



Radboud Universiteit

Master Thesis

The Relation Between Quantitative Easing and Bubbles in Stock Markets

Author: T.S.M. (Tom) Hudepohl
Student number: 4127072
Supervisor: Dr. O. Dijk
Second reader: Dr. J. Qiu
Field of study: Master Economics, track Financial Economics
Faculty: Nijmegen School of Management
Academic Year: 2015-2016
Final version: 29-07-2016

Abstract

This thesis examines the relation between quantitative easing (QE) and bubbles in stock markets. Among economists, concerns exist whether QE leads to bubbles in asset markets. Due to low interest rates, investors start looking for higher returns. In this quest for even higher returns, risk premiums reduce and asset prices increase, with the risk of bubbles. Until now, no specific research has been conducted that considers the effect(s) of QE on stock market bubbles. This thesis aims to fill this knowledge gap in the literature. In existing literature, a distinction is made between speculative bubbles and intrinsic bubbles. The presence of both types of bubbles caused by QE is investigated in the four major markets where central banks applied QE, namely the United States, the Eurozone, the United Kingdom and Japan. Based on these tests, in general there is no major indication that QE leads to bubbles in stock markets. There is only a small indication in the Eurozone during the period 2010-2016.

Table of Contents

| | |
|---|----|
| 1. Introduction..... | 4 |
| 2. Theoretical Framework | 8 |
| 2.1 From Conventional Monetary Policy to Quantitative Easing | 8 |
| 2.2 The relation between monetary policy and stock prices | 12 |
| 2.3 The effects of Unconventional Monetary Policy and Quantitative Easing | 14 |
| 2.4 Periods of applying QE | 15 |
| 2.5 Bubbles..... | 17 |
| 2.6 Rational/Speculative bubbles versus Intrinsic bubbles..... | 19 |
| 2.7 Existing evidence of the relation between monetary policy and bubbles..... | 24 |
| 3. Methodology | 26 |
| 3.1 Testing for the presence of an intrinsic bubble | 26 |
| 3.2 Testing for the presence of a rational bubble..... | 32 |
| 3.3 Obtained data..... | 37 |
| 4. Results | 44 |
| 4.1 Intrinsic bubbles | 44 |
| 4.2 Rational bubbles..... | 56 |
| 4.3 Overall result | 59 |
| 5. Discussion and conclusion..... | 60 |
| Discussion..... | 60 |
| Conclusion | 61 |
| References..... | 63 |
| Appendices | 70 |

1. Introduction

“The European Central Bank’s stimulus to revive the euro-area economy might lead to the creation of new bubbles”; “This facilitates the creation of bubbles on the financial markets”; “Looking at prices from an historical perspective, they already point toward a bubble” (Ruhe, 2014).

These quotes illustrate the concern of Klaas Knot, president of the Dutch Central Bank (De Nederlandsche Bank, DNB), that quantitative easing (QE) might lead to bubbles in financial markets. This thesis aims to provide an insight in the effects of QE on bubbles in stock markets. Almost every day, financial newspapers contain some news or opinions regarding the European Central Bank’s (ECB) current policy: quantitative easing. For example, Klaas Knot (because of his concern in the quotes above), as well as the head of the German Central Bank (Bundesbank), Jens Weidmann, do not support the bond purchases of the ECB.

Weidmann remarks that the ECB should closely scrutinize the *“increasing desire for risks on asset markets”* (Buell, 2015). He warned that property in Germany might be overvalued by 20%. According to him this is a sign that the ECB’s ease monetary policy, quantitative easing, might fuel a housing bubble in parts of Germany (Buell, 2015). In addition to Weidmann and Knot, Nouriel Roubini (professor of economics at the University of New York) points out that a *“wall of liquidity”* in the end could lead to a bubble (Miller, Kennedy, & Jamrisko, 2013). Also Lex Hoogduin (professor of economics at Rijksuniversiteit Groningen) mentions that the policy of the ECB results in financial bubbles; it keeps companies running that are actually not profitable anymore; it biases the power of the government budget and it stimulates unproductive activities (Ten Bosch & De Boer, 2016).

In contrast, Mario Draghi (chairman of the ECB) mentions that policymakers do not see evidence of possible financial bubbles in the Eurozone. He also mentions that there are no financial imbalances in the Eurozone, such as a build-up of leverage among banks which can lead to potentially risky situations (FT, 2015). Furthermore, Han de Jong, chief economist of ABN AMRO (one of the largest Dutch banks), notes that despite the warnings of bubbles in financial markets, he does not notice them. According to him, the ECB should do even more to stimulate the economy (Ten Bosch & De Boer, 2016).

The DNB however disagrees with Draghi and maintains that alertness is needed due to potential asset bubbles. In its overview of financial stability (2014), the DNB argues that low interest rates cause investors to seek higher returns. This quest for higher returns is accompanied by investors willing to tolerate more risks, as a higher return is in most cases only achieved by taking on more risks. As an effect, risk premiums reduce and asset prices increase, resulting in the risk of asset price bubbles (De Nederlandsche Bank, 2014). Due to quantitative easing, the already low interest rate gets even lower and therefore makes the risk of a bubble even bigger.

The words QE (quantitative easing) and bubbles have already been mentioned. They are not however entirely self-evident. Therefore, a clear definition is needed. An extensive definition will be provided in the theoretical framework, but two short definitions will already be provided here. QE is *“increasing the size of the central bank’s balance sheet beyond the level needed to set the short-term policy rate at zero”* (Bernanke, Reinhart, & Sack, 2004, p. 7). This kind of monetary policy was needed to achieve price stability, as the Taylor Rule could not be followed any longer with effective nominal interest rates of zero. This rule will be further explained and elaborated on in chapter 2.

The most straightforward definition of a bubble, that is relevant for this thesis, is provided by Scherbina and Schlusche (2014, p.589): *“[...] a bubble is a deviation of the market price from the asset’s fundamental value”* (and a persistent overvaluation is more likely than a persistent undervaluation, which will be explained later). The risk of a bursting bubble is clear from this definition, as a bursting bubble could lead to declining prices, when they return to their fundamental value. This problem is also described by De Nederlandsche Bank (2014), as a potential bubble could be the consequence of excessively risky investment behaviour (from an objective point of view) (De Nederlandsche Bank, 2014, p. 9). Formation of an asset price bubble could lead to sharp corrections when the bubble bursts. A potential consequence of a bursting bubble is that (Dutch) financial institutions are negatively impacted (De Nederlandsche Bank, 2014)¹.

Despite the confidently expressed opinions described above, not that much is actually known about the relation between QE and bubbles. It can be therefore questioned to which extent the concerns of Weidmann, Knot and Hoogduin, could be justified. Galí and Gambetti (2015, p. 243) point out that *“As far as we know, the literature contains no attempts to uncover the effects of monetary policy shocks on the bubble component of stock prices”*. There unfortunately does not appear to be much interest in uncovering the effects of monetary policy shocks on the bubble component of stock prices. The author of this thesis does think that it is important to obtain more knowledge of these effects and this thesis therefore aims to provide a better insight in the relation between quantitative easing and bubbles in financial markets, especially with regard to the stock market.

Galí and Gambetti (2015) consider the effect of monetary policy in general, whereas this thesis will consider especially the effects of QE. A lot of research has been conducted that considers the effects

¹ The negative impact can be due to higher funding costs of banks and losses on investments. Pension funds and insures invested in vulnerable asset categories, namely U.S. equities, bonds of financial institutions, other corporate bonds and peripheral government debt. These categories are *“potentially subject to large reversals”* (De Nederlandsche Bank, 2014, pp. 18-19). There is also an indirect effect, as counterparties could be affected by a sharp correction as well.

of QE and the effects of monetary policy on stock markets in general, which will be elaborated in the theoretical framework of this thesis. However, no research has been conducted that links QE to bubbles in stock markets. As this thesis clearly fills a gap in the existing literature, the relevance and scientific contribution of this thesis are clear. The motivation above leads to the central question: *Does quantitative easing have an effect on bubbles in stock markets?*

Literature points out that with regard to the stock market, two kinds of bubbles exist, namely intrinsic bubbles and speculative (rational) bubbles. The terms speculative and rational are used interchangeably in this thesis, as this is also done in other literature. In short, intrinsic bubbles depend on fundamentals (as expressed in dividends), whereas speculative bubbles are driven by expectations that have nothing to do with fundamentals. The differences between intrinsic bubbles and speculative bubbles will be elaborated in chapter 2.

In order to test for the presence of intrinsic bubbles, a test of Froot and Obstfeld (1991) is applied. In this test the relation between the real price/dividend ratio and a nonlinear function of real dividends is analysed. A test of Diba and Grossman (1988) is applied in order to test for speculative bubbles, which concerns stationarity characteristics of stock prices and their respective dividends. A disadvantage of this method is that it is only able to confirm the absence of a bubble, but it cannot confirm the presence.

Tests for both kinds of bubbles are conducted for the United States, the Economic and Monetary Union (EMU) (in the remainder of this thesis this region will be called 'Eurozone'), the United Kingdom, and Japan, as these are the four known regions where QE has been applied (Fawley & Neely, 2013). As mentioned, there are also concerns (mainly by Weidmann) that QE could possibly lead to a real estate bubble. However, this type of bubble is not considered in this thesis, as only stock market bubbles will be analysed.

The analysis of this thesis provides an indication that so far, the concerns of Knot and Weidmann are not based on characteristics of the available data. Based on the intrinsic bubble analysis as well as the speculative bubble analysis, in general it already seems that after the start of QE in the considered regions, there is no intrinsic nor a speculative bubble visible in the data. When specific data that concern QE are taken into account, in most cases there is either a significant negative relationship between the dependent variable and data that regard QE, or no significant relationship at all. In case there is a significant positive relation, the respective coefficients are relatively small. For the Eurozone, there is a small indication that QE could lead to a positive intrinsic bubble. However, until now there is no speculative bubble. Further research is needed in order to substantiate these claims.

In the remainder of this thesis, chapter two will cover the theoretical framework. In this chapter, for example the terms 'quantitative easing' and 'bubble' will be elaborated. Chapter three contains the methodology of this thesis. This chapter begins with how to measure bubbles in general, leading to how the presence (or absence) of bubbles should be measured on financial markets after the start of quantitative easing. Chapter four contains the results of the analysis and chapter five concludes this thesis with a discussion and a conclusion.

2. Theoretical Framework

2.1 From Conventional Monetary Policy to Quantitative Easing

As the term ‘quantitative easing’ and ‘bubble’ have already been mentioned several times in the introduction and are even used in the research question, it is clearly necessary to describe what ‘quantitative easing’ as well as ‘bubble’ actually entails, especially because the terms are not self-evident. From this section onwards, ‘quantitative easing’ and some of its effects will be elaborated, whereas ‘bubble’ will be elaborated from section 2.5 onwards. First of all, the difference between conventional monetary policy and QE will be discussed.

In the conventional situation of monetary policy, the central bank affects spending through the interest rate. Therefore, John Taylor (1993) argues that a central bank should directly think in terms of interest rates instead of money growth. He suggested a rule, that a central bank should follow, namely,

$$i_t = i^* + a(\pi_t - \pi^*) - b(u_t - u_n)$$

where:

π_t is the rate of inflation; π^* is the target rate of inflation; i_t is the nominal interest rate; i^* is the target nominal interest rate (the nominal interest rate associated with the target rate of inflation, π^* , in the medium run; u_t is the unemployment rate; u_n is the natural unemployment rate; a and b reflect the importance of unemployment versus inflation (Blanchard, 2009, p. 568).

As a consequence, in case the inflation rate is lower than the target rate or if unemployment is higher than the natural rate of unemployment, the central bank should decrease the nominal interest rate (Blanchard, 2009, p. 568). The (very) short term nominal interest rate is the conventional instrument of monetary policy (Blinder, 2010).

However, due to the persistent high unemployment following the financial crisis in many countries, applying this so-called Taylor rule would suggest that central banks should actually set *negative* nominal interest rates. However, it is basically impossible to set negative nominal rates, as they imply that you would actually lose money when you store your cash at a (central) bank. Since people always could hold cash, which bears no positive interest but also no negative interest, market interest rates have an effective Zero Lower Bound (ZLB) (Bernanke et al., 2004). Whenever the nominal interest rate hits zero, the real interest rate is by definition higher than the rate that is needed to ensure stable prices and make sure resources are fully utilized. This is the consequence of a nominal interest rate of zero, since it could be deduced from the Taylor rule that the real interest rate now is equal to the negative of expected inflation (Bernanke et al., 2004; Joyce, Miles, Scott, & Vayanos, 2012). The situation in which this zero lower bound is hit, is known as a “*liquidity trap*” (Krugman, 1998): once the nominal interest rate is zero, conventional monetary policy is out

of options as you cannot lower interest rates any further (Blinder, 2010). As this happens, the relationship between changes in official interest rates and market interest rates breaks down. Conventional monetary policy becomes ineffective, as the nominal interest rate cannot be lowered any further. This means that the official interest rate cannot be changed in the way the Taylor rule would suggest. As a consequence, market rates do not change in the expected way. Central banks turned to unconventional monetary policies, in an attempt to alleviate financial distress or to stimulate their economy. Unconventional monetary policies often consist of (dramatically) increasing monetary bases (Fawley & Neely, 2013).

A potential problem of the ZLB is described by Bernanke et al. (2004, p. 1): the high real interest rate could lead to a downward pressure on costs and prices. As a consequence, the real short term interest rate rises further and therefore, economic activity and prices are depressed further. Since we are currently in an environment of low inflation rates (see e.g. the European Central Bank, n.d.c.), this is clearly a problem. Bernanke et al. (2004) emphasize that with low inflation rates, the problems as a result of the ZLB will be encountered periodically. This raises the question what monetary policy alternatives are available if the short term nominal interest rate cannot be lowered any further.

Bernanke et al. (2004) offer three possible alternatives. One alternative involves shaping expectations of the public about the future policy rate. A second alternative consists of a shift in the composition of the central bank's balance sheet. In this way it becomes possible to affect the relative supplies of securities that are held by the public. The third alternative is *"increasing the size of the central bank's balance sheet beyond the level needed to set the short-term policy rate at zero (quantitative easing)"* (Bernanke et al., 2004, p. 7)². 'Quantitative' points to the shift in policy to targeting quantity variables (at the balance sheet), in contrast to targeting interest rates (Joyce et al., 2012). 'Easing' points toward the expansion of broad money³ (Benford, Berry, Nikolov, Young, & Robson, 2009). The third alternative will be considered further now, as this is the subject of study in this thesis. Additionally, the second alternative will be elaborated on later, as this forms together with the third alternative 'unconventional monetary policy' (Borio & Disyatat, 2010). Since differences among central banks in the implementation of QE are significant (Joyce et al., 2012), this should be considered as well, as QE is *"the most high-profile form of unconventional monetary policy"* (Joyce et al., 2012, p. F274).

² It seems that the term 'quantitative easing' is mentioned for the first time in an announcement by the Bank of Japan in March 2001, as it would set its target of bank reserves above a level that is needed to bring the policy rate to zero (Bernanke et al., 2004)

³ Benford et al. (2009, p. 91) define broad money (in the UK) as 'M4', which consists of "the UK non-bank private sector's holdings of notes and coin, sterling deposits and other sterling short-term instruments by banks and building societies, but excludes reserve balances held by banks at the Bank of England". In a similar way this definition is applicable to the other regions.

Fawley and Neely (2013, p. 54), explain the possible effect of unconventional monetary policy by making use of the following equation:

$$y_{t,t+n} = \bar{y}_{t,t+n} + TP_{t,n} - E_t\pi_n$$

“where $y_{t,t+n}$ is the expected real yield at time t on an n -year bond, $\bar{y}_{t,t+n}$ is the average expected overnight rate over the next n years at time t , $TP_{t,n}$ is the term premium on an n -year bond at time t , and $E_t\pi_n$ is the expected average rate of inflation over the next n years at time t ” (Fawley & Neely, 2013, p. 54). This equation above means that the long-term yield can decline by means of an increase in expected inflation; a fall in the expected overnight rate or a lower term premium (Fawley & Neely, 2013).

Even though due to the ZLB the short term interest rate cannot become lower, QE can be used in order to reduce other interest rate spreads, such as term premiums and risk premiums. As mentioned in the introduction, the DNB is afraid of the consequences of lowering these spreads. If lower interest rate spreads are achieved, monetary policy still can help in preventing a deflationary implosion (Blinder, 2010). In more detail, Blinder (2010) describes this as buying longer-term government securities instead of the short-term bills that central banks normally buy, which could help in shrinking term premiums. Lower term premiums help in achieving a lower real yield, as can be seen in the equation of Fawley and Neely (2013, p. 54) that was described above. Furthermore, risk or liquidity spreads could be reduced. This could help in stimulating the economy, as private borrowing, lending and spending decisions mainly depend on non-treasury rates. Consequently, a lower spread over Treasuries, reduces the interest rates that are relevant when transactions are conducted in the private sphere, even if the riskless rates are not changed (Blinder, 2010). This could help in overcoming the problem of the ZLB as described by Bernanke et al. (2004).

Price stability as goal of monetary policy

Unconventional monetary policy and QE would not have been used if these policies did not serve a goal, which will therefore be described in this section. The main purpose of monetary policy, is defined by Meier (2009, p. 5): “The key purpose of monetary policy is to preserve price stability”. These objectives will be elaborated a bit further now, for the four central banks that are subject of this study.

Preserving price stability is the main objective of the Eurosystem, as laid down in the Treaty on the Functioning of the European Union, Article 127(1). Some other relevant objectives are aiming at full employment and balanced growth. However, maintaining price stability is the most important objective (European Central Bank, n.d.d.). In an attempt to achieve price stability, the ECB announced that it would start with an ‘expanded asset purchase programme’, which consists of purchases of bonds issued by central governments in the euro area, agencies and European

institutions, to an amount of €60 billion monthly (European Central Bank, 2015). This programme is known as 'Quantitative Easing'.

One important pillar of the QE-programme of the Bank of Japan (BoJ) was to maintain the programme until the core consumer price index (CPI) stopped falling on a year-to-year basis (Kole & Martin, 2008). It can be concluded that the ECB uses QE for the same reason as the BoJ did. In the Bank of Japan Act it is stated that *"currency and monetary control by the Bank of Japan shall be aimed at achieving price stability, thereby contributing to the sound development of the national economy"*⁴. The benefits of price stability are also confirmed by the ECB: it helps in achieving high levels of economic activity and employment (European Central Bank, n.d.a.).

In addition to the ECB and the BoJ, the Bank of England (BoE) also aims to achieve price stability, since its objective is to keep CPI-inflation close to 2-percent (Meier, 2009). According to the Monetary Policy Committee of the BoE, the increased money supply (due to QE) could lead to an increase in spending, as inflation expectations are raised.

The Federal Reserve has price stability as its central objective and aims at low inflation (Meier, 2009). However, the Fed not only aims at price stability, as "The Full Employment and Balanced Growth Act" (Blanchard, 2009, p. 569) of 1978 established a dual mandate for the Federal Reserve, as the Fed should aim for maximum employment in combination with price stability. However, while price stability is often stated as one of the primary goals by the Fed, this is not the case for the maximum employment objective. The Fed prefers to state that achieving maximum employment could result by achieving price stability (Thornton, 2012). The non-standard measures taken by the Fed, can be divided into three groups. The last one of these, the large-scale asset purchase programme (LSAP), aimed at lowering interest rates to support investments and at stimulating asset prices to stimulate demand (Fratzscher, Lo Duca, & Straub, 2013, pp. 8-9), and thus this programme also aimed at increasing inflation (as it aimed to increase prices)⁵.

Based on the abovementioned, it is clear that all major central banks took measures in order to increase inflationary trends, by making use of forms of unconventional monetary policy. Unconventional monetary policy is not used in order to decrease inflationary trends. In contrast, conventional monetary policy can be used to decrease inflationary trends, simply by raising the nominal interest rate.

According to Bernanke and Kuttner (2005), objectives of monetary policy normally aim at macroeconomic variables (e.g. output, employment, inflation). However, the link between monetary policy and these macroeconomic variables is in fact not direct. At best the link is indirect.

⁴ The Bank of Japan Act, Act No. 89 of June 18, 1997, article 2

⁵ The other two (lending to financial institutions and providing liquidity to key credit markets) aimed at avoiding fire-sales of assets (Fratzscher et al., 2013, p. 8)

Direct effects of changes in monetary policy, go via the financial markets. As monetary policy could influence asset prices and returns, policymakers aim at influencing behaviour via financial markets in a way that macroeconomic objectives are achieved. Therefore, the link between monetary policy and asset prices is crucial in order to understand how the objectives of monetary policy are transmitted. Bernanke and Kuttner (2005, p. 1221) consider this link via the equity market, as they see this market as one of the most important financial markets. Therefore, the relation between monetary policy and stock prices will be considered next.

2.2 The relation between monetary policy and stock prices

QE is a special form of expansionary monetary policy, as it is monetary policy that is conducted in case the zero-lower-bound is hit (Bernanke et al., 2004) (although it can also be used in other cases). Therefore, some effects of expansionary monetary policy (especially concerning stock prices) in general will be considered first, before the effects of QE will be discussed.

In general, research points out that expansionary monetary policy is related to higher stock returns, whereas contractionary monetary policy is related to lower stock returns. This effect is already found by Thorbecke (1997). He mentions that according to theory (see for example DePamphilis (2015)), stock prices should equal the expected present value of future net cash flows. If a monetary shock has an effect on stock returns, this indicates that monetary policy either increases or decreases future cash flows or it increases or decreases the discount rates at which these future cash flows are discounted (this approach is also important later on, when bubbles will be defined). By using several ways of measuring monetary shocks and the responses of stock returns to them (such as innovations in the federal funds rate and an event study of Federal Reserve policy changes), Thorbecke (1997) shows large effects on *ex ante* and *ex post* stock returns as a result of monetary policy. The results of Thorbecke (1997) indicate that expansionary monetary policy causes stock returns to increase and are consistent with the hypothesis that in the short run, monetary policy has real and quantitatively important effects on real variables. A comparable result is found by Bernanke and Kuttner (2005), as a hypothetical surprise 25-basis-point lowering of the Federal funds rate target, leads to an approximate gain in a broad stock index of 1% in one day. However, without the surprise element, there is no reaction of the market, which is in line with the efficient market hypothesis by Fama (1970). In contrast, Patelis (1997) states that contractionary monetary policy leads to higher short-term returns in the future, whereas in the short-run it results in lower expected stock returns. In order to find this effect, he uses long-horizon regressions combined with short-horizon Vector AutoRegressions (VAR). In addition, by making use of variance

decompositions, Patelis (1997) shows that shocks in monetary policy mainly have an influence on expected excess returns and expected dividend growth, but not on expected real interest rates.

Ehrmann and Fratzscher (2004) contribute to this research, by concluding that there is not one general result of monetary policy, as the effects of monetary policy on stock market returns differ for example by industry and also depend on whether a firm is financially constrained or not. The difference per industry is for example due to the fact that interest-sensitivity of demand differs among industries; financially constrained firms are more affected by changes in interest rates.

Rigobon and Sack (2003, 2004) question whether the implied relation between monetary policy and equity returns is as clear as it seems based on the research above. They show that the causal relation between equity prices and interest rates works in both directions and thus monetary policy does not only have an effect on stock returns, but stock returns also have an influence on monetary policy. The results of Rigobon and Sack (2003, 2004) suggest a significant influence of stock prices on short-term interest rates, which are positively related. They do so on the basis of a new estimator, that is based on the heteroskedasticity that exists in high-frequency data. For this methodology, weaker assumptions are needed compared to the typical 'event-study' approach.

An alternative model to test the relation between monetary policy and stock returns, is used by Jensen, Mercer and Johnson (1996). In their analysis, the model of Fama and French (1989) that regards predictable variation in expected stock and returns is used. This model is extended, by adding the monetary sector: several monetary environments are included, by making use of a measure of monetary stringency. A main result is that business conditions explain future stock returns only in periods with expansionary monetary policy (such as periods with QE), whereas the term spread only helps in explaining expected bond returns during periods with restrictive monetary policy. Jensen and Johnson (1995) also show the link between monetary policy and stock returns, as the expected stock returns are significantly higher during periods with expansive monetary policy than in periods with restrictive monetary policy. As an extension to this kind of research, Jensen and Mercer (2002) examine the well-known Fama French three-factor model (including beta, size and book-to-market ratio), where monetary conditions could influence the relations between these factors, as well as the average stock returns. This results in the conclusion that the risk premium on beta varies significantly, depending on the monetary environment: if there is expansionary monetary policy, beta is positively and significantly related to stock returns, whereas beta is negatively related to stock returns in periods of restrictionary monetary policy (Jensen & Mercer, 2002).

Furthermore, Rosa (2012) concludes that a one percentage point surprise tightening in the federal funds rate, leads to a 5.3% drop in the S&P 500 in the half-an-hour after the event, which is in line with the effect found by Bernanke and Kuttner (2005), as they find an effect of about 4.7%.

Rosa (2012) also finds that if hypothetically the BoE would increase its policy rate by 25 basis-points, this would result in a decline of stock prices in the UK by about 2% in the half-an-hour after the event. Bredin, Hyde, Nitzsche, and O'Reilly (2007) estimate that an increase in the policy rate of the BoE by 25 basis-points would lead to a decline of the FTSE 100 of 0.8%, instead of 2%. However, Bredin et al. (2007), consider a different period than Rosa (2012).

Beforementioned papers already give a broad overview of the influence of monetary policy on stock returns. In general, expansionary monetary policy is associated with higher stock returns, whereas contractionary monetary policy is related to lower stock returns. This finding is useful in this thesis, as QE is a form of expansionary monetary policy and consequently there is an expected effect on stock returns.

2.3 The effects of Unconventional Monetary Policy and Quantitative Easing

Since unconventional monetary policy is a subcategory of monetary policy in general, the effects of unconventional monetary policy and QE will be considered next.

