A Structural Break Approach to Analysing the Impact of the QE Portfolio Balance Channel on the US Stock Market

Abstract

Following the 1929 Wall Street collapse, the initial response to the institutional failures and collapsing financial system was to allow the markets to self-correct, which led to a significant period of economic depression. In contrast the US (and UK) governments responded to the 2008 financial crisis with extra liquidity for the banking sector and a stimulus package, but why was there such a different response? Following a light touch approach to Bear Stearns and Lehmann's, it became clear that without greater intervention, the effect would become contagious throughout the financial system. One of the most important forms of intervention was Quantitative Easing (QE) and historically low interest rates. This study finds that QE substantially reduced the Equity Risk Premium (ERP) on S&P equities through a 9.6% rise in prices, thus reducing returns. Consequentially, driving portfolios to seek returns in risker asset classes to make up for the shortfall in returns. This suggests that the combination of low interest rates and QE when compared to expansion alone has had a marked increase on equity prices and the ERP. Furthermore, there is evidence that regime shifts support these findings. Such unforeseen consequences in the equity markets is of great interest to policy makers when deciding on a response to such exceptional circumstances, and researchers investigating monetary policy responses to the next inevitable extreme financial crisis.

Key words: equity risk premium, regime shifts, quantitative easing, portfolio balance channel, equity returns, US Treasuries.

JEL classification: E44, E51, E52, E58, G1

1 Introduction

Up until 2003, monetary policy in the US was mostly conducted through changes to interest rates following the Taylor principle (Taylor, 2012). Quantitative easing (QE) was largely unheard of, except for a short period when the Bank of Japan instituted a form of QE during 2001-06 (Ugai, 2007; Shiratsuka, 2010). An immediate response of the Federal Reserve to the financial crisis in 2008 was to reduce interest rates to zero, leaving them without a mechanism to influence the real economy. Hence, they embarked on a QE programme that saw the Fed increase its balance sheet with treasuries and other assets to create liquidity in the banking sector and promote renewed investment and consumption in the economy. We address the important issue of how the effects of QE were transmitted to the financial market and whether the portfolio balance mechanism led to changes in equity prices, which in turn affect investment and consumption potentially through changes to Tobin's q and a wealth effect (Case et al., 2005).

Another aspect of the normative policy doctrine adopted by the US, was to let the market self-correct by allowing those banks in financial trouble to fail, with a minimalist interventionist policy by the government. This relied on the ripples from any failure being attenuated quite quickly and the market being able to adjust with only limited intervention. Then came the Global Financial Crisis. Initially, the Fed and government adopted the same policy believing markets would adjust automatically. However, with the failure of the investment banks Bear-Sterns and Lehmann Brothers, rather than attenuating, those ripples were amplified throughout the financial markets and into the real US economy. Even with the Troubled Asset Relief Programme (TARP) and the Federal Open Market Committee (FOMC) responding by reducing the Federal Funds Rate to historically low rates, within the range of 0 to 25 basis points (bps), there was a minimal response in the economy. This approach should have stimulated the economy, but had little effect, so that confidence was lost and an alternative type of intervention was needed.

Bernanke (2010) first signalled the intention to adopt unconventional monetary policies in his 2008 Jackson Hole speech. This would take the form of Large Scale Asset Purchases (LSAP) by the Fed under the programme now referred to as QE with the aim of reducing the funding by corporates and individuals alike. To stimulate the economy, there was also a rapid expansion of bank liquidity to encourage lending and promote stability. By October 2014, the Fed's balance sheet had expanded to $4.5 trillion following the purchase of mortgage-backed securities (MBS), agency debt and longer-term Treasury bonds[1].

The questions were, how LSAPs were going to affect funding costs? How were the QE programmes going to stimulate the real economy? Many have suggested various hypotheses such as Gagnon et al. (2011), Hamilton and Wu (2012), Baumeister and Benati (2013) and D'Amico and King (2013). Although controversial, the portfolio balance channel and its potential effectiveness in reducing bond yields has received a lot of attention in the literature. One of the main areas concerns the reduction in interest rates and the signalling channel (Krishnamurthy and Vissing-Jorgensen, 2011). Whereas Christensen and Rudebusch (2012) illustrated the QE effects on interest rates in both the UK and US. A further elaboration stemmed from the approach by Kiley (2014) and Rosa (2012). However, there is little relevant academic literature covering the possible impacts of the QE programme on equity prices. Therefore, how did this unconventional policy influence the portfolios of banks and investors so that funding costs were reduced, particularly in higher risk asset classes? We seek to answer this question by an empirical analysis of QE's impact on equity prices based on shifts in private sector portfolios.

The literature regarding QE, such as Joyce et al. (2011), concludes that equity prices did not react in a uniform way and the initial QE announcements induced a fall in prices. Modest rallies were outweighed by negative responses with an approximate -3.5% total effect. Nevertheless, the overall price increase up until May 2010 amounted to a total of 50%, indicating some drawbacks with the use of event studies to analyse QE. Central to these event studies is the focus on government bond yields with respect to the portfolio balance channel. Gagnon et al. (2011) assumes government bond yields to be the primary channel through which LSAP function and with the assumption that today's asset prices are thought to reflect investors' expectation on future asset shares. Their analysis included the response of bond yields of different maturities and found that QE1 announcements caused a 91bp drop in 10-year Treasury bond yields. Krishnamurthy and Vissing-Jorgensen (2011) confirm these results with a decline of 107bp in the yields on agency debt and the 10-year Treasury bonds. They concluded that the combination of the preferred habitat for longer-term 'safe' assets as well as the signalling channel had induced such changes.

[1] See Federal Reserve (2017) annual report on open market operations for detailed breakdown of purchases.

Empirical studies exploring the feed-through of QE via the portfolio balance channel mainly focus on government bond yields. Hamilton and Wu (2012) evaluate the impact of the maturity extension programme (MEP) by modelling the impact on the term structure of outstanding Treasuries. They find that the 10-year bond yield only decreases by 14bp, which suggests that central bank debt management is of almost negligible importance. This is somewhat of a contradiction to Gagnon et al. (2011) where they find a larger decline of 30-100bp. D'Amico and King (2013) suggest that a persistent shift in the yield curve of up to 50bp -the largest effect in longer-term Treasuries resulted from the QE1 programme. Furthermore, the literature indicates that QE induces lower interest rates, whilst evidence on the effectiveness of raising equity prices is uncertain (Rosa, 2012; Kiley, 2014).

We aim to explore whether the empirical evidence supports the hypothesis that QE significantly affects equity prices though private sector portfolio shifts. To this end, we utilise a similar approach to Joyce et al. (2011) for the UK as a basis for analysing the impacts of QE in the US. They apply a framework, which analysed the responses of various asset prices to QE, including equities that we apply here to the US Treasury, equity and corporate bond markets[2].

We analyse the portfolio balance channel of QE on a variety of assets using a VAR model to explore the relationship between the relative allocation of asset shares and investors' required returns for major asset classes. We then compute the impulse response functions (IRFs) to simulate the negative supply shock in Treasury holdings by the private sector. By observing the impacts on expected equity returns we can assess the performance of the portfolio balance channel during different periods. This modelling technique allows the disentangling of the equity required rate of return and the risk-free government bond rate, enabling an estimation of the QE driven change in the equity risk premium (ERP) into equity returns. By decomposing the variance, we observe the effects of a shock to the Treasury's asset share on the other asset classes' shares and returns. A logical extension to the current literature is to find structural breaks and compare those periods in between with the QE programme. Furthermore, consideration of the various policy regimes during those prior periods allows us to assess the parameters for where QE could and could not be effective.

Finally, we test the robustness of our findings by allowing for the conditional mean of the VAR model to shift, so extending the approach of Joyce et al. (2011). We relax the assumption that the conditional mean of the VAR model is constant over time. Indeed, the literature in Belke et

[2] Although, the overall purchases conducted by both countries were similar in size in terms of GDP: roughly 20% of the size of the economy (Fawley and Neely, 2013).

al. (2016), and Su and Hung (2017) on QE effects suggest the possibility of the presence of structural breaks. However, the findings of Belke et al. (2016) are inconclusive on the matter of QE driven structural breaks. They focus on the stability of the cointegrating vector (US and German interest rates, and US/Euro exchange rates). Su and Hung (2017) suggests the presence of structural breaks in the major stock market indices that they use to measure the effect of QE. Although both studies do not consider the case of a regime shift and the potential effect of different QE announcements. For example, Belke et al. (2016) do not find any conclusive evidence on whether different QE programmes cause different effects, while Su and Hung (2017) assume implicitly a homogenous effect since they capture the QE effect after breaks in the individual indices. Much of the literature uses a slightly different context to analyse structural breaks to this paper. We consider the case of possible regime shifts by applying the Qu and Perron (2007) structural breaks test to the VAR model. The test allows for both the conditional mean and variance to shift over time. This identifies when the long run relationship between shares and returns are subject to shifts in the conditional mean and variances. Thus, we account for these shifts to assess the robustness of our findings based on the standard approach.

In summary, we demonstrate that QE, combined with near zero lower bound interest rates, has had a positive effect on equity markets and confidence by exploiting the asymmetries in the Portfolio Balance Channel. Furthermore, we demonstrate there are several structural breaks where different policy prescriptions were applied by the government and the Fed confirming that QE reduces the persistence of an event. However, just because it worked once, it does not necessary imply that, in the future, the same mechanism can be exploited again.

The rest of the paper is organised as follows. Section 2 provides a critical review of conventional and unconventional monetary policy and an explanation of the portfolio balance channel. Section 3 concentrations on an interpretation of the portfolio balance channel in the context of asset allocation, while Section 4 provides a description of the data and variables and reports key statistical summaries. Section 5 outlines the estimation methodology followed by the empirical results and discussion of the findings is in Section 6. Finally, Section 7 concludes.

2 Review and assessment of QE in the US

2.1 Quantitative easing in the US

QE is the central bank's LASP from private the financial sector with the aim of expanding the money supply in the economy. This is in an attempt to ease monetary conditions (Joyce et al., 2011). Once the Fed had exhausted all of the other possible interventions in 2008-09 and these did not have the effect that normative economic interpretations predict, the FOMC decided to embark on a programme of unconventional monetary policy, QE. Although some previous evidence was available from Japan's experience, the programme was largely experimental with uncertain outcomes. In this context, the empirical literature such as D'Amico et al. (2012), Neely (2015) and Gagnon et al. (2011) – amongst others – suggest the presence of a positive correlation between QE and the stock market. For the US, some of the largest stock market gains ever occurred after the launch of an LSAP.

There are several channels through which QE affects the stock market. In general, purchasing a large volume of assets from the private sector affects the supply of the purchased asset (Glick and Leduc, 2012). The fall in supply will induce a fall in the yield (and interest rates). Because the money base and the purchased assets are not perfect substitutes, investors have an incentive to balance their investment portfolios via buying assets with similar characteristics (e.g. maturity and yield) to those sold. Consequently, prices of the purchased assets will increase leading to the price of their substitute to increase and the rate of interest to decrease.

The stock market reacts to the Fed's activity and the news, especially, if it is relevant to forecasting economic conditions and the long-term strategy. Up until 2007, the Fed's expansionary monetary policy had been effective in pushing (asset) prices upward. This, perhaps, is because investors are attracted to the idea of rising asset prices at the early stages of an expansionary monetary policy. Interest rate levels affect the investment decisions of publicly listed companies. Lower rates imply lower borrowing costs, which gives companies an incentive to expand their economic activity. This often increases leverage by companies borrowing (bond issue) rather than issuing more equity.

QE causes interest rates to fall by increasing the price of bonds to counter the effects of markets moving to safe assets such as Treasuries, money market accounts, certificates of deposits (CDs) and highly rated bonds. Consequently, investors have incentives to switch to riskier investment in the pursuit of higher returns. This prompts some investors to invest higher amounts of their wealth in equities causing stock market prices to increase.

