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Sluggish growth in the Eurozone: Secular Stagnation versus Balance Sheet Recession

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Abstract

This paper investigates whether sluggishness in economic growth in the Eurozone following the Global Financial Crisis (GFC) is a permanent or cyclical phenomenon. Using a Vector Error Correction (VEC) methodology, we determine whether forces behind 'secular stagnation' or a 'balance sheet recession' explain sluggish post-crisis GDP and investment growth during the period 1999Q1:2015Q4. Our results indicate that post-crisis sluggishness in economic growth is mainly caused by forces underlying the balance sheet recession theory. Furthermore, we find that, whilst the money supply has a large positive impact on GDP growth, lowering the real interest rate does not. All-in-all, we determine that the current state of the Eurozone economy is depicted by cyclical sluggishness.

Keywords: secular stagnation, balance sheet recession, sluggish growth, demographics, deleveraging, natural rate of interest, monetary policy

Contents

List of Tables

List of Figures

1 Introduction

Nearly a decade after the onset of the 2007-2008 Global Financial Crisis (GFC), the Eurozone economy was still struggling with low economic growth rates. Despite a lengthy period of increasingly accommodative monetary policy – with the European Central Bank (ECB) refinancing rate at the Zero Lower Bound (ZLB) since March, 2016 – Eurozone annual GDP growth in 2015 and 2016 remained well below its pre-crisis trend (OECD, 2016). The fact that the GFC was to a large extent driven by a collapsing housing market deepened the crisis (IMF, 2012; Jordà et al., 2011). Moreover, the Eurozone experienced a second dip when Greece was unable to finance its domestic debt. A period of sluggishness in economic growth following such a major crisis is common. However, the 'normal' duration of this period is debatable. Full recovery from a financial crisis generally takes around eight years (Reinhart and Rogoff, 2009). Enduring sluggish economic growth in the Eurozone led to a debate concerning its underlying drivers and its level of persistency.

One theory argues that the Eurozone suffers from 'secular stagnation'. This theory – developed in Hansen (1939) – states that structural forces in the economy result in an indefinite period of economic growth below its potential. In Hansen (1939), such structural forces represented declining population growth rates in the US in the 1930s. Summers (2014a) states that similar changes in demographics are currently taking place in advanced economies, and thereby revived the theory of Hansen (1939). Of the advanced economies, this demographic transition is especially large in the Eurozone (European Commission, 2015). In this 'new secular stagnation' theory of Summers (2014a), structural forces – such as a demographic transition – result in a negative Full Employment Real Interest Rate (FERIR): the (theoretical) interest rate that ensures savings and investments are in equilibrium and the economy produces at its potential. A demographic transition may result in a structural decline in investment demand and a structural increase in savings supply, thereby lowering the FERIR into negative territory (Summers, 2014a). In an economy plagued by low nominal interest rates as well as a low inflation rate, this negative FERIR is unattainable via the real interest rate. A real interest rate which is unable to fall to the level of the FERIR results in a level of economic growth below its potential. As structural forces create this interest rate gap, the slowdown in economic growth may become structural as well. In this situation, returning to potential economic growth rates does not occur for an indefinite period of time.

In contrast, Koo (2014a) argues that the Eurozone is not suffering from secular stagnation. Rather, the Eurozone economy is plagued by a 'balance sheet recession'. In this view – developed in Koo (2003) – a slowdown in economic growth is caused by private sector deleveraging, following the burst of a debt-financed asset bubble. This collapsing asset bubble – the housing bubble in case of the GFC – pushes private sectors' balance sheets underwater. That is, the current value of an asset (a house) is lower than the outstanding balance on the loan (a mortgage) required to purchase the asset. This forces households and firms to pay off debts. Such deleveraging makes the private sector insensitive to low interest rates. Households and corporations do not take up loans (and invest) despite nominal interest rates being close to or at zero. The build-up in household and corporate debt in the Eurozone, and the subsequent collapse in the housing market, supports the balance sheet recession theory. The balance sheet recession theory predicts a temporary state of sluggish economic growth, returning to its pre-crisis trend after deleveraging forces subside (Koo, 2003).