Effects on stock prices and returns

Research that considers the effect of shocks in unconventional monetary policy on stock prices and returns does not lead to a general conclusion regarding this effect. Rosa (2012) finds a negative relation between shocks in 'Large-Scale Asset Purchases' (LSAP) and stock prices in the United States, which means that if the LSAP announcement is more restrictive than expected, this results in lower stock prices, whereas an LSAP announcement that is more expansionary than expected, results in higher stock prices. He does so, by estimating the effect of surprise news concerning the LSAP on stock prices. This is the factor that explicitly regards unconventional monetary policy. In contrast, in the UK it is found that stock prices do not react to QE shocks (Rosa, 2012). Joyce, Lasaoa, Stevens, and Tong (2011) conclude as well that equity prices in the UK did not react uniformly to QE news by the BoE. Nevertheless, through 2009, equity prices rose strongly (and QE by the BoE started in March 2009). Since one of the effects of quantitative easing is a lower risk free rate (see e.g. Christensen & Rudebusch (2012) and Krishnamurthy & Vissing-Jorgensen (2011)), as an effect, *ceteris paribus*, the present value of future dividends increases and therefore expectations are that equity prices should rise. Furthermore, as was also noted by De Nederlandsche Bank (2014), since investors started to look for higher yielding assets, it is expected that the additional compensation demanded by investors for holding equities, the risk premium, should decline. This contributes to an upward pressure on stock prices as well. On the other hand, announcements concerning QE might provide investors information about the outlook for the

economy. When this outlook turns out to be worse than expected, this could lower the expectations belonging to the amount of dividends, and risk premiums will increase. Consequently, this effect should lead to a downward instead of upward pressure on equity prices. Nevertheless, eventually it is expected that a successful quantitative easing policy, leads to higher equity prices (Joyce et al., 2011). Unfortunately the authors did not become any more concrete than 'eventually'.

Other effects of unconventional monetary policy

Since this thesis aims at relating the effects of QE to equities, other effects are of less importance. However, an indication of these effects will be briefly provided. Gambacorta, Hofman and Peersman (2014) conduct research on the macroeconomic effects of unconventional monetary policy. If central banks exogenously increase their balance sheets at the zero lower bound, this results in a temporary rise in economic activity and the price level. These effects are quite similar among the eight advanced countries⁶ that are used in their analysis. It is important to take into account that although unconventional monetary policy might temporarily support the economies of the particular countries, this does not mean that this policy is good in times without a crisis, since the analysis is conducted between January 2008 and June 2011 (Gambacorta et al., 2014).

Pattipeilohy, End, Tabbae, Frost, and De Haan (2013) note that a variety of empirical methods is used in order to estimate the effect of unconventional monetary policy. This could contribute to divergence among effects of unconventional monetary policy that are found. However, Pattipeilohy et al. (2013) conclude that despite these different methods, an overall conclusion exists concerning the effect of unconventional monetary policy on money market rates, as money market rates significantly decreased and therefore had an effect on financial transmission and the economy. Furthermore, they conclude that the Securities Market Programmes (SMP) had a positive, but short-lived, effect, by reducing liquidity premia. The programmes also resulted in lower yields and lower volatility of yields (Pattipeilohy et al., 2013).

2.4 Periods of applying QE

In this section, a short factual description will be provided about when QE was applied by the several central banks, as this is needed in order to determine which periods should be analysed.

The United States

QE in the United States consisted of several phases: QE1, QE2 and QE3. QE1 was announced in November 2008 and at its start, the Fed announced that it will purchase \$100 billion in debt of

⁶ United States, Eurozone, United Kingdom, Japan, Canada, Switzerland, Sweden, and Norway

government-sponsored enterprises and \$500 billion in mortgage-backed securities (MBS). In March 2011, QE2 was announced, which concretely meant that the Fed announced to purchase \$600 billion in Treasury securities. In September 2012, in a Federal Open Market Committee statement, the Fed made clear that it wanted to start an additional programme of QE, known as QE3, which consists of the purchase of \$40 billion of MBS per month as long as “*the outlook for the labor market does not improve substantially...in a context of price stability*” (Board of Governors of the Federal Reserve System, 2012; Fawley & Neely, 2013, p. 61). QE was applied in the United States until October 2014 (Board of Governors of the Federal Reserve System, 2014; Fawley & Neely, 2013; Fratzcher et al., 2013; among others).

The Eurozone

The ECB started its first purchase programme in July 2009, namely the Covered Bond Purchase Programme (CBPP1). In May 2010, Central Banks of the Eurosystem started purchasing securities, which was part of the Securities Markets Programme (SMP). In November 2011, the ECB launched a second Covered Bond Purchase Programme (CBPP2). In October 2014, the third Covered Bond Purchase Programme (CBPP3) was launched, followed by the asset-backed securities purchase programme (ABSPP) in November 2014. On the 9th of March, 2015, the Public Sector Purchase Programme (PSPP) started, better known as QE⁷. The PSPP consists of monthly asset purchases, to an amount of €60 billion, which is increased since the start of April 2016 to €80 billion (European Central Bank, 2016). Due to decreasing interest rates, less government bonds are available for the ECB, as the bank is not allowed to buy bonds with a yield that is below -0.4% (Ten Bosch, 2016).

The United Kingdom

The first UK QE Programme lasted from March 2009, till February 2010 (Joyce et al., 2012). In October 2011, a second round of QE started, which consisted of £125 billion of purchases between October 2011 and May 2012. The third QE phase started in July 2012, with another £50 billion of Gilt purchases (Steeley, 2015). Currently, the Asset Purchase Programme that is conducted by the BoE is maintained at £375 billion (Bank of England, 2016).

Japan

Japan was the first country to conduct QE and the BoJ started it in March 2001 (see Mortimer-Lee (2012), Wang, Wang, & Huang (2015), among others). In 2016, the BoJ still applies QE (see Kawa

⁷ Due to lack of data in the Eurozone (because of the short period of time that QE is applied until now), data will be used from the start of the first Asset Purchase Programme on. This will be elaborated in chapter three.

(2016), among others). However, the BoJ is running out of available government bonds that it is able to buy (Kawa, 2016).

2.5 Bubbles

Before considering the relation between QE and bubbles in financial markets, it should be clarified what a bubble actually is. According to Reinhart and Rogoff (2009), many bubbles are incited by cheap credit. As QE leads to cheap credit, the link between QE and bubbles from this perspective is clear. Aliber and Kindleberger (2015, p. 78) point out that expansion of credit helps speculative manias to develop faster. This would mean that especially a speculative bubble could be expected as a result of QE. Since literature did not consider this topic until now, this is an interesting topic for research. In order to be able to conduct this research, a clear definition of the term 'bubble' is needed. Many are available, an overview will be provided in this section.

Definitions of bubbles

Robert J. Shiller (Nobel Prize Laureate in 2013), defines a bubble as *"A situation in which news of price increases spurs investor enthusiasm which spreads by psychological contagion from person to person, in the process amplifying stories that might justify the price increase and bringing in a larger and larger class of investors, who, despite doubts about the real value of the investment, are drawn to it partly through envy of others' successes and partly through a gambler's excitement"* (Shiller, 2013).

So, for Shiller the concept of a bubble seems to be clear. This could be contrasted to Eugene Fama (another Nobel Prize Laureate in 2013), who notes *"I don't even know what a bubble means. These words have become popular. I don't think they have any meaning"* (Shiller, 2013). It is remarkable that two well-known economists, have such a different opinion with regard to the meaning of a bubble.

Gürkaynak (2008, p. 166) in addition points out that bubbles could be rational: *"Equity prices contain a rational bubble if investors are willing to pay more for the stock than they know is justified by the value of the discounted dividend stream because they expect to be able to sell it at an even higher price in the future, making the current high price an equilibrium price"*.

Scherbina and Schlusche (2014, p. 589) provide a, according to them, straightforward definition: *"[...] a bubble is a deviation of the market price from the asset's fundamental value"*. Since trading against overvaluation has the costs and risks of a short position, it is more likely that overvaluation will be persistent than that there will be persistent undervaluation. Evidence signals that the

deflation period of a bubble is in general much shorter than its build up period (Scherbina & Schlusche, 2014).

A positive bubble is defined as *“when an asset’s trading price, P_t , exceeds the discounted value of expected future cash flows (CF):*

$$P_t > E_t \left[\sum_{\tau=t+1}^{\infty} \frac{CF_{\tau}}{(1+r)^{\tau-t}} \right]$$

where r is the appropriate discount rate” (Scherbina & Schlusche, 2014, p. 590). An alternative definition uses the risk-free rate instead of the appropriate discount rate, which might be easier to obtain. In other literature on bubbles it is stated that bubbles can exist in an infinitely lived asset, but only if the growth rate of the bubble is equal to the discount rate. Important assumptions are that there is a perfectly rational world and all information is common knowledge, assumptions which are shown not to hold in reality (Scherbina & Schlusche, 2014). Tirole (1982), in contrast, shows that, under the same assumptions, in a finitely lived asset, speculative bubbles cannot exist.

Bubbles in asset prices typically have three phases (Allen & Gale, 2000). Allen and Gale (2000) define a bubble as the price of a risky asset being higher than its fundamental value, which is equivalent to the definition provided by Scherbina and Schlusche (2014). The first phase consists of an event like a central bank deciding to increase lending (or other similar events, like lowering interest rates; or in this case: QE). The first phase also includes a period in which asset prices (e.g. equities) increase, due to the expansion in credit. In the second phase, asset prices decline (often for a short period, sometimes longer), leading to a bursting bubble. The third phase includes the default of firms and those who borrowed money to buy assets during the time that prices were increasing (Allen & Gale, 2000).

This thesis particularly aims to investigate the aspects of the first phase of a bubble. Allen and Gale (2000) show that the magnitude of a bubble can increase if there is uncertainty about the extent of credit expansion. This could be applied to QE: if there is uncertainty about QE (namely, about the extent of credit expansion) applied by the major central banks, this could increase magnitudes of bubbles in the model of Allen and Gale (2000). If credit expansion in the future is anticipated, this will also contribute to higher asset prices in the future, which will feed back in the current asset price. So, current credit expansion as well as future credit expansion can contribute to bubbles in asset prices (Allen & Gale, 1999). Furthermore, bubbles will occur when substantial uncertainty exists with regard to asset payoffs (Allen & Gale, 2000).

Froot and Obstfeld (1991, p. 1189) consider bubbles that are driven by “*exogenous fundamental determinants of asset prices*”. A feature of such a bubble, which is referred to as being ‘*intrinsic*’, is that the bubble will remain constant over time if there is a given level of exogenous fundamentals. Froot and Obstfeld (1991) discovered that the component of stock prices that is not explained by a present value model such as the one used by Scherbina and Schlusche (2014), has a high positive correlation with dividends, as predicted by the intrinsic bubble.

If there is an infinitely lived asset, of which the price includes a bubble on top of the fundamental value, the price of the asset is based on:

$$P_t = E_t \left[\sum_{\tau=t+1}^{\infty} \frac{CF_{\tau}}{(1+r)^{\tau-t}} \right] + \lim_{T \rightarrow \infty} E_t \left[\frac{B_T}{(1+r)^{T-t}} \right]$$

where B_T is the bubble component (Scherbina & Schlusche, 2014, p. 591)

So, the approach of Froot and Obstfeld (1991) is different from the method denoted by Scherbina and Schlusche (2014), as the bubble is not a function of time but of fundamentals, where the bubble component in the formula above is defined as $B(D_t) = cD_t^{\lambda}$ (Froot & Obstfeld, 1991, p. 1192).

The method of Froot and Obstfeld (1991) will be elaborated in the methodology section, as this is one of the methods that is used in this thesis. The other method tests for speculative bubbles instead of intrinsic bubbles, and is the one that is applied by Diba and Grossman (1988). Having mentioned there is a difference between speculative bubbles (e.g. Tirole (1982), Shiller (2013)) and intrinsic bubbles (Froot and Obstfeld (1991)), this difference will be elaborated next.

2.6 Rational/Speculative bubbles versus Intrinsic bubbles

From the definitions of bubbles in general provided above, one can see there are different types of bubbles: intrinsic (endogenous) bubbles, rational/speculative (exogenous) bubbles and irrational bubbles. Irrational bubbles will not be taken into account, since Blanchard and Watson (1982, p. 1) point out that it is already hard to analyse rational bubbles. Analysing irrational bubbles would be even harder. Therefore, only the differences between intrinsic and speculative bubbles will be denoted in this section. Deviations in market prices from present-value prices seem to be large and lasting. An alternative to the simple present-value model existed of rational bubble models (Froot & Obstfeld, 1991), which will be explained next.

Rational/speculative bubbles

A clear definition of rational bubbles is provided by Chen, Cheng and Cheng (2009, p. 2275): *“Rational bubbles are generated by extraneous events or rumors and driven by self-fulfilling expectations which have nothing to do with the fundamentals”*. According to Blanchard and Watson (1982, p. 1), when rational behaviour and rational expectations are taken as a starting point, most economists believe that the price of an asset must reflect the market fundamentals. This means that the price of an asset should only be determined based on information about current and future returns from that asset. Deviations are seen as irrational. However, as noted by Blanchard and Watson (1982, p. 1) *“rationality of both behavior and of expectations often does not imply that the price of an asset be equal to its fundamental value”*. This means that rational deviations could exist, since deviations are not necessarily the result of irrationality. These rational deviations exist due to rational bubbles. The objection that irrational bubbles are not considered, is rejected for the reason provided above by Blanchard and Watson (1982). This is also an important reason why irrational bubbles are not considered in this paper. For an overview that considers irrational bubbles, see Vissing-Jorgensen (2004).

According to Flood and Hodrick (1990), many models that concern rational expectations have indeterminateness as a characteristic, which is the result of the aforementioned fact that the price of an asset should only be determined based on information about current and future returns. If demand depends on the expected return and supply is fixed, the price is simply determined by the intersection of demand and supply. Equilibrium demand depends upon the current price and beliefs of future returns. The current price depends on the expectation of future prices. At the same time, expectations of future prices, depend on the current price. So, the ‘simple theory’ cannot determine the market price, only sequences of prices, of which one is the price path that depends on market fundamentals. Other paths are based on market fundamentals as well but they can contain price bubbles (Flood & Hodrick, 1990, p. 86).

This is also reflected in Flood & Garber (1980), who note that when future prices determine current prices, there is a possibility of that market prices will result in a bubble. This is the result of self-fulfilling expectations of price changes that result in actual price changes, independently of fundamentals (Flood & Garber, 1980).

For that reason, in order to get models that are able to predict market prices well, restrictions to the models are needed. These restrictions help to exclude many price paths. Examples of these restrictions are provided by Tirole (1982), who shows that under the assumption of a finite number of rational, infinitely-lived traders, real asset prices will be unique and depend only on fundamentals. Additionally, Tirole (1985) provides an overlapping generations model, in

which he shows that bubble paths are possible. As argued by Flood and Garber (1980), the assumption with regard to rational expectations has helped clarifying the nature of price-bubbles, as applying it imposes precise mathematical structures on the link between actual and expected price movements. If the market price positively depends on expectations of its own change, a bubble can arise. By assuming rational expectations, there are by definition no systematic prediction errors. Therefore, the positive relation between the market price and its expected rate of change also implies a positive relation between the market price and its actual rate of change. Under these conditions, there could be arbitrary, self-fulfilling expectations of price changes which lead to changes in actual prices, which is not based on market fundamentals. This situation is defined as price bubble. However, the authors acknowledge that there is a difficulty in testing for the existence of these bubbles, as it is not necessary a bubble that contributes to the current asset price compared to the fundamentals. It can also be the case that some fundamentals are not taken into account (as they might simply be unobserved by the researcher) (Flood & Garber, 1980).

This problem is also emphasized by Hamilton and Whiteman (1985), who note that many existing tests for the presence of rational/speculative bubbles for this reason are not statistically valid. Hamilton and Whiteman (1985, p. 353) state that if there appears to be a speculative bubble in those kind of tests, this is not necessarily a bubble as this 'bubble' could also be the result of rational agents that respond to economic fundamentals that are not observed by the econometrician. All evidence at that time, depended on the restriction that there are no economic fundamentals that were only observed by the agents and not by the econometrician.

Diba and Grossman (1984) as well as Hamilton and Whiteman (1985) propose an alternative empirical strategy. This is based on stationary tests, which could be used to obtain evidence against explosive rational bubbles, and still allow for the possible effect of unobservable variables on market fundamentals. This test is implemented by Diba and Grossman (1988) and will also be used in this thesis, and therefore elaborated on in the methodology section of the thesis. This test has been used often in testing for rational bubbles, and is for example also used by Craine (1993) and Sarno and Taylor (1999). Other tests for rational bubbles can be found in e.g. Blanchard (1979), Blanchard and Watson (1982), Flood and Garber (1980).

An important disadvantage of the test of Diba and Grossman (1988) is that it might fail to detect the presence of an important class of bubbles, namely explosive rational bubbles that collapse periodically (Evans, 1991), since characteristics of bubbles are only present during a phase of expansion, not after the collapse. For example, if there is a 'bubble-period' from 2000 till 2004, with a bubble that collapses at the end of this period, but the time series measured runs from 2000 till 2006, there is a chance that the test of Diba and Grossman (1988) does not detect the bubble during 2000 till 2004.

So, when the test of Diba and Grossman (1988) shows that no rational bubble is present in the data, explosive rational bubbles still could be present and this should be kept in mind. However, Evans (1991) does not provide an alternative, he only shows that the test of Diba and Grossman (1988) is inadequate to cover explosive rational bubbles that collapse periodically. Furthermore, as relatively short periods are covered, the problem of not noticing explosive rational bubbles that collapse, is smaller compared to considering a long period. This again shows the importance of using a combination of tests and periods.

Intrinsic bubbles

According to Froot and Obstfeld (1991), academic interest in bubbles declined over time. This is partially due to the fact that econometric tests did not result in compelling evidence that (the aforementioned) rational bubbles could explain stock prices, as the empirical results are indeterminate. There are some papers that cannot reject the null hypothesis of no rational bubble in the stock price, whereas others can (Chen et al., 2009, pp. 2275-2276). Also, Naoui (2011) mentions that although rational bubble models contributed in explaining deviations of prices from their fundamental value, there is a lack of measures to classify different types of exogenous rational bubbles. This resulted in the development of models where bubbles depend on fundamentals, of which the model of Froot and Obstfeld (1991) is the main example. At the time of Froot and Obstfeld, the authors stated that, *“no one has produced a specific bubble parameterization that is both parsimonious and capable of explaining the data”* (Froot & Obstfeld, 1991, p. 1189).

For that reason, Froot and Obstfeld (1991) brought forth an alternative. The bubbles in their model depend on exogenously determined fundamentals of asset prices. Therefore, in contrast to rational bubbles, these bubbles are called intrinsic bubbles. Contrary to speculative bubbles, only fundamentals form the deterministic function of intrinsic bubbles. For that reason, these bubbles are labelled endogenous, instead of exogenous. As a result, the alternative that is offered is parsimonious, since there are no extraneous sources of variability. Froot and Obstfeld (1991) acknowledge that results with regard to bubbles could also be explained by non-bubble hypotheses, which should be kept in mind throughout this thesis. There is not a perfect test of measuring bubbles, and that is an important reason why rational bubbles as well as intrinsic bubbles are taken into account, to provide a more comprehensive analysis.

One such non-bubble hypothesis holds that deviations from present-value prices could be explained by stationary fads or noise trading. Examples of these models are provided by, e.g., Froot, Scharfstein and Stein (1992), Shiller (1984), Summers (1986). For example, both fads and intrinsic bubbles can lead to persistent deviations from the present-value model. However, fads contain opportunities for making profit by short-term speculations, which is not the case with bubbles alone

(Froot & Obstfeld, 1991). However, the test of Froot and Obstfeld (1991) is designed in such a way to separate the bubble from factors that could contribute to predictability of returns, of which fads are an example. According to Froot and Obstfeld (1991), deviations from the present value model, however, are not mainly explained by predictability in returns.

Another non-bubble hypothesis mentioned by Froot and Obstfeld (1991) regards that any bubble path could possibly also be explained by changes in the fundamental determinants of asset prices. So, instead of results that point towards bubbles, these results could also point towards changes in fundamentals. Models that include changes in fundamentals by making use of regime-switches (with different fundamentals during different 'regimes'), are for example used by Krugman (1987) and Driffill and Sola (1998).

Froot and Obstfeld (1991) state that the idea of rational bubbles is problematic. The idea of an infinite path along which price/dividend ratios eventually explode, does not make sense under the assumption of rational investors, as these rational investors then should profit from using arbitrage strategies along this infinite path. So, this already rules out rational bubbles in a theoretical way. Furthermore, since this should be anticipated by fully rational agents beforehand, a bubble should never even start. This provides an important reason to combine a test for rational bubbles with a test for intrinsic bubbles, as offered by Froot and Obstfeld (1991).

However, De Long, Shleifer, Summers, and Waldmann (1990) and Abreu and Brunnermeier (2003) show that under certain conditions, rational arbitrageurs will not eliminate the mispricing, but rather amplify it (Scherbina & Schlusche, 2014). Besides, if a bubble does not collapse but continues to grow instead, arbitrageurs must possibly meet margin calls for their short positions. This results in closing or back scaling of short positions in overvalued assets (Gromb & Vayanos, 2002; Shleifer & Vishny, 1997; Xiong, 2001). Also, if arbitrageurs are relatively small, they need to coordinate in order to burst the bubble. Without coordination, the bubble will persist (Abreu & Brunnermeier, 2003). So, rational arbitrageurs do not necessarily eliminate mispricing. Examples of other authors that use the intrinsic bubble model are Ma and Kanas (2004), Chen et al. (2009) and Naoui (2011).

Depending on the classification of the bubble, either intrinsic or speculative, different econometric tests have to be used. Considering QE, it can be argued on the one hand that a bubble as a result of QE could be based on fundamentals, as QE has an effect on the interest rates (see e.g. Krishnamurthy & Vissing-Jorgensen (2011), Christensen & Rudebusch (2012)). Those interest rates play an important role in determining the value of a company, since the risk-free rate is used in order to calculate an appropriate discount rate in the present-value model.

On the other hand, QE might possibly lead to a rational bubble, since the lower yields and interest rates as a result of QE could to a certain extent be an 'extraneous' event. The DNB argues that low interest rates cause investors to seek for higher returns. However, the quest for higher returns is accompanied by investors willing to take on more risks, as a higher return is in most cases only achieved by accepting more risks. As an effect, risk premiums reduce and asset prices increase (De Nederlandsche Bank, 2014). As stocks have more risk than bonds, demand for stocks rises, which drives up the prices, even though there is insufficient change in the fundamentals. So, if one of both types of bubbles is present, this could be supported theoretically.

2.7 Existing evidence of the relation between monetary policy and bubbles

Having explained the main effects of monetary policy on stock prices and returns, together with the definitions of bubbles and their types, some empirical evidence that considers the relation between monetary policy and stock market bubbles will be discussed.

According to Galí (2014), economic theory does not substantiate the general claim that applying tighter monetary policy could help to deflate bubbles by resulting in higher short-term nominal interest rates. This general claim comes forward in Borio and Lowe (2002); Cecchetti, Genberg and Wadhvani (2002); Roubini (2006); and White (2006, 2009), among others. In the model of Scherbina and Schlusche (2014), the bubble component of the stock price should grow at the discount rate, let's say the risk-free interest rate. As tighter monetary policy leads to higher short-term nominal interest rates, this means that the size of the bubble will increase, in contrast to the general idea that higher interest rates could deflate bubbles. Nevertheless, asset prices can still decrease, since higher interest rates result in a lower discounted fundamental component of the stock price. If central banks make use of "*leaning against the wind policy*" (raising interest rates when an asset price bubble is developing, in order to decrease the bubble) (Galí, 2014), this could raise volatility of the bubble component of asset prices and therefore of asset prices in general. It might even lead to lower welfare, since the central bank influences the real interest rate and so, real asset prices are affected. Optimal monetary policy should be based on a trade-off of two aspects: stabilizing current demand and stabilizing the bubble. The first aspect requires a positive interest rate response to the bubble, whereas the latter aspect requires a negative interest rate response to the bubble. So, the average size of the bubble is important in determining whether interest rates should increase or decrease as a response to growing bubbles Galí (2014). It is important to take into account that Galí (2014) only considers rational bubbles, but that in reality bubbles are not necessary of the rational type.

Galí and Gambetti (2015) in contrast, show that a tightening in monetary policy should lead to a decline in both the fundamental component as well as the bubble component of the stock price. They use a time-varying coefficients vector-autoregression in order to estimate the effect of monetary policy on stock market bubbles. The VAR is used on quarterly data for GDP, the GDP deflator, a commodity price index, dividends, the federal funds rate, and the S&P 500 (Galí & Gambetti, 2015). This results in estimates of time-varying impulse responses of stock prices to policy shocks. Since changes in interest rates have differential impacts on the fundamental and bubble components of the stock price (Galí, 2014), the overall effect of monetary policy on the stock price could possibly change over time, depending on the relative size of the bubble. Galí and Gambetti (2015) also note that ‘conventional wisdom’ and economic theory conclude that as a response to an exogenous tightening of monetary policy, the real interest rate should rise and dividends should decline. The fundamental component is expected to decline due to the exogenous tightening of monetary policy. Under the ‘conventional wisdom’, a tightening of monetary policy should result in a decline in the size of the bubble. So, as the expected effect of both the fundamental component and the bubble component is negative, the overall effect should be negative as well.

This should be contrasted to Galí (2014). Therefore, considering the results of Galí (2014), Galí and Gambetti (2015) alter the model, concluding that based on theory of rational bubbles, the expected effect of asset prices to a tightening of monetary policy is ambiguous (Galí & Gambetti, 2015, p. 238). In the baseline model of Galí and Gambetti (2015), stock prices increase as a result of contractionary monetary policy. Therefore, they conclude that there is no support for a *“leaning against the wind”* policy.

After having shown the relevant literature in this field of study, it is clear that there is a complete lack of studies that combine quantitative easing with bubbles. A lot of research has been conducted to the effects of monetary policy in general and there is already a substantial amount of literature that discusses QE and its effects on other macroeconomic variables, but none so far have investigated the effect of QE on bubble formation. Furthermore, many papers have been written that consider the presence of bubbles in stock markets. The studies of Galí (2014) and Galí and Gambetti (2015) try to relate monetary policy to bubbles. However, there is not yet a study that conducts research on the link between QE specifically and bubbles in stock markets, even though it is a topic of debate. This thesis aims at filling exactly this gap in the existing literature.