In normal circumstances, market prices are determined by the forces of supply and demand. However, intervention by the Fed via financial asset purchases manipulates price signals through three channels: (i) lower interest rates, (ii) higher demand for assets and (iii) reduced purchasing power of money. These signals render stock prices inefficient, as they do not generally reflect companies' valuations and investors demand. They instead push agents to adjust their strategies by switching to stocks that grow without a change in the fundamental underlying demand or supply including increases in a firm's value. Consequently, 'unconstrained' QE, as was the case in the US and UK, needs to be accompanied with 'constraining' policies that channel the expansionary monetary policy into boosting consumption and investments (Ballati et al., 2016). Table 1 below summarises highlights key elements of the various QE programmes since 2008. Further discussion and details of the QE timeline can be found in the online appendix (OA.1).

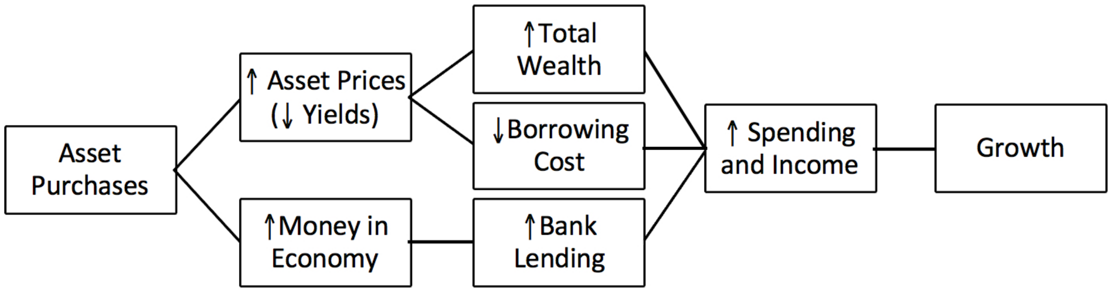
Table 1. QE Timeline

Programme	Period	Key aims and objectives	Outcomes
QE1	25 Nov 2008 to 31 Mar 2010	Reducing mortgage and raise the credit supply for house purchases. Plans to purchase $600 billion in treasuries.	Gains in the financial markets convincing the Fed to keep interest rates between 0 and 0.25%.
	2008 (Nov, Dec)	Pump liquidity into market to stop financial institutions failing	Stopping the domino effect between financial institutions
	2008-9 (Dec-March)	Large scale purchase of MBS and GSE with $600bn treasuries	Slowed the decline
	2009-10 (March onwards)	Expanded QE1 programme with $750bn MBS and %175bn of GSE	Started the gains.
QE2	3 Nov 2010-20 Jun 2012	Reduce unemployment and increase inflation. The purchase of $600 billion of long-term US treasuries.	US credit rating was downgraded. Higher unemployment rate.
	To Q2 2011	$600bn long maturity treasuries and aligning with Treasuring issuance	
	To June 2012	Operation Twist – to decrease long term interest rates and push up short term rebalancing the yield curve Managing the adverse effects of the government shutdown	Flattened out the yield curve to a more sensible level. However, unemployment and US credit downgrade eventuated
QE3	13 Sep 2012	Maturity extension programme. Monthly purchases of MS and long-term US treasuries.	Lower pressure on long term interest rates.
		Monthly MBS purchases $40bn, & $45bn treasuries to simulate demand thus reducing unemployment	
		QE-infinity programme to keep long term yield flatter and support housing market	Stability, investment and growth after downgrade and unemployment

2.2 Transmission QE to the economy

In 2007/8 crisis, liquidity and lending where in short supply. QE boosts the monetary base by increasing reserves though the purchase of bonds from banks and other financial institutions. By buying up government securities, the Central Bank increases their asset prices, reducing yields and encouraging investors to place investments with equity and corporate bond markets, this in turn supresses yields, reducing funding costs for business. Furthermore, increasing lending, with a rise in labour demand should reflect in greater consumer demand. If the Central Bank keeps ahead of the flow of government securities, it can supress the yields, hence reduce the borrowing costs to firms and with increasing consumer demand, firms will be encouraged to invest. This is the QE transmission channel to the real economy illustrated in figure 1.

Fig. 1. QE transmission mechanism channels.



Source: Joyce et al. (2012).

One can observe, two channels, the top being the *'Portfolio Balance Channel'* (PBC) that operates though investors biasing their investments away from low yielding government securities to higher yielding corporate bonds and equity and the lower being the credit flow channel increasing the money available in the economy. This PBC introduced by the Fed to the US economy in 2010, summarised by Ben Bernanke[3] "*I see the evidence as most favourable to the view that such purchases work primarily through the so-called portfolio balance channel, …. the Federal Reserve's purchases of longer-term securities affect financial conditions by changing the quantity and mix of financial assets held by the public*".

This implies that the Fed can manipulate the yields to recalibrate investor's expectations by increasing prices on 'safer' assets thus reducing the expected returns forcing the investors to rebalance their portfolio depending on the finding suitable substitutions, possibly equities. With this mechanism, the Fed (and Bank of England) can manipulate the yield curve by purchasing long maturity bonds in favour of short maturities. The increasing asset prices increases has positive wealth effects on investors.

Tobin (1958), Brunner and Meltzer (1968) argue that central bank asset purchases and money should not be perfect substitutes for the PBC to work. If this was the case, then investors would

[3] See Chairman Bernanke's speech at the Federal Reserve Bank of Kansas City Economic Symposium, Jackson Hole, Wyoming. August 27, 2010.

refrain from reinvesting funds from asset sales resulting in no change to portfolios. This would give rise to a liquidity from though an 'relevance proposition'[4] (Eggertsson and Woodford, 2004). At ZLB and largely being risk free, makes short dated bonds close substitutes to money. Nevertheless, by purchasing longer maturity bonds, this money injection effect can be attenuated encouraging a portfolio balance effect (Bowdler and Raida, 2012).

The literature explains the mechanism driving the PBC via the effects of either 'preferred habitat' or 'duration risk'. The Preferred Habitat effect normally is associated with long term investors (pension funds etc) holding long dated maturities to their expiration. Fed buying up long term bonds in a market with strong demand induces a scarcity effect on the longer end of the yield curve creating an incentive to rebalance towards risker equity assets[5]. Alternatively, Duration risk is reflected though term premiums in the bond price reflecting the aversion towards the risk of holding longer maturities. Fed purchases reduce the private sector's average duration thus reducing the term premium in the market. Investors desiring a certain level of risk will pay a higher price or rebalance their portfolio towards risker equity assets.

A complication is that US government has persistently run fiscal deficits funded by debt, particularly over the time of QE to, in part, substitute for recession generated reduced tax revenues. For the QE programme to be effective, the Fed would need to buy more Treasuries to have the price effect. Over the period, the supply of Treasuries did not diminish (debt was increasing), more they increased to compensate for recessionary impacts. Effectively, the Fed would need to soak up any additional Treasuries to have an QE effect. The only way the fiscal government could induce a negative shock similar effect would be to slow the flow of Treasuries, hence reduce the yield, or positive shock by issuing considerably more debt than the market was expecting increasing treasury yields. The Fed could quite easily adjust its programme, by selling treasuries back into the market or increasing the buy up, to suit either shock nullifying the shock effects.

2.3 Assessment of QE

QE potentially raises stock prices. Although many commentators see a rising stock market as a positive indicator, one could argue that inflated stock prices may lead to another adverse event. Normally, increases in a company's stock price, over a medium timeframe, accompany an improvement in the performance or anticipated performance. Therefore, it would be irrational if such gains were not supported by the requisite increases in company profitability along with

[4] Central Bank buys short maturity 'one-period' bonds as part of QE, thus making them worthless to investors.
[5] price effect is dependent on the maturities targeted in the QE programme, this effect has often been referred to as the 'local supply effect' (Joyce et al., 2012).

productivity gains and rising efficiency, and long-term R&D/intellectual property etc. In the period from 2010 to 2012 (and onwards), the stock market continued to grow with many larger firms performing share buybacks (Warusawitharana and Whited, 2016) increasing their debt to fund such purchase to rebalance to an optimum level for the Weighted Average Cost of Capital. This has continued largely unabated with cheap debt financed from historically unheard of low interest rates compared to equity finance (Liu and Swanson, 2016). Share buybacks also have the effect of increasing shares price and as the number of shares decrease, the earning per share changes little. However, firms become overburdened with debt and with the Fed increasing interest rates might find it difficult to rebalance from debt back to equity (Covas and Den Haan, 2012). If the main use of debt finance is to perform share buybacks and not investment to improve productivity and profitability, then it is unsustainable and may potentially lead to a cyclical decline in profits as interest rates rise. Furthermore, this may put corporate bonds under stress with firm's debt service costs influencing credit ratings and with a number of secondary offerings, a decline in share prices reducing the funds made available to firms. We can only speculate as to the outcome and will leave this for future research.

3 Unconventional monetary policy in theory and application

3.1 Foundation

We use the modelling approach in Joyce et al. (2011) for the portfolio balance model summarised briefly here. This is derived from Tobin (1958) with further elaboration in such papers as Roley (1981, 1982), Walsh (1982) provided a sound theoretical background to this method. The portfolio balance channel is quite controversial since its inception by Tobin (1958). It relies on the principle that if the government can alter the expected returns on any asset class then this will be transmitted through the market to investors resulting in the rebalancing of their portfolios. The Fed was relying on this channel to transmit the desired outcomes they wish to effect on the market, hence the name *portfolio balance channel.*

The model states that the investor chooses the asset shares, λ_t of their current wealth W_t, to generate real wealth $E(W_{t+1})$. The asset share may not be optiminal given their wealth though constraints in total quantity available for purchase and would need greater returns to hold excess quantities of assets. A policy maker can exploit this mechanism by changing the asset quantities thus affecting the price of the asset and hence, the ex-ante risk premia to hold the available quantities of assets.

Formally, the investor will attempt to maximise their end of period real wealth by choosing the allocations to assets that provide the maximum return subject to the current wealth and the availability of those assets, hence that limits their allocations and returns. Formally:

$$\max_{\lambda_t} U[E_t(W_{t+1}),\ V_t(W_{t+1})] \quad (1)$$

Subject to the real wealth mean and variance. Taking the first order conditions and equating the investor's asset demand with their availability to find the equilibrium condition:

$$E_t(r_{t+1}) = z\Omega\lambda_t \quad (2)$$

where $E_t(r_{t+1})$ is a vector of expected excess asset returns over one benchmark numeraire asset, namely money, z is the coefficient of constant relative risk aversion (CRRA) and Ω is the covariance matrix of the assets' expected returns, λ_t is a vector of asset shares of the total investment portfolio. We assume that CRRA and Ω are constant following the Frankel and Engel (1984) approach. Importantly, the covariance matrix determines the entire excess returns over the benchmark asset and the relative cost of substituting between the different assets. The covariance matrix with the CRRA coefficient provides insights into the impact of any change to the relative quantities of the assets within the investor's portfolio.

This brings us to the question, what effect is QE exploiting? The inability of investors to allocate optimally though say supply limitations or regulation that is exogenously constrained, then the investor will choose a second-best allocation. The first best unconstrained choice being an optimal allocation dictated by the covariance matrix. This provides an opening for policy makers to alter the investor's portfolio balance by lowering the returns on less risky assets, namely sovereign bonds. This encourages the investor to rebalance their portfolio to more risky assets[6] to achieve higher returns. This progressively increases the price of risker assets and lowers their returns. If the policy is sustained, then this will eventually be reflected though the whole portfolio and the market. The hope therefore is this would encourage investment. Hence the Fed can manipulate the banks into altering their portfolios and encouraging trading in the markets by increasing liquidity.