In both secular stagnation and a balance sheet recession, low nominal interest rates do not effectively stimulate aggregate demand. However, the factors underlying this lack of stimulus differ from one theory to the other. In a state of secular stagnation, the gap between the real interest rate and the FERIR results in an inability to effectively stimulate demand. This gap is caused by structural factors, such as changes in demographics. On the other hand, in a balance sheet recession, a low interest rate does not stimulate aggregate demand due to cyclical private sector deleveraging and hence the unwillingness for the private sector to take on debt despite low interest rates. As these underlying causes of sluggish economic growth differ between both theories, different cures are required as well. Lowering the real interest rate via (un)conventional expansionary monetary policies may be ineffective in a balance sheet recession, whereas it is an effective way to spur demand in a state of secular stagnation. This discrepancy is of utmost importance concerning the Quantitative Easing (QE) program conducted by the ECB. With this policy, the ECB makes monthly purchases of government bonds − as well as corporate bonds since March, 2016 − for an amount of 60 billion Euros. The main goal of this policy is lowering nominal interest rates and increasing the inflation rate, thereby stimulating aggregate demand. This program is effective in case the economy suffers from secular stagnation, but is ineffective in case of a balance sheet recession.

This paper investigates which of the two theories fits the case of the Eurozone best. We distinguish between both theories by using a Vector Error Correction Model (VECM) for the Eurozone economy over the period 1999Q1:2015Q4. We focus on post-crisis GDP and investment growth rates, and determine whether changes in the forces underlying secular stagnation or a balance sheet recession explain the movement in these variables well. Furthermore, we determine the responsiveness of the Eurozone economy to expansionary monetary policy shocks. This provides us with further knowledge on the current state of the Eurozone economy.

To the best of our knowledge, this paper is the first to directly distinguish between the secular stagnation and balance sheet recession theories in the Eurozone in an empirical manner. The research question we aim to answer is the following: *is the Eurozone in secular stagnation, or is the area suffering from a balance sheet recession?* In order to effectively answer this main question, we develop the following hypotheses:

H1: *Sluggish post-crisis investment growth in the Eurozone is mainly the result of demographic, as opposed to deleveraging forces;*

H2: *Sluggish post-crisis GDP growth in the Eurozone is mainly the result of demographic, as opposed to deleveraging forces;*

H3: *An increase in broad money supply growth does not result in an increase in GDP growth in the long-run;*

H4: *A decline in the real interest rate does not result in GDP growth returning to potential in the long-run.*

This paper proceeds as follows. Section 2 offers an overview of the existing literature on secular stagnation and balance sheet recessions. This section also links both theories to the Eurozone economy and provides the main differences between the theories. The section concludes with the formulation of testable hypotheses, and the method behind answering the hypotheses. Section 3 introduces the data used in the empirical section of this paper. Subsequently, section 4 presents the methodology used in this paper. Section 5 provides the main results and answers our hypotheses. Section 6 offers a discussion of these results and section 7 concludes.

2 Literature Review

This section provides an evaluation of the literature on the secular stagnation and balance sheet recession theories. To this end, section 2.1 introduces the secular stagnation theory. Section 2.2 describes the applicability of this theory to the Eurozone economy and section 2.3 analyses the impact of the main drivers of secular stagnation on macro-economic aggregates. Subsequently, section 2.4 introduces the balance sheet recession theory and its applicability to the Eurozone economy. The impact of the drivers of balance sheet recessions on macro-economic aggregates is on the basis of section 2.5. Section 2.6 compares the secular stagnation theory with that of the balance sheet recession. This provides us with several testable hypotheses, presented in section 2.7.

2.1 Secular Stagnation

The secular stagnation theory was first introduced by the Keynesian economist Alvin Hansen (1939) in his presidential address to the American Economic Association. Herein, Hansen (1939, p.1) states the U.S. economy was '*moving swiftly out of the order in which those of our generation were brought up, into no one knows what*'. Hansen argued that the main threat to the U.S. economy at the time was lower population growth. On the basis of this threat is the notion of full employment of productive resources. This theoretical concept enables the economy to operate at its potential, and is to a large extent determined by the level of investments. Population growth has a large impact on this level of investments, primarily in the field of residential construction. Thus, a declining population growth rate substantially lowers the level of investments via this path. In turn, a structural inability to attain full employment of productive resources results. Hansen (1939) defines this period of sub-potential economic growth as 'secular stagnation'. Notably, interest rates do not play a large role in this theory. In general, a declining level of investments results in lower interest rates. Classical economic theory states investments would rise again after these lower interest rates, eliminating the threat of secular stagnation. However, Hansen (1939) reasons that the largest driver of new investments is the prospective rate of profit, not the interest rate. This view − originating from Wicksell (1898) − looks beyond the pure impact of the costs of interest expenses on the level of investments to the structure of this interest rate, depending on the prospective rate of profit. This profit rate is shaped by economic progress, strongly hinging on population growth. Via this mechanism, a lower population growth rate lowers the prospective rate of profit, giving rise to secular stagnation via a decline in investments. This secular stagnation theory of Hansen (1939) rapidly lost weight. After the outbreak of WWII, the U.S. observed a positive shock in government spending. Furthermore, the baby boom following WWII resulted in a further impulse to the U.S. economy. As a response, the economy revived and the secular stagnation theory rapidly lost attention.