3. Methodology

The analysis conducted in this thesis is based on two different methods. Beside the model of Froot and Obstfeld (1991), also the methodology of Diba and Grossman (1988) will be applied. In the previous chapter, two types of bubbles were distinguished from each other, namely intrinsic bubbles and rational/speculative bubbles. By applying both of these methods, the data will be tested for the presence or absence of both types of bubbles. The model of Froot and Obstfeld (1991) is used because this is the only one that specifically tests for intrinsic bubbles in stock markets (and it is currently still in use, see e.g. Chen et al. (2009) and Naoui (2011)). The model of Diba and Grossman (1988) is used because of its attractive simplicity and since it overcomes the problem of unobserved fundamentals that was noted in the theoretical framework. Even though Evans (1991) argues that there are measurement problems with bubbles when time series are measured for a longer period than there is a bubble, he does not propose an alternative. By considering short periods, this problem is (hopefully) mitigated. An alternative to the model of Diba and Grossman (1988) could consist of regime-switching models, with different fundamentals under different regimes. However, these models need assumptions with regard to the switching probabilities as functions of size of the model or Monte Carlo experiments (Gürkaynak, 2008). In order not to make the model too complicated and full of assumptions, this thesis makes use of the model of Diba and Grossman (1988), even though periodically collapsing bubbles cannot be detected. At first glance it might seem that the model is a bit outdated. However, currently papers still refer to the test of Diba and Grossman (1988) as relevant comparable work in this field and alternatives often consist of simulations (Phillips, Wu & Yu, 2011). Phillips et al. (2011) for example note that the test from the Diba and Grossman (1988) paper that uses standard unit root tests, enables the determination of the explosive characteristics of B_t .

Before the analysis is conducted based on the obtained data, it should be determined whether the model is specified in the correct way. In order to do this, data of Shiller (n.d.) is used for a similar period as in the analysis of Froot and Obstfeld (1991) and this provides similar results as their analysis. All statistical tests are performed in the STATA software package, all calculations that were necessary with regard to the parameters are performed in Microsoft Excel.

3.1 Testing for the presence of an intrinsic bubble

Firstly, a test will be conducted with respect to intrinsic bubbles. The model for intrinsic bubbles as estimated by Froot and Obstfeld (1991, p. 1190) fits the data well in both bull markets and bear markets. The model *“is based on a simple condition that links the time-series of real stock prices to the time-series of real dividend payments when the expected rate of return is constant”* (Froot & Obstfeld, 1991, p. 1191). In other words, real stock prices are linked to their corresponding real

dividend payments, with a constant expected rate of return. The present value model of the stock price can be denoted as:

$$P_t = e^{-r} E_t(D_t + P_{t+1}) \quad (1)$$

In this equation, P_t is the real price of a share at the beginning of period t ; D_t consists of the real dividends per share paid out over period t ; r is the constant, real rate of interest and E_t is the market's expectation, conditional on information known at the start of period t (Froot & Obstfeld, 1991, p. 1191).

The fundamental value of the stock price, is simply the present value of equation (1). This present value, P_t^{PV} , equates the price of a stock, to the present discounted value of expected future dividend payments:

$$P_t^{PV} = \sum_{s=t}^{\infty} e_t^{-r(s-t+1)} E_t(D_s) \quad (2)$$

Froot and Obstfeld (1991, p. 1191) assume that it is always possible to obtain the present value, which means that the continuously compounded growth rate of expected dividends is less than r , a condition that is needed in order to let the sum of the discounted dividend stream be finite (Gürkaynak, 2008, p. 169).

A bubble, $\{B_t\}_{t=0}^{\infty}$, is defined as “any sequence of random variables such that

$$B_t = e^{-r} E_t(B_{t+1})” \quad (3)$$

(Froot & Obstfeld, 1991, p. 1192)

A solution to equation (1) is then provided by $P_t = P_t^{PV} + B_t$, which means that the real stock price consists of the sum of the present value, P_t^{PV} , and a bubble, B_t .

If there is a nonlinear function of fundamentals that satisfies (3), an intrinsic bubble is constructed. In this particular model, there is only one stochastic (unpredictable) fundamental factor, namely the dividend process and therefore the intrinsic bubble just depends on dividends.

If the process of log dividends, $d_t = \ln(D_t)$, is assumed to be a random walk with drift μ we have:

$$d_{t+1} = \mu + d_t + \xi_{t+1} \quad (4)$$

μ is the trend growth in dividends, and is estimated by making use of the following formula:

$$\left[\frac{1}{T-1} * LN \left(\frac{Real\ Dividend\ Final}{Real\ Dividend\ Start} \right) \right] \quad (5)$$

where T is the number of months used and which results in the average monthly growth rate of dividends.

Furthermore, ξ_{t+1} is a normal random variable with a conditional mean of zero and variance σ^2 . When it is assumed that period- t dividends are known when P_t is set, and by making use of (4), the present value of the stock price in (2) becomes directly proportional to dividends:

$$P_t^{PV} = \kappa D_t \quad (6)$$

$$\text{where } \kappa = \frac{1}{e^r - e^{\mu + \frac{\sigma^2}{2}}}$$

(Froot & Obstfeld, 1991, p. 1192).

Based on the formula for κ , the present value of stock price is increasing in the drift of the dividend process and the standard deviation.

The assumption of Froot and Obstfeld (1991, p. 1191) with regard to equation (2) implies

$$r > \mu + \frac{\sigma^2}{2} \quad (7)$$

$B(D_t)$ is defined as

$$B(D_t) = c D_t^\lambda \quad (8)$$

where λ is determined by making use of the equation:

$$\frac{\lambda^2 \sigma^2}{2} + \lambda \mu - r = 0 \quad (9)$$

(Froot & Obstfeld, 1991, p. 1192)

and c is an arbitrary constant. Equation (9) shows that if λ satisfies (9), equation (8) satisfies the bubble definition in equation (3) and therefore can be defined as an intrinsic bubble (Ma & Kanas, 2004, p. 240), which can also be derived from equation (11).

λ is obtained by solving the following equation:

$$\lambda = \frac{-\mu \pm \sqrt{\mu^2 + 2*r*\sigma^2}}{\sigma^2} \quad (10)$$

(Naoui, 2011, p. 127)

Of this equation, only the positive root will be considered, as the negative root could result in negative stock prices (like Froot and Obstfeld, 1991, p. 1192).

It could now be verified that equation (8) satisfies equation (3):

$$\begin{aligned} e^{-r} E_t(B(D_{t+1})) &= e^{-r} E_t(cD_t^\lambda e^{\lambda(\mu + \xi_{t+1})}) \\ &= e^{-r} \left(cD_t^\lambda e^{\lambda\mu + \frac{\lambda^2\sigma^2}{2}} \right) = e^{-r} (cD_t^\lambda e^r) = B(D_t) \end{aligned} \quad (11)$$

(Froot & Obstfeld, 1991, p. 1192)

If the present-value price and the bubble are summed, the basic stock-price equation is obtained:

$$P(D_t) = P_t^{PV} + B(D_t) = \kappa D_t + cD_t^\lambda \quad (12)$$

If (12) contains a bubble ($c \neq 0$), the price is still completely driven by fundamentals. So, $B(D_t)$ is an example of an intrinsic bubble.

Due to equation (7), it is implied that λ must always exceed 1. Due to this “*explosive nonlinearity*” (Froot & Obstfeld, 1991, p. 1192), $B(D_t)$ in expectation grows at rate r .

Applying the model to the stock market

When the described model is applied to the stock market, time t prices are given by

$$P_t = e^{-r} E_t(D_t + P_{t+1}) + e^{-r} u_t \quad (1')$$

In (1'), u_t is a predictable single-period excess return (Froot & Obstfeld, 1991, p. 1198).

Froot and Obstfeld (1991) note that (12) is replaced by a statistical model:

$$P_t = c_0 D_t + c D_t^\lambda + \varepsilon_t \quad (13)$$

In which $c_0 = \kappa = \frac{1}{e^r - e^{\mu + \frac{\sigma^2}{2}}}$ and where ε_t is the present value of the errors in (1')

(Froot & Obstfeld, 1991, p. 1198)

However, estimation of this equation is complicated due to multicollinearity among independent variables (as dividends at period t is used two times). This problem is mitigated when the whole equation is divided by D_t , which results in:

$$\frac{P_t}{D_t} = c_0 + c D_t^{\lambda-1} + \eta_t \quad (14)$$

In which $\eta \equiv \frac{\varepsilon_t}{D_t}$

(Froot & Obstfeld, 1991, p. 1198)

The natural logarithm is taken from the real price divided by real dividend each month. Furthermore, the natural logarithm of real dividends is used as independent variable, and this number is raised to the power $(\lambda-1)$.

The null hypothesis is that the data do not contain an intrinsic bubble. This means that c should not be bigger than zero (and c_0 should equal κ). Consequently, prices are a linear function of dividends and the price/dividend ratio is a constant, κ . The presence of intrinsic bubbles results in non-linearity in the relation between stock prices and dividends. Finding a non-linear relationship between prices and dividends, signals the presence of an intrinsic bubble (Gürkaynak, 2008, p. 181).

Incorporating QE into the model

A first indication whether quantitative easing results in bubbles, could be obtained by comparing coefficients in the equation above in the period before QE started, with coefficients in the equation in the period during and after QE. However, it is important to note that QE has been applied during and after a crisis period (see Fawley and Neely (2013), among others). Clearly, as a crisis period is not 'normal', there are more factors that play a role in the process of determining whether a bubble is present or not, as the economy is in a crisis state.

QE is firstly analysed in the tested equation by using a dummy during the period that QE is applied (as Kurihara (2006) for example did as well), and creating an interaction term between the dummy and $D_t^{\lambda-1}$. Afterwards, an interaction term is created consisting of the relevant data that considers QE (these data differ per central bank that is considered, which will be elaborated later, but could for example consist of total purchases or total assets), multiplied by $D_t^{\lambda-1}$. Furthermore, the delta with regard to total assets or total purchases will be considered. Finally, if total assets or the current account balance are considered (in the case of the United States and Japan, respectively), also the average of these figures before the start of QE, will be deducted. This is done in an attempt to approximate QE more closely by means of the total assets or the current account balance, since the start of QE. Both the delta and the adjusted current account balance/total assets, will be multiplied by $D_t^{\lambda-1}$. In this way, all relevant aspects of intrinsic bubbles are still taken into account, as they are captured by $D_t^{\lambda-1}$ and as a consequence, it is harder to note that it is purely coincidence whether QE creates an intrinsic bubble, since the relevant QE variable is combined with the factor that is mentioned to be the one that creates the intrinsic bubble (see e.g., Chen et al. (2009), Gürkaynak (2008), Froot & Obstfeld (1991), Naoui (2011)). If the interaction term turns out to be significantly positive, this provides an indication that QE is positively related to intrinsic bubbles.

The previous explanation results in the following regression:

$$\frac{P_t}{D_t} = \beta_0 + \beta_1 D_t^{\lambda-1} + \beta_2 D_t^{\lambda-1} * QE_t + \eta_t \quad (15)$$

where:

$\frac{P_t}{D_t}$ is the natural logarithm of real prices divided by real dividends

β replaces c (of Froot and Obstfeld, 1991) in order to denote the coefficients that correspond to the different variables

$D_t^{\lambda-1}$ is the term that captures all relevant aspect with regard to intrinsic bubbles

QE_t is the relevant term concerning quantitative easing: either a dummy or specific data about the (delta of) purchases of a particular central bank.

In order to conduct this analysis, several data sets are necessary, which are obtained from Thomson Reuters Datastream (except for the central bank data):

- Dividends (or dividend yields)
- Nominal stock prices

- Consumer Price Indices
- The risk-free interest rate, which is approximated by using the yield on 10-year government bonds (Damodaran, 2008)
- Data regarding QE or total assets of central banks that applied QE

This data will be obtained for the United States, the Eurozone, the United Kingdom and Japan, since these regions are the four (major) regions where QE has been applied (Fawley & Neely, 2013). As Datastream contains national indices, (which in the case of e.g. United States includes approximately 1000 stocks), these indices will be used to analyse the results of QE on the stock market of a particular country. In Datastream, these indices are known as 'Global Indices', which are available for many countries. Of all indices, the dividend yield is available. Based on the dividend yield and nominal prices, the dividends of the indices can be calculated. These indices are also available for a complete region, like the Eurozone or the European Union, which is a great advantage. The calculation method of these indices can be found at the website of Thomson Reuters, in the file '*Thomson Reuters Global Equity Indices – Index Methodology*' (Thomson Reuters, 2016).

Based on the nominal stock prices and the dividend yields, the nominal dividends can be calculated. Furthermore, with the use of Consumer Price Indices, the nominal data can be transformed into real data. This is necessary, since only by making use of real data, the value of the obtained nominal return in practice can be determined. Furthermore, Froot and Obstfeld (1991) make use of real data as well. Shiller (n.d.) calculates the real data in his dataset also based on the Consumer Price Index, which is done by making use of the following equation:

$$\text{Nominal data} * \left(\frac{CPI_{final\ date}}{CPI_t} \right) \quad (16)$$

where CPI_t is the Consumer Price Index at time t and $CPI_{final\ date}$ denotes the CPI value at the latest date in the dataset that is used (Shiller, n.d.). Therefore, $CPI_{final\ date}$ is the CPI of March 2016, as this is the latest month that is included in the analysis of this thesis.

3.2 Testing for the presence of a rational bubble

The second way to test for the presence of a bubble, concerns testing for specific characteristics of bubbles. According to Gürkaynak (2008, p. 176), bubbles have certain theoretical properties. These properties could be used in order to detect a bubble. Gürkaynak (2008, p. 182) also points out that there is not one obvious bubble interpretation and test, as for every measure of a bubble, another

paper questions the interpretation of this bubble. Based on the fact that bubbles have certain theoretical characteristics, in combination with the statement that every bubble interpretation is disputed by another paper, an additional methodology to the one of Froot and Obstfeld (1991) will be used in order to detect bubbles. As Gürkaynak (2008) points out that each methodology has its own advantages and disadvantages, combining them ensures that the analysis is more robust. Moreover, in this way not only a test is conducted with regard to the presence of intrinsic bubbles, but also concerning rational bubbles. In order to do this, the methodology of Diba and Grossman (1988) is applied. In contrast to the test of Froot and Obstfeld (1991), Diba and Grossman (1988) test for the presence of rational bubbles. The authors define a rational bubble as follows: “A *rational bubble* reflects a self-confirming belief that an asset’s price depends on a variable (or a combination of variables) that is intrinsically irrelevant [...]” (Diba & Grossman, 1988, p. 520). The test of Diba and Grossman (1988) allows for unobserved fundamentals and consequently the problem that was described in the theoretical framework does not apply here.

The model of Diba and Grossman (1988) is a test for explosive rational bubbles in stock prices. The model assumes a constant discount rate, but unobserved variables are allowed to affect fundamentals. If there are no rational bubbles, and if first differences of the unobserved variables and dividends are stationary, then first differences of stock prices should be stationary (Diba & Grossman, 1988, p. 520). However, if the first differences of stock prices are non-stationary or if the result is that stock prices and dividends are not cointegrated, this does not mean that rational bubbles do exist. The argumentation holds the other way around though. This means that if there is evidence that first differences of stock prices are stationary, or that stock prices and dividends are cointegrated, this is evidence against the existence of a rational bubble. As a result, this property can be used in order to test for the absence of rational bubbles. Consequently, only the absence of rational bubbles can be confirmed by means of this test, but if the absence is not confirmed, this does not mean that there is a rational bubble.

The model that is used by Diba and Grossman (1988, p. 521) consists of a single equation:

$$P_t = \frac{1}{1+r} * E_t(P_{t+1} + \alpha d_{t+1} + u_{t+1}) \quad (17)$$

P_t is the real stock price (which is computed the same way as with the intrinsic bubble method); r is a constant real interest rate; E_t is the conditional expectations operator; α is a positive constant that valuates expected dividends relative to expected capital gains; d_{t+1} is the real before-tax dividend paid to the owner of the stock between t and $t+1$; u_{t+1} is the error term, which accounts for unobserved variables and is expected to be zero (Diba & Grossman, 1988, p. 521).

The applicable market-fundamentals component is denoted as:

$$F_t = \sum_{j=1}^{\infty} (1+r)^{-j} E_t(\alpha d_{t+j} + u_{t+j}) \quad (18)$$

If α would be equal to one and u_t equal to zero, equation (18) means that the market-fundamentals component of the stock price is equal to the present value of expected real dividends, discounted at the constant real rate r (Diba & Grossman, 1988, p. 521)

A general solution to equation (17) would be the sum of the market-fundamentals component, and a rational bubbles component:

$$P_t = B_t + F_t \quad (19)$$

where B_t is the rational bubbles component and F_t is the market-fundamentals component. With a lack of arbitrage opportunities, holding an asset with a bubble component, does not provide excess returns:

$$E_t(B_{t+1}) = (1+r)B_t \quad (20)$$

(Diba & Grossman, 1988, p. 522)

If holding an asset with a bubble component would provide excess returns for a while, rational arbitrageurs should make use of the corresponding arbitrage opportunity, which results in its disappearance. However, as already noted before, even for arbitrageurs it could be rational to ride the bubble, rather than deflating it (see e.g. Abreu and Brunnermeier (2003), De Long et al. (1990)).

An indication for the existence of a rational bubble is the property that B_t is not equal to zero. Unfortunately, it is impossible to measure the bubble component directly. When it is assumed that the bubble is stochastic, the actual bubbles process follows the stochastic difference equation:

$$B_{t+1} - (1+r)B_t = z_{t+1} \quad (21)$$

z_{t+1} is a random variable, generated by a stochastic process, satisfying

$$E_{t-j}z_{t+1} = 0, \text{ for all } j \geq 0 \quad (22)$$

(Diba & Grossman, 1988, p. 522)

When in equation (18), the process that generates d_t is non-stationary in levels, but first differences of d_t and u_t are stationary and in case rational bubbles do not exist, stock prices are non-stationary

in levels but stationary in first differences. The logic behind this, is that when stock prices are not more explosive than the fundamentals underlying these stock prices (dividends), rational bubbles are not present. If they were, this would result in an explosive component in the stock prices. Additionally, in case there is a rational bubble in the stock prices, taking the differences of stock prices (a bounded number of times) would not result in a stationary process of the stock price (Diba & Grossman, 1988, p. 522). From equation (21), the n th difference of the bubble process results in the generating process:

$$(1 - L)^n[1 - (1 + r)L]B_t = (1 - L)^n z_t \quad (23)$$

L is used as lag operator.

(Gürkaynak, 2008, p. 177)

Based on the description above, a test for the absence of rational bubbles is provided. Dickey-Fuller tests for unit roots are used in order to determine whether the price-process is stationary or non-stationary. The null-hypothesis is that the series is non-stationary. In case the null-hypothesis is not rejected, there is a non-stationary process and the series has a unit root. The Dickey-Fuller test exists in a nonaugmented version and an augmented version. The augmented version allows for the possibility that the error term is autocorrelated, which is likely to occur if insufficient lags are included *“to capture the full dynamic nature of the process”* (Hill, Griffiths, & Lim, 2012, p. 485). As many lags are added as needed to make sure that residuals are not autocorrelated. The appropriate number of lags is determined by making use of Akaike’s Information Criterion (AIC). The AIC is given by:

$$AIC = \ln\left(\frac{SSE}{N}\right) + \frac{2K}{N} \quad (24)$$

where SSE is the Sum of Squared Errors and K is the number of variables (Hill et al., 2012, p. 238).

The maximum number of applied lags is 12, to cover a maximum of a full year, as is for example also done by Pan (2010). Within this amount, the number of applicable lags while testing for a unit root, will be determined based on the smallest AIC value. The first term in (24) becomes smaller when additional variables are added (due to a decline in SSE), but the second term becomes larger, as K increases (Hill et al., 2012, p. 238). According to Hill et al. (2012), the alternative for using the AIC is using the Schwarz Criterion (SC), also known as the Bayesian Information Criterion (BIC). Burnham and Anderson (2002, p. 299) note that, *“predictions based on the AIC-selected model are stochastically closer to the true $E(y)$ values than are the predictions from the BIC-selected model”*. Furthermore, there is no theoretical basis with regard to the selection procedure in the BIC selection model (Burnham & Anderson, 2002, p. 295). Therefore, AIC will be used as a criterium in

order to determine the appropriate number of lags⁸. The tested equations are provided in appendix A.

Diba and Grossman (1988, p. 525) note that in case the unobservable variable of fundamentals, u_t , is stationary in levels, if dividends are stationary in first differences and the sum given by the right-hand side of equation (A1) in appendix A is stationary, then rational bubbles do not exist. Accordingly, even though P_t and d_t are non-stationary, their linear combination is stationary. As noted by Gürkaynak (2008, p. 178), the null hypothesis is that there are no bubbles in stock prices.

When it is assumed that the unobservable variable is stationary, then dividends and stock prices should be cointegrated. Hill et al. (2012, p. 488) mention that cointegration could be tested by testing whether errors are stationary. As the error term cannot be observed, the stationarity of the least squares residuals is tested

$$\hat{e}_t = y_t - b_1 - b_2 x_t \quad (25)$$

by using a Dickey-Fuller test. So, testing for cointegration actually means testing the stationarity of residuals. If the residuals turn out to be stationary, y_t and x_t are cointegrated. If the residuals turn out to be non-stationary, y_t and x_t are not cointegrated and if there seems to be a relationship between the two variables, this is said to be spurious (Hill et al., 2012). The tested equations can again be found in appendix A. The tables with critical values of Dickey-Fuller are provided in appendices B1 and B2.

A clear disadvantage of the methods that concern testing for stationarity and cointegration, is that only the general case whether a rational bubble is present in the data, could be tested, not whether QE has a specific influence on it. Therefore, probably the method of Froot and Obstfeld (1991) is the best one in order to test for the specific consequences of QE on intrinsic bubbles in stock prices. However, if this test indicates that there is no intrinsic bubble due to QE, the absence of a rational bubble (and so, the absence of bubbles at all (except for the irrational type)) can be confirmed by the methodology as applied by Diba and Grossman (1988). So, in case there is an indication of an intrinsic bubble due to QE, the method of Diba and Grossman is not able to confirm that this bubble is due to QE, it could only help in indicating whether a rational bubble is present or not. The power of this method is in confirming the absence of a bubble, not in confirming the presence.

⁸ Getting values for both criteria is based on the "varsoc" command in Stata

For each analysis, the considered period is split into two periods, namely the period before the start of QE and the period since the start of QE onwards. This is done since the analysis obviously is better when the period before and after QE are split, to see whether that makes a difference and whether QE really leads to a bubble, compared to the period before QE.

3.3 Obtained data

Based on the introduction, it can be expected that the most relevant analysis with regard to the claims of Knot and Weidmann will consider the effects of the QE policy applied by the ECB. However, as this programme started only in March 2015 (European Central Bank, 2015), the QE programmes of the other three central banks will be considered as well. In this way, more data is available (e.g. QE in Japan started in March 2001 (Mortimer-Lee, 2012)) and therefore, the analysis is more comprehensive and hopefully robust. In the coming paragraphs a description will be provided about the procedure of obtaining the relevant data.

Time span

For all aforementioned regions, three analyses will be conducted that consider the presence of intrinsic bubbles in the particular stock markets. These three analyses are constructed based on different periods and parameters. The first analysis starts five years before the start of QE in a particular country or region until March 2016, with the abovementioned parameters estimated since this starting date. The second analysis regards the same period, but with parameters estimated from the first moment that data was available. The third analysis is estimated from the first moment that data was available until March 2016. By conducting these three analyses, a robustness test is provided as well, since the regression and parameters are estimated based on different periods. The advantage of using a longer period is that it provides more reliable estimates of the parameters, as more business cycles are included. The disadvantage of using a longer period, is that the data before the period of QE gets a more important influence on the parameters. However, the shorter the period, the higher the influence of the data obtained during the crisis, and this could result in a biased outcome. Therefore, the analysis is conducted three times, with estimations of the parameters based on both longer and shorter periods.

An alternative specification could for example consist of periods that are equal in length, which would mean that the period before the start of QE depends on the length of the period after the start of QE. This way of analyzing has been considered. However, for example with regard to the United States, periods of equal length would already have as a disadvantage that the period before QE would include the aftermath of the crash after the dotcom bubble and the telecoms crash (Aliber & Kindleberger, 2015; Kam, 2006). Furthermore, analyzing periods that are equal in

length before and after QE, would mean that for all four regions, different lengths of periods before the start of QE would be considered (e.g. Japan already started QE in 2001 but the United States in 2008). In order to conduct a consistent analysis, it is deliberately decided to start in every region five years before the start of QE.

The analysis of Froot and Obstfeld (1991) is based on yearly data. However, using yearly data in this analysis would result in only 13 years with data (2003-2016) in the example of the United States, which obviously would not result in a robust analysis. Using daily and weekly data would result in a data set that is possibly too volatile compared to the analysis of Froot and Obstfeld (1991). An even more important reason to make use of monthly data is the reason that certain data, such as the Consumer Price Index and the risk-free rate, are only available on monthly basis.

The United States

In the United States, QE has been applied by the Federal Reserve from November 2008 till October 2014 (Fratzscher et al. (2013), Fawley & Neeley (2013), Board of Governors of the Federal Reserve System (2014), among others). Since QE in the United States started in November 2008, data is used from November 2003 onwards. So, the three periods that will be tested for the presence of an intrinsic bubble in the U.S., are November 2003 till March 2016 with parameters estimated since November 2003; November 2003 till March 2016 with parameters estimated since January 1973 (the first moment that data was available concerning the global index) and January 1973 till March 2016. The periods that will be tested for the absence of a speculative bubble, are November 2003 till October 2008 and November 2008 till March 2016. An overview of these periods is provided in a timeline in table 1.

The global index of Datastream corresponding to the United States, is coded TOTMKUS. The proxy for QE in the United States that is used, is 'total assets' of the Federal Reserve, obtained from The Federal Reserve Bank of St Louis (n.d.) (which is part of the system of the Federal Reserve). This is done, since no specific data was available regarding the purchases done by the Federal Reserve. Total assets form a good proxy, as the purchases as part of QE, increase the balance sheet of the Federal Reserve and as mentioned by Joyce et al. (2012, p. F272), among others, massive expansion of central banks' balance sheets is a characteristic of unconventional monetary policy. Blinder (2010) also mentions that during the period of QE in the United States, the balance sheet and bank reserves of the FED expanded to a great extent (Blinder, 2010, p. 468). Based on the references just mentioned, total assets form a good proxy for QE. The total amount of assets of the FED is depicted in figure 1.