[6] By risky assets, we mean corporate bonds and shares rather than Treasury bonds. There is a small increase in risk noting that most of the risker assets are likely to be gilt edged.

3.2 *Empirical Application*

Expectations is unobserved, therefore the equilibrium condition in (2) cannot be quantified from the data. As with Joyce et al. (2011), we assume that investors' decisions are based on rational expectations. Hence, the measurement between ex-ante and ex-post is determined by the orthogonal estimation error of the portfolio share. Thus:

$$r_{t+1} - E_t(r_{t+1}) = \varepsilon_{t+1} \tag{3}$$

where $E_t(\varepsilon_{t+1}) = 0$ and $E_t(\varepsilon_{t+1}|\lambda_t) = 0$. Combining equation 2 and 3 and by adding a constant term, A, as in Engel et al (1995), the model can be rewritten[7] as:

$$r_{t+1} = A + z\Omega\lambda_t + \varepsilon_{t+1}, \tag{4}$$

Where $\Omega_t = E_t\varepsilon_t\varepsilon'_t$, and the vector of excess returns r_{t+1} on each asset, λ_t is as before a vector of asset shares, with weights proportional to the variance-covariance matrix of the assets' excess returns Ω and the degree of relative risk aversion z (Fraser and Groenewold, 2001).

One could argue that this model's over-simplified assumptions could provide dubious results. Yellen (2011), finds that these assumptions play little role during financial or economic turmoil and substantially simplifies the variables affecting expected asset returns. Nevertheless, using the co-movements between expected excess returns and asset shares in a VAR model to build an understanding of the effect of QE on the US stock market.

4 Data description and preliminary statistics

Utilising the same methodology as in Joyce et al. (2011), our data consists of end of month realised returns, asset shares and broad money (M2) spanning the period January 1984 to January 2017. This covers an extensive period prior to the 2007/8 financial crisis as a benchmark and continues over an extended period that includes all the QE measures implemented by the Fed. All the data was sourced from Thomson Reuters Datastream subscription service. Detailed description and definitions of the data is in the online appendix, OA3.

Table 2 below reports key summary statistics for excess returns and the return on money i.e. the Fed funds target rate, over the sample investigated. At this point, it is again emphasised that due to the rational expectations assumption, the excess returns can be understood as expected excess returns. Each shows the excess returns of other assets over money (M2).

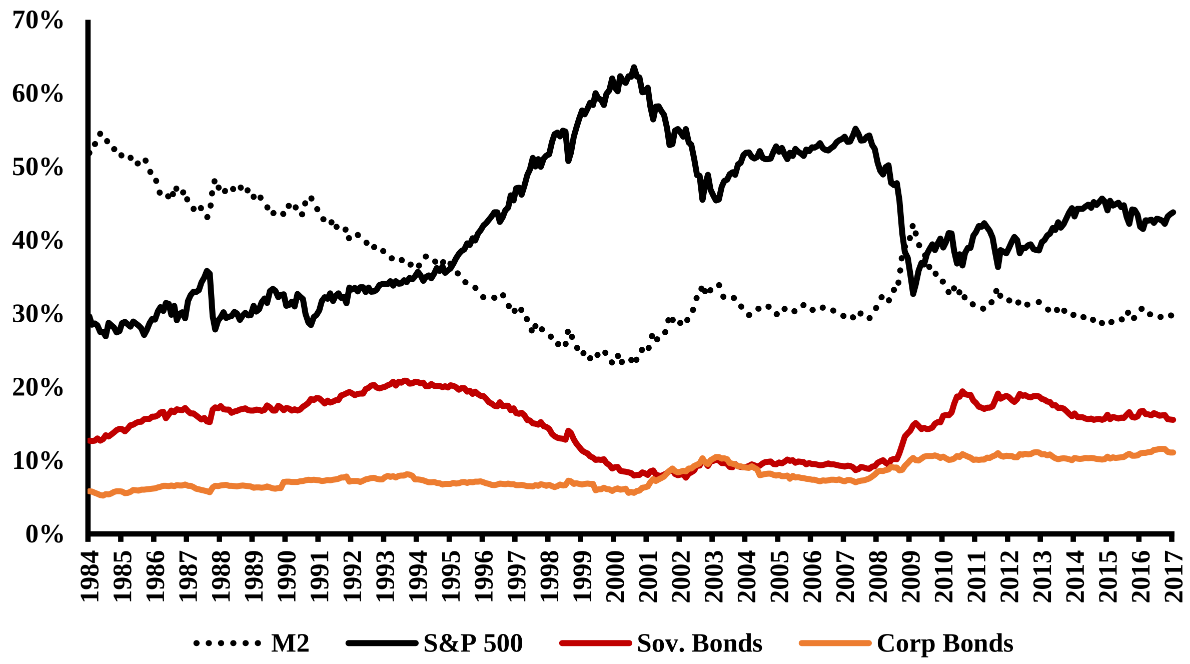
[7] See online appendix, OA.2 for detailed derivation.

Table 2. Excess returns and money return summary statistics

	Mean	Standard Deviation	Maximum	Minimum	Kurtosis	Skewness	JB P-value
Excess Return on Equities	8.2%	16.2%	53.4%	-43.6%	0.5	-0.6	0.00
Excess Return on Corp. Bonds	6.8%	10.2%	62.8%	-15.7%	5.1	1.5	0.00
Excess Return on Tres. Bonds	5.2%	7.8%	40.3%	-10.0%	3.6	1.4	0.00
Return on Money	4.0%	2.9%	11.4%	0.3%	-1.0	0.2	0.00

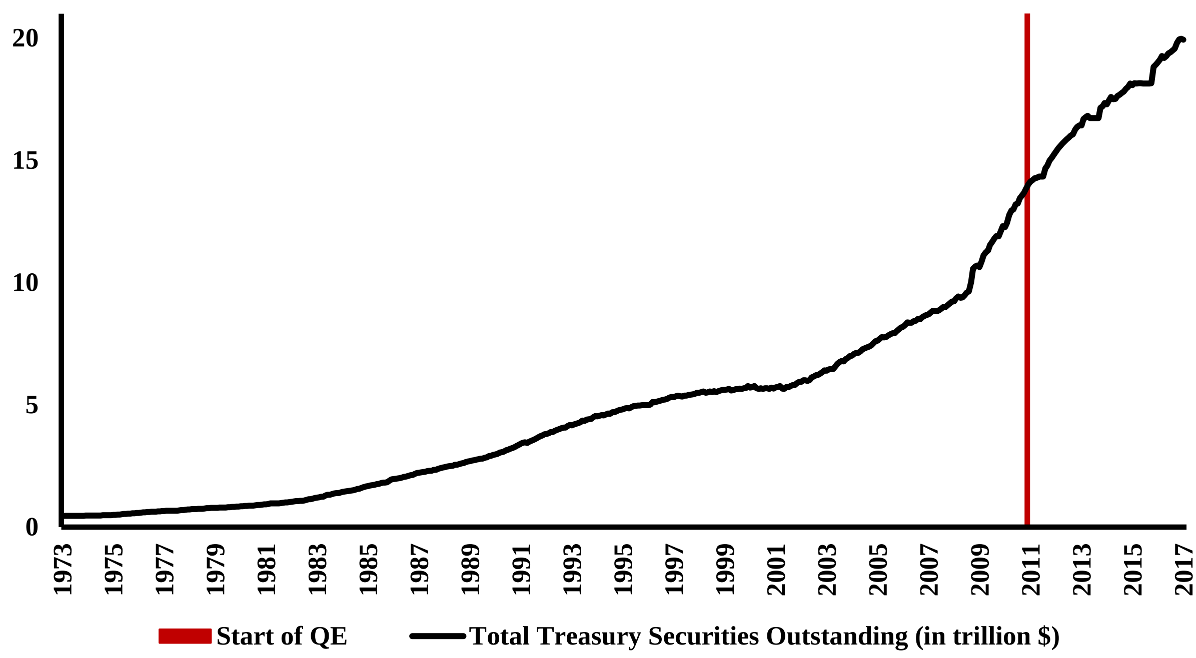
Although all three classes have higher returns than money, they do so at greater volatility, particularly with equities. The results are not unexpected confirming that riskier assets are characterised by a higher average return. One interesting point is that Barclays bond indices' maximum observation is incoherent with the other asset classes. An explanation is that there were initial complications, for example pricing, during the first years after inception of the total return indices. This was exemplified in some of the early data from 1973 to 1984, where some of the year-on-year returns show significant deviations, for example up to 166% on corporate bonds. By 1984 the indices had settled down, therefore we limit our data to post 1984 inclusive.

Fig. 2. Financial market indicators development from 1984-2017



If Joyce et al. (2012) findings are applicable to the US economy; we should observe a negative correlation between broad money and equity share. Fig. 2 confirms that Joyce et al (2012) findings are generally applicable. Another effect is that up to 1994 equity and Treasuries were almost parallel, then after they became negatively correlated, particularly around the financial crisis. The 2007 onwards shares are coherent with the action taken by the Treasury and Fed in implementing the QE programmes.

Fig. 3. Total Treasury securities outstanding and QE



Source: Federal Reserve balance sheet statistics soured from Thomson Reuter's Datastream

Fig. 3 depicts the Total Treasury securities outstanding (held by Fed and Government Holdings). We note that the issuance of Treasuries picked up significantly in the middle of 2008 from $9.5 trillion to approximately $20 trillion in October of 2016, showing a more than doubling of the government bond market over the duration of the global financial crisis and QE programme. Considering that the purchases by the Fed only comprised $1.6 trillion of Treasury securities, this implies a substantial expansion in the market value and probably explains the increase of the share in government bonds as shown in Fig. 2.

5 Estimation methodology

The data covers a long period prior to the financial crisis and as commented above, includes a change in the dynamics of the market in 1994. Our interest lay in the period leading up to and subsequent to the initiation of QE in the US and its effect on equity markets. We utilise a VAR model to assess the effect of the portfolio balance channel on the market, focusing on equities. Once estimated, we use an IRF with a negative shock on the asset share of US Treasuries to observe the effect on the equity share and returns. In the QE period, the main issuance of US Treasuries above the normal cycling of US government debt was principally driving QE (Christensen and Rudebusch, 2012). Regarding the QE shock, QE mostly involved the Fed buying government bonds, which increased their demand and price. This would have reduced their yield and increased liquidity in the banking sector. This lower yield would have affected parts of the economy, such as mortgage rates and housing that are influenced by long-term interest rates. We follow Joyce et al. (2011) although they use UK gilts as their representation of the sovereign bond share of assets. As with Christensen and Rudebusch (2012) and Joyce et al. (2011), we interpret QE shock as innovations to the Treasuries share identified by ordering Treasuries first in the lower triangle Cholesky matrix (6). This ordering has also been used in the context of portfolio balance channel literature as in Weale and Wieladek (2016), in which asset purchasing affects real economy from government bonds to equity. We use US Treasuries as our sovereign bond asset share; it follows, therefore, US Treasuries random shocks are interpreted as US QE shocks.

5.1 The VAR model: A portfolio balance channel

We estimate a VAR model to analyse the portfolio balance effect on a variety of assets to investigate the impact of monetary policy on both asset shares and excess returns. The parameters are estimated for multiple equations by OLS. Our VAR (p) take the following reduced-form:

$$y_t = a_0 + \sum_{i=1}^{\rho} A_i y_{t-i} + u_t \tag{5}$$

where y_t is a vector of $(n \times 1)$ endogenous random variables, a_0 is $(n \times 1)$ vector of intercepts, , A_i is $(n \times n)$ matrix of coefficients and u_t is $(n \times 1)$ vector of errors with time invariant covariance. The vector of all endogenous variables y_t includes corporate bonds, government bonds and equities in both shares and returns form.