Decades after Hansen (1939) presented his theory, Summers (2014a) revived the term stating its applicability to 21st century advanced economies. Contrary to Hansen (1939), Summers (2014a) does stress the importance of interest rates in his theory:

the FERIR in particular. This interest rate (hereafter referred to as the natural rate of interest, originating from Wicksell (1898)) ensures savings and investments are in equilibrium, and full employment of productive resources occurs. According to Summers (2014a,b), structural forces such as increased income inequality, cheaper capital goods and a declining population growth rate either result in a structural decline in investment demand or an increase in saving supply. Thereby, the natural rate of interest is forced downward, possibly into negative territory. As real interest rates can fall below zero as well, this negative natural rate of interest does not have to be a cause for concern. In this case, the natural rate of interest is still attainable and the economy produces at its potential rate. However, many advanced economies − the Eurozone in particular − currently face nominal interest rates constrained by the ZLB in combination with a low inflation rate. In this case, the negative natural rate of interest cannot be attained. This inability to attain the natural rate of interest results in an output gap for an indefinite period of time, and is referred to by Summers (2014) as secular stagnation. Summers' (2014a) reasoning differs slightly from the classical secular stagnation theory of Hansen (1939). Nonetheless, the factors underlying both theories are similar. The theory provided by Summers (2014a) is regularly referred to as the 'new secular stagnation' theory.

2.1.1 Testing the New Secular Stagnation Theory

Using an Overlapping Generations (OLG) model, Eggertson and Mehrothra (2014) provide a basis for the new secular stagnation theory. In their theoretical model, individuals go through three stages of life: young, middle-aged and old. The young cohort is the source of borrowing, with loans provided to them by the middle-aged cohort. The middle-aged cohort provides these loans in order to save for its retirement (in which the individual will be a net consumer). The model tests the impact of an exogenous reduction in the debt limit, a lower rate of population growth and an increase in income inequality. We focus on the impact of a lower rate of population growth.

A negative shock in population growth results in a smaller cohort of young people and thus has an immediate negative impact on the demand for loans. This lowers the natural rate of interest via a structural decline in investments. As the young cohort demands fewer loans, aggregate debt repayments − relative to the former middle-aged cohort − will be lower as well. This enables this cohort to supply relatively more loans (i.e. save) during their middle age. In turn, the natural rate of interest declines further. When the shock in population growth is substantial, the natural rate of interest becomes negative. This theoretical model thus establishes the potential existence of secular stagnation following a demographic shock.

2.1.2 Response to the New Secular Stagnation Theory

Several renowned economists support the idea of an era of secular stagnation in advanced economies. However, various distinct interpretations of the current economic state of the world economy are formed as well. In Mokyr (2014), improvements in ICT, genetic engineering and the creation of new materials are named as factors resulting in increasing economic growth rates. Eichengreen (2014) supports this notion, stating innovation is key. Bernanke (2015) − in line with his paper on the global savings glut (Bernanke, 2005) − stresses the role of international financial markets in locating investments. A country suffering from secular stagnation relocates investments abroad to compensate for the lack of domestic investment, thereby lowering the domestic exchange rate. A declining domestic exchange rate results in increasing exports, and full employment of productive resources is attained via this path.

Furthermore, where Summers (2014a) describes the threat to advanced economies by centering on a structural deficiency in demand, Gordon (2014) focuses on supply-side economics. In his view, four 'headwinds' lead to a structural decline in potential output growth: demographics, education, income inequality and government debt. Due to this declining level of potential output growth, the output gap is not as large as suggested in the new secular stagnation theory. Summers (2015) responds by stating that although supply-side factors may have had a significant impact on potential output growth, the ZLB on interest rates still gives rise to demand-side secular stagnation. Thus, declining population growth may influence the supply of potential employment and thereby potential output. In turn, this impact on potential output lowers the natural rate of interest and once again gives rise to the new secular stagnation theory.