The Eurozone

The ECB was the last of the four major central banks in the world to decide to apply QE. QE started in the Eurozone in March 2015 (European Central Bank, 2015). However, in order to extend the analysis, not only the effects on bubbles after the start of QE will be analysed, but also the effects of the several asset purchase programmes combined will be analysed.

Since the analysis that starts five years before the start of QE is relatively short and thus as a consequence little data is available, this thesis deliberately decides to take as a starting point five years before the start of the first asset purchase programme. Accordingly, the analysis starts in July 2004. The ECB provides specific data on all separate purchase programmes. Consequently, this analysis will be even more extensive than those applicable to the other regions, namely consisting of an estimation concerning all purchase programmes together and one consisting only of QE. Data about the purchase programmes is obtained from the ECB (European Central Bank, n.d.b.) and is depicted in figure 2. The global index of Datastream that corresponds to the Eurozone, is coded TOTMKEM.

Concerning the Eurozone, an additional period will be considered when contrasted to the other three countries, as not only QE will be considered but also the other asset purchase programmes. Therefore, the periods that will be considered regarding an intrinsic bubble are: July 2004 till March 2016, based on parameters since 2004; March 2010 till March 2016, based on parameters since 2010; July 2004 till March 2016, based on parameters since 1990 and the full period of January 1990 till March 2016. January 1990 is the first moment that data about the EMU is available. The periods that will be tested for the absence of a speculative bubble, are July 2004 till June 2009; July 2009 till March 2016; March 2010 till February 2015 and March 2015 till March 2016. An overview of these periods is provided in a timeline in table 2.

The United Kingdom

The Bank of England started its QE Programme in March 2009 (Joyce, Tong, & Woods, 2011 Q3). Again, a longer period as well as a shorter period will be used to estimate the different parameters. The longer period will start from 1988 on, as Datastream did not contain data on the CPI in the United Kingdom before 1988. Also the Office for National Statistics did not contain data on the CPI before 1988. As in all analyses real prices and real dividends are used, the estimation of parameters could only be done from 1988 onwards. The shorter period again will consist of five years before the start of QE, from March 2004 onwards. The global index of Datastream that corresponds to the United Kingdom, is coded TOTMKUK. Datastream also contains specific data about the purchases

that are made by the BoE as part of the QE-policy. Therefore this data will be used in order to estimate the effect of QE and no proxy is necessary. The data are graphically provided in figure 3.

Concerning intrinsic bubbles, the three periods that will be analysed are March 2004 till March 2016 with parameters estimated since March 2004; March 2004 till March 2016 with parameters estimated since January 1988 (the first moment that data was available about the Consumer Price Index in the UK, which is necessary to calculate real prices and real dividends) and January 1988 till March 2016. Concerning speculative bubbles, the periods that will be analysed are March 2004 till February 2009 and March 2009 till March 2016, as can also be seen in table 3.

Japan

In Japan, QE started in March 2001 (see Mortimer-Lee (2012), Wang et al. (2015), among others) and it is still applied today (Kawa, 2016). Again, parameters are estimated both during a longer period (since 1973) as well as during a shorter period (since 1996, five years before the start of QE, following the reasoning in the 'Time span' section) and monthly data are used. The global index of Datastream corresponding to Japan, is coded TOTMKJP. Data about quantitative easing are obtained from the Bank of Japan (Bank of Japan, n.d.). The data that is used as a proxy for QE, is the current account balance, since the BoJ sets an operating target to achieve with regard to the current account balance, during the different phases of QE. By using the excess current account balance of banks with the BoJ as operating policy target, the BoJ could maintain ample liquidity supply (Mortimer-Lee, 2012; Ueda, 2012). The development of the current account balance of the BoJ is provided in figure 4.

The three periods that will be analysed for the intrinsic bubble test are March 1996 till March 2016 with parameters estimated since March 1996; March 1996 till March 2016 with parameters estimated since January 1973 (the first moment that the global index-data was available) and January 1973 till March 2016. The periods that will be tested regarding the speculative bubble test, are March 1996 till February 2001 and March 2001 till March 2016. A timeline with these periods is provided in table 4.

A summary of the main variables of the analyses, such as the natural log of real prices divided by real dividends, is provided in appendix C.

Figure 1: Total Assets of the Federal Reserve

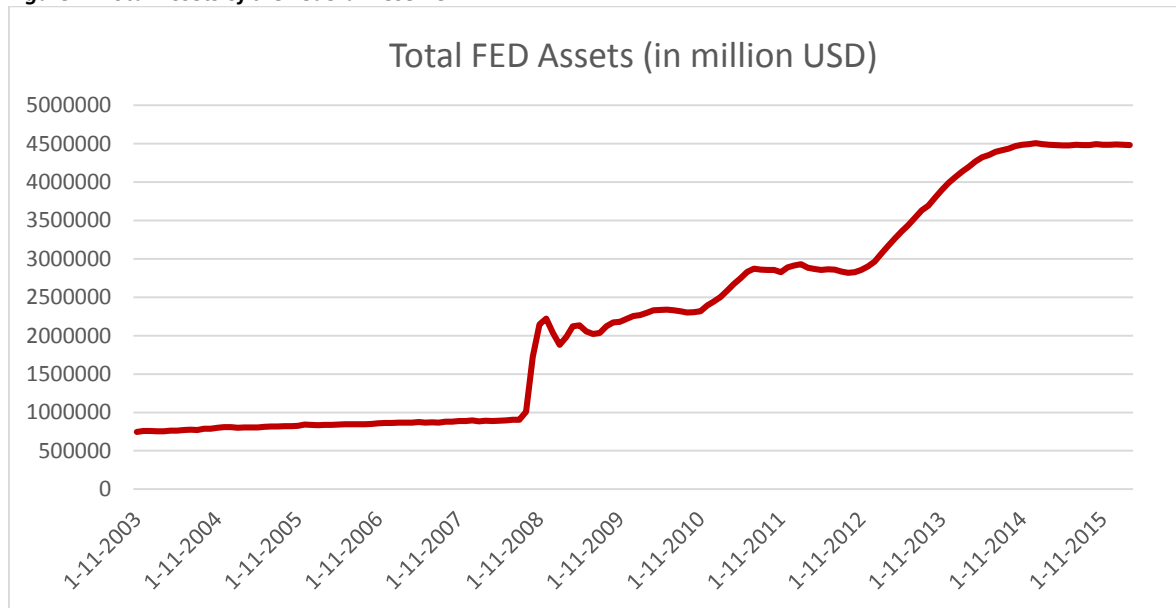


Figure 2: Total Asset Purchases by the European Central Bank

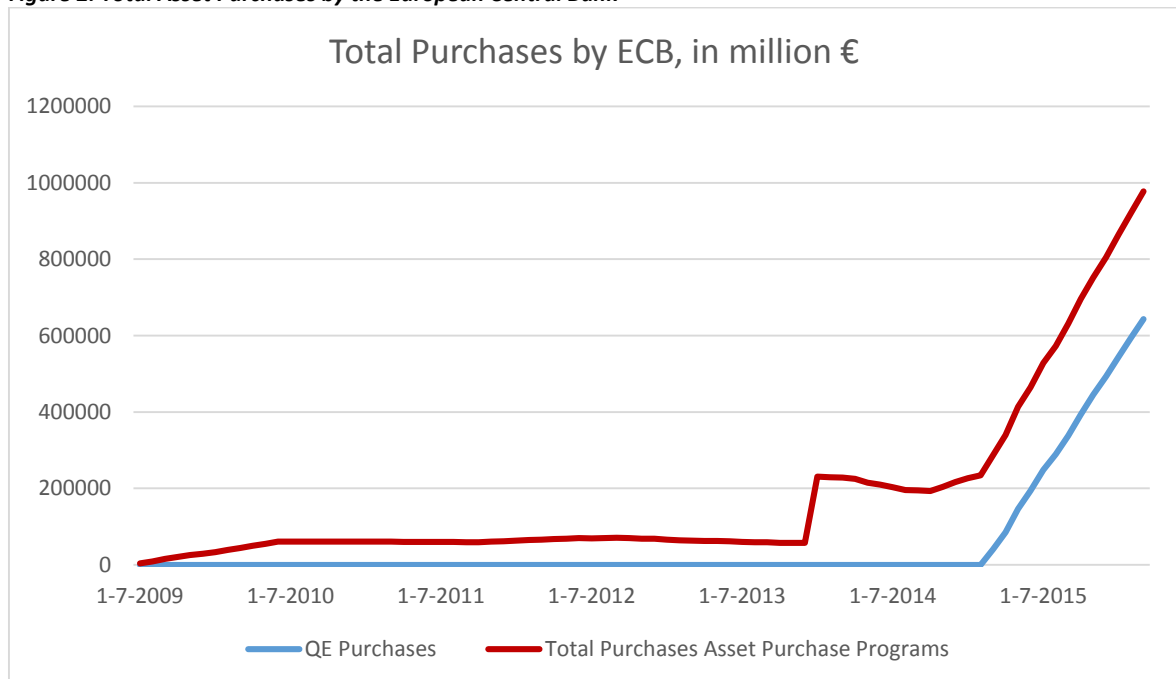


Figure 3: Total Asset Purchases by the Bank of England

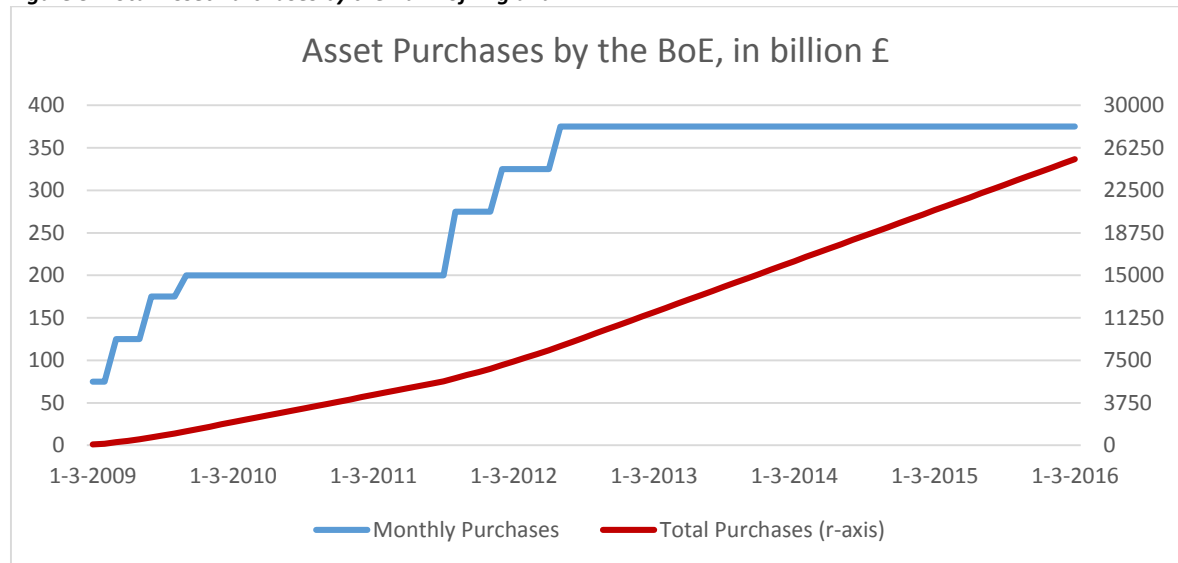


Figure 4: Development of the Current Account Balance of the BOJ

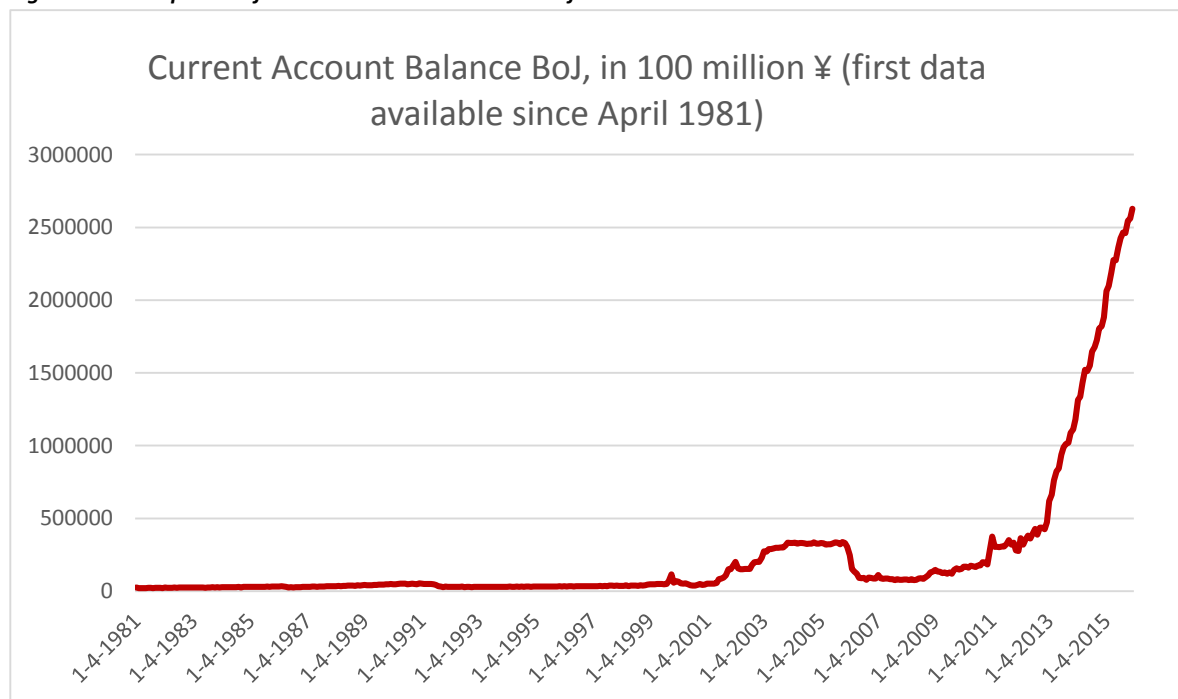


Table 1: overview of tested periods in the United States

| 1973 | 2003 | 2008 | 2016 |
|------|---|-----------------------------|------|
| | Intrinsic bubble analysis 1 (parameters since 2003) | | |
| | Intrinsic bubble analysis 2 (parameters since 1973) | | |
| | Intrinsic bubble analysis 3 | | |
| | Speculative bubble period 1 | | |
| | Speculative bubble period 2 | | |
| | | Speculative bubble period 3 | |

Table 2: overview of tested periods in the Eurozone

| 1990 | 2004 | 2009 | 2010 | 2015 | 2016 |
|-----------------------------|---|------|-----------------------------|-----------------------------|-----------------------------|
| | Intrinsic bubble analysis 1 (parameters since 2004) | | | | |
| | Intrinsic bubble analysis 2 (parameters since 1990) | | | | |
| | | | | Intrinsic bubble analysis 3 | |
| Intrinsic bubble analysis 4 | | | | | |
| | Speculative bubble period 1 | | | | |
| | Speculative bubble period 2 | | | | |
| | | | Speculative bubble period 3 | | |
| | | | Speculative bubble period 4 | | |
| | | | | | Speculative bubble period 5 |

Table 3: overview of tested periods in the United Kingdom

| 1988 | 2004 | 2008 | 2016 |
|------|---|-----------------------------|------|
| | Intrinsic bubble analysis 1 (parameters since 2004) | | |
| | Intrinsic bubble analysis 2 (parameters since 1988) | | |
| | Intrinsic bubble analysis 3 | | |
| | Speculative bubble period 1 | | |
| | Speculative bubble period 2 | | |
| | | Speculative bubble period 3 | |

Table 4: overview of tested periods in Japan

| 1973 | 2001 | 2008 | 2016 |
|------|---|-----------------------------|------|
| | Intrinsic bubble analysis 1 (parameters since 2001) | | |
| | Intrinsic bubble analysis 2 (parameters since 1973) | | |
| | Intrinsic bubble analysis 3 | | |
| | Speculative bubble period 1 | | |
| | Speculative bubble period 2 | | |
| | | Speculative bubble period 3 | |

4. Results

In this chapter, the results of the analyses will be presented. Firstly, the complete analysis with regard to intrinsic bubbles will be presented. Graphical insights are provided in appendix D for the United States, appendix E for the Eurozone, appendix F for the United Kingdom and appendix G for Japan.

4.1 Intrinsic bubbles

The United States

In the United States, there is no indication of a significant positive relation between QE and intrinsic bubbles. Based on the real dividends from November 2003 till March 2016, the trend growth, μ , is estimated to be 0.5%. The standard deviation, σ , is calculated to be 0.2061. The nominal yields on 10-year US Government Bonds are converted into real yields. In order to use a constant real rate of interest, the average real 10-year bond yield is used. This results in an estimate of the risk free real rate of return, r , of 3.7313%. Based on these estimates, κ can be calculated to be 89.12⁹. Furthermore, λ is 1.21¹⁰, and in consequence the condition that λ should be bigger than 1 is fulfilled¹¹. The estimates of the parameters for the other analyses can be found in table 12.

The previous calculations will be used to conduct the OLS-regression as conducted by Froot and Obstfeld (1991). In order to derive equation (14), Froot and Obstfeld (1991) assumed that the log-dividend process follows a (martingale) stochastic process with trend. However, this assumption should be tested, which is done by a unit root test. The procedure of this test is already described in the ‘Methodology’ section of this thesis. The number of applied lags is 4, based on the outcome of the AIC test. Like Froot and Obstfeld (1991), the test is conducted with and without time trend, which results in the following test statistics:

Table 5: unit root test with regard to the stationarity of the natural log of monthly real dividends

| Variable | With time trend | Without time trend |
|---------------------|-----------------|--------------------|
| LN dividends, d_t | -1.796 | -0.701 |

$$^9 \kappa = \frac{1}{e^r - e^{\mu + \frac{\sigma^2}{2}}} = \frac{1}{e^{0.037129744} - e^{0.005031 + \frac{0.20605009^2}{2}}} = 89.12$$

$$^{10} \lambda = \frac{-\mu \pm \sqrt{\mu^2 + 2 * r * \sigma^2}}{\sigma^2} = \frac{-0.005031 + \sqrt{0.005031^2 + 2 * 0.037129744 * 0.20605009^2}}{0.20605009^2} = 1.21$$

¹¹ It is however important to note that Froot and Obstfeld (1991) are not consistent in their use of r . On page 1191, they define r as “the constant, instantaneous, real rate of interest”, whereas on p. 1199, e^r is defined to be the “sample average gross real return on stocks”. In order to determine e^r in this analysis, r is used to be the constant, real interest rate (which is calculated as the average real yield on 10-year bonds in the particular period). This is done, since this is also the way Naoui (2011) and Chen et al. (2009) define r . This is applied for all different countries.

This test is performed for each separate analysed period for each country, and the test statistics are provided in table 11. When the values of table 5 are contrasted to the critical values in appendix B1, one can conclude that the null hypothesis that the series is non-stationary is not rejected, for both the case with time trend and without time trend and therefore the analysis of Froot and Obstfeld (1991) can be conducted.

The first indication of the presence of an intrinsic bubble, can be obtained by an analysis that is conducted separately in the period that starts five years before QE (for the reason mentioned before, in section 3.3) until the moment QE starts. Afterwards, the intrinsic bubble analysis is conducted for the period since the start of QE until March 2016. Furthermore, the estimates over the full period as well as the estimates for the period before QE since 1973 (the first moment that data was available) can be found. These results are provided in table 6¹².

For the United States it can be concluded that without taking specific data with regard to QE into account, there is a sign change from negative to positive after QE started. However, this positive coefficient is not significant. Furthermore, when the coefficients are considered over a longer period of time, the coefficient that concerns $D_t^{\lambda-1}$ turns from significantly positive into insignificantly positive. So, since there is already no indication of an intrinsic bubble in the United States without considering QE, QE probably does not lead to a bubble in the stock market. Despite this indication, as there is quite a big difference in coefficients, a more specific analysis concerning the effect of QE is needed. This is done in accordance with the three aforementioned ways and can be found in table 7.

When the analysis from 2003-2016 with parameters from 2003 onwards is considered, there is a negative sign, instead of the 'expected' positive sign with regard to $D_t^{\lambda-1}$ when QE is taken into account. However, the coefficient concerning $D_t^{\lambda-1}$ becomes insignificant when total assets of the FED are taken into account. Also, the applied dummy during the period of QE already indicates that there is a negative relationship between QE and intrinsic bubbles in financial markets, which is confirmed by the analysis in which total assets of the Federal Reserve are taken into account, although the coefficient is relatively small. This is also the case when the delta of total assets is considered. No significant relation is found with the adjusted amount of total assets.

Looking at the analysis from 2003-2016 with parameters from 1973 onwards, the coefficients that only consider the intrinsic bubble variable, have become smaller, but are as significant as the first analysis.

¹² In all analyses, R^2 is deliberately left out of the tables, as the goal is not to 'explain' the natural log of real prices divided by real dividends, but only to see whether the coefficients that regard the intrinsic bubble and interaction term are significant or not.

However, an interesting contrast is obtained when the regression is run from 1973-2016, since this results in the conclusion of the presence of a positive intrinsic bubble overall. Nevertheless, except for the interaction between $D_t^{\lambda-1}$ and adjusted assets, a conclusion can be drawn, that the three other interaction terms that capture the relation between QE and intrinsic bubbles, show a significant negative relation between QE and intrinsic bubbles in the US stock market. Clearly, the interaction between $D_t^{\lambda-1}$ and adjusted assets is positive. However, the coefficient is relatively small and thus there is almost no effect.

As a result, all three analyses of the United States lead to the conclusion that there is no indication that QE causes an intrinsic bubble in the stock market.

The Eurozone

Like the United States, the analysis of the EMU does not provide evidence of a significant positive relation between QE and intrinsic bubbles.

The first analyses concerning the relevant periods in the EMU, again consist of testing the properties of the time series of the natural log of monthly real dividends, to see whether the series is stationary or not. These results can be found in table 11. As can be seen, in all cases the null-hypothesis that the series is non-stationary is not rejected. As a result, the assumption holds and the analysis of Froot and Obstfeld (1991) can be conducted.

Before QE is specifically taken into account, a first notion about the presence of intrinsic bubbles since the start of QE, can already be obtained without considering data on QE, but only the separate periods five year before the start of the purchase programmes/QE and the periods after the start of the purchase programmes/QE. This is done based on parameters from 1990 onwards and the results can be found in table 6.

The conclusion that can be drawn is that no matter whether the purchase programme is considered (row 4 and 5 in the EMU part of table 6) or QE (row 6 and 7), there is no indication of an intrinsic bubble in any of the cases. In general, the large coefficients in absolute terms are remarkable, especially when this is contrasted to the other countries in table 6. Furthermore, table 8 also shows that the coefficients of $D_t^{\lambda-1}$ are very large in absolute terms when parameters are estimated from 1990 onwards, compared to the period in which parameters are estimated dating from 2004. This is remarkable and there is no obvious explanation for this, as there has not been a big change in the data itself, except for the fact that the parameters are estimated based on a longer period of time. However, κ is also much bigger, as the difference between the constant real interest rate and $\mu + \sigma^2/2$ is much smaller compared to the shorter periods.

Table 6: Analysis of Intrinsic Bubbles without considering QE, parameters are estimated for the longest available period

| United States | | | | Eurozone | | | | United Kingdom | | | | Japan | | | |
|-------------------|------|--------------------|--------------------|---------------------|------|--------------------|---------------------|-------------------|------|-------------------|---------------------|---------------------|------|-------------------|--------------------|
| Period | Obs. | β_o | $D_t^{\lambda-1}$ | Period | Obs. | β_o | $D_t^{\lambda-1}$ | Period | Obs. | β_o | $D_t^{\lambda-1}$ | Period | Obs. | β_o | $D_t^{\lambda-1}$ |
| 1973-2016 | 518 | 0.425* 0.184 | 1.200*** 0.069 | 1990-2016 | 315 | 96.56*** 10.056 | -91.43*** 9.886 | 1988-2016 | 339 | 2.018*** 0.194 | 0.0624*** 0.009 | 1973-2016 | 519 | 14.18*** 0.913 | -9.452*** 0.884 |
| 1973-Oct 2008 | 429 | -2.464*** 0.263 | 2.332*** 0.101 | 1990-Feb 2015 | 302 | 97.72*** 10.281 | -92.58*** 10.108 | 1988-Feb 2009 | 254 | 1.623*** 0.229 | 0.0810*** 0.011 | 1973-Feb 2001 | 338 | 10.04** 3.647 | -5.41 3.57 |
| Nov 2003-Oct 2008 | 60 | 5.694*** 0.223 | -0.567*** 0.077 | 1990-June 2009 | 234 | 74.41*** 12.633 | -69.63*** 12.424 | Mar 2004-Feb 2009 | 60 | 5.223*** 0.380 | -0.0813*** 0.017 | March 1996-Feb 2001 | 60 | 30.89*** 4.278 | -25.59*** 4.211 |
| Nov 2008-2016 | 89 | 3.838*** 0.215 | 0.0121 0.070 | July 2004-June 2009 | 60 | 216.6*** 44.768 | -209.2*** 43.945 | Mar 2009-2016 | 85 | 5.550*** 0.353 | -0.0981*** 0.016 | March 2001-2016 | 181 | 15.29*** 0.696 | -10.50*** 0.661 |
| | | | | July 2009-2016 | 81 | 284.5*** 38.575 | -276.1*** 37.884 | | | | | | | | |
| | | | | Mar 2010-Feb 2015 | 60 | 180.7* 86.755 | -174.1* 85.200 | | | | | | | | |
| | | | | Mar 2015-2016 | 13 | 726.8** 168.116 | -710.6* 165.177 | | | | | | | | |

* = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$

Dependent variable: LN (Real Price/Real Dividend)

Standard errors in italic

Table 7: Analysis of Intrinsic bubbles in the United States, including the effect of QE

| | Analysis 2003-2016, parameters since 2003 | | | | | Analysis 2003-2016, parameters since 1973 | | | | | Analysis 1973-2016 | | | | |
|---------------------------------------|---|--------------------|-----------------------|-------------------|---------------------|---|---------------------|-----------------------|----------------------|---------------------|--------------------|---------------------|-----------------------|----------------------|---------------------|
| | No QE (1) | Dummy (2) | Assets (3) | Adj. Assets (4) | Delta (5) | No QE (1) | Dummy (2) | Assets (3) | Adj. Assets (4) | Delta (5) | No QE (1) | Dummy (2) | Assets (3) | Adj. Assets (4) | Delta (5) |
| $D_t^{\lambda-1}$ | -3.195*** 0.626 | -2.941*** 0.515 | 0.0458 1.036 | -0.705 0.838 | -3.050*** 0.622 | -0.304*** 0.061 | -0.270*** 0.050 | 0.0241 0.110 | -1.532*** 0.105 | -0.291*** 0.060 | 1.200*** 0.069 | 1.426*** 0.081 | -0.00900 0.099 | -1.532*** 0.162 | -0.296*** 0.054 |
| $D_t^{\lambda-1} \cdot \text{Dummy}$ | | -0.113*** 0.013 | | | | | -0.0477*** 0.006 | | | | | -0.0910*** 0.019 | | | |
| $D_t^{\lambda-1} \cdot \text{Assets}$ | | | -3.71e-08*** 0.000 | | | | | -1.48e-08*** 0.000 | | | | | -1.42e-08*** 0.000 | | |
| $D_t^{\lambda-1} \cdot \text{AdjAss}$ | | | | 3.47e-08 0.000 | | | | | 9.06e-08*** 0.000 | | | | | 9.06e-08*** 0.000 | |
| $D_t^{\lambda-1} \cdot \text{Delta}$ | | | | | -8.61e-08* 0.000 | | | | | -9.57e-08* 0.000 | | | | | -9.63e-08* 0.000 |
| β_o | 8.044*** 0.802 | 7.788*** 0.660 | 3.997** 1.305 | 4.655*** 1.047 | 7.865*** 0.797 | 4.858*** 0.181 | 4.822*** 0.150 | 3.979*** 0.304 | 7.883*** 0.431 | 4.824*** 0.180 | 0.425* 0.184 | -0.14 0.214 | 4.076*** 0.272 | 7.883*** 0.431 | 4.840*** 0.160 |
| Obs | 149 | 149 | 149 | 89 | 149 | 149 | 149 | 149 | 89 | 149 | 518 | 518 | 159 | 89 | 158 |

* = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$

Dependent variable: LN (Real Price/Real Dividend)

AdjAss stands for the total FED Assets of which the average assets over the period 2003-2008 are subtracted

Standard errors in italic

The more detailed analysis, that includes the relevant aspects of QE (a dummy during the asset purchase programme, a dummy during QE, the total amount of purchases, the total amount of QE, the delta in purchases and the delta in QE) is provided in table 8.