We analyse VAR model using IRFs. Because this analysis is interested in dividing the impact of a shock to the share in sovereign (US Treasuries) bonds, the VAR can be rewritten such that the shock to a certain variable is uncorrelated to the others and therefore the only innovation affecting the system. An application of identification restriction is the Cholesky decomposition. This essentially pre-multiplies the left-hand side of the equation by the inverse of a lower triangular matrix A, comprising the standard deviations of u_t. This results is a diagonal variance-covariance matrix Σ_{ε}.

$$\varepsilon_t = A^{-1} u_t \tag{6}$$

where A is equal to:

$$A = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \end{bmatrix}$$

Formally this restriction is computed by setting zero-restrictions on $a_{ij} = 0$ for $i < j$. The transformation reflects that a shock to variable i has no contemporaneous effect on the other variables $i > j$, but rather exhibits a recursive behaviour. This implies that the first variable in the VAR is only affected contemporaneously by the shock to itself, while the second variable is affected by the shocks to the first variable and the shock to itself, etc. Given this importance of the relative ordering of variables within the matrix, one problem with this procedure is that an appropriate ordering cannot be determined by statistical methods. It is therefore subjectively selected which variables are most endogenous, relative to what the economic background of the model implies.

When studying the portfolio rebalancing effect, we assume that asset shares are the most exogenous followed by the returns, thus implying an ordering where asset shares are first and returns second. A negative shock is a fall in the share (including Fed holdings of USTs) of Treasuries available to the market as the Fed has effectively removed them from public market. By ordering Treasuries asset shares before returns, we can observe the effects of innovations to Treasuries on the equity, bond and Treasury returns. QE shocks are the source of random shocks in US Treasuries bonds. This latter can be used as a proxy to capturing the effect of a QE shock on equity, bond and Treasury returns. It is herewith suggested that investors with relatively risk-free portfolios, such as pension funds and insurance companies, will shift into slightly riskier assets, such as corporate bonds and equities to meet return requirements (Joyce et al., 2017). The prices of these assets are affected correspondingly. For a robustness check, we also estimated the model (6) with returns first followed by shares reported in section 6.2. In general, however, the IRF findings based on the first original order are more plausible and are consistent with literature.

5.2 The expected excess return and the equity risk premium

The objective is to view the effect on ERP of a QE shock by first estimating a VAR and then simulating a positive QE shock though the (6) above in an IRF. This should show a negative ERP effect. In addition, we intend to compute the impact of QE on excess returns.

The model captures the change in expected excess return on the various asset classes induced by the central bank's programme. At this point, it is worth emphasising again that in the framework of this analysis the expected excess return is understood as required rate of return and is not to be confused with actual price returns. Although the resulting fluctuations in expected excess return from the IRFs to bonds can be understood as a revision to their yield, the interpretation for equities, however, is not quite as straight-forward. The equity required rate of return (r^{eq}) is defined as the sum of the risk-free government bond yield[8] (r^{f}) and the equity risk premium (ρ^{eq}) and expresses the compensation investors involve for bearing the additional risk from holding this asset.

Following the Capital Asset Pricing Model (Sharpe, 1964):

$$r_{EQ,t} = r_{TR,t} + \rho_{EQ,t} \tag{7}$$

Joyce et al. (2011) provided a method for determining the QE effect on the stock market by converting the IRF results, from simulation of a shock, to equity returns using the Dividend Discount Model. We seek a variation on this model that disentangles the IRF's shock to the equity required rate of return from the Treasury rate to identify the ERP by effectively reversing (7).

$$\hat{\rho}_{EQ,t} = IRF_{EQ,t} - IRF_{TR,t} \tag{8}$$

where $\hat{\rho}_{EQ,t}$ is the estimated expected ERP at time t periods after the shock, $IRF_{EQ,t}$ is the IRFs simulated result for equity returns in response to a shock, likewise $IRF_{TR,t}$ is the impulse response (IRs) for the asset returns, namely US Treasuries. Finally, we calculate the scaled ERP over 20 periods using the estimated ERP and the coefficient for the change in ERP between periods.

$$ERP_{QE,t} = \hat{\rho}_{EQ,t} S_{QE} \Delta ERP_{t,t-1} \tag{9}$$

where $ERP_{QE,t}$ is a vector of the expected ERP for each QE programme, $QE = \{QE1, QE2, QE3\}$, S_{QE} is the scaling factor for that QE programme (see Table OA4.3 in the online appendix) and $\Delta ERP_{t,t-1}$ is the coefficient for the inter-period change in ERP (see Table OA4.4 in the online appendix). The resulting difference in expected ERP, is thereafter interpreted as a respective change in the price level given the historic relationship between ERP and equity prices as follows.

[8] We proxy US Treasuries rate as the risk free rate.

5.3 The impact of QE on equity price returns

The historical ERP can be derived by the dividend yield method, also known as the Gordon growth model (Gordon and Sharpio, 1956). The theory suggests that the excess return of a stock can be calculated by incorporating the dividend yield to a constant dividend growth rate. Our objective here is to show the impact of QE shock on the equity price returns.

$$r_{EQ,t} = \frac{D_t}{P_t} + g \qquad (10)$$

$\frac{D_t}{P_t}$ is the dividend yield (dividend expressed as percentage of current price of the stock index) and $g(\Delta div)$ constant dividend growth rate. Rearranging the above and substituting equation 11 into it, the ERP can be calculated as follows:

$$\rho_{EQ,t} = \frac{D_t}{P_t} + g - r_{TR,t} \qquad (11)$$

At this point, an assumption requires to be made on how long-term dividend growth is defined. Herewith, the latter is set equal to the year-on-year dividend growth of the sample average (8.5%). Due to long-term dividend growth being constant, changes in the ERP are therefore solely induced by changes in the risk-free rate and the dividend yield prevailing in time t. The advantages of this approach is its intuitive nature. However, it relies on a perpetuity assumption and is therefore sensible to which one is adopted.

The ERP is a key factor in deciding how much wealth an investor is willing to attribute to this specific asset class. On the basis that the value of an asset is determined by the present value of excepted cash flow and discounted back to estimate a current price level, the risk-free rate and ERP play a crucial role. The risk aversion of an investor herewith determines how much their is willing to pay for a certain asset – the higher the perception of risk, the higher its price and consequently the lower the willingness to pay for the same set of expected cash flows (Brealey et al., 2008).

Fig. 4. Historical equity risk premium and price index

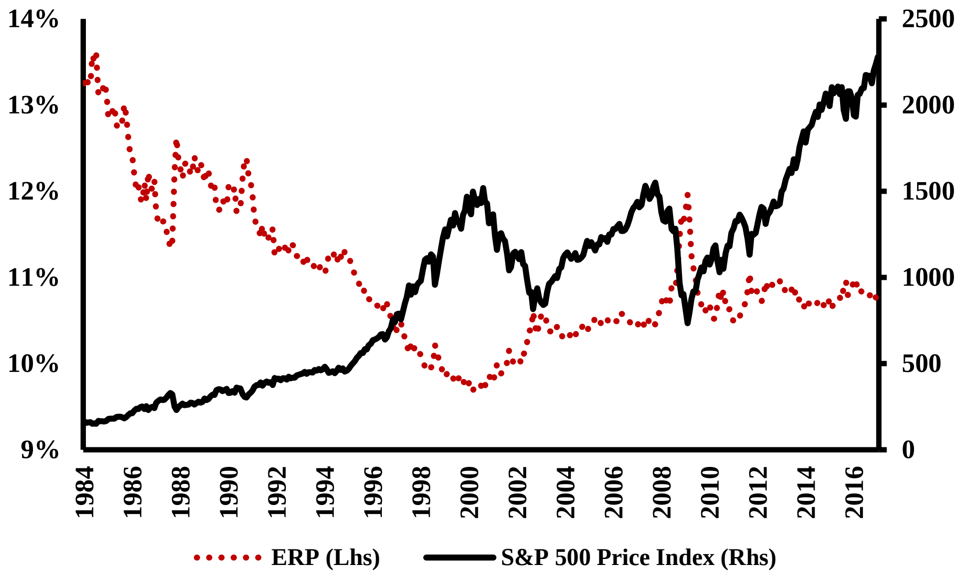


Fig. 4 illustrates an inverse relationship between the calculated ERP and the price index. This association can also be confirmed by the regression outlined below (Neely et al., 2014).

$$\Delta p_{t,t-1}^{eq} = c + \beta \Delta \rho_{t,t-1}^{eq} + u_t \qquad (12)$$

In this way, a conclusion on how changes in the ERP induced by QE, alter yoy equity price returns (p^{eq}) for the S&P 500, can be drawn. The 1% change in ERP is scaled to the purchases conducted by the Fed for a more accurate estimation. Because stock indices are usually quoted in price returns, applying the price index rather than the total return index, circumvents the drawback of having to disentangle the return in terms of capital gains from other cash distributions (Brealey et al., 2008).

5.4 Regime shifts and stability of the VAR(p) model

We also investigate the stability of the VAR model and examine whether there exist regimes consistent with economic or financial events that may prompt monetary policy regimes in the US. In the previous exercise, we assumed a constant conditional mean and variance-covariance matrix in the VAR. The main drawback of this assumption is it implicitly captures a constant average effect of all monetary policy announcements over the time period covered by the sample. This is very restrictive and does not offer any insight on the extent to which various monetary policies affect the market. Thus, we relax this assumption and allow for the conditional mean and variance-covariance matrix to shift in the VAR system. We aim to test for the presence of structural breaks in the VAR, which may indicate a response of the model's parameters to economic and financial changes.

We implement Qu and Perron (2007) (QP, henceforth) test to identify structural breaks in a multivariate context. QP introduced a multiple structural breaks test that can be applied to multivariate regressions and considers a very general model. This test is an extension of the previously developed by Bai and Perron (1998, 2003) that considers the null hypothesis of *l* breaks versus the alternative of *l+1* breaks for linear (univariate) regression. In our case, we deal with a VAR model that is characterized by stationary long run relationships, and thus, QP can be a suitable test to identify break dates in the system. QP test also allows for the variance and covariance matrix to shift with the conditional mean, thus the test allows for a more general framework to capture regime shifts. QP suggest a range of test statistics, which includes: the $\sup LR_T$, the sequential test and the double maximum tests. The $\sup LR_T$ formally defined as:

$$\sup LR_T(m, p_b, n_{bd}, n_{bo}, \varepsilon) = \sup_{(\lambda_1,\ldots,\lambda_m)\in\Lambda_\varepsilon} 2\left[\log \hat{L}_T(T_1,\ldots,T_m) - \log \tilde{L}_T\right] = 2\left[\log \hat{L}_T(\hat{T}_1,\ldots,\hat{T}_m) - \log \tilde{L}_T\right] \quad (13)$$

Where m is the maximum number of breaks found, $(\hat{T}_1,\ldots,\hat{T}_m)$ are the Quasi Maximum Likelihood Estimator estimates of dates (partitions) using the partitions defined in $\Lambda_\varepsilon = (\lambda_1,\ldots,\lambda_m)$ and ε is the trimming rate or minimum distance between each partition. Testing the changes can be done sequentially. Formally, the test statistic can be written as:

$$SEQ_T(l+1 \setminus l) = \max_{1\le j\le l+1} \sup_{\tau\in\Lambda_{j,\varepsilon}} lr_T\left(\hat{T}_1,\ldots,\hat{T}_{j-1},\tau,\hat{T}_j,\ldots,\hat{T}_l\right) - lr_T\left(\hat{T}_1,\ldots,\hat{T}_l\right) \quad (14)$$

where: $\Lambda_{j,\varepsilon} = \left\{\tau; \hat{T}_{j-1} + \left(\hat{T}_j - \hat{T}_{j-1}\right)\varepsilon \le \tau \le \hat{T}_j + \left(\hat{T}_j - \hat{T}_{j-1}\right)\varepsilon\right\}$.

