0.017	0.477***	0.315**	0.227*
	1.224	*2.206*	*1.885*	*0.959*	*1.410*	*0.916*	*2.910*	*2.034*	*1.617*
Comm15(-1)	-0.003	-0.283	-0.179	-0.208	0.025	0.020	0.111	0.271	0.343
	-0.041	*-0.801*	*-0.596*	*-0.790*	*0.354*	*0.452*	*0.289*	*0.747*	*1.046*
Comm15(-2)	-0.066	-0.143	-0.282	-0.052	-0.034	-0.017	-0.283	-0.258	-0.223
	-0.816	*-0.405*	*-0.944*	*-0.199*	*-0.478*	*-0.388*	*-0.742*	*-0.716*	*-0.681*
Comm15(-3)	-0.018	0.280	0.226	0.197	0.162*	0.050	-0.304	0.228	0.141
	-0.229	*0.801*	*0.763*	*0.759*	*2.301*	*1.168*	*-0.802*	*0.639*	*0.434*
Comm15(-4)	-0.097	-0.293	-0.130	-0.037	-0.066	0.012	-0.354	-0.098	-0.075
	-1.211	*-0.834*	*-0.436*	*-0.142*	*-0.929*	*0.271*	*-0.933*	*-0.273*	*-0.230*
Comm25(-1)	-0.044	0.004	0.002	0.170	-0.007	-0.019	-0.352	-0.345	-0.278
	-0.605	*0.011*	*0.006*	*0.710*	*-0.105*	*-0.492*	*-1.009*	*-1.049*	*-0.931*
Comm25(-2)	0.143	0.373	0.481***	0.201	0.079	0.062	0.501*	0.742***	0.693***
	1.947	*1.160*	*1.765*	*0.843*	*1.220*	*1.572*	*1.441*	*2.256*	*2.325*
Comm25(-3)	0.023	-0.120	-0.232	-0.253	-0.123	-0.028	0.300	-0.305	-0.172
	0.311	*-0.367*	*-0.836*	*-1.045*	*-1.871*	*-0.694*	*0.848*	*-0.913*	*-0.567*
Comm25(-4)	0.018	0.073	-0.013	-0.030	0.094	-0.006	-0.070	-0.242	-0.123
	0.244	*0.230*	*-0.047*	*-0.127*	*1.471*	*-0.144*	*-0.205*	*-0.746*	*-0.418*
Dollar(-1)	-0.073	0.047	-0.136	0.033	0.197***	-0.062***	-0.254	-0.577**	-0.447**
	-1.016	*0.151*	*-0.510*	*0.140*	*3.121*	*-1.620*	*-0.749*	*-1.798*	*-1.535*
Dollar(-2)	-0.116**	-0.030	-0.061	0.034	-0.115	-0.033	-0.286	-0.013	-0.020
	-1.594	*-0.095*	*-0.226*	*0.145*	*-1.789*	*-0.838*	*-0.825*	*-0.039*	*-0.068*
Dollar(-3)	-0.013	0.551***	0.453*	0.199	0.174	0.112	0.735	0.821**	0.598*
	-0.177	*1.730*	*1.676*	*0.840*	*2.701*	*2.892*	*2.130*	*2.518*	*2.020*
Dollar(-4)	0.157*	-0.093	-0.056	0.201	-0.090	-0.056	-0.027	-0.083	0.067
	2.230	*-0.301*	*-0.212*	*0.878*	*-1.451*	*-1.479*	*-0.080*	*-0.262*	*0.235*

Notes. Dependent Variables are shown along the first row. T-stats are given in the second row of each section, and are shown in italics.

A-Table 1.1b Coefficient Table Commercial Yield Model

	FTSE 100	Comm 5	Comm 15	Comm 25	Dollar	Euro	Govt 5	Govt 15	Govt 25
Euro(-1)	-0.342**	0.050	0.019	-0.319	-0.111	0.280***	0.107	0.404	0.037
	-3.216	*0.108*	*0.049*	*-0.923*	*-1.184*	*4.926*	*0.212*	*0.848*	*0.086*
Euro(-2)	-0.022	0.158	0.542	0.641	-0.231***	-0.116***	0.317	0.520	0.803
	-0.197	*0.326*	*1.315*	*1.778*	*-2.360*	*-1.955*	*0.602*	*1.046*	*1.782*
Euro(-3)	0.030	-0.281	-0.740**	-0.631***	0.036	-0.018	-0.461	-0.924*	-0.997***
	0.266	*-0.573*	*-1.782*	*-1.735*	*0.361*	*-0.307*	*-0.869*	*-1.845*	*-2.194*
Euro(-4)	-0.274**	-0.263	-0.239	-0.461	0.061	0.091**	-0.556	-0.375	-0.550
	-2.522	*-0.552*	*-0.591*	*-1.305*	*0.632*	*1.576*	*-1.080*	*-0.771*	*-1.245*
Govt5(-1)	-0.004	0.460***	0.383***	0.305***	0.013	0.019	0.517***	0.360**	0.243*
	-0.120	*3.134*	*3.079*	*2.800*	*0.455*	*1.054*	*3.251*	*2.398*	*1.783*
Govt5(-2)	0.133**	-0.114	-0.025	-0.024	0.032	0.004	-0.063	0.032	0.002
	4.089	*-0.803*	*-0.210*	*-0.228*	*1.114*	*0.248*	*-0.408*	*0.221*	*0.012*
Govt5(-3)	0.030	0.330**	0.104	0.038	0.001	-0.004	0.153	0.057	0.010
	0.895	*2.276*	*0.847*	*0.356*	*0.024*	*-0.199*	*0.973*	*0.387*	*0.077*
Govt5(-4)	-0.045**	-0.240***	-0.196***	-0.062	-0.009	0.020*	-0.315***	-0.226**	-0.149
	-1.399	*-1.690*	*-1.628*	*-0.590*	*-0.331*	*1.130*	*-2.049*	*-1.555*	*-1.128*
Govt15(-1)	0.022	-0.230	-0.057	-0.008	-0.017	-0.003	-0.437**	-0.067	-0.124
	0.418	*-1.013*	*-0.294*	*-0.048*	*-0.369*	*-0.124*	*-1.775*	*-0.289*	*-0.588*
Govt15(-2)	0.045	0.531***	0.544***	0.490***	-0.033	-0.024	0.405**	0.265*	0.344**
	0.876	*2.369*	*2.864*	*2.945*	*-0.727*	*-0.889*	*1.669*	*1.155*	*1.656*
Govt15(-3)	-0.040	-0.267	-0.062	-0.008	-0.059	-0.015	0.033	0.055	0.235
	-0.773	*-1.183*	*-0.326*	*-0.049*	*-1.307*	*-0.540*	*0.133*	*0.238*	*1.125*
Govt15(-4)	0.064	0.206	0.151	0.070	-0.023	-0.087***	0.161	0.154	0.062
	1.275	*0.941*	*0.813*	*0.431*	*-0.518*	*-3.266*	*0.678*	*0.686*	*0.307*
Govt25(-1)	-0.023	0.146	0.143	0.047	-0.009	0.007	0.301	0.154	0.094
	-0.463	*0.685*	*0.790*	*0.296*	*-0.201*	*0.265*	*1.307*	*0.709*	*0.475*
Govt25(-2)	-0.105***	-0.489***	-0.592***	-0.551***	-0.001	-0.005	-0.310**	-0.553***	-0.679***
	-2.214	*-2.346*	*-3.349*	*-3.559*	*-0.023*	*-0.186*	*-1.373*	*-2.595*	*-3.515*
Govt25(-3)	0.040	0.010	-0.003	0.012	0.037	0.011	-0.210	-0.076	-0.294
	0.819	*0.049*	*-0.017*	*0.073*	*0.849*	*0.435*	*-0.908*	*-0.346*	*-1.482*
Govt25(-4)	-0.025	-0.073	-0.058	-0.049	-0.010	0.064***	0.106	0.072	0.046
	-0.544	*-0.360*	*-0.336*	*-0.326*	*-0.250*	*2.570*	*0.483*	*0.348*	*0.242*

Notes. Dependent Variables are shown along the first row. T-stats are given in the second row of each section, and are shown in italics.