On the basis of table 8, a conclusion can be drawn that for the analysis during 2004-2016, with parameters from 2004 onwards, the coefficient that concerns the intrinsic bubble, is significantly negative, no matter whether QE or the total purchase programme is considered. Furthermore, five out of six relations between a purchase programme or QE and $D_t^{\lambda-1}$, turn out to be insignificant, whereas the dummy during the time of purchases turns out to be significantly negative.

This conclusion does not change when the regression 2004-2016 is run with estimated parameters from 1990 onwards. So, there is again no indication of intrinsic bubbles as an effect of QE. However, it is remarkable that the coefficients became much larger in absolute terms compared to those of the estimated regression with parameters dating from 2004. As mentioned before, there is no obvious explanation for this.

The analysis that is estimated based on five years before the start of QE, dating from March 2010, shows some interesting contrasting results though, since the interaction between $D_t^{\lambda-1}$ and the dummy during QE turns out to be positive and significant on a 10%-level, just like the interaction between the delta of total purchases and the delta in QE. Furthermore, the interaction between $D_t^{\lambda-1}$ and the total amount that is purchased from the start of the purchase programmes in 2009 onwards, is positive and significant on a 5%-level. These results indicate that the intrinsic bubble increases as QE increases. It is however important to note that the corresponding coefficients are relatively small, as an increase of for example the interaction term with regard to the total amount of purchases by one, only leads to an increase in the dependent variable of 0.00000000602. Furthermore, only 73 months are taken into account.

The final period that is considered, concerns the regression for the full available period of data with regard to the EMU, namely from 1990 till 2016. The coefficients are again clearly higher in absolute terms than those of the first two analyses of the EMU. However, the conclusions do not change. As these analysis contains the largest quantity of data, this one is probably the most reliable. So, there is no indication of a positive relation between QE and intrinsic bubbles in the EMU.

Table 8: Analysis of Intrinsic bubbles in the Economic and Monetary Union, with several approximations for QE

| | Analysis 2004-2016, parameters since 2004 | | | | | | | Analysis 2010-2016, parameters since 2010 | | | | | | |
|-------------------------------------|---|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---|---------------------|--------------------|---------------------|---------------------|---------------------|--------------------|
| | No QE (1) | Dummy Pur (2) | Dummy QE (3) | Purchases (4) | QE (5) | Delta Pur (6) | Delta QE (7) | No QE (1) | Dummy Pur (2) | Dummy QE (3) | Purchases (4) | QE (5) | Delta Pur (6) | Delta QE (7) |
| $D_t^{\lambda-1}$ | -2.651*** 0.455 | -3.596*** 0.457 | -2.507*** 0.486 | -2.626*** 0.501 | -2.613*** 0.477 | -2.564*** 0.473 | -2.515*** 0.485 | -0.0392*** 0.008 | -1.01 5.400 | -0.0244* 0.010 | -0.0235* 0.009 | -0.0350*** 0.009 | -0.0314*** 0.008 | -0.0255* 0.010 |
| $D_t^{\lambda-1} * \text{DumPur}$ | | -0.0971*** 0.019 | | | | | | | 0.971 5.401 | | | | | |
| $D_t^{\lambda-1} * \text{DumQE}$ | | | 0.0298 0.035 | | | | | | | 0.00314* 0.001 | | | | |
| $D_t^{\lambda-1} * \text{Purch}$ | | | | 6.44E-09 0.000 | | | | | | | 6.02e-09** 0.000 | | | |
| $D_t^{\lambda-1} * \text{QE}$ | | | | | 2.38E-08 0.000 | | | | | | | 2.76E-09 0.000 | | |
| $D_t^{\lambda-1} * \text{DeltaPur}$ | | | | | | 3.03E-07 0.000 | | | | | | | 3.12e-08* 0.000 | |
| $D_t^{\lambda-1} * \text{DeltaQE}$ | | | | | | | 5.72E-07 0.000 | | | | | | | 5.93e-08* 0.000 |
| β_0 | 8.357*** 0.846 | 10.22*** 0.858 | 8.083*** 0.905 | 8.310*** 0.937 | 8.284*** 0.889 | 8.191*** 0.882 | 8.099*** 0.904 | 4.922*** 0.295 | 4.914*** 0.300 | 4.336*** 0.390 | 4.276*** 0.365 | 4.755*** 0.353 | 4.608*** 0.324 | 4.379*** 0.386 |
| Obs | 141 | 141 | 141 | 141 | 141 | 141 | 141 | 73 | 73 | 73 | 73 | 73 | 73 | 73 |
| | Analysis 2004-2016, parameters since 1990 | | | | | | | Analysis 1990-2016 | | | | | | |
| | No QE (1) | Dummy Pur (2) | Dummy QE (3) | Purchases (4) | QE (5) | Delta Pur (6) | Delta QE (7) | No QE (1) | Dummy Pur (2) | Dummy QE (3) | Purchases (4) | QE (5) | Delta Pur (6) | Delta QE (7) |
| $D_t^{\lambda-1}$ | -165.7*** 28.386 | -225.1*** 28.634 | -156.8*** 30.349 | -164.2*** 31.316 | -163.4*** 29.792 | -160.2*** 29.582 | -157.3*** 30.299 | -91.43*** 9.886 | -74.59*** 11.135 | -92.67*** 9.926 | -92.79*** 10.107 | -92.05*** 9.935 | -92.60*** 9.960 | -92.63*** 9.928 |
| $D_t^{\lambda-1} * \text{DumPur}$ | | -0.175*** 0.034 | | | | | | | -0.104** 0.033 | | | | | |
| $D_t^{\lambda-1} * \text{DumQE}$ | | | 0.0519 0.062 | | | | | | | 0.0815 0.065 | | | | |
| $D_t^{\lambda-1} * \text{Purch}$ | | | | 1.06E-08 0.000 | | | | | | | 6.29E-08 0.000 | | | |
| $D_t^{\lambda-1} * \text{QE}$ | | | | | 4E-08 0.000 | | | | | | | 1.50E-07 0.000 | | |
| $D_t^{\lambda-1} * \text{DeltaPur}$ | | | | | | 5.40E-07 0.000 | | | | | | | 8.37E-07 0.000 | |
| $D_t^{\lambda-1} * \text{DeltaQE}$ | | | | | | | 9.97E-07 0.000 | | | | | | | 1.59E-06 0.000 |
| β_0 | 172.2*** 28.910 | 232.8*** 29.170 | 163.1*** 30.911 | 170.7*** 31.899 | 169.9*** 30.343 | 166.6*** 30.129 | 163.6*** 30.860 | 96.56*** 10.056 | 79.45*** 11.321 | 97.81*** 10.096 | 97.94*** 10.280 | 97.19*** 10.105 | 97.74*** 10.130 | 97.77*** 10.098 |
| Obs | 141 | 141 | 141 | 141 | 141 | 141 | 141 | 315 | 315 | 315 | 315 | 315 | 315 | 315 |

* = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$

Dependent variable: LN (Real Price/Real Dividend)

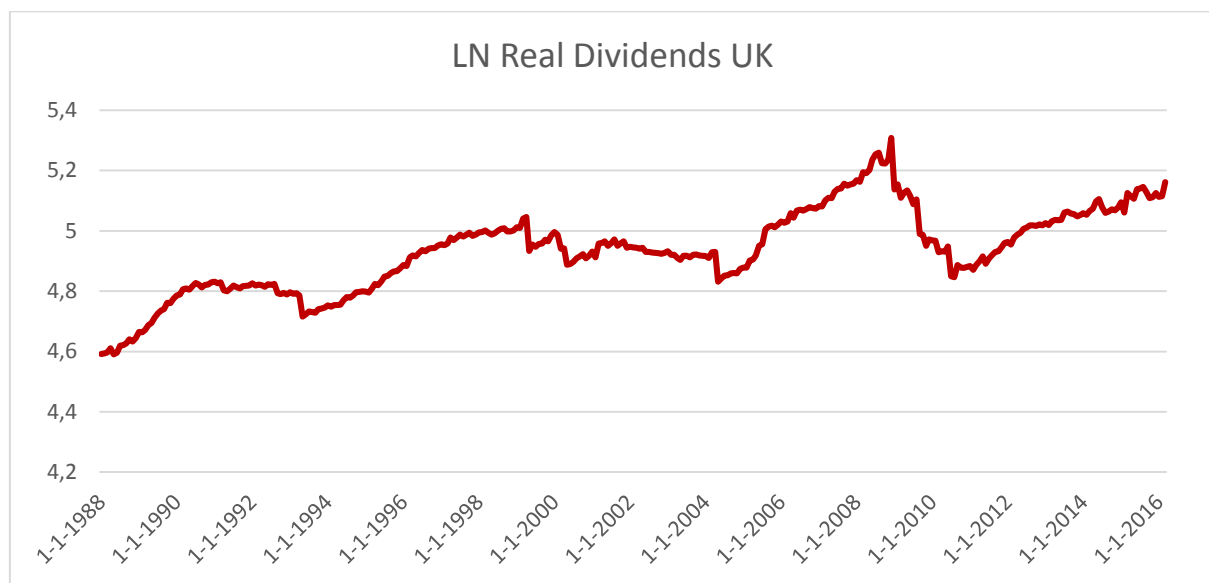
Pur means that the total asset purchases of the ECB are taken into account, whereas QE means that only QE is taken into account

Standard errors in italic

The United Kingdom

For the UK there is also no indication of a significant positive relation between QE and intrinsic bubbles. The calculated parameters for the three periods, can be found in table 12. The test statistics about the stationarity of the natural logarithm of real dividends are provided in table 11. The calculated parameters do not show any remarkable results. However, the test for non-stationarity of the real dividend process, shows that there could be reason to question whether the time series is non-stationary during the period 1988-2016. When contrasted to the critical values in appendix B1, the time series with trend seems to be stationary, as the critical value with time trend is -3.41, whereas the tau-statistic in the analysis is -3.47. However, the series without time trend is non-stationary. Therefore, it should be determined whether the series has a trend or not. This is needed to determine whether the intrinsic bubbles analysis can be conducted, as the assumption made by Froot and Obstfeld (1991) is that the time series of the natural log of real dividends is non-stationary. In order to get an idea about the presence of a trend, the data will be plotted in a graph first:

Figure 5: the natural logarithm for monthly real dividends of TOTMKUK over time, January 1988-March 2016



Based on figure 5, there seems to be an upward trend. In order to determine whether this trend is significant or not, the results of the conducted Augmented Dickey Fuller tests have to be consulted. If the trend is significant, the tau-statistic based on a time trend will be used; if the trend is insignificant, the tau-statistic of the analysis without time trend will be used. As the trend turns out to be significant (see appendix I), the tau-statistic of -3.470 will be used and this means that the series is stationary. This means that the assumption of Froot and Obstfeld (1991) is not fulfilled and the analysis cannot be conducted. In contrast, the analysis can be conducted for the period 2004-2016, which means there is still data to analyse for the presense of intrinsic bubbles. These analyses can be found in table 9.

In order to check whether an intrinsic bubble is present in the data at all, separate periods are used. These consist of March 2004-February 2009 and March 2009-March 2016, which contain the five-year period before the start of QE and the whole period after QE. Furthermore, the presence of an intrinsic bubble over the full period since 1988 is tested, as well as from 1988 till the start of QE. These results can be found in table 6.

The analysis in table 6 shows that the coefficient for $D_t^{\lambda-1}$ is negative before the start of QE and becomes even more negative during the period that QE is applied, which is, to say the least, remarkable. When the regression is run for a longer period, the coefficient corresponding to the intrinsic bubble even turns from positive into negative after March 2009, hence there is clearly no indication of intrinsic bubbles as an effect of QE. A more precise analysis, that includes the relevant aspects of QE (a dummy, the total purchases and the increase in purchases each month) is shown in table 9.

In all four cases (without considering QE, approximating QE with a dummy, approximating QE by the total amount of purchases and approximating the effect of QE by the difference in purchases), there is a negative coefficient corresponding to $D_t^{\lambda-1}$. Furthermore, the interaction term between the dummy and the intrinsic bubble variable, has a negative coefficient, which is significant on a 10%-level. The coefficient concerning the interaction of the total purchases and the intrinsic bubble, is positive, but insignificant. This is also the case for the coefficient that belongs to delta.

When the regression of the period 2004-2016 is considered with estimated parameters from 1988 onwards, this results in the same conclusion, with the only difference that the coefficients have become smaller in absolute terms.

Additionally, even though the assumption concerning non-stationarity of the natural log of monthly real dividends does not hold, the results of the analysis 1988-2016 are shown in table 9 as well. In this way, an indication is provided about the coefficient of $D_t^{\lambda-1}$ when it is estimated over a longer time. This coefficient shows a positive relation between $D_t^{\lambda-1}$ and the natural log of real prices divided by real dividends. Still, these results are not really valuable as the assumption of Froot and Obstfeld (1991) does not hold.

In conclusion, there is no significant positive relation between QE and intrinsic bubbles in the United Kingdom.

Japan

Finally, for Japan there is also no indication of a significant positive link between QE and intrinsic bubbles. The relevant parameters for the three analyses can be found in table 12. Since the estimated parameters for the period 1996-2016 result in some remarkable outcomes, these will be elaborated on.

If real dividends are taken into account from March 1996 till March 2016, the trend growth, μ , is estimated to be 0.399%. Furthermore, σ is calculated to be 0.3679. Real yields on 10-year Japan government bonds are used in order to determine the constant real rate of interest. To calculate the constant real rate of interest, the average yield on these 10-year bonds is used, 1.3788%. These parameters provide remarkable results, as κ can be calculated to be negative, namely -16.55¹³, and λ is smaller than one, hence the condition of Froot and Obstfeld that λ should be bigger than one, is not fulfilled¹⁴. A negative κ means a negative constant Real Price to Real Dividend Ratio, which is counterintuitive. As λ is smaller than one, the intrinsic bubble analysis cannot be conducted for the period 1996-2016, based on parameters that are estimated from 1996 onwards. This shows the importance of estimating parameters based on a longer period. A possible explanation for these results is the Lost Decade in Japan, which is a description for the 1990s (Hayashi & Prescott, 2002). Aoki (2012) and Sudo, Ueda and Watanabe (2014) even speak of a plural form, as they also consider the first decade of this millennium to be lost.

So, the intrinsic bubble model cannot be estimated when parameters are calculated dating from 1996. However, the analyses can be conducted when parameters are estimated from 1973 onwards, since λ is bigger than one (see table 12). The two remaining analyses for Japan have to be tested for the non-stationarity of monthly real dividends, and these results can be found in table 11. As the null-hypothesis of non-stationarity is not rejected (based on the critical values in appendix B1), the assumption of Froot and Obstfeld (1991) holds and the analysis can be conducted. Firstly, to get an idea whether intrinsic bubbles are present in the data at all, the data will be tested for the presence of intrinsic bubbles without taking QE into consideration. This is based on a division of the data in two periods, namely five years before the start of QE until the start of QE and from the start of QE onwards. These results can be found in table 6.

$$^{13} \kappa = \frac{1}{e^r - e^{\mu + \frac{\sigma^2}{2}}} = \frac{1}{e^{0.013788} - e^{0.00399 + \frac{0.367907^2}{2}}} = -16.55$$

$$^{14} \lambda = \frac{-\mu \pm \sqrt{\mu^2 + 2 * r * \sigma^2}}{\sigma^2} = \frac{-0.00399 + \sqrt{0.00399^2 + 2 * 0.013788 * 0.367907^2}}{0.367907^2} = 0.42$$

It is very clear that there is no positive intrinsic bubble in the data. After QE started, the coefficient corresponding to $D_t^{\lambda-1}$, only becomes 'less negative' compared to the five years before QE. When the period dating from 1973 is considered, there is no significant intrinsic bubble whereas this turns into significantly negative after the start of QE.

As the purpose of this thesis is to estimate the specific effect of QE on bubbles, the analysis is conducted again, by considering the periods 1996-2016 and 1973-2016, including the relevant data of QE (which contains a dummy, the Current Account Balance by the BoJ, the Adjusted Current Account Balance of the BoJ (with the average balance from 1981 (first moment of data) till March 2001 deducted) and a delta, the first difference of the current account balance). The full analysis can be found in table 10.

For the analysis of the period 1996-2016, with estimated parameters from 1973 onwards, there is a negative sign corresponding to the coefficient of the intrinsic bubble, $D_t^{\lambda-1}$.

Furthermore, when a dummy is applied during QE, there is an indication that the relation between QE and intrinsic bubbles in financial markets, is negative. This, however, cannot be completely confirmed when specific data about the current account balance of the BoJ are taken into account, as the coefficient that concerns the interaction between $D_t^{\lambda-1}$ and either the current account balance or the adjusted current account balance is relatively small, positive number, which is significant on a 10%-level. The data nevertheless provide sufficient indication that QE did not fuel intrinsic bubbles in Japan.

For the analysis during the period 1973-2016, again the assumption of Froot and Obstfeld (1991) about non-stationarity holds (see table 11). When these results are compared to the estimated regression 1996-2016, there are no real differences between the effects of QE on intrinsic bubbles. There is already no positive intrinsic bubble in the data when QE is not taken into account and this is still the case when QE is taken into account. The only thing that changes is that the significant negative sign with regard to the dummy, is not significant anymore. However, there is still no indication that QE contributes to a positive intrinsic bubble.

Additionally, in appendix H, an overview of the development of the intrinsic bubble coefficients over time is provided per periods of five years, on the basis of which the conclusion can be drawn that the intrinsic bubble did not already decline since the start of the analyses (so that QE would not fuel intrinsic bubbles as they already declined anyway).

Table 9: Analysis of Intrinsic bubbles in the United Kingdom, including the effect of QE

| | Analysis 2004-2016, parameters since 2004 | | | | Analysis 2004-2016, parameters since 1988 | | | | Analysis 1988-2016 | | | |
|--|---|---------------------------|---------------------------|---------------------------|---|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| | No QE (1) | Dummy (2) | Purchases (3) | Delta (4) | No QE (1) | Dummy (2) | Purchases (3) | Delta (4) | No QE (1) | Dummy (2) | Purchases (3) | Delta (4) |
| $D_t^{\lambda-1}$ | -0.183*** <i>0.025</i> | -0.191*** <i>0.025</i> | -0.192*** <i>0.026</i> | -0.183*** <i>0.025</i> | -0.0834*** <i>0.011</i> | -0.0870*** <i>0.011</i> | -0.0874*** <i>0.012</i> | -0.0834*** <i>0.011</i> | 0.0624*** <i>0.009</i> | 0.0621*** <i>0.010</i> | 0.0641*** <i>0.010</i> | 0.0614*** <i>0.010</i> |
| $D_t^{\lambda-1} * \text{Dummy QE}$ | | -0.00362* <i>0.002</i> | | | | -0.00204* <i>0.001</i> | | | | 0.0000816 <i>0.001</i> | | |
| $D_t^{\lambda-1} * \text{Total Purchases}$ | | | 1.72e-07 <i>0.000</i> | | | | 9.55e-08 <i>0.000</i> | | | | -3.49e-08 <i>0.000</i> | |
| $D_t^{\lambda-1} * \text{Delta Purchases}$ | | | | 3.3e-07 <i>0.000</i> | | | | 1.63e-07 <i>0.000</i> | | | | 8.71e-07 <i>0.000</i> |
| β_0 | 5.664*** <i>0.312</i> | 5.791*** <i>0.313</i> | 5.760*** <i>0.315</i> | 5.664*** <i>0.313</i> | 5.243*** <i>0.253</i> | 5.350*** <i>0.254</i> | 5.319*** <i>0.255</i> | 5.243*** <i>0.254</i> | 2.018*** <i>0.194</i> | 2.022*** <i>0.207</i> | 1.983*** <i>0.211</i> | 2.036*** <i>0.209</i> |
| Obs | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 339 | 339 | 339 | 339 |

* = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$; Dependent variable: LN (Real Price/Real Dividend); Standard errors in italic; Non-stationarity assumption does not hold for 1988-2016

Table 10: Analysis of Intrinsic bubbles in Japan, Including QE

| | Analysis 1996-2016, parameters since 1973 | | | | | Analysis 1973-2016 | | | | |
|---------------------------------------|---|---------------------------|---------------------------|----------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| | No QE (1) | Dummy (2) | Current Account (3) | Adj. Curr. Acc. (4) | Delta (5) | No QE (1) | Dummy (2) | Current Account (3) | Adj. Curr. Acc. (4) | Delta (5) |
| $D_t^{\lambda-1}$ | -12.87*** <i>0.542</i> | -10.37*** <i>0.629</i> | -13.76*** <i>0.638</i> | -11.39*** <i>0.639</i> | -12.78*** <i>0.572</i> | -9.452*** <i>0.884</i> | -9.733*** <i>1.203</i> | -10.66*** <i>1.109</i> | -11.39*** <i>0.899</i> | -12.31*** <i>0.765</i> |
| $D_t^{\lambda-1} * \text{Dummy QE}$ | | -0.256*** <i>0.039</i> | | | | | 0.0188 <i>0.054</i> | | | |
| $D_t^{\lambda-1} * \text{CurrAcc}$ | | | 7.33e-08* <i>0.000</i> | | | | | 9.62E-08 <i>0.000</i> | | |
| $D_t^{\lambda-1} * \text{AdjCurrAcc}$ | | | | 7.59e-08** <i>0.000</i> | | | | | 7.59e-08 <i>0.000</i> | |
| $D_t^{\lambda-1} * \text{Delta}$ | | | | | -2.27E-07 <i>0.000</i> | | | | | -7.32e-07 <i>0.000</i> |
| β_0 | 17.82*** <i>0.566</i> | 15.42*** <i>0.638</i> | 18.73*** <i>0.660</i> | 16.19*** <i>0.763</i> | 17.74*** <i>0.596</i> | 14.18*** <i>0.913</i> | 14.46*** <i>1.229</i> | 15.41*** <i>1.139</i> | 16.19*** <i>0.763</i> | 17.30*** <i>0.790</i> |
| Obs | 241 | 241 | 241 | 181 | 241 | 519 | 519 | 519 | 181 | 419 |

* = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$

Dependent variable: LN (Real Price/Real Dividend)

CurrAcc stands for the Current Account of the BoJ, whereas AdjCurrAcc stands for the Adjusted Current Account, where the average of the Current Account before QE started is subtracted
Standard errors in italic

Table 11: Unit Root tests that regard the stationarity of the natural logarithm of the monthly real dividends

| Country | Period | With time trend | Without time trend |
|----------------|-----------|-----------------|--------------------|
| United States | 2003-2016 | -1.796 | -0.701 |
| | 1973-2016 | -0.917 | 1.205 |
| Japan | 1996-2016 | -2.468 | -0.601 |
| | 1973-2016 | -1.820 | -0.335 |
| United Kingdom | 2004-2016 | -2.789 | -2.813 |
| | 1988-2016 | -3.470** | -2.305 |
| EMU | 2010-2016 | -3.236 | -1.562 |
| | 2004-2016 | -1.834 | -1.299 |
| | 1990-2016 | -1.299 | -1.300 |

* = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$

Table 12: Parameters needed for the analysis of an intrinsic bubble

| Country | Parameters since? | μ | σ | r | κ | λ | $\lambda > 1?$ |
|----------|-----------------------|----------|----------|----------|----------|-----------|----------------|
| US | Parameters since 2003 | 0.005031 | 0.2061 | 0.03713 | 89.12 | 1.21 | ✓ |
| | Parameters since 1973 | 0.000012 | 0.2830 | 0.15197 | 9.00 | 1.95 | ✓ |
| Japan | Parameters since 1996 | 0.00399 | 0.3679 | 0.013788 | -16.55 | 0.42 | * |
| | Parameters since 1973 | 0.001165 | 0.2961 | 0.0553 | 92.50 | 1.11 | ✓ |
| UK | Parameters since 2004 | 0.001611 | 0.1052 | 0.040283 | 29.47 | 2.56 | ✓ |
| | Parameters since 1988 | 0.001684 | 0.137397 | 0.085145 | 12.87 | 2.91 | ✓ |
| Eurozone | Parameters since 2010 | -0.0023 | 0.074736 | 0.029213 | 34.38 | 3.66 | ✓ |
| | Parameters since 2004 | 0.004689 | 0.1865 | 0.03701 | 50.82 | 1.45 | ✓ |
| | Parameters since 1990 | 0.002115 | 0.368378 | 0.071788 | 511.54 | 1.01 | ✓ |

4.2 Rational bubbles

The analyses above indicate the absence of an intrinsic bubble in the data sets, and, more importantly, no significant positive relation between QE and intrinsic bubbles, which is a strong concern of the DNB. However, the absence of an intrinsic bubble does not mean there is no rational bubble. Therefore, a test that concerns the presence of rational bubbles is conducted. This is done by making use of the test of Diba and Grossman (1988). The results for the full periods of each country (again starting five years before the start of QE) are included in table 13.