First, we estimate breaks over the sample period endogenously. Within the VAR, we allow for all the coefficients in the conditional mean and variance-covariance matrix to change. Subsequently, we are able to analyse the VAR properties for every identified regime using IRFs.

6 Empirical analysis

6.1 Model specification: unit root tests and VAR (p)

In the context of the VAR model, failure to demonstrate stationarity would lead shocks to the system, not only to be persistent through time, but also to propagate. We analysis the time series properties of the variables by using the unit root tests that include the extension of the M class tests analysed in Ng and Perron (2001) and the feasible point optimal statistic of Elliott et al. (1996). The resulting test-statistics exceed the critical value (in absolute terms), rejecting the null hypothesis of the excess returns having a unit root. Table 3 indicates that all asset returns and shares are found to be stationary at level.

Table 3. Unit root test results

	DF-GLS	PP	MZa	MZt	MSB	MPT
Excess Return on Equities	-3.42**	-4.50**	-31.21**	-3.94**	0.13**	0.83**
Excess Return on Corp. Bonds	-3.54**	-4.17**	-10.27**	-2.24**	0.21**	2.48**
Excess Return on Sov. Bonds	-3.56**	-3.84**	-26.73**	-3.62**	0.14**	1.04**
Share of Equities (YOY%)	-2.86**	- 3.92**	-16.60**	-2.86**	0.17*	1.54**
Share of Corp. Bonds (YOY%)	-3.29**	-3.66**	-30.92*	-3.93**	0.12*	0.80**
Share of Sov. Bonds (YOY%)	-3.54**	-3.11**	-15.26**	-2.70**	0.18*	1.85**

Note: ** indicate the level of significance at 5%. The unit root tests with structural breaks in essentially trend-stationary series, namely, (MZt) Elliott-Rothenberg-Stock, (MZa) Ng-Perron (MSB) Silvestre-Kim-Perron, SKP-MZT Silvestre-Kim-Perron and PP- Zα Phillips-Perron.

We estimated the VAR model by using monthly data on a sample from 1984M1 to 2017M1. It is commonly known that the results of a VAR analysis are sensitive to the lag-length selected. In order to construct accurate IRF, it is hence crucial to account for this (Eadie et al., 1971). The optimal lag length has been set using Akaike, Schwarz and Hannan-Quinn information criteria[9]. The VAR (2) model is found to be stable and does not suffer from serial correlation[10]. These results are an important confirmation that the selected lag-length for the model is appropriate, and it is therefore considered as adequate to proceed with structural analysis of the IRFs and variance decomposition.

6.2 The impulse response functions

The shock of Treasuries asset share (a QE shock) effects can be observed though the IRFs. This latter is assumed to take three forms. First, we consider the form when the relationship is governed by a constant conditional mean. This form refers to the situation when the response of excess returns and asset shares to the shock of Treasuries share is constant and the same over time. We relax the assumption of constant conditional mean and allow for the possibility of structural breaks and regime shifts. In this context, shocks of Treasuries share might prompt different responses from excess returns and excess shares due to shifts in the conditional mean of the model.

Fig. 5 shows the IRFs the red dashed lines show a one standard error 95% confidence band around the estimates of the coefficients of the IRFs. Fig. 5d-5f shows the responses of returns

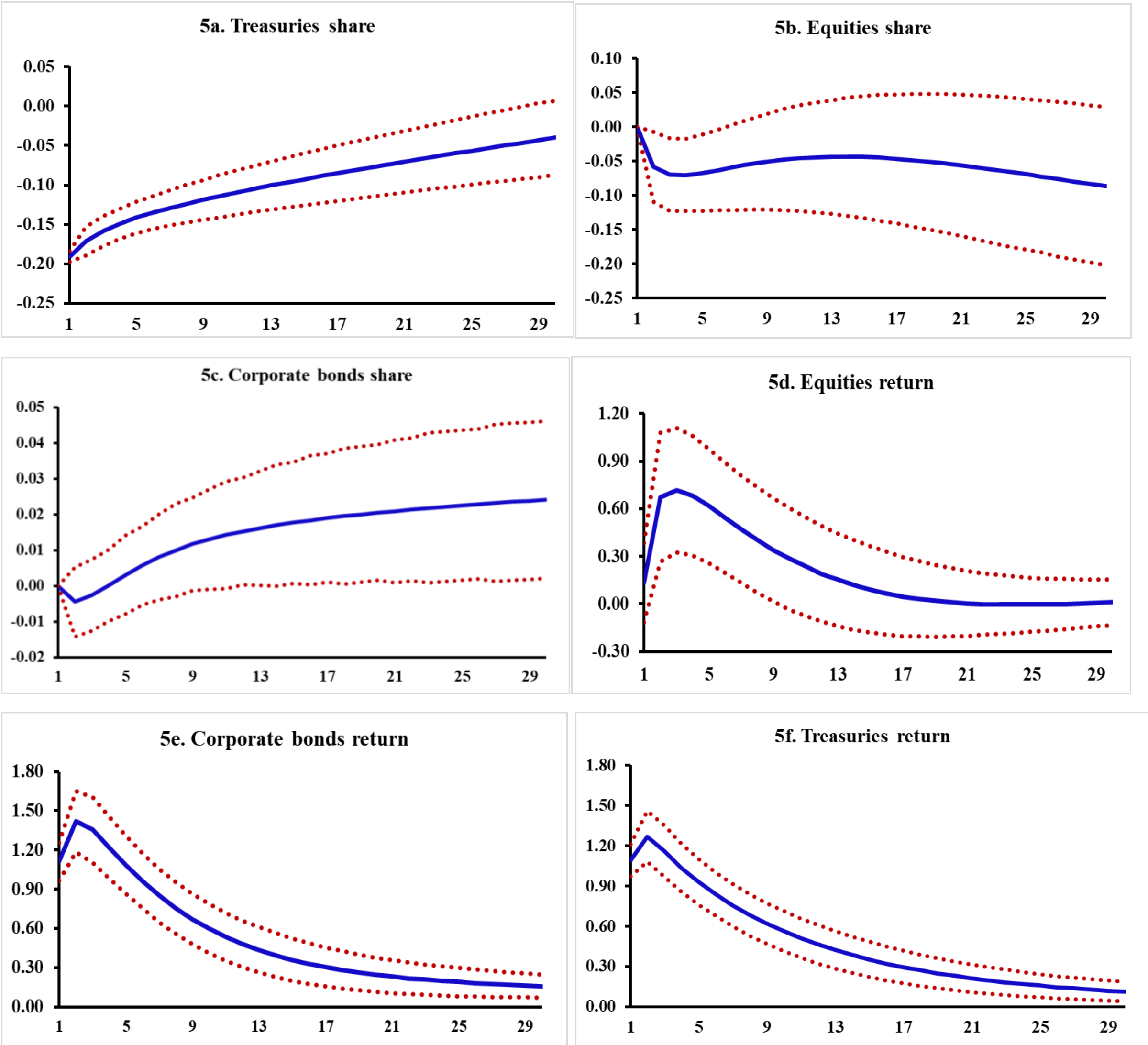
[9] See Table AO4.1 in the online appendix.
[10] Table OA4.1 in the online appendix also reports maximum chrematistics root, which lies within the unit circle and confirms the stability of the VAR system (Lütkepohl, 2013). The LM test for the presence of serial correlation is reported in the online appendix, Table OA4.2.

for a one-standard deviation fall in the share of Treasuries (a positive QE shock). As expected, a QE shock has a significant positive impact on equity, corporate and Treasury returns. This implies that when the government implements a QE programme, Treasury asset shares decline pushing investors to move to risky assets such as corporate bonds and equities. Our findings are consistent with those of Fratzscher et al. (2018). They highlight a positive impact of unconventional monetary policy on the expected excess returns in the US private sector. These findings suggest the typical response of the stock market to the Fed's announcement, which features a rise in excess returns when the policy is expansionary and vice versa. This is due to the positive effect of an expansionary policy on investors' expectations.

The expectation is that as the Fed buys up the stock of Treasuries in the QE programme, investors will transfer their assets to corporate bonds and equities. Fig. 5a-5c shows a gradual increase in the corporate bond share in response to the QE intervention. Initially, the equity share shows a small increase followed by a long period of slow decline. Both are not significant and one cannot draw any meaningful conclusions. At the same time as QE, the US economy was weak with output significantly attenuated and growing unemployment. This would have a marked effect on equity prices and volatility as the corporate sector struggles with the dynamics of the economy. During QE, the US government continued to increase the stock of US Treasuries to fund the normal fiscal expenditure demanded by the economy. We observe a significant and gradual return of US Treasury asset share towards the equilibrium.

Although this result is not compatible with the portfolio balance theory, it is consistent with the findings of Joyce et al (2012). The findings might reflect the strong inverse relationship in shares of equities to broad money over the sample. Moreover, the effect from a reduction in US Treasuries produces a moderate adjustment to all variables over time. In fact, an alteration in relative asset shares triggers a portfolio rebalancing into riskier assets, whilst adjusting the expectation of future returns down. This is reflected as a decline in bond yields of similar magnitude for both government and investment grade securities, as well as a shrinking of the required rate of return on equities. Whilst the initial reaction to a one standard deviation shock leads to a decline in Treasury and corporates bonds yields of 1% and 2% respectively, it is already reverted to half the size after 8 months. Nevertheless, the Treasury returns seems to reduce at a faster pace equity returns.

Fig. 5. Expected excess returns and asset shares responses to fall in Treasuries share
Form 1: Constant conditional mean



We further computed the IRFs by ordering returns first in the lower triangle Cholesky matrix (6)[11], which provides a robustness check on the validity of the ordering adopted earlier. Although the findings suggest similarity in the sign, the responses are not significant. Furthermore, we observe considerable differences indicating that the transmission is through the channel and not the shock itself.

6.3 Variance decomposition

In addition, variance decomposition is used to measure the proportion of fluctuations in returns and shares caused by a QE shock. Table 4 shows the variance decomposition of shares and returns, which highly supports our initial findings. We notice that, simultaneously, the role of QE in explaining expected excess returns is important in the short run. The monetary policy shock accounts for sizable components of the variation in the Treasury (21%), the corporate

[11] Results are available on request.

(16%) and equity returns (4%). In contrast, Treasury shocks explain only 0.44% and 1.47% of the variation of equity and corporate shares respectively. This is in line with the corresponding results of IRs analysis. Because QE play a rather import role in excess returns.