A-Table 1.2a Coefficient Table Corporate Yield Model

	FTSE 100	**Corp 5**	**Corp 15**	**Corp 30**	**Dollar**	**Euro**	**Govt 5**	**Govt 15**	**Govt 25**
FTSE100 (-1)	0.094*	-2.124***	-0.823***	-2.322**	-0.054*	0.028	-0.447	-0.189	-0.214
	1.572	-4.422	-2.171	-1.596	-1.053	0.908	-1.637	-0.726	-0.915
FTSE100 (-2)	0.030	-0.359	-0.487**	-1.263*	0.154***	0.029	0.710	0.328	0.272
	0.483	-0.722	-1.240	-0.838	2.910	0.914	2.510	1.218	1.120
FTSE100 (-3)	-0.014	-0.610**	-0.927	0.214	0.043**	-0.055	-0.128	-0.190	-0.017
	-0.226	-1.200	-2.315	0.139	0.799	-1.681	-0.444	-0.692	-0.070
FTSE100 (-4)	-0.019	-0.447	-0.312	-0.770**	0.070*	0.079**	0.256	0.080	-0.245
	-0.299	-0.870	-0.769	-0.494	1.285	2.409	0.874	0.288	-0.978
FTSE100 (-5)	0.090	0.735*	0.170	-2.160**	0.131***	0.039	0.769***	0.271	-0.016
	1.411	1.428	0.419	-1.386	2.403	1.183	2.625	0.973	-0.066
Corp5(-1)	0.008	0.134***	0.250	0.071	0.008***	-0.007*	0.122***	0.083***	0.067***
	1.038	2.105	4.977	0.369	1.131	-1.837	3.351	2.414	2.159
Corp5(-2)	0.009***	-0.266***	-0.257	0.066	0.016***	0.001	0.085	0.077**	0.072***
	1.063	-3.887	-4.774	0.318	2.202	0.226	2.178	2.097	2.153
Corp5(-3)	0.005	0.098**	-0.275***	0.009	0.000	0.004	0.041	0.017	0.003
	0.514	1.344	-4.799	0.042	-0.052	0.798	0.984	0.426	0.096
Corp5(-4)	0.006*	0.075	0.133	-0.277*	0.012**	-0.002	0.078***	0.080***	0.066***
	0.639	1.006	2.272	-1.230	1.486	-0.519	1.838	1.985	1.815
Corp5(-5)	0.002	-0.251***	-0.179***	-0.182	-0.018***	-0.002	-0.087***	-0.082***	-0.059***
	0.210	-3.653	-3.305	-0.875	-2.514	-0.440	-2.215	-2.221	-1.758
Corp15(-1)	-0.011**	-0.068	-0.433	-0.175	0.005	-0.004	-0.052	-0.051	-0.046
	-1.099	-0.817	-6.630	-0.699	0.518	-0.731	-1.110	-1.146	-1.128
Corp15(-2)	0.000	-0.027	-0.125	-0.303*	-0.008	-0.011*	0.001	-0.024	-0.052**
	-0.041	-0.321	-1.862	-1.179	-0.865	-2.102	0.014	-0.512	-1.255
Corp15(-3)	0.000	-0.227**	-0.215**	-0.006	-0.006*	-0.003	-0.061	-0.060**	-0.064***
	-0.017	-2.853	-3.437	-0.027	-0.679	-0.643	-1.348	-1.404	-1.641
Corp15(-4)	-0.003	-0.055	-0.164**	0.225	0.000	-0.004	-0.052**	-0.091***	-0.065
	-0.324	-0.773	-2.949	1.054	0.034	-0.831	-1.304	-2.380	-1.890
Corp15(-5)	-0.007	-0.051	0.022	0.161	0.006***	-0.007	0.006	-0.038**	-0.024
	-0.875	-0.756	0.421	0.786	0.848	-1.580	0.147	-1.037	-0.722

Notes. Dependent Variables are shown along the first row. T-stats are given in the second row of each section, and are shown in italics.

A-Table 1.2b Coefficient Table Corporate Yield Model

	FTSE 100	**Corp 5**	**Corp 15**	**Corp 30**	**Dollar**	**Euro**	**Govt 5**	**Govt 15**	**Govt 25**
Corp30(-1)	-0.001	0.006	0.011	-0.312***	0.001	0.000	0.004	0.012***	0.014***
	-0.392	0.340	0.778	-5.841	0.470	-0.238	0.406	1.217	1.655
Corp30(-2)	0.001***	0.010***	0.005	-0.208***	0.000	0.003***	0.001	0.011***	0.015***
	0.546	0.549	0.318	-3.792	0.212	2.666	0.097	1.138	1.671
Corp30(-3)	0.000	0.018**	-0.006	-0.279***	0.003***	0.002	0.017***	0.017***	0.017***
	-0.132	0.981	-0.429	-5.086	1.369	1.523	1.687	1.719	1.929
Corp30(-4)	-0.001***	-0.013**	0.001	-0.216***	0.001***	-0.001	-0.002	0.003	-0.002
	-0.581	-0.719	0.049	-3.865	0.732	-0.516	-0.166	0.305	-0.198
Corp30(-5)	0.000	-0.005	0.011**	-0.132***	0.000	0.001	0.003	0.006***	0.001
	-0.102	-0.264	0.797	-2.451	-0.091	0.743	0.330	0.607	0.129
Dollar(-1)	-0.063	-0.967**	-0.854	-1.329*	0.202***	-0.050**	-0.276	-0.454**	-0.275
	-0.865	-1.639	-1.836	-0.744	3.230	-1.326	-0.821	-1.424	-0.957
Dollar(-2)	-0.201**	0.063	0.054	2.499	-0.129**	-0.055**	-0.433	-0.191	-0.108
	-2.618	0.102	0.110	1.335	-1.965	-1.386	-1.232	-0.572	-0.358
Dollar(-3)	0.004	-0.145	0.046	-0.741	0.220	0.123	0.693	0.699**	0.475
	0.058	-0.239	0.097	-0.404	3.429	3.165	2.010	2.135	1.607
Dollar(-4)	0.107*	0.766	-0.716	1.704	-0.072**	-0.031	0.110	-0.234	-0.181
	1.405	1.244	-1.475	0.914	-1.108	-0.791	0.315	-0.704	-0.604
Dollar(-5)	0.121***	-0.572	-0.357	0.114	-0.120**	-0.083	-0.120	0.144	0.291
	1.628	-0.957	-0.756	0.063	-1.884	-2.165	-0.353	0.444	0.998
Euro(-1)	-0.308**	-1.685	0.511	-2.462**	-0.162**	0.234***	0.155	0.247	-0.137
	-2.658	-1.803	0.694	-0.870	-1.632	3.921	0.292	0.490	-0.301
Euro(-2)	-0.022	0.757	-0.363	-2.396	-0.153**	-0.097	0.731	0.552	0.798
	-0.187	0.786	-0.477	-0.821	-1.500	-1.575	1.332	1.059	1.697
Euro(-3)	0.043	-0.191	-0.467	-2.510***	0.028	-0.046	-0.631	-1.102***	-1.062***
	0.365	-0.200	-0.621	-0.870	0.273	-0.748	-1.165	-2.140	-2.287
Euro(-4)	-0.223***	-1.665	-0.947	-3.075*	0.025	0.097	-0.223	0.266	0.111
	-1.905	-1.766	-1.273	-1.077	0.254	1.616	-0.416	0.522	0.240
Euro(-5)	0.132*	1.546***	0.038	-7.948	0.235***	0.052	0.016	-1.014	-1.083
	1.156	1.678	0.052	-2.846	2.401	0.876	0.031	-2.035	-2.408