Additionally, real dividends and real stock prices are tested for cointegration. The tau-statistics are provided in the right most column of table 13. The applicable critical values for a cointegration test differ from the critical values for the 'normal' Dickey-Fuller test, as can be seen in appendix B2.

Based on this analysis, the conclusion can be drawn that for the United States, there is no indication of rational bubbles in the data. Since the tau-statistic with regard to levels does not reject the null-hypothesis of non-stationarity, but the tau-statistic of the first differences does reject the null-hypothesis of non-stationarity, it can be concluded that real stock prices are non-stationary in levels, but stationary in first differences. This is the case for all three periods (2003-2016, 2003-2008 and 2008-2016). Furthermore, as can be concluded based on table 13, the residuals of the regression of real dividends on real prices are non-stationary in levels, but stationary in first differences, and so, are cointegrated. Hence, both tests that concern stationarity, indicate that no rational bubble is present in the data.

When the stock market of Japan is tested for the presence of rational bubbles, this results in the same conclusion as for the United States: when QE started, the stationarity tests of real stock prices in Japan, do not indicate that the stock market contains a speculative bubble. This analysis is substantiated by a cointegration test, which shows that the error term, μ_{t+j} , is stationary in first differences. As mentioned, cointegration between dividends and stock prices in levels and stationarity in first differences, indicates the absence of speculative bubbles. As was the case for the United States, this also holds for Japan.

For the speculative bubble analysis concerning the United Kingdom, there are some remarkable results. For the considered period 2004-2016, there is no indication of rational bubbles, as the stock prices are non-stationary in levels, but stationary in first differences. However, when this period is split, it is remarkable that during 2004-2009, first differences are non-stationary and additionally, real stock prices are stationary during 2009-2016. Accordingly, after and during the implementation

of QE, there is still no indication of speculative bubbles, since the first differences of the real stock prices are stationary. This cannot be said about the period prior to the start of QE, as the first differences are non-stationary. So, this could be an indication of a speculative bubble before the start of QE. However, this finding does not necessarily mean that during 2004-2009 there is a speculative bubble, as it was already mentioned before that the test for a rational bubble only functions to confirm the absence of a bubble. If this cannot be confirmed, this does not necessarily mean that there is a rational bubble (Diba & Grossman, 1988, p. 520). Based on these findings, the main result is that there does not appear to be a rational bubble during the period that QE is applied.

When the test for cointegration is consulted, the same conclusion is applicable as with respect to the first differences of real prices, and therefore there is again no indication of a speculative bubble during the period that QE is applied.

When the Eurozone is considered, the conclusion can be drawn that in all five periods that are considered (since periods are considered five year before the start of the first Asset Purchase Programme as well as five year before the start of QE), real prices are non-stationary, whereas their first differences are stationary (based on a 1%-level of significance).

The test for cointegration between real prices and real dividends for the EMU clearly shows that during 2009-2016, after the start of the first asset purchase programme, there is no indication of a speculative bubble, as the residuals of real prices and real differences are stationary in first differences, based on a significance-level of 1%.

Table 13: Unit Root tests that regard the stationarity of real stock prices (middle columns) and of residuals of real stock prices and real dividends (most right column)

| Country | Variable | Period | With time trend | Without time trend | Variable | Without time trend |
|----------------|-------------------|-----------|-----------------|--------------------|-------------------|--------------------|
| United States | Real Stock Price | 2003-2016 | -1.480 | -0.928 | Residuals | -2.45 |
| | First Differences | | -12.065*** | -12.081*** | First Differences | -11.864** |
| | Real Stock Price | 2003-2008 | 0.186 | -1.233 | Residuals | -0.11 |
| | First Differences | | -6.769*** | -6.376*** | First Differences | -6.696** |
| Japan | Real Stock Price | 2008-2016 | -2.478 | -1.252 | Residuals | -3.509* |
| | First Differences | | -7.974*** | -7.995*** | First Difference | -10.508** |
| | Real Stock Price | 1996-2016 | -2.275 | -2.347 | Residuals | -2.57 |
| | First Differences | | -9.190*** | -9.188*** | First Differences | -5.194** |
| | Real Stock Price | 1996-2001 | -1.550 | -1.447 | Residuals | -1.98 |
| | First Differences | | -7.256*** | -7.319*** | First Differences | -7.461** |
| United Kingdom | Real Stock Price | 2001-2016 | -1.883 | -1.857 | Residuals | -2.18 |
| | First Differences | | -8.161*** | -8.147*** | First Differences | -8.093** |
| | Real Stock Price | 2004-2016 | -2.114 | -2.137 | Residuals | -2.77 |
| | First Differences | | -11.731*** | -11.751*** | First Differences | -12.002** |
| Eurozone | Real Stock Price | 2004-2009 | 2.004 | -1.156 | Residuals | -0.80 |
| | First Differences | | -2.695 | -1.066 | First Differences | -1.07 |
| | Real Stock Price | 2009-2016 | -3.457** | -3.499*** | Residuals | -3.974** |
| | First Differences | | -9.949*** | -9.745*** | First Differences | -9.396** |
| | Real Stock Price | 2004-2016 | -2.704 | -2.212 | Residuals | -2.52 |
| | First Differences | | -7.639*** | -7.617*** | First Differences | -7.189** |
| | Real Stock Price | 2004-2009 | -2.062 | -1.881 | Residuals | -2.09 |
| | First Differences | | -4.898*** | -4.504*** | First Differences | -4.313** |
| | Real Stock Price | 2009-2016 | -2.161 | -2.159 | Residuals | -2.13 |
| | First Differences | | -9.323*** | -9.266*** | First Differences | -9.270** |
| | Real Stock Price | 2010-2015 | -2.087 | -1.781 | Residuals | -1.46 |
| | First Differences | | -7.894*** | -7.938*** | First Differences | -7.619** |
| | Real Stock Price | 2015-2016 | -3.301 | -0.654 | Residuals | 0.14 |
| | First Differences | | -3.694** | -3.733*** | First Differences | -3.395** |

* = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$

4.3 Overall result

From the analysis of the United States, Japan, the United Kingdom and the Eurozone, it can be concluded that there seems to be no positive relation between QE and bubbles in financial markets. This is the case for intrinsic bubbles as well as speculative bubbles. Based on the intrinsic bubble analysis, there even seems to be some weak evidence for a negative relation. This result could possibly be explained by means of the paper of Galí (2014). He shows that raising interest rates does not necessarily decrease bubbles and could even increase them. So, lower interest rates as an effect of QE (due to lower risk and term premia) could in line with this argument contribute to decreasing rational bubbles, as in bubble models it is generally assumed that the 'bubble component' must grow at the rate of interest. Hence, a decreasing rate of interest results in a smaller 'bubble component' in asset prices. Furthermore, Galí and Gambetti (2015) provide evidence of their baseline model that in periods with contractionary monetary policy, stock prices increase, which is also at odds with the conventional view. Again, this reasoning can be used the other way around in order to link decreasing stock prices (and probably a decreasing bubble component) to expansionary monetary policy such as QE. Furthermore, this effect could be due to the 'outlook-effect', which was mentioned by Joyce et al. (2011) as QE might provide investors with information about the outlook for the economy that is worse than expected.

5. Discussion and conclusion

Discussion

This thesis tested the relation between quantitative easing and bubbles in the stock markets, based on an intrinsic bubble analysis as well as a speculative bubble analysis. However, there are clearly some important limitations and these will be considered next.

A major limitation regards the fact that the significance and magnitude of the coefficients and relations, depends on the period in which the regression is run and in which the parameters are estimated. Nevertheless, only in the Eurozone does this lead to differences in results between periods, as in three out of the four periods that are considered, there is no significant positive relation between QE and intrinsic bubbles, whereas there is only one during the period 2010-2016. Further research could substantiate this analysis, by providing a model in which there is less (or even no) dependency on the period in which the parameters are estimated. Also, in Japan, κ (the constant in the regression) is calculated to be negative in the period of the 'Lost Decade'. It can be questioned to what extent the model of Froot and Obstfeld (1991) is applicable in an accurate way during these kind of periods. An interesting addition to this study would consist of a more dynamic analysis, as is for example applied by Galí and Gambetti (2015). They analyse the response of stock prices to monetary policy shocks in general by making use of a time-varying coefficients VAR. As interest rates have a different impact on the fundamental component of the stock price compared to the bubble component, the overall effect might change over time. The possibility of a changing effect over time is not really captured in this thesis. Applying a similar model as Galí and Gambetti (2015) to quantitative easing could provide additional results to the effect of QE on bubbles in financial markets.

Furthermore, it can be questioned to what extent the effects of QE on bubbles in financial markets, especially in the Eurozone, can already be measured, as the QE programme of the ECB only started a little over a year ago. In general, it is not clear to what extent QE directly results in effects on the stock market or whether this happens with some delay. In addition, research that considers the international spillovers of QE policy by central banks is interesting, in order to measure whether QE in for example the Eurozone, contributes to bubbles in other financial markets.

Also, considering more advanced models that for example apply Monte Carlo simulations or regime-switches and allow for periodically collapsing bubbles, are interesting topics for research. Besides, a different kind of model could consist of testing for the effect of communication by central banks on stock prices and bubbles, instead of only taking the quantitative data as is done in this study. This is more related to the efficient market hypothesis by Fama (1970). Analysing the effects

of communication about QE is for example already done by Gagnon, Raskin, Remache and Sack (2011) and Meier (2009). An extension to bubbles will be an interesting addition.

Finally, this thesis only considered bubbles in stock markets. However, in the introduction it already became clear that the concerns of for example Jens Weidmann regarded bubbles in the real estate market as an effect of QE. Therefore, research to the effect of QE on bubbles in real estate markets is needed in order to provide a broader view of the effects of QE on bubbles in general.

Based on the abovementioned, there seems to be a notable amount of limitations to this thesis. This is partially due to the fact that this is the first study that links QE to bubbles in stock markets, and therefore is explorative and provides reasons for further research. Research in this field is important, as in the introduction it was already shown that it is a topic of debate and it even leads presidents of local European central banks to oppose the QE policy. More importantly, if QE really leads to bubbles, this is a risky situation for an economy, because of the possibility of sharp corrections. Given these limitations, this thesis finds that there is currently no evidence that QE leads to bubbles in stock markets. However, more research in this field is needed.

Conclusion

This study examined the relation between quantitative easing and bubbles in the stock markets of the United States, the Eurozone, the United Kingdom and Japan. Since the president of the DNB, Klaas Knot, among others claims that the policy of QE will result in bubbles in financial markets, it is interesting to see whether this claim could be substantiated by research. However, existing research did not particularly include the effects of QE on bubbles and only very recently, Galí (2014) and Galí and Gambetti (2015) considered the effect of monetary policy in general on stock market bubbles. This led to the formulation of the research question: *Does quantitative easing have an effect on bubbles in stock markets?*

In order to answer this question, a distinction is made between intrinsic bubbles and speculative bubbles, as this distinction is found in existing literature. As for every bubble interpretation, there is another paper that questions this interpretation (Gürkaynak, 2008), combining methodologies and different types of bubbles makes the analysis more robust.

By testing for intrinsic bubbles as well as speculative bubbles and especially accounting for the effects of quantitative easing, this study aimed at estimating the effects of QE on bubbles. This results in the conclusion, that in general there is no indication that quantitative easing is significantly positively related to bubbles in the stock markets of the United States, the Eurozone, the United Kingdom and Japan. A small indication is only provided in the period 2010-2016 in the

Eurozone, in which there are some significant, though relatively small, positive significant coefficients that regard the interaction of the intrinsic bubble component and the relevant variables of QE. Furthermore, the test for speculative bubbles also does not provide any indication of the presence of a bubble after QE started in the several regions. Even though on the basis of the speculative bubble test only the absence of speculative bubbles can be confirmed and not the presence, in all cases the absence of a speculative bubble can be confirmed after QE started.

Based on the results, there is currently no evidence of excessively risky behaviour of investors (at least not with regard to bubbles) and furthermore this thesis does not provide evidence that there will be a sharp correction soon, as there is no indication of a bubble, which is clearly an advantageous situation compared to the risk of a sharp correction, as described in the introduction.

In conclusion, the results of this thesis bring into doubt whether the claims of the president of the DNB, could be substantiated, as generally speaking, there is no indication that QE contributes significantly to a bubble in stock markets. This is a relevant result for policymakers at for example central banks like the European Central Bank, as the critics of quantitative easing that are afraid of bubbles, do not have any evidence for this claim. As Mario Draghi already noted (FT, 2015), policymakers do not see evidence of a potential financial bubble, and based on this study, he seems to be right. However, since asset price bubbles can lead to sharp corrections, the situation should be monitored and measures can be taken if necessary. Hopefully this study contributes to an interesting debate and additional research in the field of 'QE and bubbles'.

References

- Abreu, D., & Brunnermeier, M. (2003). Bubbles and Crashes. *Econometrica*, 71(1), 173-204.
- Aliber, R., & Kindleberger, C. (2015). *Manias, Panics and Crashes* (7th ed.). UK: Hampshire, US: New York: Palgrave Macmillan.
- Allen, F., & Gale, D. (1999). Bubbles, Crises, and Policy. *Oxford Review of Economic Policy*, 15(3), 9-18.
- Allen, F., & Gale, D. (2000). Bubbles and Crises. *The Economic Journal*, 110, 236-255.
- Aoki, R. (2012). A Demographic Perspective on Japan's "Lost Decades". *Population and Development Review*, 38, 103-112.
- Bank of England. (2016). *Inflation Report May 2016*. Bank of England.
- Bank of Japan. (n.d.). *BOJ Time-Series Data Search*. Retrieved April 12, 2016, from Bank of Japan: http://www.stat-search.boj.or.jp/index_en.html#
- Benford, J., Berry, S., Nikolov, K., Young, C., & Robson, M. (2009 Q2). Quantitative easing. *Bank of England Quarterly Bulletin*, 90-100.
- Bernanke, B., & Kuttner, K. (2005). What Explains the Stock Market's Reaction to Federal Reserve Policy? *The Journal of Finance*, 60(3), 1221-1257.
- Bernanke, B., Reinhart, V., & Sack, B. (2004). Monetary Policy Alternatives at the Zero Bound: An Empirical Assessment. *Brookings Papers on Economic Activity*, 2, 1-100.
- Blanchard, O. (1979). Speculative Bubbles, Crashes and Rational Expectations. *Economics Letters*, 3, 387-389.
- Blanchard, O. (2009). *Macroeconomics* (5th ed.). London: Pearson Education.
- Blanchard, O., & Watson, M. (1982). Bubbles, Rational Expectations and Financial Markets. *NBER Working Paper*(945), 1-28.
- Blinder, A. (2010). Quantitative Easing: Entrance and Exit Strategies. *Federal Reserve Bank of St. Louis Review*, 92(6), 465-479.
- Board of Governors of the Federal Reserve System. (2012, September 13). *Monetary Policy Press Release*. Retrieved from The Federal Reserve: <https://www.federalreserve.gov/newsevents/press/monetary/20120913a.htm>
- Board of Governors of the Federal Reserve System. (2014, October 29). *Federal Reserve Issues FOMC Statement*. Retrieved March 14, 2016, from The Federal Reserve: <https://www.federalreserve.gov/newsevents/press/monetary/20141029a.htm>
- Borio, C., & Disyatat, P. (2010). Unconventional Monetary Policies: An Appraisal. *The Manchester School*, 78, 53-89.
- Borio, C., & Lowe, P. (2002). Asset prices, financial and monetary stability: exploring the nexus. *BIS Working Papers*(114), 1-39.

- Bredin, D., Hyde, S., Nitzsche, D., & O'Reilly, G. (2007). UK Stock Returns and the Impact of Domestic Monetary Policy Shocks. *Journal of Business Finance & Accounting*, 34,35(5,6(resp.)), 872-888.
- Buell, T. (2015, March 25). *Germany's Weidmann Warns of Overvalued Urban Housing*. Retrieved January 13, 2016, from The Wall Street Journal: <http://www.wsj.com/articles/germanys-weidmann-warns-of-overvalued-urban-housing-1427310549>
- Burnham, K., & Anderson, D. (2002). *Model Selection and Multimodel Inference* (2nd ed.). New York: Springer.
- Cecchetti, S., Genberg, H., & Wadhvani, S. (2002). Asset Prices in a Flexible Inflation Targeting Framework. *NBER Working Paper Series*(8970), 1-22.
- Chen, A.-S., Cheng, L.-Y., & Cheng, K.-F. (2009). Intrinsic bubbles and Granger causality in the S&P 500: Evidence from long-term data. *Journal of Banking and Finance*, 33, 2275-2281.
- Christensen, J., & Rudebusch, G. (2012). The Response of Interest Rates to US and UK Quantitative Easing. *The Economic Journal*, 122, F385-F414.
- Craine, R. (1993). Rational bubbles. A test. *Journal of Economic Dynamics and Control*, 17, 829-846.
- Damodaran, A. (2008). *What is the riskfree rate? A Search for the Basic Building Block*. New York University, Stern School of Business, New York.
- Datastream International. (2016, April).
- De Long, J., Shleifer, A., Summers, L., & Waldmann, R. (1990). Positive Feedback Investment Strategies and Destabilizing Rational Speculation. *The Journal of Finance*, 45(2), 379-395.
- De Nederlandsche Bank. (2014). *Overview of Financial Stability, Autumn 2014*. Amsterdam: De Nederlandsche Bank.
- DePamphilis, D. (2015). *Mergers, Acquisitions and Other Restructuring Activities* (8th ed.). Oxford: Academic Press.
- Diba, B., & Grossman, H. (1984). Rational Bubbles in the Price of Gold. *NBER Working Paper*(1300).
- Diba, B., & Grossman, H. (1988). Explosive Rational Bubbles in Stock Prices? *The American Economic Review*, 78(3), 520-530.
- Driffill, J., & Sola, M. (1998). Intrinsic bubbles and regime-switching. *Journal of Monetary Economics*, 42, 357-373.
- Ehrmann, M., & Fratzscher, M. (2004). Taking Stock: Monetary Policy Transmission to Equity Markets. *Journal of Money, Credit, and Banking*, 36(4), 719-737.
- European Central Bank. (2015, January 22). *ECB announces expanded asset purchase programme*. Retrieved March 5, 2016, from European Central Bank: https://www.ecb.europa.eu/press/pr/date/2015/html/pr150122_1.en.html
- European Central Bank. (2016, March 10). *ECB adds corporate sector purchase programme (CSPP) to the asset purchase programme (APP) and announces changes to APP*. Retrieved April

- 14, 2016, from European Central Bank:
https://www.ecb.europa.eu/press/pr/date/2016/html/pr160310_2.en.html
- European Central Bank. (n.d.a.). *Benefits of price stability*. Retrieved March 5, 2016, from European Central Bank:
<https://www.ecb.europa.eu/mopo/intro/benefits/html/index.en.html>
- European Central Bank. (n.d.b.). *Minimum reserves and liquidity*. Retrieved April 15, 2016, from European Central Bank:
<https://www.ecb.europa.eu/stats/monetary/res/html/index.en.html>
- European Central Bank. (n.d.c.). *Monetary Policy*. Retrieved May 18, 2016, from European Central Bank: <https://www.ecb.europa.eu/mopo/html/index.en.html>
- European Central Bank. (n.d.d.). *Objective of monetary policy*. Retrieved March 5, 2016, from European Central Bank:
<https://www.ecb.europa.eu/mopo/intro/objective/html/index.en.html>
- Evans, G. (1991). Pitfalls in Testing for Explosive Bubbles in Asset Prices. *The American Economic Review*, 81(4), 922-930.
- Fama, E. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *The Journal of Finance*, 25(2), 383-417.
- Fama, E., & French, K. (1989). Business conditions and expected returns on stocks and bonds. *Journal of Financial Economics*, 25, 23-49.
- Fawley, B., & Neely, C. (2013). Four Stories of Quantitative Easing. *Federal Reserve Bank of St. Louis Review*, 95(1), 51-88.
- Flood, R., & Garber, P. (1980). Market Fundamentals versus Price-Level Bubbles: The First Tests. *Journal of Political Economy*, 88(4), 745-770.
- Flood, R., & Hodrick, R. (1990). On Testing for Speculative Bubbles. *The Journal of Economic Perspectives*, 4(2), 85-101.
- Fratzscher, M., Lo Duca, M., & Straub, R. (2013). On the International Spillovers of US Quantitative Easing. *European Central Bank Working Paper Series*(1557).
- Froot, K., & Obstfeld, M. (1991). Intrinsic Bubbles: The Case of Stock Prices. *The American Economic Review*, 81(5), 1189-1214.
- Froot, K., Scharfstein, D., & Stein, J. (1992). Herd on the Street: Informational Inefficiencies in a Market with Short-Term Speculation. *The Journal of Finance*, 47(4), 1461-1484.
- FT. (2015, April 15). *ECB's Draghi says no evidence of QE bubbles*. Retrieved March 6, 2016, from Financial Times: <http://www.ft.com/fastft/2015/04/15/ecbs-draghi-says-bond-shortage-fears-exaggerated/>
- Gagnon, J., Raskin, M., Remache, J., & Sack, B. (2011). The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases. *International Journal of Central Banking*, 7(1), 3-43.
- Galí, J. (2014). Monetary Policy and Rational Asset Price Bubbles. *The American Economic Review*, 104(3), 721-752.

- Galí, J., & Gambetti, L. (2015). The Effects of Monetary Policy on Stock Market Bubbles: Some Evidence. *American Economic Journal: Macroeconomics*, 7(1), 233-257.
- Gambacorta, L., Hofmann, B., & Peersman, G. (2014). The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis. *Journal of Money, Credit and Banking*, 46(4), 615-642.
- Gromb, D., & Vayanos, D. (2002). Equilibrium and welfare in markets with financially constrained arbitrageurs. *Journal of Financial Economics*, 66, 361-407.
- Gürkaynak, R. (2008). Econometric Tests of Asset Price Bubbles: Taking Stock. *Journal of Economic Surveys*, 22(1), 166-186.
- Hamilton, J., & Whiteman, C. (1985). On Testing for Self-Fulfilling Speculative Price Bubbles. *Journal of Monetary Economics*, 16, 353-373.
- Hayashi, F., & Prescott, E. (2002). The 1990s in Japan: A Lost Decade. *Review of Economic Dynamics*, 5, 206-235.
- Hill, R., Griffiths, W., & Lim, G. (2012). *Principles of Econometrics*. Hoboken: John Wiley & Sons.
- Jensen, G., & Johnson, R. (1995). Discount rate changes and security returns in the U.S., 1962-1991. *Journal of Banking and Finance*, 19, 79-95.
- Jensen, G., & Mercer, J. (2002). Monetary Policy and the Cross-Section of Expected Stock Returns. *The Journal of Financial Research*, 25(2), 125-139.
- Jensen, G., Mercer, J., & Johnson, R. (1996). Business Conditions, monetary policy, and expected security returns. *Journal of Financial Economics*, 40, 213-237.
- Joyce, M., Lasasosa, A., Stevens, I., & Tong, M. (2011). The Financial Market Impact of Quantitative Easing in the United Kingdom. *International Journal of Central Banking*, 7(3), 113-161.
- Joyce, M., Miles, D., Scott, A., & Vayanos, D. (2012). Quantitative Easing and Unconventional Monetary Policy - An Introduction. *The Economic Journal*, 122, F271-F288.
- Joyce, M., Tong, M., & Woods, R. (2011, Q3). The United Kingdom's quantitative easing policy: design, operation and impact. *Bank of England Quarterly Bulletin*, 200-212.
- Kam, J. (2006). No Pain, No Gain: Rethinking the Telecoms Crash. *Technology Analysis & Strategic Management*, 18(5), 497-514.
- Kawa, L. (2016, April 6). *Japan is Fast Approaching the Quantitative Limits of Quantitative Easing*. Retrieved May 24, 2016, from Bloomberg:
<http://www.bloomberg.com/news/articles/2016-04-06/japan-is-fast-approaching-the-quantitative-limits-of-quantitative-easing>
- Kole, L., & Martin, R. (2008, December 5). *Overview of Japan's Monetary Policy Responses to Deflation*. Retrieved from Federal Reserve:
<http://www.federalreserve.gov/monetarypolicy/files/FOMC20081212memo03.pdf>
- Krishnamurthy, A., & Vissing-Jorgensen, A. (2011). The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy. *Brookings Papers on Economic Activity*, 215-265.