Table 4. Variance decomposition to shock of US Treasuries share

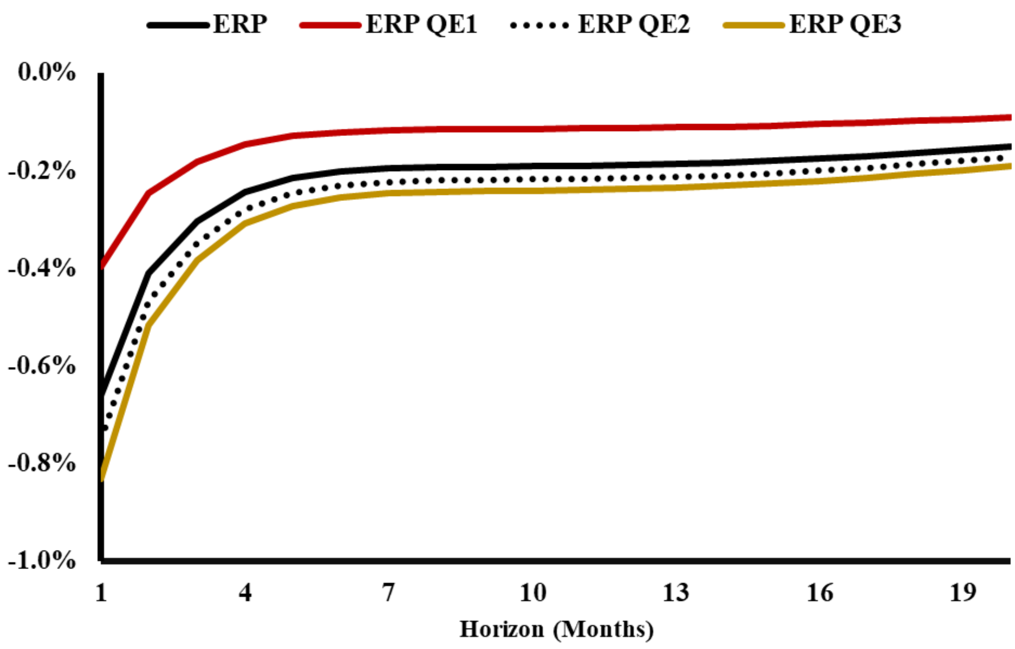
Period	Eq_share	Corps_share	Tres_share	Tres_return	Corps_return	Eq_return
1	0.00	0.00	33.54	16.96	11.29	1.18
2	0.18	0.21	30.45	18.32	12.99	2.02
4	0.39	0.34	27.28	18.98	14.08	2.55
6	0.45	0.45	25.21	19.34	14.57	2.91
8	0.46	0.60	21.66	19.65	14.89	3.35
10	0.44	0.73	21.41	19.94	15.11	3.61
12	0.42	0.85	19.95	20.19	15.26	3.78
16	0.37	0.97	16.77	20.61	15.41	3.90
20	0.35	1.09	14.00	20.90	15.47	3.97
24	0.36	1.21	13.88	21.09	15.49	4.01
28	0.41	1.34	09.88	21.21	15.52	4.03
30	0.44	1.47	09.10	21.25	15.53	4.04

6.4 The equity risk premium and equity price returns

Following the methodology outlined in Section 5.2, we calculate the ERP response to a simulated one standard deviation shock though an IRF from the estimates of the VAR. We then translate that shock into the three QE programmes, at the month of inception, ranging from approximately $850 billion to $1.4 trillion. Fig. 6 depicts the negative impact of unconventional monetary policy shocks on the ERP in all three QE programmes[12]. We observe an average reduction in the ERP of 0.23% over a 12-month period. This implies that the changes in the ERP have a negative effect on the returns of the S&P 500 thus reducing the investment in riskier assets such as equities. These results concur with those of Poshakwale and Chandorkar (2016) and Bredin et al. (2007).

Fig. 6. ERP implied from IRFs

[12] After seven periods responses are stationary therefore limited it 20 periods shows persistence in the response.



The range of estimates found can be plotted into price returns by the computed historical ERP. The result shows that a 1% rise in the ERP from one period to the other corresponds to a 4.14% price reduction of the S&P 500[13]. Alternatively, a reduction in the ERP suggests a positive impact on annualised equity returns. This is consistent with the evidence from Fig.4, where a clear inverse relationship between these two variables is revealed.

The potential impact on equity prices is estimated, where the ERP reaches its minimum after 18 months. This occurs in order to allow the market to fully price in the shock, rather than just considering the instant impact and foregoing a potential slower feed-through of QE to equity markets. In the Table 5 the yearly equity price return contributions from each of the QE programmes is exhibited.

Table 5. Estimated impact of QE on yearly S&P 500 returns

	Response in S&P 500 price index
QE 1 ($300 bn)	1.9%
QE 2 ($600 bn)	3.7%
QE 3 ($755 bn)	4.0%
Cumulative rise	9.6%

[13] See Table OA4.4 in the online appendix

With the last programme being the most effective in raising equity prices, the evidence suggests only a minor difference in effect between the QE2 and QE3. Overall, the portfolio balance effect induced by QE seems to have successfully contributed to a boost in equity prices by 9.6% over the duration of the programme. The findings of this paper are in line with recent literature that finds a positive relationship between monetary policy expansion and stock market (Laopodis, 2013; Liu and Asako, 2013; Poshakwale and Chandorkar, 2016).

Furthermore, we explore the response of the ERP to monetary policy shocks before and after the introduction of QE. For this purpose, we divide the sample into two groups, with the pre-QE sample running from January 1984 to November 2008 and the post-QE sample from December 2008 until January 2017. Table 6 indicates the response of the ERPs of the Treasuries share, with and without QE. We can see that the ERPs respond negatively to the monetary policy shocks before and after QE. However, there is a sizeable difference between the responses of the ERPs to expansionary monetary policy shocks over the two periods. This is in line with the findings of Karras (2013) that the effectiveness of monetary policy shocks decreases with their magnitude.

Table 6. ERP implied from IRFs before and after QE

	Before QE	**After QE**			
	ERP	ERP	ERP QE1	ERP QE2	ERP QE3
1	-0.75%	-0.63%	-0.38%	-0.71%	-0.79%
2	-0.60%	-0.03%	-0.02%	-0.03%	-0.03%
3	-0.52%	-0.02%	-0.01%	-0.02%	-0.02%
4	-0.42%	-0.09%	-0.05%	-0.10%	-0.11%
6	-0.30%	-0.19%	-0.11%	-0.21%	-0.23%
8	-0.21%	-0.26%	-0.16%	-0.30%	-0.33%
10	-0.15%	-0.27%	-0.16%	-0.30%	-0.33%
12	-0.11%	-0.23%	-0.14%	-0.26%	-0.29%
Average	-0.33%	-0.22%	-0.13%	-0.25%	-0.27%

Finally, we further examine the impact on annual S&P 500 returns after QE in order to compare it without QE. Table 7 reports that individual and cumulative rises in the S&P 500 returns are about 13% after QE, which is significantly higher than returns without QE. One possible explanation for the size asymmetric response is that during QE, the Fed purchased high quality fixed income securities provided by central bank reserves hence effectively replacing relatively illiquid money with liquid cash reserves. This led to a fall in both short and long-term bond yields so leading to higher excess equity returns.

Table 7. Estimated impact of QE on yearly S&P 500 returns after QE

	Response in S&P 500 Price Index After QE
QE 1 ($300 bn)	2.60%
QE 2 ($600 bn)	4.94%
QE 3 ($755 bn)	5.46%
Cumulative Rise	13.0%

6.5 *Empirical evidence of regime Shifts*

We extend the analysis in this section by exploring the possible effects of the presence of structural breaks in the VAR system. This presents a natural extension of the literature, which assumes – either implicitly or explicitly – that the long run relationship is stable[14] (e.g. Joyce et al 2011, 2012). The aim here is twofold. We first test for the stability of the VAR model by using the QP test outlined in Section 5.4. The presence of structural breaks and monetary policy regimes is well documented in the literature such as de Medeiros et al. (2016), Duffy, and Engle-Warnick (2006). In the context of QE literature, recent literature in Hayashi and Koeda (2014), Belke et al. (2016), and Su and Hung (2017) highlight the importance of such extension. The evidence in the previous literature suggest that monetary policy and QE may exhibit regime shifts, and thus a stable VAR framework may be too restrictive. In other words, the analysis – so far – investigates financial market responses to the changes in monetary policy without making any distinguishing between the effects of QE regime and pre-QE regimes. Thus, the hypothesis we test in this section is whether the effect of monetary policy is stable over time given the different tools implemented by the US Fed (i.e. whether the impact of monetary policy on the financial market differ between conventional and unconventional policies). This hypothesis is of great empirical and policy importance since it informs us whether conventional and unconventional policy tools have the same effect[15]. Thus, a stable VAR implies stable effect over time where both conventional and unconventional monetary policy have the same effects on financial market indicators. The presence of structural breaks, on the other hand, implies that the effect is not the same. We therefore need to examine the IRFs for the identified regimes, which provides us with guidance on how the effect of unconventional – and thus QE – monetary policy may differ from that of conventional monetary policy.

[14] Stable in the sense that the relationship does not exhibit regime shifts.
[15] In the context of this paper, unconventional policy tools refer to QE.

Table 8 below reports the QP test results including structural breaks estimated dates and statistics. The value of the SupLR test reports an estimated value of 1139.13, which is greater than the 1% critical value. The WDmax and *SEQ* tests confirm that the number of breaks identified is the same as the maximum number allowed (e.g. 3 breaks allowed). The dates identified coincide with the end of QE on one occasion including the QE in 2008, which is estimated as the final break. While the first closely coincides with the 1992 recession in the US, the second break coincides with the Asian financial crisis in 1998. Thus, the break dates we estimated using the QP approach do not cover all the QE announcements, but capture key events.

Table 8. Structural breaks test results

Qu-Perron Procedure	
Tests	**Statistics**
Sup*LR*	1139.13*
WDmax	495.86*
Seq (2/1)	384.32*
Seq (3/2)	343.06*
Estimated Breaks	
Break Dates	**95% C.I.**
Jan 1992	(Jan 1991, Feb1992)
Jun 1998	(May 1998, Jul 1998)
Jun 2010	(May 2010, Jul 2010)

Notes: * denotes significance at 1%. Sup*LR* tests the null of no breaks versus the alternative of 3 breaks. WDmax tests the null of no breaks against the alternative of unknown number of changes up to 3 breaks. Seq (2/1) tests the null of 1 break against the alternative of 2 breaks. Seq (3/2) tests the null of 2 break against the alternative of 3 breaks. The shifts occur on conditional mean and variance-covariance matrix.

This is typical when using structural break tests that identify breaks endogenously using computational algorithms as argued by Crafts and Mills (2017). In the context of QP test, this could be due to the nature of the procedure and algorithm implemented to identify the breaks. First, the QP approach allows for common breaks in the system, which is its strength and at the same time a restricting feature. This latter imposes a common date of the occurrence of shifts in regimes on all the equations in the system, which does not necessarily reflect the true break date in each equation of the system. Second, as argued by Crafts and Mills (2017), the properties of this class of structural break tests in dynamic systems is yet to be fully established, which may explain failing to identify the exact date. Nonetheless, given the stationarity property of our data, the break dates may be useful as a guide to approximate the effect of regime shifts in the VAR model.

The break dates in Table 8 imply that we have four regimes, three of which cover the period during which conventional monetary policy was the policy tool. The final regime covers the period during which QE has been implemented. Accounting for these shifts in regimes, we can identify the IRs specific in each regime. Unlike the first exercise, where the VAR model is assumed to have a constant conditional mean and variance-covariance matrix (and consequently the responses are constant over the sample), when accounting for the shifts in the conditional mean and variance-covariance matrix of the VAR model we identify relatively different responses to fall in Treasuries share. Figs. 7, 8, 9 and 10 depict these responses for regimes 1, 2, 3 and 4 respectively.