Notes. Dependent Variables are shown along the first row. T-stats are given in the second row of each section, and are shown in italics.

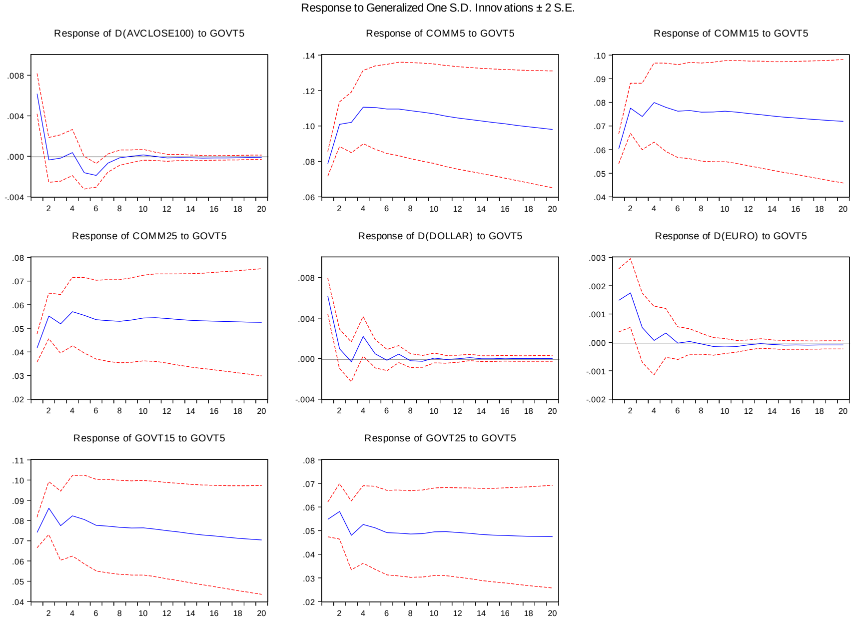
A-Table 1.2c Coefficient Table Corporate Yield Model

	FTSE 100	**Corp 5**	**Corp 15**	**Corp 30**	**Dollar**	**Euro**	**Govt 5**	**Govt 15**	**Govt 25**
Govt5(-1)	-0.002	0.002	-0.374	0.095	0.003	0.029*	0.209***	-0.056	-0.091*
	-0.080	0.010	-2.277	0.151	0.141	2.195	1.763	-0.497	-0.892
Govt5(-2)	-0.001	0.141	0.161	-0.108	-0.012	0.003	-0.354**	-0.232*	-0.232**
	-0.019	0.653	0.943	-0.164	-0.522	0.225	-2.880	-1.980	-2.195
Govt5(-3)	0.012	-0.112	0.120	0.227*	0.031***	-0.014*	0.159	0.080	0.042
	0.460	-0.515	0.700	0.345	1.352	-0.997	1.286	0.681	0.398
Govt5(-4)	-0.053***	-0.176	-0.069	-0.142	-0.002	0.029**	-0.082	-0.147	-0.170**
	-2.016	-0.827	-0.412	-0.221	-0.105	2.120	-0.678	-1.275	-1.641
Govt5(-5)	-0.007	0.214*	0.229	1.152	0.044***	0.010	0.131	0.149	0.134
	-0.269	1.068	1.447	1.900	2.074	0.775	1.145	1.372	1.367
Govt15(-1)	0.055***	0.056	0.865	0.450	-0.017	-0.021	-0.096	0.336	0.283*
	1.185	0.152	2.954	0.401	-0.428	-0.905	-0.453	1.676	1.562
Govt15(-2)	0.046***	0.249	0.408	0.252	-0.007	-0.006	0.460**	0.342***	0.426***
	0.983	0.656	1.363	0.219	-0.167	-0.231	2.133	1.667	2.302
Govt15(-3)	-0.024	0.204	0.519	-0.675	-0.020	0.006	-0.149	0.039	0.192*
	-0.531	0.556	1.796	-0.608	-0.508	0.240	-0.712	0.195	1.076
Govt15(-4)	0.052***	0.133	0.415*	0.264	-0.015	-0.057***	0.242**	0.508***	0.478*
	1.146	0.362	1.430	0.237	-0.384	-2.419	1.157	2.552	2.661
Govt15(-5)	0.008	0.790	-0.186	-0.568	-0.074***	-0.013	-0.168	-0.368	-0.383*
	0.189	2.205	-0.659	-0.523	-1.948	-0.565	-0.825	-1.897	-2.189
Govt25(-1)	-0.057***	0.007	-0.234	-0.640***	0.004	0.014	0.007	-0.145	-0.168
	-1.531	0.022	-0.981	-0.699	0.131	0.738	0.038	-0.888	-1.137
Govt25(-2)	-0.050***	0.010	-0.279*	0.301	0.033	0.019	-0.222	-0.319***	-0.418***
	-1.342	0.033	-1.189	0.333	1.029	0.995	-1.310	-1.977	-2.875
Govt25(-3)	0.029	-0.154	-0.388	1.349	0.001	0.012	-0.020	-0.079	-0.244**
	0.796	-0.528	-1.687	1.528	0.028	0.619	-0.123	-0.502	-1.719
Govt25(-4)	-0.041***	-0.016	-0.624	0.064	0.018	0.045	-0.168	-0.380**	-0.344
	-1.132	-0.054	-2.707	0.073	0.564	2.409	-1.013	-2.404	-2.412
Govt25(-5)	-0.048	-1.116**	0.069	-0.010	0.034*	0.002	0.036	0.283	0.260*
	-1.316	-3.826	0.299	-0.012	1.093	0.130	0.215	1.793	1.829