- Krugman, P. (1987). Trigger Strategies and Price Dynamics in Equity and Foreign Exchange Markets. *NBER Working Paper Series*(2459).
- Krugman, P. (1998). It's Baaack: Japan's Slump and the Return of the Liquidity Trap. *Brookings Papers on Economic Activity*, 1998(2), 137-205.
- Kurihara, Y. (2006). The Relationship between Exchange Rate and Stock Prices during the Quantitative Easing Policy in Japan. *International Journal of Business*, 11(4), 375-386.
- Ma, Y., & Kanas, A. (2004). Intrinsic Bubbles Revisited: Evidence from Nonlinear Cointegration and Forecasting. *Journal of Forecasting*, 23, 237-250.
- Meier, A. (2009). Panacea, Curse, or Nonevent? Unconventional Monetary Policy in the United Kingdom. *IMF Working Paper*(09/163), 1-47.
- Miller, R., Kennedy, S., & Jamrisko, M. (2013, November 13). *Central Banks Risk Asset Bubbles in Battle With Deflation*. Retrieved 03 30, 2016, from Bloomberg: <http://www.bloomberg.com/news/articles/2013-11-13/central-banks-risk-asset-bubbles-in-battle-with-deflation-danger>
- Mortimer-Lee, P. (2012). The effects and risks of quantitative easing. *Journal of Risk Management in Financial Institutions*, 5(4), 372-389.
- Naoui, K. (2011). Intrinsic Bubbles in the American Stock Exchange: The case of the S&P 500 Index. *International Journal of Economics and Finance*, 3(1), 124-132.
- Pan, M.-S. (2010). Autocorrelation, returns horizons and momentum in stock returns. *Journal of Economics and Finance*, 34, 284-300.
- Patelis, A. (1997). Stock Return Predictability and The Role of Monetary Policy. *The Journal of Finance*, 52(5), 1951-1972.
- Pattipeilohy, C., End, J. v., Tabbae, M., Frost, J., & De Haan, J. (2013, May). Unconventional monetary policy of the ECB during the financial crisis: An assessment and new evidence. *DNB Working Paper*(381).
- Phillips, P., Wu, Y., & Yu, W. (2011). Explosive Behavior in the 1990s NASDAQ: when did exuberance escalate asset values? *International Economic Review*, 52(1), 201-226.
- Reinhart, C., & Rogoff, K. (2009). *This Time is Different: Eight Centuries of Financial Folly* (1st ed.). Princeton, NJ: Princeton University Press.
- Rigobon, R., & Sack, B. (2003). Measuring the reaction of monetary policy to the stock market. *The Quarterly Journal of Economics*, 118(2), 639-669.
- Rigobon, R., & Sack, B. (2004). The impact of monetary policy on asset prices. *Journal of Monetary Economics*, 51, 1553-1575.
- Rosa, C. (2012). How "Unconventional" Are Large-Scale Asset Purchases? The Impact of Monetary Policy on Asset Prices. *Federal Reserve Bank of New York Staff Reports*(560), 1-31.
- Roubini, N. (2006). Why Central Banks Should Burst Bubbles. *International Finance*, 9(1), 87-107.
- Ruhe, C. (2014, October 7). *ECB Stimulus Raises Risk of Bubbles, Dutch Central Bank Says*. Retrieved January 14, 2016, from Bloomberg:

- <http://www.bloomberg.com/news/articles/2014-10-07/ecb-stimulus-raises-risk-of-bubbles-dutch-central-bank-says>
- Sarno, L., & Taylor, M. (1999). Moral hazard, asset price bubbles, capital flows, and the East Asian crisis: the first tests. *Journal of International Money and Finance*, 18, 637-657.
- Scherbina, A., & Schlusche, B. (2014). Asset price bubbles: a survey. *Quantitative Finance*, 14(4), 589-604.
- Shiller, R. (1984). Stock Prices and Social Dynamics. *Brookings Papers on Economic Activity*, 2, 457-498.
- Shiller, R. (2013, July 19). *Speculative bubbles don't just pop - they may deflate and reflate*. Retrieved March 13, 2016, from The Guardian: <http://www.theguardian.com/business/economics-blog/2013/jul/19/speculative-bubbles-property-stocks-bonds>
- Shiller, R. (n.d.). *Online Data Robert Shiller*. Retrieved 04 26, 2015, from Home Page of Robert J. Shiller: <http://www.econ.yale.edu/~shiller/data.htm>
- Shleifer, A., & Vishny, R. (1997). The Limits of Arbitrage. *The Journal of Finance*, 52(1), 35-55.
- Steeley, J. (2015). The side effects of quantitative easing: Evidence from the UK bond market. *Journal of International Money and Finance*, 51, 303-336.
- Sudo, N., Ueda, K., & Watanabe, K. (2014). Micro Price Dynamics during Japan's Lost Decades. *Asian Economic Policy Review*, 9, 44-64.
- Summers, L. (1986). Does the Stock Market Rationally Reflect Fundamental Values? *The Journal of Finance*, 41(3), 591-601.
- Taylor, J. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy*, 39, 195-214.
- Ten Bosch, G. (2016, July 20). *Tekort aan obligaties dreigt voor ECB*. Retrieved July 20, 2016, from Het Financieele Dagblad: <http://fd.nl/beurs/1160288/tekort-aan-obligaties-dreigt-voor-ecb>
- Ten Bosch, G., & De Boer, M. (2016, March 5). *Ziet ECB het goed of verkeerd? Economen zijn verdeeld*. Retrieved March 5, 2016, from Het Financieele Dagblad: <http://fd.nl/economie-politiek/1142171/ziet-ecb-het-goed-of-verkeerd-economen-zijn-verdeeld>
- Thomson Reuters. (2016, May). *Global Equity Indices*. Retrieved from Thomson Reutes Financial & Risk: <http://financial.thomsonreuters.com/en/products/data-analytics/market-data/indices/global-equity-index.html>
- Thorbecke, W. (1997). On Stock Market Returns and Monetary Policy. *The Journal of Finance*, 52(2), 635-654.
- Tirole, J. (1982). On the Possibility of Speculation under Rational Expectations. *Econometrica*, 50(5), 1163-1181.
- Tirole, J. (1985). Asset Bubbles and Overlapping Generations. *Econometrica*, 53(5), 1071-1100.
- Ueda, K. (2012). The Effectiveness of Non-Traditional Monetary Policy Measures: The case of the Bank of Japan. *The Japanese Economic Review*, 63(1), 1-22.

- Vissing-Jorgensen, A. (2004). Perspectives on Behavioral Finance: Does "Irrationality" Disappear with Wealth? Evidence from Expectations and Actions. In M. Gertler, & K. Rogoff, *NBER Macroeconomics Annual 2003* (18 ed., pp. 139-208). Cambridge MA: The MIT Press.
- Wang, Y.-C., Wang, C.-W., & Huang, C.-H. (2015). The impact of unconventional monetary policy on the tail risks of stock markets between US and Japan. *International Review of Financial Analysis*, 41, 41-51.
- White, W. (2006). Is price stability enough? *BIS Working Papers*(205), 1-18.
- White, W. (2009). Should Monetary Policy "Lean or Clean"? *Federal Reserve Bank of Dallas Working Papers*(34), 1-24.
- Xiong, W. (2001). Convergence trading with wealth effects: an amplification mechanism in financial markets. *Journal of Financial Economics*, 62, 247-292.

Appendices

Appendix A: tested equations with regard to stationarity

The test equation/estimated regression, is

$$\Delta y_t = \alpha + \gamma y_{t-1} + \sum_{s=1}^m a_s \Delta y_{t-s} + v_t \quad (\text{A1})$$

where $\Delta y_{t-1} = (y_{t-1} - y_{t-2})$, $\Delta y_{t-2} = (y_{t-2} - y_{t-3})$

(Hill, Griffiths, & Lim, 2012, p. 485) (Diba & Grossman, 1988, p. 523)

Furthermore, if equation (18) and (19) are combined, this results in:

$$P_t - \alpha r^{-1} d_t = B_t + \alpha r^{-1} \left[\sum_{j=1}^{\infty} (1+r)^{1-j} E_t \Delta d_{t+j} \right] + \sum_{j=1}^{\infty} (1+r)^{-j} E_t u_{t+j} \quad (\text{A2})$$

(Diba & Grossman, 1988, p. 524)

The applicable equation for testing stationarity of residuals, is the equation

$$\Delta \hat{e}_t = \gamma \hat{e}_{t-1} + v_t \quad (\text{A3})$$

where $\Delta \hat{e}_t = \hat{e}_t - \hat{e}_{t-1}$

(Hill et al., 2012, p. 489)

Appendix B: Critical Values for the Dickey-Fuller tests

B1: Critical Values for the Dickey-Fuller Test

| Critical Values for the Dickey-Fuller Test | | | |
|--|-------|-------|-------|
| Model | 1% | 5% | 10% |
| $\Delta y_t = \gamma y_{t-1} + v_t$ | -2.56 | -1.94 | -1.62 |
| $\Delta y_t = \alpha + \gamma y_{t-1} + v_t$ | -3.43 | -2.86 | -2.57 |
| $\Delta y_t = \alpha + \lambda t + \gamma y_{t-1} + v_t$ | -3.96 | -3.41 | -3.13 |

(Hill et al., 2012, p. 486)

B2: Critical Values for the Cointegration Test

| Critical Values for the Cointegration Test | | | |
|--|-------|-------|-------|
| Model | 1% | 5% | 10% |
| $y_t = \beta x_t + e_t$ | -3.39 | -2.76 | -2.45 |
| $y_t = \beta_1 + \beta_2 x_t + e_t$ | -3.96 | -3.37 | -3.07 |
| $y_t = \beta_1 + \delta t + \beta_2 x_t + e_t$ | -3.98 | -3.42 | -3.13 |

(Hill et al., 2012, p. 489)

Appendix C: summary of the main variables**C1: United States since 1973**

| | Obs | Mean | Std. Dev. | Min | Max |
|--|-----|-----------|-----------|-----------|----------|
| LN Real Dividends | 518 | 2.907723 | 0.2830482 | 2.535384 | 3.706835 |
| LN Real Price/Real Dividends | 518 | 3.631995 | 0.4706003 | 2.734908 | 4.656464 |
| LN Real Dividends to the power Lambda -1 | 518 | 2.672243 | 0.2388908 | 2.356141 | 3.343185 |
| Interaction with dummy during QE | 518 | 0.4279186 | 1.050652 | 0 | 3.251625 |
| Interaction Div Assets | 159 | 6628660 | 4546842 | 1911766 | 1.50e+07 |
| Interaction Div Assets Minus Average | 89 | 7409860 | 3244383 | 3071469 | 1.22e+07 |
| Interaction with Delta Assets | 158 | 72219.66 | 229396.9 | -564631.8 | 2159308 |
| Real Price | 518 | 858.8625 | 529.2691 | 212.6824 | 1994.248 |
| Real Dividends | 518 | 19.13404 | 6.261841 | 12.62127 | 40.72471 |

C2: United States since 2003

| | Obs | Mean | Std. Dev. | Min | Max |
|--|-----|-----------|-----------|-----------|----------|
| LN Real Dividends | 149 | 3.281376 | 0.2060501 | 2.951692 | 3.706835 |
| LN Real Price/Real Dividends | 149 | 3.948136 | 0.1372871 | 3.417327 | 4.18646 |
| LN Real Dividends to the power Lambda -1 | 149 | 1.281978 | 0.0166733 | 1.254278 | 1.315533 |
| Interaction with dummy during QE | 149 | 0.6198852 | 0.6432881 | 0 | 1.307259 |
| Interaction Div Assets | 149 | 2915541 | 1787077 | 937950 | 6906578 |
| Interaction Div Assets Minus Average | 89 | 3674292 | 789170.1 | 2327774 | 5270162 |
| Interaction with Delta Assets | 149 | 83785.51 | 258952.8 | -620080.5 | 2372560 |
| Real Price | 149 | 1406.6 | 276.8045 | 728.4605 | 1994.248 |
| Real Dividends | 149 | 24.19819 | 5.899732 | 19.14 | 40.72 |

C3: Eurozone since 1990

| | Obs | Mean | Std. Dev. | Min | Max |
|--|-----|-----------|-----------|-----------|----------|
| LN Real Dividends | 315 | 3.671791 | 0.3683777 | 3.06778 | 4.501413 |
| LN Real Price/Real Dividends | 315 | 3.558412 | 0.2625566 | 2.650725 | 4.219908 |
| LN Real Dividends to the power Lambda -1 | 315 | 1.017158 | 0.0013303 | 1.014826 | 1.019948 |
| Interaction with dummy during purchases | 315 | 0.2618352 | 0.4457424 | 0 | 1.019299 |
| Interaction with dummy during QE | 315 | 0.0420042 | 0.2027752 | 0 | 1.017915 |
| Interaction Div Purchases | 315 | 46160.83 | 140980.6 | 0 | 995258.4 |
| Interaction Div QE | 315 | 14402.12 | 79694 | 0 | 654787.1 |
| Interaction with Delta Purchases | 315 | 3159.61 | 15363.65 | -9581.142 | 177410.4 |
| Interaction with Delta QE | 315 | 2078.45 | 10102.31 | 0 | 62767.54 |
| Real Price | 315 | 1459.205 | 486.3003 | 719.637 | 2845.156 |
| Real Dividends | 315 | 42.14014 | 16.22902 | 21.49413 | 90.14439 |

C4: Eurozone since 2004

| | Obs | Mean | Std. Dev. | Min | Max |
|--|-----|-----------|-----------|-----------|----------|
| LN Real Dividends | 141 | 4.032121 | 0.1865224 | 3.790071 | 4.501413 |
| LN Real Price/Real Dividends | 141 | 3.426439 | 0.2268435 | 2.650725 | 3.759302 |
| LN Real Dividends to the power Lambda -1 | 141 | 1.859827 | 0.0379158 | 1.809734 | 1.953763 |
| Interaction with dummy during purchases | 141 | 1.060737 | 0.9163447 | 0 | 1.912048 |
| Interaction with dummy during QE | 141 | 0.1676745 | 0.5280163 | 0 | 1.825983 |
| Interaction Div Purchases | 141 | 185403.4 | 351735.3 | 0 | 1785341 |
| Interaction Div QE | 141 | 57535.77 | 209137.9 | 0 | 1174587 |
| Interaction with Delta Purchases | 141 | 12670.72 | 40310.84 | -17399.67 | 322120.3 |
| Interaction with Delta QE | 141 | 8297.977 | 26322.98 | 0 | 112166.2 |
| Real Price | 141 | 1778.564 | 415.0867 | 1021.89 | 2845.156 |
| Real Dividends | 141 | 57.41503 | 11.59394 | 44.25953 | 90.14439 |

C5: Eurozone since 2010

| | Obs | Mean | Std. Dev. | Min | Max |
|--|-----|----------|-----------|----------|----------|
| LN Real Dividends | 73 | 3.939844 | 0.0747364 | 3.790071 | 4.114971 |
| LN Real Price/Real Dividends | 73 | 3.419439 | 0.1466165 | 3.094448 | 3.661264 |
| LN Real Dividends to the power Lambda -1 | 73 | 38.34026 | 1.93572 | 34.55902 | 43.00667 |
| Interaction with dummy during purchases | 73 | 38.34055 | 1.935339 | 34.56 | 43.01 |
| Interaction with dummy during QE | 73 | 6.337945 | 13.71225 | 0 | 36.45 |
| Interaction Div Purchases | 73 | 7131170 | 8312053 | 1799004 | 3.56e+07 |
| Interaction Div QE | 73 | 2183362 | 5533147 | 0 | 2.34e+07 |
| Interaction with Delta Purchases | 73 | 466929.8 | 1098984 | -369950 | 6842030 |
| Interaction with Delta QE | 73 | 313859.8 | 685065.2 | 0 | 2195918 |
| Real Price | 73 | 1582.588 | 191.3814 | 1110.672 | 1909.147 |
| Real Dividends | 73 | 51.55267 | 3.869068 | 44.25953 | 61.25046 |

C6: United Kingdom since 1988

| | Obs | Mean | Std. Dev. | Min | Max |
|--|-----|----------|-----------|----------|----------|
| LN Real Dividends | 339 | 4.933878 | 0.1373975 | 4.590059 | 5.308241 |
| LN Real Price/Real Dividends | 339 | 3.344874 | 0.2023327 | 2.783852 | 3.803169 |
| LN Real Dividends to the power Lambda -1 | 339 | 21.288 | 1.133067 | 18.52461 | 24.47275 |
| Interaction with dummy during QE | 339 | 5.512203 | 9.549212 | 0 | 23.18887 |
| Interaction Div Purchases | 339 | 60100.35 | 136785.8 | 0 | 585518.9 |
| Interaction with Delta Purchases | 339 | 1645.794 | 3047.576 | 0 | 8695.824 |
| Real Price | 339 | 4089.648 | 1063.503 | 2155.302 | 6211.336 |
| Real Dividends | 339 | 140.2226 | 19.17002 | 98.50021 | 201.9946 |

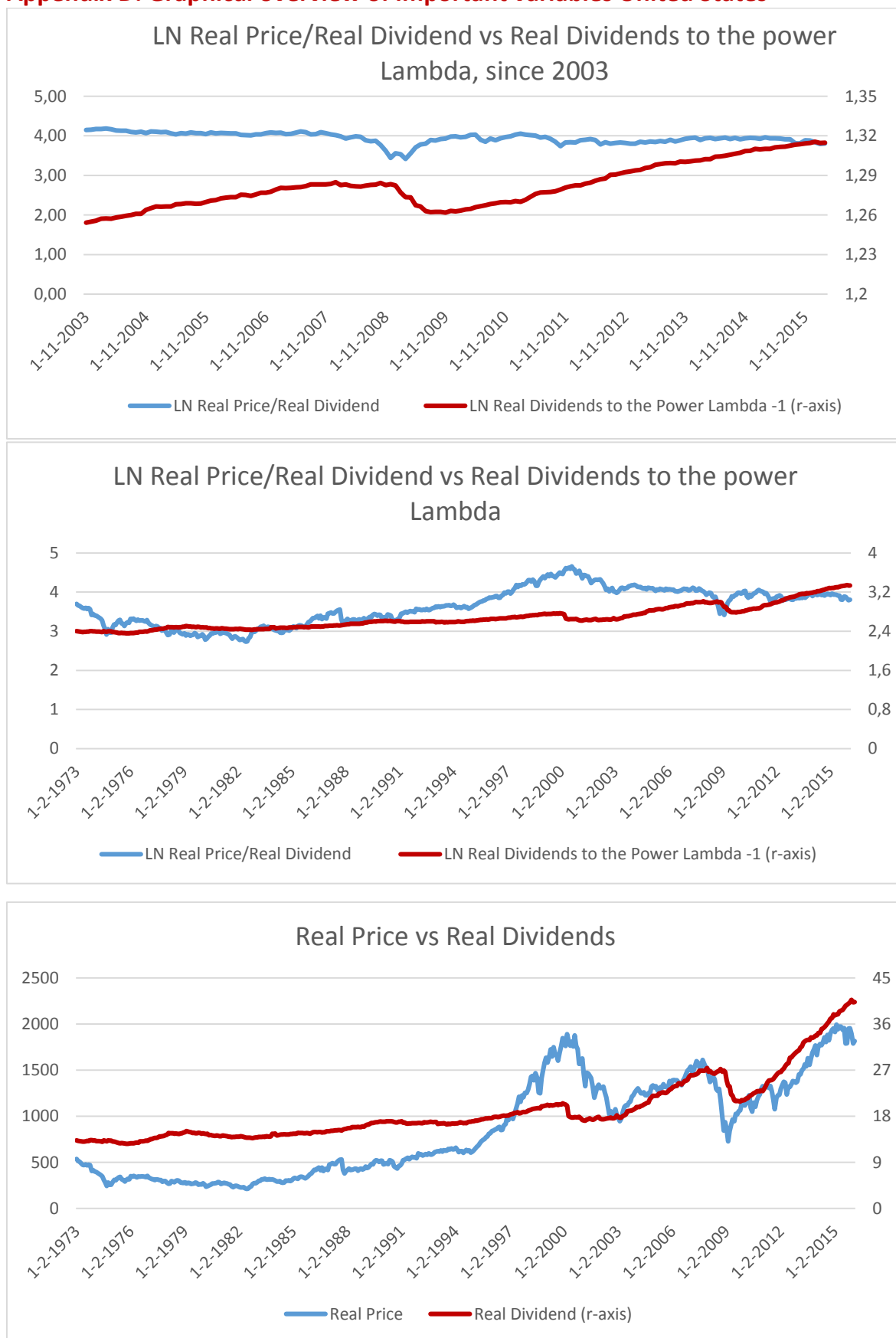
C7: United Kingdom since 2004

| | Obs | Mean | Std. Dev. | Min | Max |
|--|-----|----------|-----------|----------|----------|
| LN Real Dividends | 145 | 5.033606 | 0.1052323 | 4.831655 | 5.308241 |
| LN Real Price/Real Dividends | 145 | 3.400102 | 0.1417082 | 2.783852 | 3.58994 |
| LN Real Dividends to the power Lambda -1 | 145 | 12.35982 | 0.4018882 | 11.59484 | 13.42219 |
| Interaction with dummy during QE | 145 | 7.211295 | 6.084618 | 0 | 12.84744 |
| Interaction Div Purchases | 145 | 78397.09 | 100354.7 | 0 | 324397.8 |
| Interaction with Delta Purchases | 145 | 2151.069 | 2032.228 | 0 | 4817.789 |
| Real Price | 145 | 4634.523 | 558.9564 | 2941.207 | 5864.974 |
| Real Dividends | 145 | 154.3311 | 16.24815 | 125.4184 | 201.9946 |

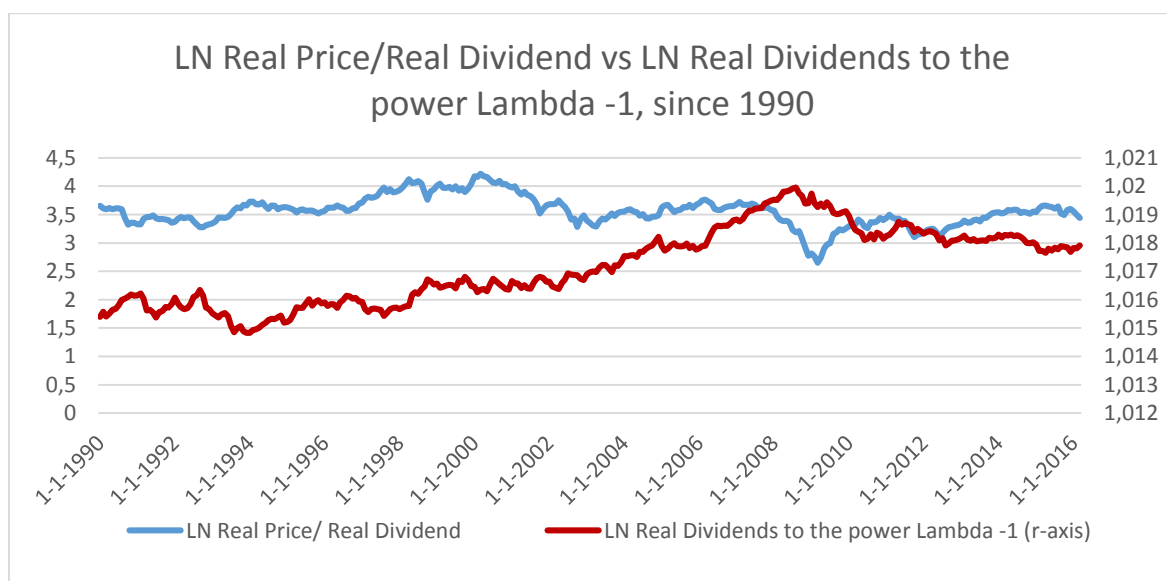
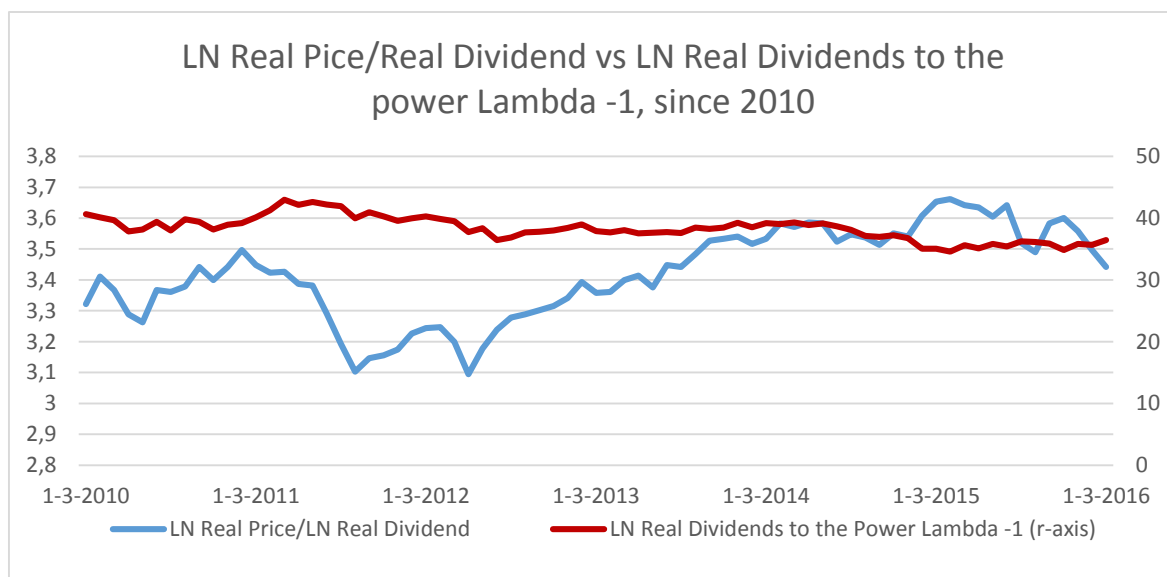
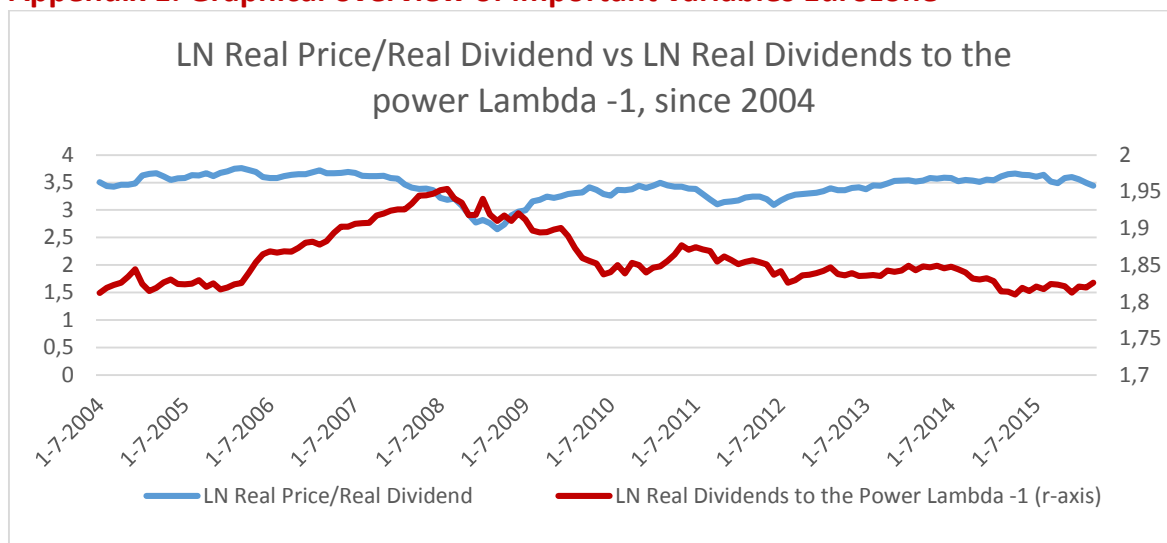
C8: Japan since 1973