Fig. 7. Expected excess returns and asset shares responses to fall in Treasuries share - regime 1 (1985m03-1992m01)

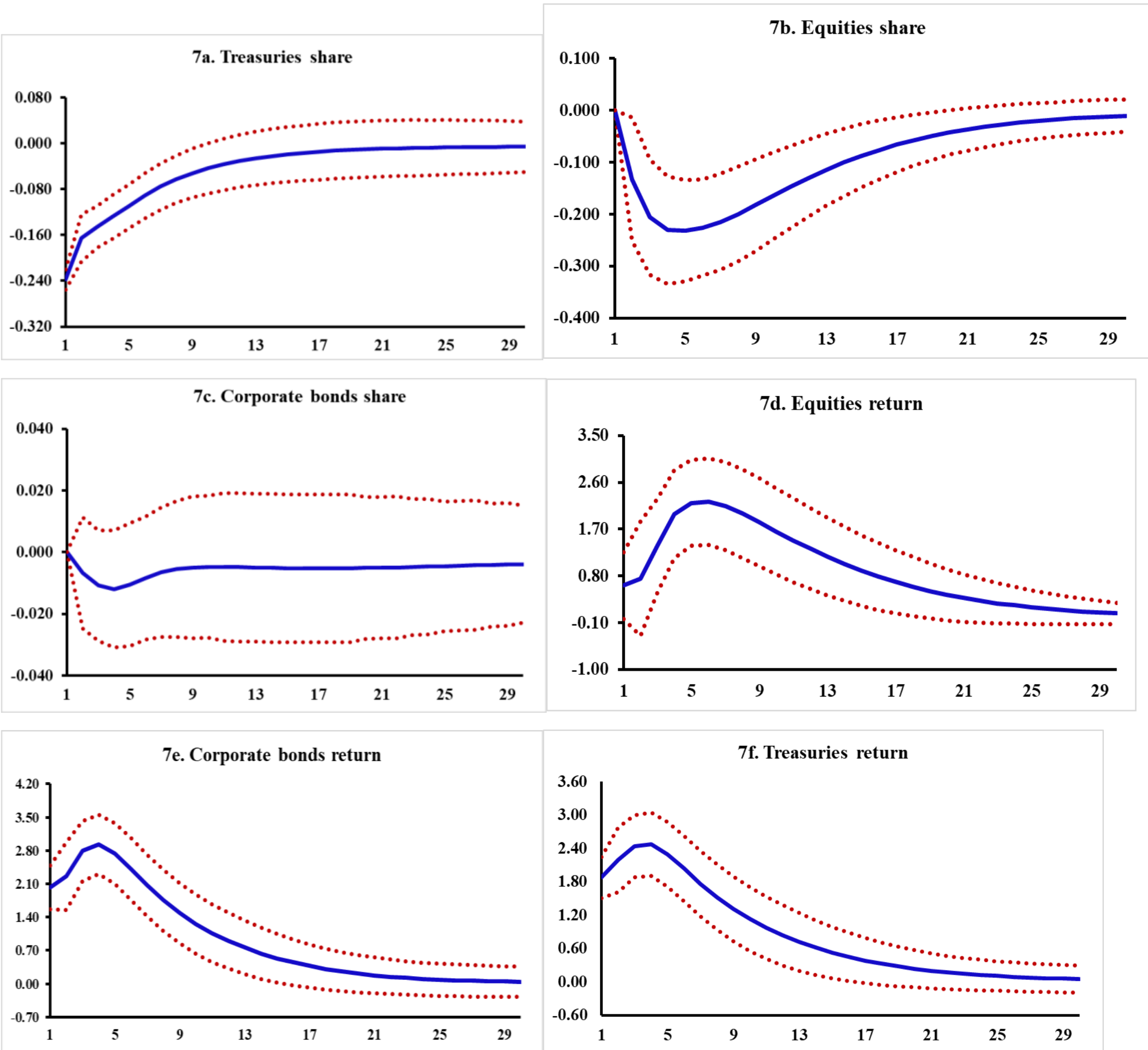


Fig. 8. Expected excess returns and asset shares responses to fall in Treasuries share - regime 2 (1902m02-1998m06)

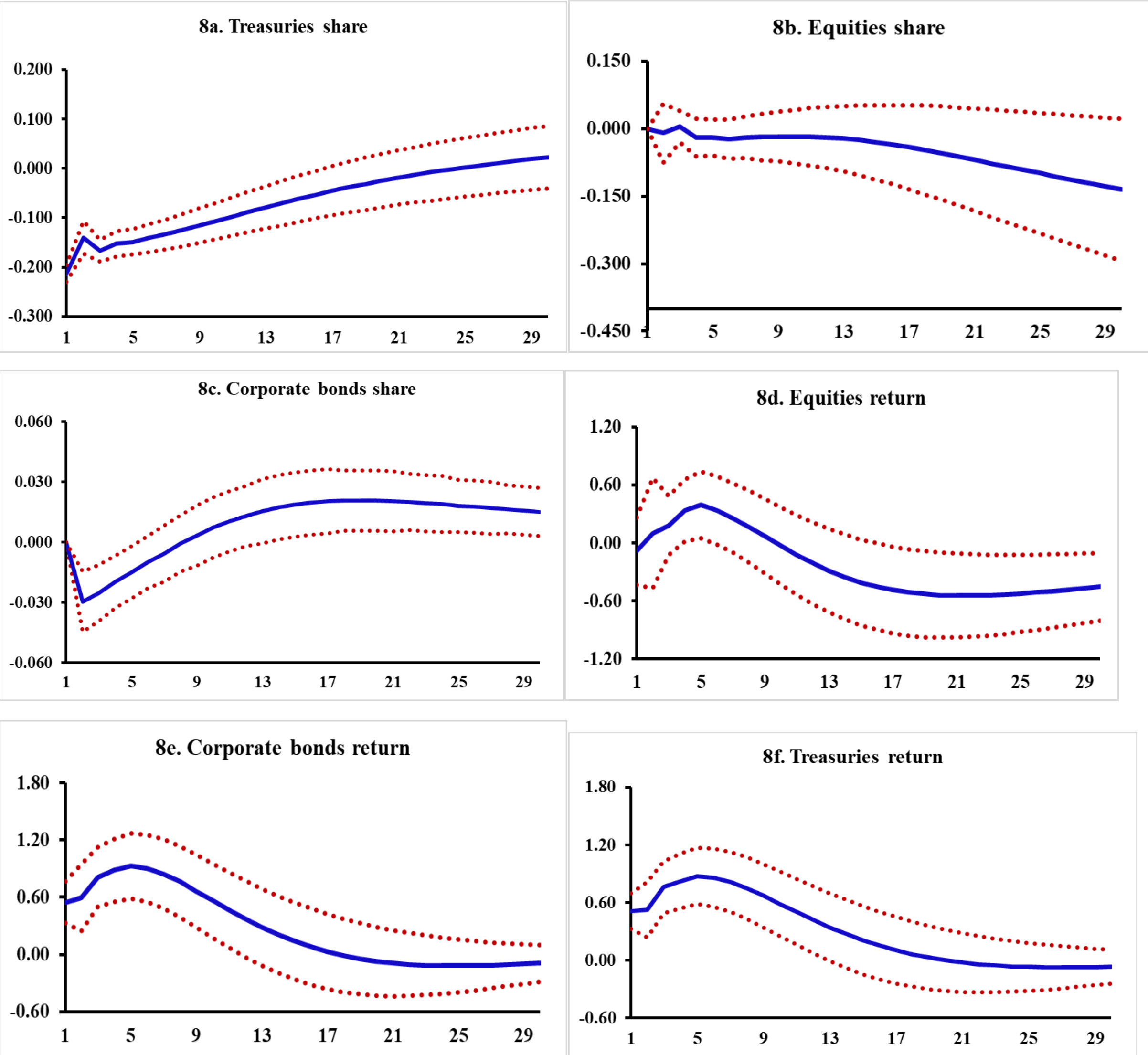
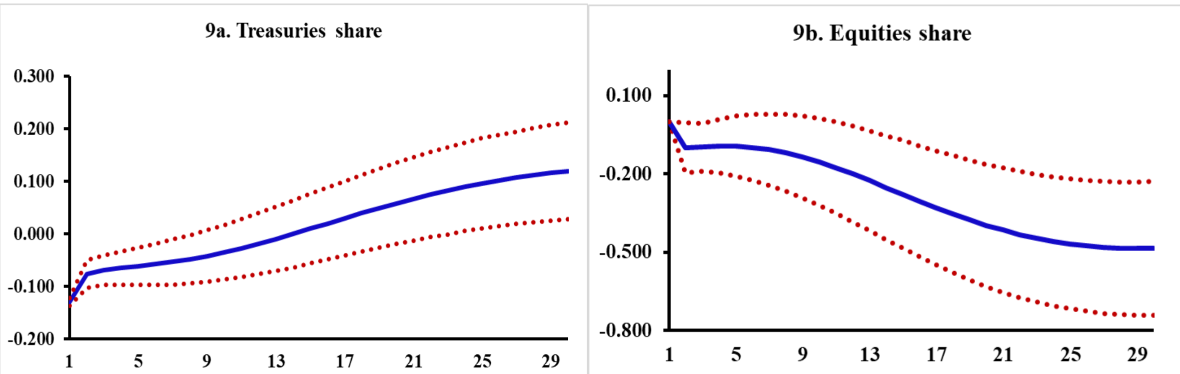


Fig. 9. Expected excess returns and asset shares responses to fall in Treasuries share -regime 3 (1998m07-2010m06)