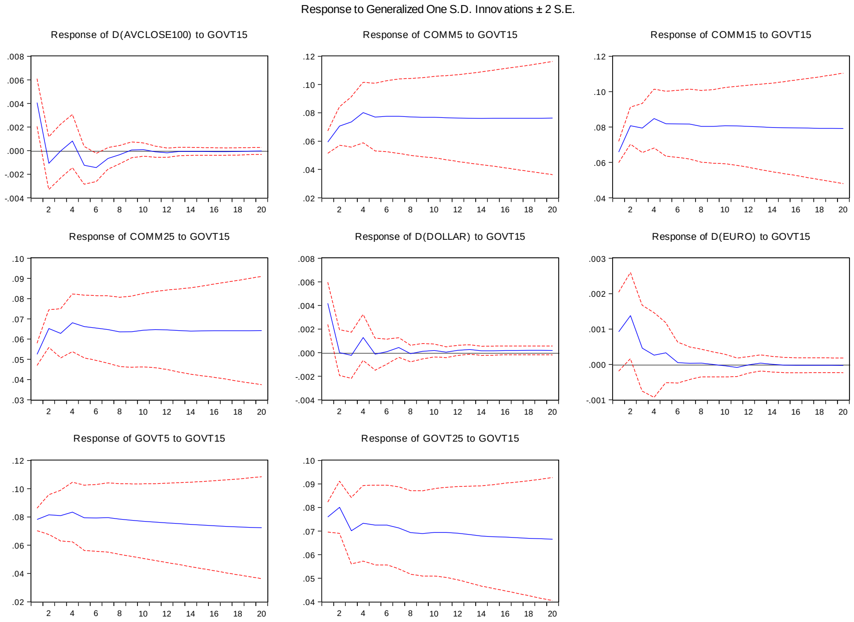
Notes. Dependent Variables are shown along the first row. T-stats are given in the second row of each section, and are shown in italics.

7.1.2 Impulse Responses Yields in levels model

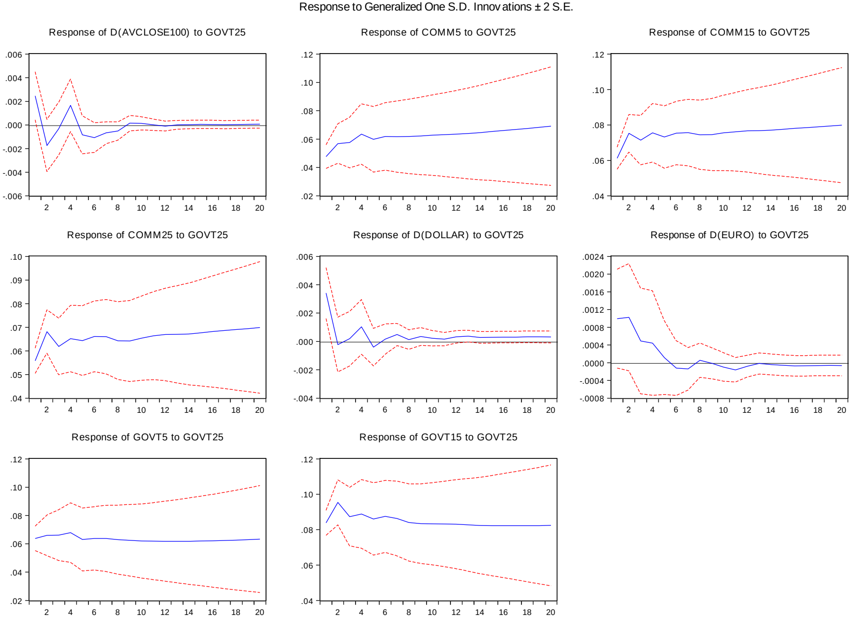
A-Figure 1.1 Yields in Levels GOVT5 Impulse Responses Commercial Yield model



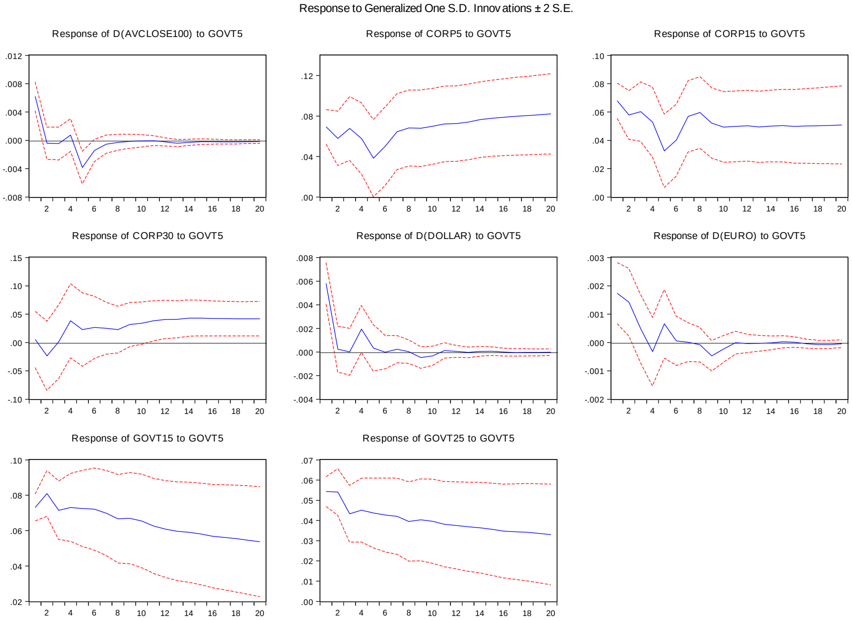
A-Figure 1.2 Yields in Levels GOVT15 Impulse Responses Commercial Yield model



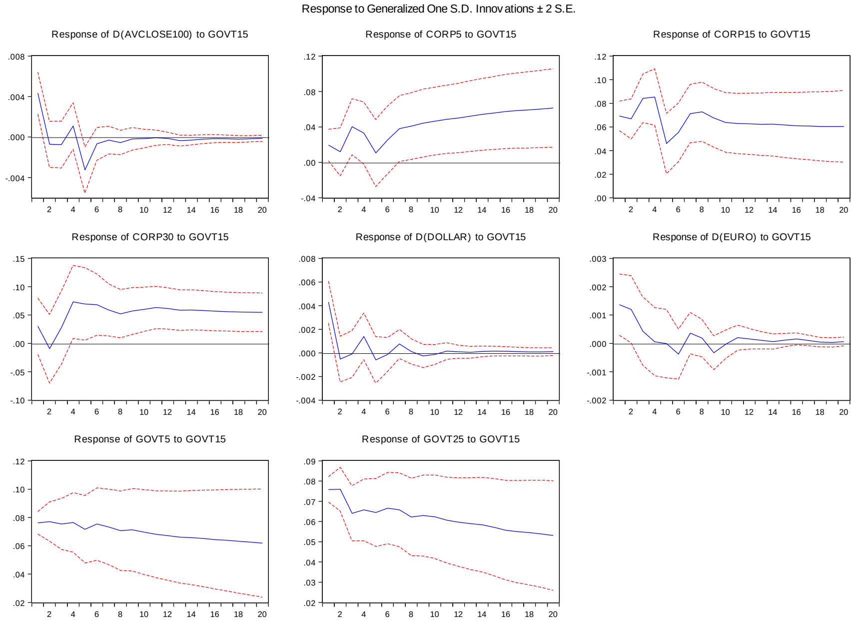
A-Figure 1.3 Yields in Levels GOVT25 Impulse Responses Commercial Yield model