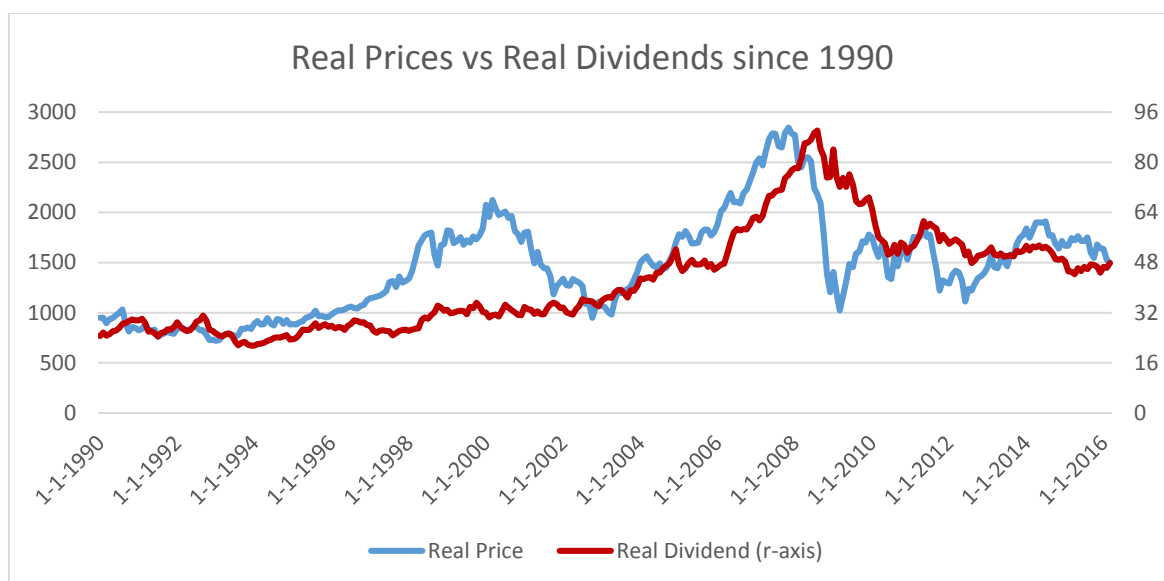
| | Obs | Mean | Std. Dev. | Min | Max |
|--|-----|-----------|-----------|-----------|----------|
| LN Real Dividends | 519 | 1.364037 | 0.2960669 | 1.00904 | 2.157559 |
| LN Real Price/Real Dividends | 519 | 4.417662 | 0.5050272 | 3.490029 | 5.44914 |
| LN Real Dividends to the power Lambda -1 | 519 | 1.032555 | 0.227756 | 1.000989 | 1.088115 |
| Interaction with dummy during QE | 519 | 0.3674181 | 0.5028332 | 0 | 1.09 |
| Interaction Div Current Account Balance | 519 | 199808.8 | 474161.4 | 0 | 2858455 |
| Interaction Div Curr Acc Minus Average | 181 | 490370.5 | 693483.5 | 11118.59 | 2821041 |
| Interaction with Delta Current Account | 419 | 6648.746 | 26954.83 | -101314.3 | 193792.1 |
| Real Price | 519 | 359.2447 | 159.0214 | 122.6008 | 854.2098 |
| Real Dividends | 519 | 4.106287 | 1.42015 | 2.742965 | 8.540001 |

Appendix D: Graphical overview of important variables United States

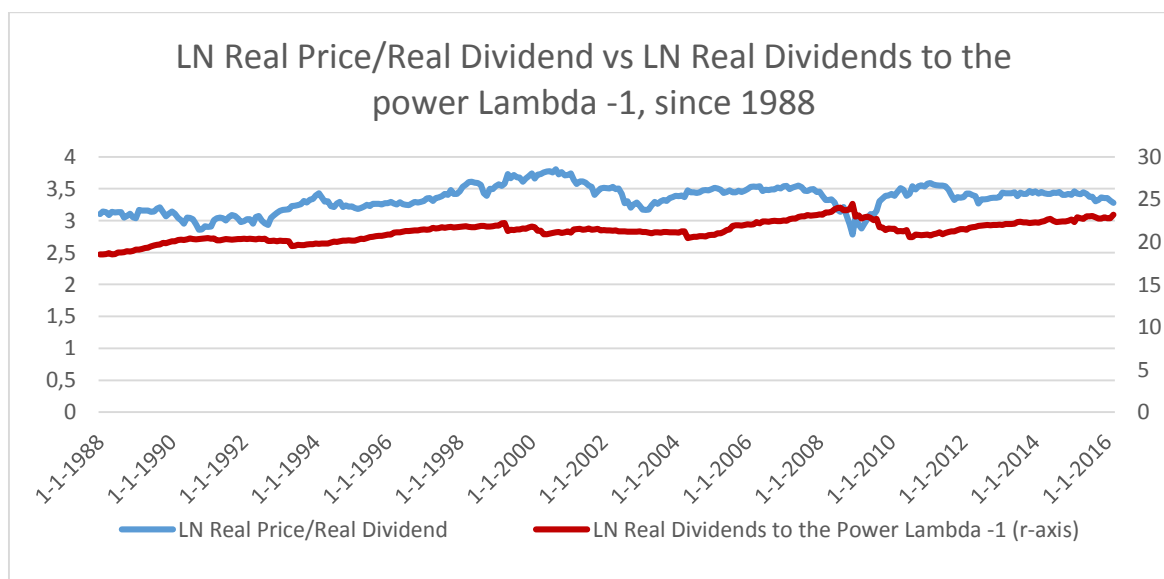
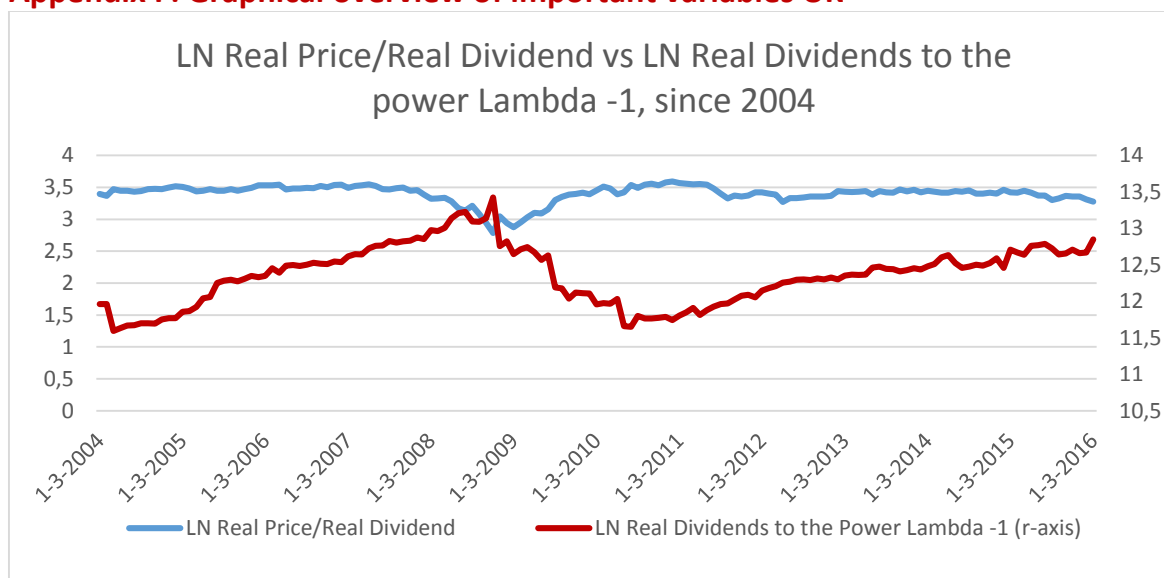


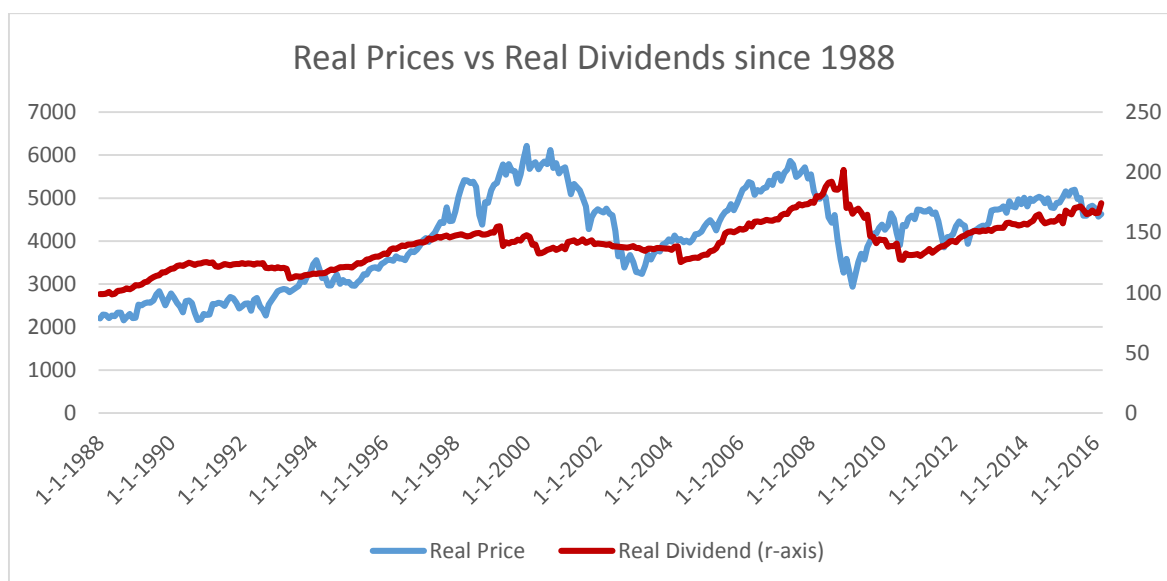
Appendix E: Graphical overview of important variables Eurozone



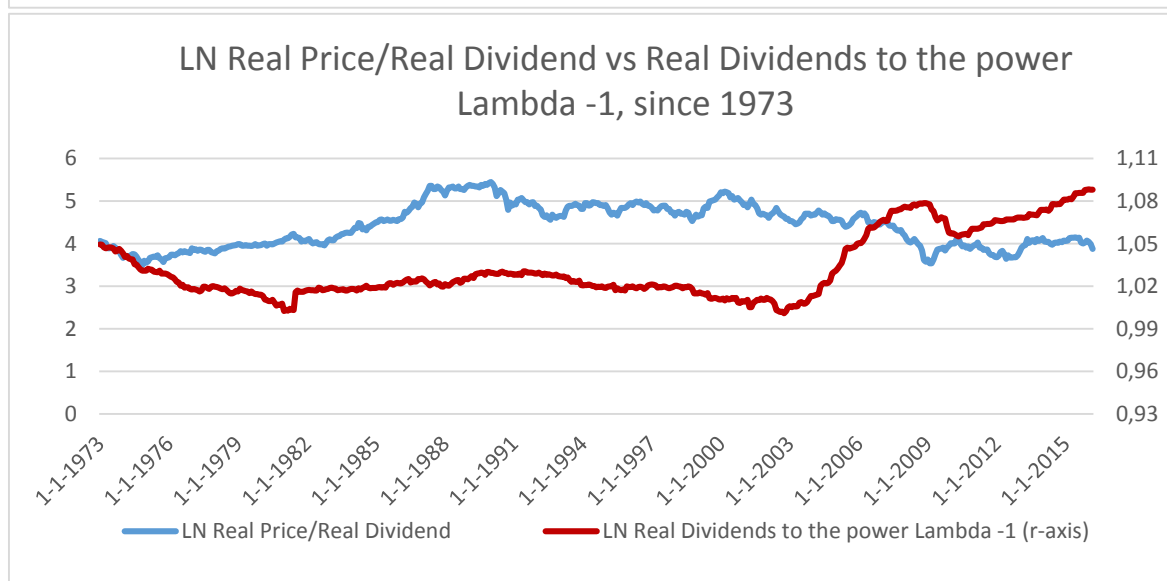
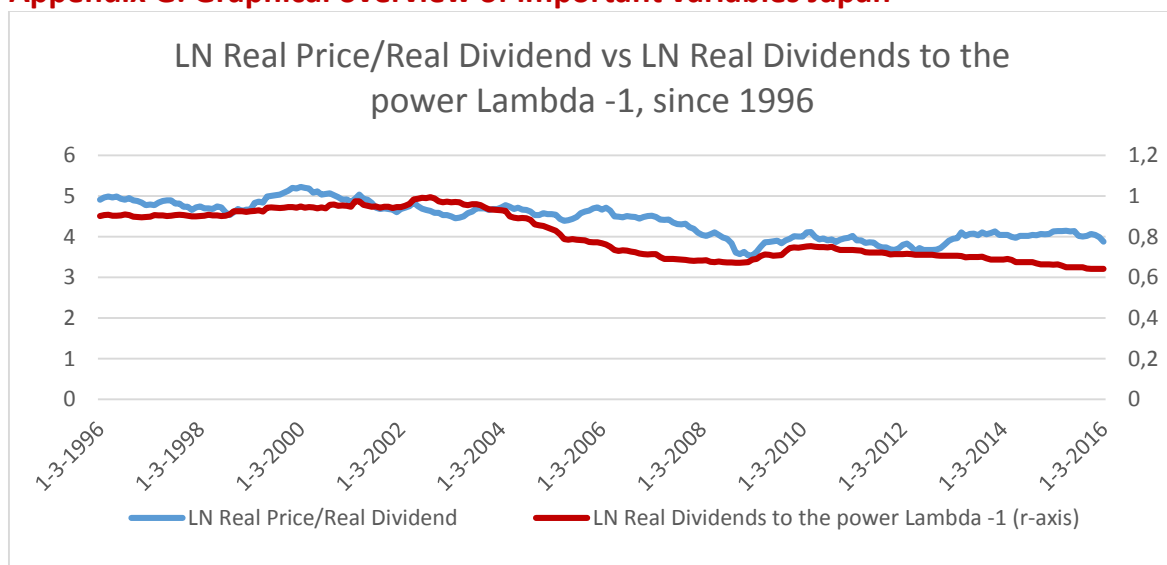


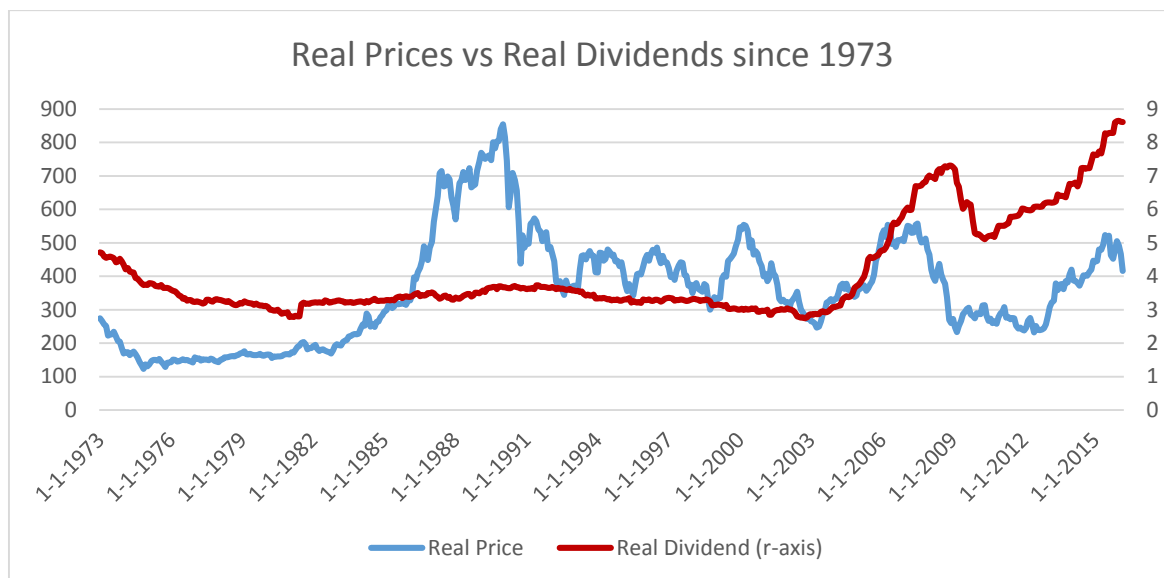
Appendix F: Graphical overview of important variables UK





Appendix G: Graphical overview of important variables Japan





Appendix H: development of intrinsic bubble coefficients in periods of five years (with parameters used since the first day data was available)

| Period | Coefficient $D_t^{\lambda-1}$ United States | Coefficient $D_t^{\lambda-1}$ United Kingdom | Coefficient $D_t^{\lambda-1}$ Japan | Period and Coefficient Eurozone | |
|-----------|--|---|--|------------------------------------|--------------|
| 1973-1977 | -1.866482* | | 2.142205 | | |
| 1978-1982 | 1.103519** | | -10.17844*** | | |
| 1983-1987 | 5.356356*** | | 98.86132 | | |
| 1988-1992 | 2.524931*** | -0.0758138*** | -29.00835** | | |
| 1993-1997 | 4.657211*** | 0.0455455*** | -9.650398* | 1990-1994 | -256.7301*** |
| 1998-2002 | 0.2463296 | -0.0849597 | -6.939022 | 1995-1999 | 197.7153*** |
| 2003-2007 | -0.1043485** | 0.0570054*** | -3.033899*** | 2000-2004 | -354.6558*** |
| 2008-2012 | -0.4001558** | -0.1404486*** | -5.659923** | 2005-2009 | -257.011*** |
| 2013-2016 | 0.027769 | -0.0897378*** | 2.517095 | 2010-2016 | -284.0251*** |

* = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$

Appendix I: stationarity test for LN Real Dividends in the UK during 1988-2016

Augmented Dickey-Fuller test for unit root Number of obs = 329

| Test Statistic | Interpolated Dickey-Fuller | | |
|-------------------|----------------------------|----------------------|-----------------------|
| | 1% Critical Value | 5% Critical Value | 10% Critical Value |
| Z(t) | -3.470 | -3.987 | -3.427 |

MacKinnon approximate p-value for Z(t) = 0.0427

| D.LNREALDIV | Coef. | Std. Err. | t | P> t | [95% Conf. Interval] | |
|-------------|-----------|-----------|-------|-------|----------------------|-----------|
| LNREALDIV | | | | | | |
| L1. | -.0487225 | .014041 | -3.47 | 0.001 | -.0763478 | -.0210971 |
| LD. | -.1691679 | .0556205 | -3.04 | 0.003 | -.2785999 | -.059736 |
| L2D. | .0078006 | .0557921 | 0.14 | 0.889 | -.101969 | .1175702 |
| L3D. | .0361515 | .0557465 | 0.65 | 0.517 | -.0735282 | .1458313 |
| L4D. | .0956108 | .055218 | 1.73 | 0.084 | -.0130292 | .2042508 |
| L5D. | .0755988 | .0554137 | 1.36 | 0.173 | -.0334264 | .184624 |
| L6D. | .1584539 | .0555768 | 2.85 | 0.005 | .0491079 | .2677998 |
| L7D. | -.0035428 | .056426 | -0.06 | 0.950 | -.1145597 | .1074741 |
| L8D. | .1922005 | .0563992 | 3.41 | 0.001 | .0812365 | .3031646 |
| L9D. | .0948457 | .0561819 | 1.69 | 0.092 | -.0156908 | .2053822 |
| _trend | .0000484 | .0000187 | 2.58 | 0.010 | .0000115 | .0000853 |
| _cons | .2331521 | .0668055 | 3.49 | 0.001 | .1017139 | .3645903 |

Appendix J: example of Stata .do-files (differ per period and country because of the number of applicable lags and titles in tables). Separate datasets per period and country

```
* Analysis without QE included
sum LNREALDIV
reg LNPDLNDLAMBDA
est sto t1, title(United States without QE)
* Analysis including QE dummy
reg LNPDLNDLAMBDA InteractionDummy
est sto t2, title(United States with QE, based on QE dummy)
* Analysis including TotalAssets
reg LNPDLNDLAMBDA DivAssets
est sto t3, title(United States with QE, based on Total Assets)
* Analysis including Total Assets minus average 2003-2008
reg LNPDLNDLAMBDA DivAssetsMinAve
est sto t4, title(United States with QE, based on Total Assets minus average 2003-2008)
* Analysis including Delta Assets
reg LNPDLNDLAMBDA InteractionDelta
est sto t5, title(United States with QE, based on delta Total Assets)
* Display in a good way
esttab t1 t2 t3 t4 t5, label title(Bubbles in the United States with QE) varwidth (31)
nonumbers mtitles("without QE""QE dummy""QE Total Assets""QE Assets minus 2003-2008""QE
Delta Assets") model (26) note(dependent variable: Real Price-Dividend Ratio) cells(b(star
fmt(a3)) se(fmt(3) par))
* Test for non-stationarity
tsset t
* Test for number of lags
varsoc LNREALDIV, maxlag(12)
* Apply 4 lags
tsline LNREALDIV
dfuller LNREALDIV, reg trend lags(4)
dfuller LNREALDIV, reg lags(4)
* Now test for stationarity of Real Prices and first differences
varsoc realprice, maxlag(12)
* Apply 1 lag
tsline realprice
dfuller realprice, reg trend lags(1)
dfuller realprice, reg lags(1)
* Test first differences on stationarity, first differences are created by "generate
realpriceD1=D1.realprice" and "generate realdividendsD1=D1.realdividends"
generate realpriceD1=D1.realprice
generate realdividendsD1=D1.realdividends
varsoc realpriceD1, maxlag(12)
* Apply 0 lags
tsline realpriceD1
dfuller realpriceD1, reg trend
dfuller realpriceD1, reg
* Now test for cointegration
reg realprice realdividends
predict u, residual
gen uD1=D1.u
tsline u
tsline uD1
varsoc u, maxlag(12)
* Apply 1 lag
dfuller u, lag(1) reg
varsoc uD1, maxlag(12)
dfuller uD1, reg
```

example of how to get a merged table

```
*2003-2016, parameters since 2003
reg LNPDLNDLAMBDA
est sto t1, title(United States without QE)
* Analysis including QE dummy
reg LNPDLNDLAMBDA InteractionDummy
est sto t2, title(United States with QE, based on QE dummy)
* Analysis including TotalAssets
reg LNPDLNDLAMBDA DivAssets
est sto t3, title(United States with QE, based on Total Assets)
* Analysis including Total Assets minus average 2003-2008
reg LNPDLNDLAMBDA DivAssetsMinAve
est sto t4, title(United States with QE, based on Total Assets minus average 2003-2008)
* Analysis including Delta Assets
reg LNPDLNDLAMBDA InteractionDelta
est sto t5, title(United States with QE, based on delta Total Assets)
* Analysis 2003-2016, parameters since 1973
reg LNPDLNDLAMBDA_01
est sto t6, title(United States without QE)
* Analysis including QE dummy
reg LNPDLNDLAMBDA_01 InteractionDummy_01
est sto t7, title(United States with QE, based on QE dummy)
* Analysis including TotalAssets
reg LNPDLNDLAMBDA_01 DivAssets_01
est sto t8, title(United States with QE, based on Total Assets)
* Analysis including Total Assets minus average 2003-2008
reg LNPDLNDLAMBDA_01 DivAssetsMinAve_01
est sto t9, title(United States with QE, based on Total Assets minus average 2003-2008)
* Analysis including Delta Assets
reg LNPDLNDLAMBDA_01 InteractionDelta_01
est sto t10, title(United States with QE, based on delta Total Assets)
* Analysis since 1973
reg LNPDLNDLAMBDA_02
est sto t11, title(United States without QE)
* Analysis including QE dummy
reg LNPDLNDLAMBDA_02 InteractionDummy_02
est sto t12, title(United States with QE, based on QE dummy)
* Analysis including TotalAssets
reg LNPDLNDLAMBDA_02 DivAssets_02
est sto t13, title(United States with QE, based on Total Assets)
* Analysis including Total Assets minus average 2003-2008
reg LNPDLNDLAMBDA_02 DivAssetsMinAve_02
est sto t14, title(United States with QE, based on Total Assets minus average 2003-2008)
* Analysis including Delta Assets
reg LNPDLNDLAMBDA_02 InteractionDelta_02
est sto t15, title(United States with QE, based on delta Total Assets)

* Display in a good way
esttab t1 t2 t3 t4 t5 t6 t7 t8 t9 t10 t11 t12 t13 t14 t15, label title(Bubbles in the
United States with QE) varwidth (8) nonumbers mtitles("No QE""Dummy""Assets""Assets min
2003-2008""Delta""No QE""Dummy""Assets""Assets min 2003-2008""Delta""No
QE""Dummy""Assets""Assets min 2003-2008""Delta") model (8) note(dependent variable: Real
Price-Dividend Ratio) cells(b(star fmt(a3)) se(fmt(3) par))
esttab t1 t2 t3 t4 t5 t6 t7 t8 t9 t10 t11 t12 t13 t14 t15 using `STATAUS.xls'', replace
label title (Bubbles in US with QE) varwidth(25) mtitles model (8) ar2 cells(b(star
fmt(a3)) se(fmt(3) par))
```