2.2 The Eurozone in Secular Stagnation

The Eurozone, of all the advanced economies, seems most susceptible to enter − or be in the midst of − a period of secular stagnation. Both Hansen (1939) and Summers (2014a) argue that demographic change plays a vital role in the secular stagnation theory. A demographic transition is occurring in the majority of advanced economies, however it seems to be most severe in the Eurozone. An extensive European Commission (2015) report shows the demographic forecasts for the Eurozone over the period: 2013:2060. Fertility rates remain below the natural replacement rate, whilst migration flows will add 40 million people to the Eurozone's total population. Overall, the total population is projected to increase slowly until 2045, after which it declines. The most striking observation is that of labor supply, which is projected to fall by 14 million people (9.2% of the total labor supply) between 2023 and 2060. In line with this declining labor supply, the old-age dependency ratio (measured as the ratio of individuals aged 65 and older to individuals aged 15-64 years old) increases substantially; from 29% in 2013 to 51% in 2060. This large impact on labor supply and the dependency ratio is the result of a transition in population growth rates between cohorts. The 'baby boom' cohort born in the 50s and 60s is now retiring. This large cohort is replaced by a smaller cohort of individuals born after the baby boom. Possibly strengthening this transition is the introduction of the contraceptive pill in the 1970s (Lu and Teulings, 2016). This further strengthens the impact on a declining labor supply growth rate and an increasing old-age dependency ratio.

Besides demographics, several theoretical papers provide different arguments supporting secular stagnation in the Eurozone. Crafts (2014) argues potential productivity growth will be low within the area due to a slow exploitation of ICT potential and reliance on the U.S. for new technology. Furthermore, high public debt levels of the Member States and commitment to the Stability and Growth Pact (SGP) gaurantees that a prolonged period of fiscal consolidation occurs. Such fiscal consolidation initiates a further decline in potential output growth. Jimeno et. al (2014) further state that a structural deficiency in the level of investments might occur in the Eurozone due to the rising cost of capital after stricter financial regulations following the GFC. This structural decline in investment demand may lower the natural rate of interest into negative territory, giving rise to secular stagnation.

2.2.1 Measuring the Natural Rate of Interest

Along the theoretical concepts linking demographic change to economic growth directly, few papers test the secular stagnation theory empirically. As the natural rate of interest is central in Summers (2014a), measuring this interest rate is vital when putting the secular stagnation theory to the test. However, as this interest rate has mere theoretical foundations, complexity exists when performing such measurements.

The natural rate of interest is conventionally defined as an interest rate equilibrating savings and investments, consistent with a zero output gap and a stable inflation rate (Bernhardsen and Gerdrup, 2007). Theoretically, the natural rate of interest should thus respond to structural changes in savings and investments. That is, excess savings or a level of investment demand below the level of savings results in a decline of the natural rate of interest. Furthermore, Laubach and Williams (2003) argue that potential GDP growth is positively related to the natural rate of interest. Nonetheless, Giammarioli and Valla (2004) state that severe heterogeneity exists in the 'true' empirical strategy underlying estimates of the natural rate of interest.

Laubach and Williams (2016) estimate the natural rate of interest for the U.S. from 1980 through 2015. Within their model, developed in Laubach and Williams (2003), the natural rate of interest depends on the estimated trend growth rate of potential GDP and an unobserved component capturing the effects of unspecified influences on the natural rate. Using this methodology, the authors find a negative natural rate of interest for the U.S. in the first half of 2015. The authors observe a large decline in the natural rate of interest before and after the GFC, with potential GDP growth playing the largest role in this decline. The variables explaining potential GDP growth are not further specified in their analysis.

Besides the large impact of potential output growth on the natural rate of interest, several papers find other factors explaining trends in the natural rate of interest. Pescatori and Turunen (2015) argue that global excess savings explains a large share of the decline in the natural rate of interest. Furthermore, Hamilton et al. (2015) argue forces such as altered personal discount rates, stricter financial regulation, inflation trends, bubbles and cyclical headwinds are important in explaining movements in the natural rate of interest via structurally altering the level of savings and investments.

2.2.2 The Eurozone Natural Rate of Interest

Relatively few papers measure the natural rate of interest within the Eurozone. However, obtaining insights in movements of this interest rate in the area is of utmost importance in determining whether the area suffers from secular stagnation.