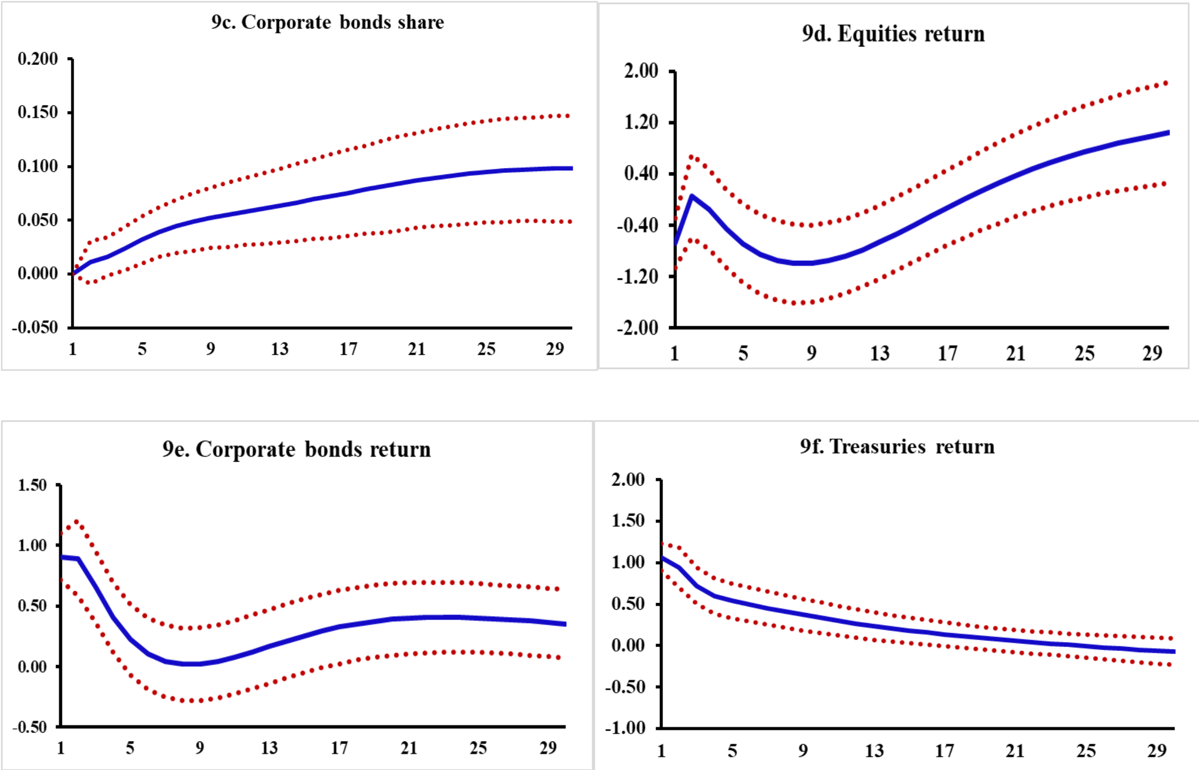
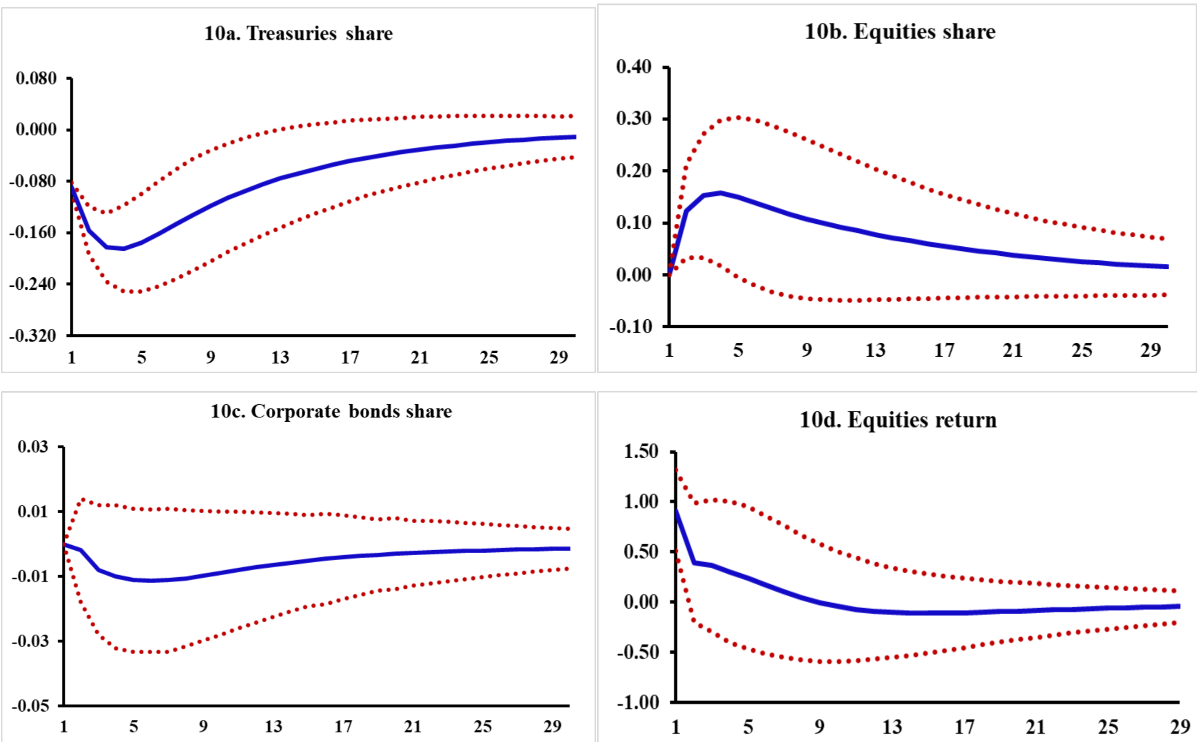
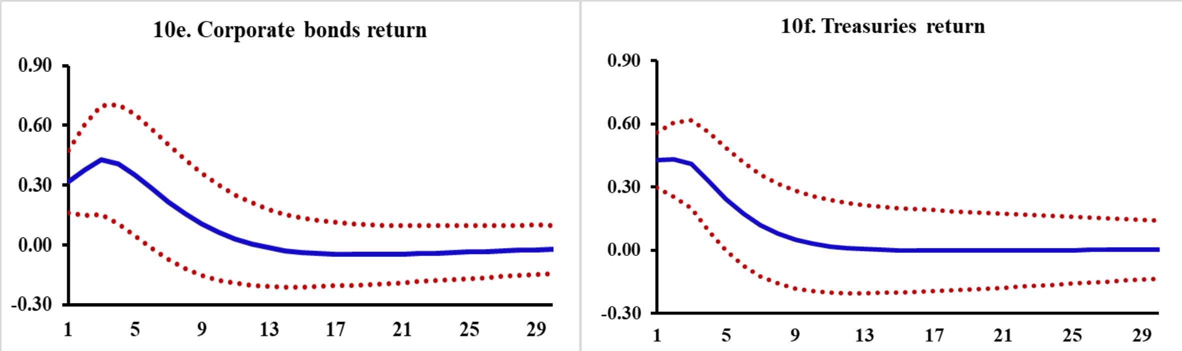


Fig. 10. Expected excess returns and asset shares responses to fall in Treasuries share -regime 4 (2010m07-2017m01)





The regimes identified using QP test do not assess the effectiveness of QE. Regime shifts can only capture potential changes in the statistical structure of the model. In the context of this paper, both conditional mean and variance-covariance matrix are allowed to shift. The break dates, as discussed earlier, coincide with major economic events that all have a direct link to monetary policy. For example, the first two breaks coincide with the 1992 recession and 1998 Asia crisis. The former was a domestic, while the latter had an international scope. In both occasions, the Fed played crucial role via conventional monetary policy to reduce the effect of these crises (Pettis, 2001; Teeter and Sandberg, 2017). The third break, in 2010, coincides with the period during which the Fed was preparing to launch the second QE. The subsequent periods cover all three QE programmes, which may plausibly be interpreted as a QE regime (or more generally, 'unconventional monetary policy regime'). In summary, we do not argue that the estimated breaks are caused by shifts in monetary policy; we rather offer an interpretation of what might these shifts represent. Coincidently, the regimes occurred approximately in the period during which the Fed adopted two versions of monetary policy, conventional and unconventional. Thus, it is plausible to assume that Regimes 1 to 3 represent conventional monetary policy responses, while Regime 4 represents the unconventional monetary policy response.

In order to assess the effectiveness of the QE programme, we observe the dynamic behaviour of returns via IRFs under the identified regimes. In this context, the effectiveness of the policy is assessed by the degree of persistence and magnitude of the shock, the properties which the IRFs can depict graphically. According to the IRFs, accounting for regime shifts provide slightly different responses to a shock in Treasuries share. Regime 1, as in Fig. 7, display similar shape to those estimated using the full sample, generally. The IRFs estimated for regime 1, however, illustrate lower persistence and adjustment for Treasuries share and Equities share, the dynamics that has not captured by the full sample IRFs. The behaviour of corporate bonds share is flat below zero with wider confidence intervals. Unlike the full sample, the responses of returns in Fig. 7d-f show the effect of Treasuries share shock larger in magnitude and relatively persistent. The main feature the IRFs of regime 2 (Fig. 8a-f) is the response of corporate bonds share, which seems to have lower persistence and dynamics converging to zero with narrower confidence interval. Regime 2 illustrates responses of smaller magnitude to Treasuries share shock, with higher persistence, however. The responses of share series in Regime 3 (Fig. 9a-f) behave in similar fashion to those estimated using the full sample. In addition to the divergent dynamic behaviour, they display a relatively higher persistence. Treasuries share shock; however, has a different impact on all returns series. According to the estimated IRFs, the equities and corporate bond returns are divergent and highly persistent. Treasuries returns, on the other hand, are convergent to zero with low persistence and smooth response to Treasures share shock. Regime 4, on the other hand, show a convergent behaviour of all assets following Treasuries share shock. The magnitude of the responses to the shock is relatively smaller and the dynamic adjustment is relatively faster. Moreover, Treasuries share and equities responses to the shock is different from those reported in other regimes and full sample. In short, Regime 4 shows relatively smaller effect of the shock and less persistence[16].

7 Conclusion

We set out to test the effects of unconventional monetary policy programmes on the equity market, particularly the equity risk premium. Although we use Joyce et al (2011, 2012) as a basis, we make considerable extensions to apply similar logic to the US equity, corporate bond and Treasury markets. We find evidence that QE has a direct effect on corporate bonds, equities and US Treasuries, through the portfolio balance channel. We provide support to the normative belief that the US QE programme had a substantial positive influence on equity prices. The mechanism is through a QE shock inducing a negative response to the ERP that increases the price leading to higher S&P 500 returns. Furthermore, equity returns tend to show persistence only returning to equilibrium slowly, and more gradually than US Treasuries. This demonstrates that the portfolio balance channel has some asymmetry across the different asset classes. This effect is repeated across all three of the QE programme instances and is dependent on the position that the Fed takes in the market.

[16] We also allowed for the possibility of time varying variances in the VAR model. An M-GARCH(1,1) is estimated for both the full sample and regime shifts cases. According to the estimated models, we found that (i) , the range of volatility when accounting for regime shifts is generally smaller than that estimated for the full sample and (ii) QE regime's volatility estimates are within smaller range for all variables in the system. For further details, please refer to the online appendix OA.5.

On aspect is that QE effectively increased equity prices by 9.6% on average, driven by lowering of the ERP. We can conclude that the portfolio balance channel has a direct impact on equities' rate of return in excess of that on Treasuries bond yields. The price adjustment exclusively stems from a readjustment of the equity yield through the risk premium. Moreover, our empirical findings indicate that before and after the implementation of QE, the monetary policy shocks have a negative effect on the aggregate market's ERPs implying that QE leads to a negative impact on ERP that causes higher returns on the S&P 500. We show, empirically, the asymmetric response of the equity market size to the Fed's policy with and without QE.

In contrast to most of the literature's presumption that the conditional mean of the VAR model is constant over the sample, we find evidence that there is an unstable relationship between government bonds, investment-grade corporate bonds and equities. We identify three structural breaks that coincide with key economic events. One of the structural breaks occur after implementing the first QE programme, which may capture the response of the market to the Fed's unconventional monetary policy. According to the IRFs during this regime, the shocks in response to QE has become smaller in magnitude and less persistent.

The first policy consideration is that if the dynamics of the market is found to be unstable then the outcomes may not conform to the expected regime drawn from the 2008-12 QE programme. We find that, in the long run, the relationship between the asset classes has many other influencing factors outside of any QE programme. It may be fortuitous that the speed at which the QE programme was put together did not have disastrous unintended consequences within the timeframe[17]. The next policy consideration is that during the period of investigation there are at least four policy regimes that are only broken by economic events and policy shifts. The first is separated from the second by the fallout from the equity market breakdown. Regime 2 is in the period where there was central bank independence and the development of 'conventional monetary policy'. Both regimes 1 and 2 experienced a continuing relaxation of financial regulation. Regime 3 covers the period from the DotCom bubble to the initiation of the financial crisis, the period of the *great moderation*. The 4th regime is the QE era where unconventional monetary policy, near lower bound interest rates and financial fragility dominated much of the policy debate. Unlike the UK where austerity took hold in 2010, the US continued a moderate expansionary fiscal policy as well. The IRs to all these periods show a

[17] The authors note an unintended consequence may be that QE effect of increasing in equity asset prices and stimulating buoyant equity markets appears to contribute to the increasing concentration of wealth. This is a matter for further investigation.

number of significant differences in the way that equity markets respond to monetary policies. A policy maker needs to be cognisant of the potentially unforeseen implications of prior policies and events on any similar QE activity.

Lastly, a policy consideration relates to the effectiveness of QE. We find that the pre-2007 crises (1992, 1998) had experienced relatively persistent shocks with long lasting effects though the portfolio balance channel. This is particularly evident for regimes 2 and 3, in which the US faced the early 1990s recession and the Asian financial crisis. This contrasts with the last regime in our study, the period of QE, where relatively quick recoveries occur considering the relative depth of this financial crisis to the prior events. Moreover, although all estimated regimes display smaller volatility to those estimated in the data full sample, QE regime has particularly smaller range of volatility. This may indicate the effectiveness of QE in reducing the uncertainty in the market as opposed to traditional monetary policy intervention and is consistent with Shogbuyi and Steeley (2017).

We conclude that, under a regime similar to that leading up to the financial crisis that a programme framed in a similar way to that of QE could improve financial market liquidity and confidence. The conduct of QE, with other unconventional monetary policies, post the US financial crisis largely conformed to what the policy makers anticipated and intended. In a world with highly interconnected capital markets, QE is likely to have contributed to a portfolio reallocation and re-pricing of financial securities on a global level (Fratzscher et al., 2012). Although the full effects of QE and its exact consequences on equity returns may not have been fully captured by this paper, it clearly demonstrates that policy makers could exploit the asymmetric nature of the portfolio balance channel to manipulate the required rate of return on a range of assets with different risk profiles.

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