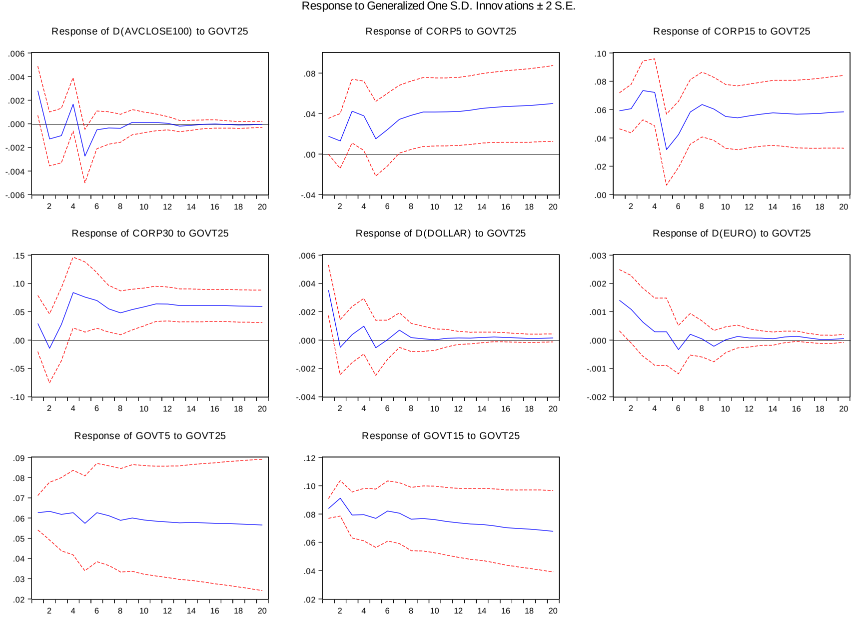
A-Figure 1.4 Yields in Levels GOVT5 Impulse Responses Corporate Yield model



A-Figure 1.5 Yields in Levels GOVT15 Impulse Responses Corporate Yield model



A-Figure 1.6 Yields in Levels GOVT25 Impulse Responses Corporate Yield model



7.2 Appendix to Chapter 4

7.2.1 Principal Component Model Selection Tables

A-Table 1.3 FTSE100 Principal Component Model Selection

Model Stats FTSE100	**AIC**	**SIC**	**Adj-R^2**
PC1 Tech**	**5.819451**	**5.839948**	**-0.002604**
PC1 +PC2	5.823142	5.853887	-0.003724
PC1 +PC2 +PC3	5.826617	5.867611	-0.004637
PC1 Econ	5.62124	5.645066	0.006177
PC1 +PC2**	**5.619177**	**5.654916**	**0.011344**
PC1 +PC2 +PC3	5.624289	5.671941	0.009392
PC1 +PC2 +PC3 +PC4	5.626382	5.685947	0.010417
PC1 +PC2 +PC3 +PC4 +PC5	5.629417	5.700894	0.0105
PC1 All	5.629483	5.653309	-0.002049
PC1+PC2	5.624667	5.660405	0.005902
PC1+PC2+PC3	5.625001	5.672653	0.008686
PC1+PC2+PC3+PC4	5.62992	5.689485	0.006909
PC1 +PC2 +PC3 +PC4 +PC5**	**5.629183**	**5.700661**	**0.010731**

A-Table 1.4 FTSEALLSHARE Principal Component Model Selection

Model Stats FTSEALL	**AIC**	**SIC**	**Adj-R^2**
PC1 Tech**	**5.887883**	**5.904924**	**-0.001039**
PC1+PC2	5.891517	5.917078	-0.002657
PC1+PC2+PC3	5.895392	5.929473	-0.004525
PC1 Econ	5.616692	5.640518	0.008685
PC1 +PC2	5.617338	5.653077	0.011163
PC1 +PC2 +PC3**	**5.619395**	**5.667046**	**0.012233**
PC1 +PC2 +PC3 +PC4	5.624654	5.684219	0.010125
PC1+PC2+PC3+PC4+PC5	5.6253	5.696778	0.01257
PC1 All	5.628205	5.652031	-0.002794
PC1+PC2	5.621601	5.657339	0.006939
PC1+PC2+PC3	5.623386	5.671037	0.008283
PC1+PC2+PC3+PC4	5.625288	5.684852	0.009498
PC1+PC2+PC3+PC4+PC5**	**5.626423**	**5.6979**	**0.011461**

7.2.2 In-Sample Predictor Performance FSI sample (Unbalanced Sample)

A-Table 1.5 FTSE100 In-Sample Predictor Performance FSI sample

FTSE100	R^2	R^2_{OS}**Rec**	R^2_{OS}**Exp**	$R^2_{OS}FS$	$R^2_{OS}NFS$
Sample	**1991m01 -2017m02**				
TBL	0.0017	-0.0017	0.0048	0.0023	0.0016
LTY(5)	0.0010	-0.0014	0.0031	-0.0003	0.0014
LTY(10)	0.0002	-0.0009	0.0012	-0.0005	0.0004
LTY(15)	0.0000	0.0001	-0.0001	0.0001	0.0000
TMS(3-5)	0.0014	0.0000	0.0027	0.0068	-0.0001
TMS(3-10)	0.0039	0.0017	0.0059	0.0099	0.0022
TMS(3-15)	0.0056	0.0029	0.0080	0.0109	0.0041
DRS(5)	0.0059	0.0103	0.0019	0.0146	0.0034
DRS(10)	0.0026	-0.0010	0.0058	-0.0073	0.0054
DRS(15)	0.0027	-0.0019	0.0066	-0.0176	0.0084
INF(-1)	0.0012	-0.0027	0.0049	0.0108	-0.0015
INF(-2)	0.0011	-0.0017	0.0037	0.0125	-0.0021
INDMAN	0.0108	0.0078	0.0134	0.0150	0.0096
INDPROD	0.0024	-0.0017	0.0061	-0.0032	0.0040
DY	0.0177	-0.0014	0.0351	-0.0488	0.0367
PE	0.0014	-0.0029	0.0051	-0.0142	0.0073
MA(1,9)	0.0023	0.0013	0.0032	0.0081	0.0007
MA(1,12)	0.0009	0.0031	-0.0011	0.0064	-0.0006
MA(2,9)	0.0015	0.0043	-0.0010	0.0037	0.0009
MA(2,12)	0.0007	0.0036	-0.0020	0.0032	-0.0001
MA(3,9)	0.0000	0.0003	-0.0003	0.0002	-0.0001
MA(3,12)	0.0017	0.0060	-0.0023	0.0037	0.0011
MOM(9)	0.0068	0.0104	0.0035	0.0137	0.0048
MOM(12)	0.0008	0.0032	-0.0013	0.0077	-0.0011
OBV(1,9)	0.0001	0.0008	-0.0004	-0.0026	0.0021
OBV(1,12)	0.0010	0.0014	0.0006	-0.0080	0.0039
OBV(2,9)	0.0038	0.0073	0.0009	0.0207	0.0003
OBV(2,12)	0.0010	0.0014	0.0006	-0.0080	0.0039
OBV(3,9)	0.0027	0.0043	0.0013	0.0092	0.0020
OBV(3,12)	0.0063	0.0142	-0.0004	0.0168	0.0037
DYS	0.0043	0.0147	-0.0051	0.0297	-0.0029
SVAR	0.0000	0.0000	0.0000	-0.0002	0.0001
PC Tech	0.0155	0.0418	-0.0072	0.0078	0.0177
PC Econ	0.0237	0.0140	0.0321	0.031121	0.021317
PC All	0.0172	0.0208	0.0147	0.0114	0.0190