In ECB (2004) a gradual decline in the natural rate of interest in the Eurozone over the period 1995:2004 is found. The main factors contributing to this decline are: a slowdown in productivity growth, lower population growth and the process of fiscal consolidation in the Eurozone. Using an OECD measure, Bouis et al (2013) find a secular decline in the natural rate of interest towards 0% over the last decade. Falling potential GDP growth rates due to the demographic drag and slower capital stock growth explain this decline to the largest extent. Uncertainty in their estimates originates from imprecise OECD measures of potential output growth. Kleczka (2015) finds that the Eurozone's natural rate of interest has been on a declining path since the beginning of the Great Recession. From 1997 to 2015, the natural rate of interest declined from 2.14% to 0.45%. Thus, the author does not find a negative natural rate of interest. Rawdanowicz et al. (2014) estimate the natural rate of interest within several OECD economies, including the Eurozone. Taking into account GFC hysteresis effects on potential output, a negative natural rate of interest is found within the Eurozone from 2009 onwards. The authors find a natural rate of interest of -0.5% in 2015.

All in all, doubt exists concerning the case of secular stagnation within the Eurozone. There is no general consensus on the current value of the natural rate of interest. The literature does agree on the fact that the Eurozone is more susceptible than other western economies to enter a period of secular stagnation. The impact of demographic change on the natural rate of interest plays a critical role in this susceptibility. The next section further investigates the impact of demographics on economic aggregates.

2.3 Demographics and Secular Stagnation

As observed in the previous section, demographic change is often claimed as − via its impact on the natural rate of interest − being on the basis of secular stagnation. According to the European Commission (2015) report, the largest demographic transition for the Eurozone involves lower labor supply growth and an increasing (old-age) dependency ratio. In order to link demographics to secular stagnation, this section gives an overview of the literature concerning the relationship between demographic changes and macroeconomic aggregates.

Numerous theoretical papers examine the relationship between labor supply growth and macroeconomic aggregates. Dating back to Keynes (1937) − and following Hansen (1939) − the link between population growth and demand for investments is of utmost importance. A falling rate of population growth creates a smaller labor force over time, resulting in a negative shock in investment-demand in the long-run. Consequently, this structural deficiency in investment-demand lowers output growth. Summers (2014a) further argues that lower investment demand via a decline in labor supply growth lowers the natural rate of interest into negative territory, giving rise to the new secular stagnation theory.

On the other hand, Gordon (2015) argues declining population growth rates result in falling potential GDP growth via its impact on potential labor input. Summers (2014a) states that this channel does not reject the secular stagnation theory. Rather, as shown in section 2.2.1, it provides an additional channel for demographic variables to influence the natural rate of interest. To this end, we investigate the impact of changes in demographic variables on savings and investments in section 2.3.1 and its impact on potential output in section 2.3.2.

2.3.1 Demographic Change, Savings and Investments

Changes in population growth may directly influence saving rates, and thus (assuming the OLG model as in section 2.1.1) demand for loans. Lu and Teulings (2016) investigate the impact of a negative fertility shock after introduction of the contraceptive pill around 1970. The introduction results in a transition period in labor supply growth, from the pre-pill cohort to the post-pill cohort. The pre-pill cohort is significantly larger than the cohort born after introduction of the pill. Assuming consumption-smoothing over the life-cycle, individuals build up debt during the early stages of life and save during their active years on the labor market. The large cohort born before the introduction of the pill thus has a disproportionately high level of savings compared to the loan demand of the small cohort born after introduction of the pill. This transition is currently ongoing in the Eurozone, and hence a possible explanation for falling (natural) real interest rates. The authors argue that real interest rates will fall untill 2035, when the large pre-pill cohort retires.

A large share of the literature merely considers the effect of a change in dependency ratio's on the macro-economy. Kim and Lee (2008) use a Vector Autoregressive (VAR) model to deduce the effects of shocks to the total dependency rate (individuals aged 65 and above and 14 and below as a percentage of individuals aged 15-64) on national saving, interest rates and several additional variables. By means of panel data of G-7 countries over the period 1979:2001, the authors find a strong negative relationship between the dependency rate and saving. Again, assuming consumption-smoothing over the life-cycle, this negative relationship between the dependency ratio and saving makes sense. As the dependency ratio consists of consumers in the numerator and savers in the denominator, an increase in this ratio may occur from two sources. The period investigated in Kim and Lee (2008) takes into account lower population growth, and thus leads to a smaller denominator. As a result, the dependency ratio rises. As the individuals in the denominator are net savers, the total level of savings declines.

Rachel and Smith (2015) investigate secular drivers of global interest rates over the period 1990:2015. The impact of the total dependency ratio on savings is found to be negative. The authors state that that the global dependency rate has fallen over the past 30 years, significantly increasing the supply of savings. As the authors take into account the total dependency ratio, declining population growth significantly impacts the number of individuals aged 14 years old and younger.

Using data of 22 advanced economies over the period 1955 to 2010, Juselius and

Takats (2015) find a positive relationship between the total dependency ratio and inflation rates. The authors control for variables such as the real interest rate and the output gap to effectively measure the impact of demographics on inflation. The demand-channel is named as the main channel behind the results found within their paper. In Ciocyte et al (2016), the long-run determinants of interest rates are investigated, demography is found to have an impact. The share of people aged 20-39 years old is positively correlated with the real interest rate.

Carvalho et al. (2016) find that for a representative developed economy, the natural rate of interest fell by 1.5 percentage points between 1990 and 2014. The main demographic factor attributing to this decline is an increase in life expectancy. Due to this increasing life expectancy, individuals at all stages of their life save more to finance consumption over a longer period of retirement. Thus, the old-age dependency ratio influences the natural rate of interest to a larger extent than declining population growth does in isolation.

2.3.2 Demographic Change and Potential Output

Using panel regressions, Balakrishnan et al. (2015) determine whether the decline in labor force participation in the U.S. during the period 2007:2013 is determined by cyclical factors related to the Great Recession, or by more structural demographic factors. The authors find that the largest share of the decline - at least 50 percent - in the labor force participation rate is concerned with ageing populations. Subsequently, potential output growth is largely affected via this path. In an IMF (2015) report, potential output growth rates for the Eurozone are measured. In estimating potential output, the authors make use of a standard Cobb-Douglas production function:

$$\bar{Y}_t = \bar{A}_t K_t^a \bar{L}_t^{1-a} \tag{1}$$

In this measure, $\bar{Y}_t$ represents potential output, K_t is the stock of productive capital, $\bar{L}_t$ is potential employment, $\bar{A}$ is potential total factor productivity (TFP) and a is the share of capital in potential output at time t. Potential employment is determined by the following formula:

$$\bar{L}_t = (1 - \bar{U}_t) W_t \overline{LFPR}_t \tag{2}$$

Here, $\bar{U}_t$ represents the Nonaccelerating Inflation Rate of Unemployment (NAIRU), the unemployment rate below which inflation rises. W_t is the working-age population and $\overline{LFPR}_t$ is the trend labor force participation rate. Using this framework, the authors are able to observe how demographic factors explain potential GDP growth. The working-age population is directly affected by population growth rates and dependency ratio's. A decline in population growth and an increase in the share of older people in the population result in lower potential employment, and thereby lower potential output growth. The trend labor force participation rate on the other hand estimates age-gender-specific determinants of labor supply such as school enrolment rates and marital status. Using this methodology, the IMF (2015) report finds a large role for potential employment growth in declining potential output growth in the post-crisis period in the

Eurozone. Changes in employment as a result of the GFC are not important in this decline unlike persistent demographic factors such as lower population growth rates and declining participation rates.

2.4 Balance Sheet Recession

Koo (2003) introduces the 'balance sheet recession' theory. He defines a balance sheet recession as a period of deleveraging by both households and businesses, despite nominal interest rates being close – or equal to – zero. Such deleveraging occurs after the bursting of a nation-wide debt-financed asset price bubble. Koo (2003) originally links this concept to the bursting of Japan's asset price bubble and its 'lost decade' in the 1990s. After this bubble burst, balance sheets of the private sector are forced underwater. In other words, the value of a large share of assets is pushed below the level of debt used to purchase these assets before the bursting of the bubble. The 'real' value of equity is now negative. The main goal for households and businesses exposed to the asset in question is debt minimization, as opposed to profit maximization. After an extensive period of deleveraging, balance sheets recover. Households and firms are now again willing to take on loans in order to fund consumption and investments. Aggregate demand picks up, and returns to its pre-crisis growth trend.

This balance sheet recession theory has some parallels with the debt-deflation theory introduced by Fisher (1933). The starting point of the debt-deflation theory is private sector indebtedness. Initially, over-indebtedness – possibly as a result of a collapsing asset price bubble – results in deleveraging, contracting the amount of currency in circulation. This declining velocity of currency subsequently causes deflation. As debt is denominated in nominal terms, deflation causes debt in real terms to increase. Higher real indebtedness further reduces both output and the price-level, forcing the economy into a vicious circle. When deleveraging is no longer necessary, GDP growth returns to its pre-crisis trend.