A-Table 1.6 FTSEALLSHARE In-Sample Predictor Performance FSI sample

FTSEALLSHARE	$\boldsymbol{R^2}$	$\boldsymbol{R^2_{OS}}$**Rec**	$\boldsymbol{R^2_{OS}}$**Exp**	$\boldsymbol{R^2_{OS}FS}$	$\boldsymbol{R^2_{OS}NFS}$
Sample	**1991m01 -2017m02**				
TBL	0.0037	-0.0013	0.0084	0.0030	0.0039
LTY(5)	0.0034	-0.0008	0.0073	-0.0025	0.0050
LTY(10)	0.0018	-0.0013	0.0047	-0.0035	0.0033
LTY(15)	0.0007	-0.0011	0.0025	-0.0029	0.0018
TMS(3-5)	0.0007	-0.0004	0.0017	0.0066	-0.0010
TMS(3-10)	0.0032	0.0007	0.0056	0.0130	0.0004
TMS(3-15)	0.0051	0.0018	0.0082	0.0155	0.0021
DRS(5)	0.0046	0.0078	0.0016	0.0209	0.0000
DRS(10)	0.0024	-0.0016	0.0062	-0.0037	0.0041
DRS(15)	0.0024	-0.0018	0.0062	-0.0140	0.0077
INF(-1)	0.0019	-0.0022	0.0057	0.0145	-0.0017
INF(-2)	0.0016	-0.0013	0.0043	0.0155	-0.0024
INDMAN	0.0102	0.0056	0.0147	0.0170	0.0083
INDPROD	0.0021	-0.0020	0.0059	-0.0024	0.0033
DY	0.0117	-0.0017	0.0245	-0.0353	0.0252
PE	0.0023	-0.0037	0.0074	-0.0184	0.0083
MA(1,9)	0.0023	0.0081	-0.0033	0.0038	0.0018
MA(1,12)	0.0034	0.0153	-0.0079	0.0047	0.0030
MA(2,9)	0.0000	0.0001	-0.0001	0.0001	0.0000
MA(2,12)	0.0007	0.0067	-0.0049	0.0062	-0.0008
MA(3,9)	0.0003	-0.0013	0.0019	-0.0022	0.0010
MA(3,12)	0.0002	-0.0025	0.0027	-0.0031	0.0011
MOM(9)	0.0038	0.0018	0.0057	0.0115	0.0016
MOM(12)	0.0000	0.0001	0.0000	0.0003	-0.0001
OBV(1,9)	0.0016	0.0000	0.0032	0.0114	-0.0012
OBV(1,12)	0.0007	0.0005	0.0009	0.0158	-0.0020
OBV(2,9)	0.0114	0.0064	0.0161	0.0437	0.0020
OBV(2,12)	0.0007	0.0005	0.0009	0.0158	-0.0020
OBV(3,9)	0.0016	-0.0003	0.0034	0.0083	-0.0003
OBV(3,12)	0.0074	0.0011	0.0132	0.0248	0.0040
DYS	0.0026	0.0101	-0.0044	0.0243	-0.0036
SVAR	0.0171	0.0102	0.0236	-0.0049	0.0233
PC Tech	0.0055	0.0077	0.0035	0.0248	-0.0002
PC Econ	0.0310	0.0288	0.0331	0.0365	0.0293
PC All	0.0405	0.0366	0.0440	0.0503	0.0377

7.2.3 Out-of-Sample Predictor Performance (Un-balanced Sample)

A-Table 1.7 FTSE100 Out-of-Sample Predictor Performance Unbalanced Sample

FTSE100 OOS	**OOS Start**	R_{OS}^2	R_{OS}^2**Rec**	R_{OS}^2**Exp**	$R_{OS}^2 FS$	$R_{OS}^2 NFS$
TBL	1994m01	-0.0369	-0.0576	-0.0186	-0.0341	-0.0377
LTY(5)	1994m01	-0.0306	-0.0509	-0.0126	-0.0334	-0.0298
LTY(10)	1994m01	-0.0371	-0.0619	-0.0152	-0.0384	-0.0367
LTY(15)	1994m01	-0.0409	-0.0678	-0.0171	-0.0391	-0.0413
TMS(3-5)	1994m01	-0.0012	0.0051	-0.0068	0.0170	-0.0065
TMS(3-10)	1994m01	0.0011	0.0071	-0.0042	0.0148	-0.0029
TMS(3-15)	1994m01	0.0014	0.0050	-0.0018	0.0105	-0.0013
DRS(5)	2001m01	0.0210	0.0561	-0.0099	0.0655	0.0068
DRS(10)	2001m01	0.0110	0.0344	-0.0096	0.0303	0.0049
DRS(15)	2007m09	-0.0016	-0.0126	0.0097	-0.0112	0.0039
INF(-1)	1994m01	-0.0017	-0.0014	-0.0020	0.0179	-0.0074
INF(-2)	1994m01	-0.0058	-0.0094	-0.0026	0.0191	-0.0130
INDMAN	1994m01	-0.1052	-0.0805	-0.1271	-0.0713	-0.1150
INDPROD	1994m01	-0.0084	0.0108	-0.0254	0.0196	-0.0165
DY	1996m02	-0.0305	-0.0284	-0.0323	-0.0165	-0.0348
PE	2003m08	-0.0177	-0.0229	-0.0129	-0.0232	-0.0150
MA(1,9)	1994m10	-0.0863	-0.1019	-0.0722	-0.0726	-0.0905
MA(1,12)	1995m01	-0.0373	-0.0543	-0.0221	-0.0338	-0.0384
MA(2,9)	1994m10	-0.0753	-0.0956	-0.0570	-0.0578	-0.0807
MA(2,12)	1995m01	-0.0851	-0.1288	-0.0460	-0.0781	-0.0872
MA(3,9)	1994m10	-0.0786	-0.1055	-0.0543	-0.0806	-0.0780
MA(3,12)	1995m01	-0.0964	-0.1289	-0.0674	-0.0797	-0.1015
MOM(9)	1994m11	-0.0301	-0.0246	-0.0351	-0.0079	-0.0369
MOM(12)	1995m02	-0.0592	-0.0957	-0.0273	-0.0819	-0.0525
OBV(1,9)	2003m11	-0.0106	0.0004	-0.0205	-0.0142	-0.0090
OBV(1,12)	2004m02	0.0001	-0.0001	0.0003	-0.0190	0.0090
OBV(2,9)	2003m11	0.0013	0.0157	-0.0115	0.0371	-0.0157
OBV(2,12)	2004m02	0.0062	-0.0001	0.0116	0.0221	-0.0012
OBV(3,9)	2003m11	-0.0096	-0.0016	-0.0167	0.0381	-0.0323
OBV(3,12)	2004m02	0.0068	0.0066	0.0069	0.0348	-0.0062
DYS	1994m01	-0.0528	-0.0817	-0.0273	-0.1291	-0.0308
SVAR	1994M03	-0.0443	-0.0557	-0.0344	-0.0521	-0.0421
PC Tech	2004M02	-0.0021	0.0165	-0.0179	0.0251	-0.0148
PC Econ	2007M09	-0.0253	-0.0552	0.0051	-0.0646	-0.0032
PC All	2007M09	-0.0681	-0.0312	-0.1056	0.0179	-0.1165