2.4.1 Testing the Balance Sheet Recession Theory

Eggertson and Krugman (2012) empirically test the theoretical concepts of Koo (2003) and Fisher (1933). The impact of an abrupt change in borrower's view on a safe level of leverage, and its subsequent move to deleveraging, is tested within this model. This abrupt change may originate from a collapsing asset price bubble – as in Koo (2003) – or a more general 'Minsky moment' (originating from Minsky and Kaufman, 2008). The authors find evidence supporting the debt-deflation theory, although via a different path than suggested in Fisher (1933). In their model, deleveraging temporarily gives rise to a negative natural rate of interest. The authors assume that the natural rate of interest is an endogenous variable, reliant on the level of private debt in the economy. To reach this negative natural rate of interest via the real interest rate, the price level must drop, only to rise again later. The observed deflation increases real debt levels, lowering the natural rate of interest even further. In turn, this results in more deflation, providing evidence for a debt-deflation cycle. The authors find that a debt overhang of

30% results in a drop in output of 7% on impact. The ZLB is binding for 10 quarters, after which nominal interest rates turn positive. The recovery is completed whenever deleveraging forces subside, and the natural rate of interest becomes positive. At this point, GDP is once again able to grow at its potential rate.

Eggertson and Krugman (2010) indicate that forces underlying a balance sheet recession give rise to changes in the natural rate of interest. As this natural rate of interest is on the basis of the secular stagnation theory as well, it is vital to effectively distinguish between both theories. Although Koo (2003) does not incorporate the natural rate of interest in his analysis, Eggertson and Krugman (2010) do. The largest difference between the theories is concerned with the duration a negative natural rate of interest persists. Eggertson and Krugman (2010) argue that the macroeconomic effects of a deleveraging shock are in essence temporary. For this reason, the natural rate of interest is negative for only a temporary period as well. After deleveraging is completed, the natural rate of interest becomes positive again. In contrast, the secular stagnation theory argues that the natural rate of interest remains negative for a long period of time. This is the case as the underlying factor causing the negative natural rate of interest (i.e. the demographic transition) is permanent as well.

2.4.2 The Eurozone in a Balance Sheet Recession

Participating in the debate, Koo (2014a) argues that the Eurozone is not suffering from secular stagnation at all, rather it is amid a balance sheet recession. The Eurozone has seen its private non-financial sector debt level increase rapidly in the years following the dotcom bubble burst in 2000 until the outbreak of the GFC. Underlying this increase in private sector debt were loose credit constraints for both households and non-financial corporations, in combination with de-regulation of the financial sector as well as the ability for Southern European economies to borrow cheaply after creation of the European Monetary Union (EMU). Furthermore, an optimistic view of the economy − being in a state of 'Great Moderation' − induced households and businesses to take on excessive debt. Figure 14 of Appendix A shows the combined level of household and non-financial corporate debt as a percentage of GDP in the Eurozone over the period 2000:2016. After the outbreak of the GFC in the U.S, the housing market in the Eurozone collapsed. Households and businesses reliant on the housing market saw their balance sheets deteriorate, initiating a period of deleveraging. During this period price levels fell, indicating Fisherian debt-deflation may have been at play. Figure 15 in Appendix A shows this movement of inflation in the Eurozone.

Despite a period of deleveraging following the GFC, Cuerpo et al. (2015) argue that many EU Member States still face severe deleveraging needs. This reasoning is in line with the analysis performed in Lo and Rogoff (2015). These authors state that the largest reason for sluggish economic growth in advanced economies is private sector debt overhang. The lack of severe deleveraging results in an inability to spend.

Possibly strengthening the balance sheet recession theory in the Eurozone is the fact that multiple sectors were indebted. The GFC evolved in a euro-crisis, with Eurozone governments holding large amounts of debt. Bornhorst and Ruiz-Arranz (2013) state that the impact of debt on growth in any sector is strengthened whenever other sectors are indebted as well.

2.5 Deleveraging and Economic Aggregates

This section focuses on the macro-economic impact of private sector deleveraging. We focus on a subset of studies investigating the impact of post-crisis deleveraging on the economy. We distinguish between deleveraging performed by households (2.5.1) on the one hand, and non-financial corporations (2.5.2) on the other.

2.5.1 Household Deleveraging

A key feature of the 2007-2008 GFC was the level of household mortgage debt and the bursting of the housing bubble that followed. The required deleveraging for households was mainly concerned with paying off mortgage debt. Albuquerque and Krustev (2015) determine the impact of household indebtedness on U.S. consumption during 2007:2012. Using a panel regression fixed effects estimation method, the authors find that household deleveraging had a large impact on consumption growth in the U.S. during this period. Importantly, a non-linear relationship between deleveraging and consumption growth is found. Deleveraging of debt above a certain threshold is found to be a more important driver of lower consumption growth than deleveraging below this threshold. This finding is in line with the results found in Mian et al. (2013). Mian et al. (2013) exploit cross-sectional differences in housing wealth in the U.S, and find that neighborhoods with high levels of debt were more likely to experience a fall in house prices compared to similar areas with a low level of indebtedness. Furthermore, the authors determine the impact of such wealth shocks for household consumption. An elasticity of consumption with respect to housing net worth of 0.6 to 0.8 is found, and the Marginal Propensity to Consume (MPC) is significantly larger for more indebted households as opposed to their less indebted counterparts. Whether these results hold in the Eurozone as well, is debatable.