A-Table 1.8 FTSEALLSHARE Out-of-Sample Predictor Performance Unbalanced Sample

FTSEALLSHARE OOS	**OOS Start**	R^2_{OS}	R^2_{OS}**Rec**	R^2_{OS}**Exp**	$R^2_{OS}FS$	$R^2_{OS}NFS$
TBL	1985m03	-0.0048	0.0270	-0.0280	0.0259	-0.0101
LTY(5)	1985m03	0.0024	0.0324	-0.0194	0.0303	-0.0024
LTY(10)	1985m03	0.0052	0.0336	-0.0156	0.0310	0.0007
LTY(15)	1985m03	-0.0101	0.0423	-0.0482	0.0414	-0.0189
TMS(3-5)	1985m03	-0.0076	-0.0105	-0.0055	-0.0086	-0.0075
TMS(3-10)	1985m03	-0.0091	-0.0123	-0.0067	-0.0092	-0.0091
TMS(3-15)	1985m03	-0.0013	0.0023	-0.0039	0.0027	-0.0020
DRS(5)	2001m01	0.0065	0.0332	-0.0167	0.0365	-0.0036
DRS(10)	2001m01	0.0075	0.0306	-0.0128	0.0298	-0.0001
DRS(15)	2007m09	-0.0025	-0.0145	0.0100	-0.0121	0.0036
INF(-1)	1985m03	0.0078	0.0342	-0.0115	0.0229	0.0052
INF(-2)	1985m03	0.0095	0.0329	-0.0076	0.0236	0.0071
INDMAN	1985m03	0.0037	0.0118	-0.0022	0.0187	0.0011
INDPROD	1985m03	0.0038	0.0125	-0.0026	0.0092	0.0029
DY	1985m03	-0.0718	-0.0561	-0.0832	-0.0387	-0.0774
PE	2003m08	-0.0745	-0.1245	-0.0313	-0.1206	-0.0506
MA(1,9)	1985m12	-0.0124	-0.0273	-0.0015	-0.0259	-0.0101
MA(1,12)	1986m03	-0.0292	-0.0766	0.0056	-0.0533	-0.0250
MA(2,9)	1985m12	-0.0055	0.0036	-0.0122	0.0064	-0.0076
MA(2,12)	1986m03	-0.0459	-0.1147	0.0045	-0.1117	-0.0345
MA(3,9)	1985m12	-0.0034	-0.0058	-0.0017	-0.0052	-0.0031
MA(3,12)	1986m03	-0.0026	-0.0178	0.0086	-0.0221	0.0008
MOM(9)	1985m12	-0.0986	-0.1438	-0.0654	-0.1636	-0.0872
MOM(12)	1986m03	-0.1140	-0.2167	-0.0387	-0.2448	-0.0913
OBV(1,9)	2008m02	0.0018	0.0025	0.0011	0.0180	-0.0091
OBV(1,12)	2008m05	0.0160	0.0002	0.0291	0.0125	0.0180
OBV(2,9)	2008m02	0.0116	0.0057	0.0170	0.0562	-0.0183
OBV(2,12)	2008m05	0.0124	-0.0074	0.0289	0.0479	-0.0089
OBV(3,9)	2008m02	0.0017	0.0024	0.0010	0.0180	-0.0093
OBV(3,12)	2008m05	0.0204	0.0067	0.0319	0.0372	0.0105
DYS	1985m03	-0.0011	0.0113	-0.0102	-0.0520	0.0076
SVAR	1995M03	0.0142	0.0092	0.0187	-0.0192	0.0243
PC Tech	2008M05	0.0188	0.0107	0.0256	0.0413	0.0054
PC Econ	2007M09	0.0400	0.0563	0.0231	0.0813	0.0137
PC All	2008M05	0.0635	0.0120	0.1065	0.0704	0.0594

7.2.4 Out-of-Sample Predictor Performance (Balanced Sample)

A-Table 1.9 FTSE100 Out-of-Sample Predictor Performance Balanced Sample

FTSE100 OOS 1995m01	R^2_{OS}	**MSFE-Adjusted**	**RMSE**	**MAE**	R^2_{OS}**Rec**	R^2_{OS}**Exp**
HA			0.0171	0.0131		
TBL	0.0014	0.6782	0.0171	0.0130	-0.0058	0.0078
LTY(5)	-0.0026	-0.5846	0.0171	0.0131	-0.0023	-0.0028
LTY(10)	-0.0116	-1.2971	0.0172	0.0132	0.0025	-0.0241
LTY(15)	-0.0390	-1.0775	0.0174	0.0136	0.0024	-0.0761
TMS(3-5)	-0.0016	-0.3210	0.0171	0.0131	0.0022	-0.0050
TMS(3-10)	0.0005	0.3567	0.0171	0.0131	0.0027	-0.0014
TMS(3-15)	0.0022	0.8764	0.0171	0.0131	0.0027	0.0019
INF(-1)	-0.0017	0.1447	0.0171	0.0131	0.0004	-0.0036
INF(-2)	0.0000	0.3393	0.0171	0.0130	-0.0003	0.0002
INDMAN	-0.1171	-1.8000	0.0181	0.0138	-0.0966	-0.1354
INDPROD	-0.0182	-1.3253	0.0173	0.0132	-0.0046	-0.0303
DY	-0.4335	0.2758	0.0205	0.0170	-0.4069	-0.4573
MA(1,9)	-0.0884	-1.6778	0.0178	0.0136	-0.1058	-0.0728
MA(1,12)	-0.0373	-1.4903	0.0174	0.0134	-0.0543	-0.0221
MA(2,9)	-0.0729	-1.5750	0.0177	0.0135	-0.0948	-0.0533
MA(2,12)	-0.0851	-1.1711	0.0178	0.0137	-0.1288	-0.0460
MA(3,9)	-0.0761	-0.9043	0.0177	0.0135	-0.1042	-0.0510
MA(3,12)	-0.0964	-1.6335	0.0179	0.0137	-0.1289	-0.0674
MOM(9)	-0.0237	-2.4401	0.0173	0.0133	-0.0227	-0.0246
MOM(12)	-0.0757	-1.3404	0.0177	0.0136	-0.1139	-0.0416
DYS	-0.0870	-1.4642	0.0178	0.0136	-0.1537	-0.0274
SVAR	-0.0464	-0.1652	0.0175	0.0135	-0.0583	-0.0356

A-Table 1.10 FTSEALLSHARE Out-of-Sample Predictor Performance Balanced Sample

FTSEALLSHARE OOS 1995m01	R^2_{OS}	**MSFE-Adjusted**	**RMSE**	**MAE**	R^2_{OS}**Rec**	R^2_{OS}**Exp**
HA			0.0169	0.0128		
TBL	0.0024	0.9595	0.0169	0.0127	-0.0073	0.0114
LTY(5)	0.0010	0.9001	0.0170	0.0127	-0.0148	0.0158
LTY(10)	-0.0021	-0.2377	0.0170	0.0128	-0.0022	-0.0020
LTY(15)	-0.0275	-0.7852	0.0172	0.0133	0.0074	-0.0602
TMS(3-5)	-0.0039	-0.3598	0.0170	0.0130	0.0057	-0.0129
TMS(3-10)	-0.0005	0.2041	0.0170	0.0129	0.0063	-0.0069
TMS(3-15)	0.0021	0.6894	0.0169	0.0129	0.0059	-0.0014
INF(-1)	-0.0007	0.1447	0.0170	0.0128	0.0037	-0.0048
INF(-2)	0.0002	0.3393	0.0170	0.0128	0.0027	-0.0022
INDMAN	-0.1082	-1.8949	0.0179	0.0135	-0.0748	-0.1395
INDPROD	-0.0174	-1.3723	0.0171	0.0130	0.0023	-0.0359
DY	-0.2922	0.3386	0.0193	0.0158	-0.2169	-0.3628
MA(1,9)	-0.1244	-1.5862	0.0180	0.0137	-0.1562	-0.0947
MA(1,12)	-0.0860	-2.2110	0.0177	0.0135	-0.1163	-0.0576
MA(2,9)	-0.0409	-1.0895	0.0173	0.0131	-0.0383	-0.0434
MA(2,12)	-0.0544	-1.5947	0.0174	0.0133	-0.0723	-0.0377
MA(3,9)	-0.0631	-0.7244	0.0175	0.0133	-0.0763	-0.0507
MA(3,12)	-0.0606	-1.1707	0.0175	0.0133	-0.0797	-0.0428
MOM(9)	-0.0470	-2.2385	0.0174	0.0132	-0.0407	-0.0530
MOM(12)	-0.0560	-1.1965	0.0174	0.0132	-0.0766	-0.0367
DYS	-0.1164	-1.1744	0.0179	0.0136	-0.1921	-0.0454
SVAR	0.0063	1.1708	0.0169	0.0131	0.0189	-0.0055

7.2.5 Out-of-Sample R-squared Statistics Comparisons (Balanced Sample)

A-Table 1.11 FTSE100 Out-of-Sample R-Squared Statistics Comparisons Balanced Sample

FTSE100 OOS 1995m01	R^2_{OS}	R^2_{OS}**Rec**	R^2_{OS}**Exp**	$R^2_{OS}FS$	$R^2_{OS}NFS$
TBL	0.0014	-0.0058	0.0078	0.0000	0.0018
LTY(5)	-0.0026	-0.0023	-0.0028	0.0042	-0.0047
LTY(10)	-0.0116	0.0025	-0.0241	0.0112	-0.0184
LTY(15)	-0.0390	0.0024	-0.0761	0.0185	-0.0564
TMS(3-5)	-0.0016	0.0022	-0.0050	0.0083	-0.0046
TMS(3-10)	0.0005	0.0027	-0.0014	0.0076	-0.0016
TMS(3-15)	0.0022	0.0027	0.0019	0.0062	0.0011
INF(-1)	-0.0017	0.0004	-0.0036	0.0099	-0.0052
INF(-2)	0.0000	-0.0003	0.0002	0.0117	-0.0035
INDMAN	-0.1171	-0.0966	-0.1354	-0.0845	-0.1269
INDPROD	-0.0182	-0.0046	-0.0303	0.0068	-0.0257
DY	-0.0433	-0.0406	-0.0457	-0.0210	-0.0500
MA(1,9)	-0.0884	-0.1058	-0.0728	-0.0755	-0.0923
MA(1,12)	-0.0373	-0.0543	-0.0221	-0.0338	-0.0384
MA(2,9)	-0.0729	-0.0948	-0.0533	-0.0580	-0.0774
MA(2,12)	-0.0851	-0.1288	-0.0460	-0.0781	-0.0872
MA(3,9)	-0.0761	-0.1042	-0.0510	-0.0800	-0.0750
MA(3,12)	-0.0964	-0.1289	-0.0674	-0.0797	-0.1015
MOM(9)	-0.0237	-0.0227	-0.0246	-0.0113	-0.0275
MOM(12)	-0.0757	-0.1139	-0.0416	-0.0945	-0.0701
DYS	-0.0870	-0.1537	-0.0274	-0.2154	-0.0483
SVAR	-0.0464	-0.0583	-0.0356	-0.0581	-0.0428

A-Table 1.12 FTSEALLSHARE Out-of-Sample R-Squared Statistics Comparisons Balanced Sample

FTSEALLSHARE OOS 1995m01	R^2_{OS}	R^2_{OS}**Rec**	R^2_{OS}**Exp**	$R^2_{OS}FS$	$R^2_{OS}NFS$
TBL	0.0024	-0.0073	0.0114	-0.0002	0.0032
LTY(5)	0.0010	-0.0148	0.0158	-0.0080	0.0038
LTY(10)	-0.0021	-0.0022	-0.0020	0.0041	-0.0040
LTY(15)	-0.0275	0.0074	-0.0602	0.0192	-0.0420
TMS(3-5)	-0.0039	0.0057	-0.0129	0.0142	-0.0096
TMS(3-10)	-0.0005	0.0063	-0.0069	0.0137	-0.0049
TMS(3-15)	0.0021	0.0059	-0.0014	0.0120	-0.0010
INF(-1)	-0.0007	0.0037	-0.0048	0.0161	-0.0059
INF(-2)	0.0002	0.0027	-0.0022	0.0186	-0.0055
INDMAN	-0.1082	-0.0748	-0.1395	-0.0785	-0.1174
INDPROD	-0.0174	0.0023	-0.0359	0.0098	-0.0259
DY	-0.0292	-0.0216	-0.0362	-0.0114	-0.0347
MA(1,9)	-0.1244	-0.1562	-0.0947	-0.0959	-0.1333
MA(1,12)	-0.0860	-0.1163	-0.0576	-0.0592	-0.0943
MA(2,9)	-0.0409	-0.0383	-0.0434	-0.0344	-0.0429
MA(2,12)	-0.0544	-0.0723	-0.0377	-0.0623	-0.0520
MA(3,9)	-0.0631	-0.0763	-0.0507	-0.0737	-0.0597
MA(3,12)	-0.0606	-0.0797	-0.0428	-0.0765	-0.0557
MOM(9)	-0.0470	-0.0407	-0.0530	-0.0303	-0.0522
MOM(12)	-0.0560	-0.0766	-0.0367	-0.0760	-0.0498
DYS	-0.1164	-0.1921	-0.0454	-0.2864	-0.0635
SVAR	0.0063	0.0189	-0.0055	-0.0069	0.0104

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