Cussen et al. (2012) show that mortgages count for the largest share of household debt in Eurozone Member States. Repayment of mortgage debt may lower economic activity via a reduction in household consumption. Using a DSGE-model, Cuerpo et al. (2015) measure the impact of household deleveraging on GDP growth within the Eurozone. The model is calibrated for Spain, identified as having a large need for household deleveraging. In particular, a shock in access to credit and a drop in house prices cause a decline in the household debt-to-GDP ratio of 9% after 6 years. In turn, GDP falls by a maximum of around 3% after 3 years, after which it slowly returns to its initial level. The authors indicate that household deleveraging impacts GDP growth via (i) a contraction in household investments and consumption, (ii) additional deleveraging as a result of debt-deflation, (iii) lower investments in physical capital, due to increasing real interest rates.

These findings relate to the literature on housing bubbles and its impact on the business cycle. Housing busts preceded by large run-ups in household debt generally lead to a significantly larger contraction in economic activity compared to crises where household debt is lower (IMF, 2012; Jordà et al. 2011). In general, an economic recession that is preceded by a run-up in household debt is found to be long-lasting.

2.5.2 Corporate Deleveraging

Deleveraging of non-financial corporations primarily affects economic aggregates via its impact on investments. Ruscher and Wolff (2012) investigate the macro-economic impact of corporate balance sheet adjustments for Japan, Germany and a sample of 30 additional countries. The authors find that a negative equity price shock has a significant impact on corporate deleveraging. Furthermore, deleveraging is more likely to occur when the initial level of corporate indebtedness is high. A combination of lower corporate investments and higher savings enables this balance sheet adjustment to occur. This, in return, has a negative impact on GDP growth.

As stated earlier, the initial debt-level plays a large role in the impact of deleveraging on economic aggregates. Sørensen et al. (2009) find that by the end of 2006, the Eurozone corporate debt overhang was as large as 15 percent. That is, corporate debt was 15 percent above its estimated equilibrium level. Intuitively, a period of corporate deleveraging should thus follow. Pontuch (2014) states that although corporate debt saw a significant reduction in several EU Member States in the period 2008:2013, corporate debt levels generally remain unsustainably high. The author states that deleveraging has not yet compensated for the large increase in corporate debt before the crisis. Bornhorst and Ruiz-Arranz (2013) support this finding. The authors state that non-financial firms' leverage ratios have fallen in the period following the crisis, but remain elevated in several Member States.

2.6 Secular Stagnation versus Balance Sheet Recession

After exploring the theory and empirics behind secular stagnation and balance sheet recessions, we are able to distinguish between the two theories. This is vital for assessing the current situation in the Eurozone.

Firstly, the drivers underlying secular stagnation and a balance sheet recession vary substantially. Where secular stagnation is triggered by structural forces such as the demographic transition, a balance sheet recession uniquely originates from the bursting of an asset price bubble and the subsequent period of deleveraging.

Secondly, the duration of stagnation and manner of recovery differs between the two theories. With secular stagnation, demand stagnates for an indefinite period of time. Summers (2014b) further states that recovery occurs after demand-fed hysteresis effects create a sufficient decline in supply potential. The natural rate of interest may rise again leading to an equilibrium, albeit not a good one. Typically, a very slow recovery is forecasted, with post-secular stagnation potential GDP growth at a lower level than in the pre-stagnation era. Per contrast, the balance sheet recession theory conjectures that deleveraging occurs until balance sheets have recovered. The length of this period is not indefinite but may be protracted, especially when multiple sectors are indebted.

Recovering from a balance sheet recession occurs whenever deleveraging pressures abate. The economy recovers and follows its pre-crisis growth path.

Finally, as both secular stagnation and a balance sheet recession originate from alternative sources, their cures differ as well. Secular stagnation occurs whenever the real interest rate is unable to reach the natural rate of interest for an indefinite period of time. Summers (2014b) argues that recovery occurs after i) further lowering real interest rates and/or ii) increasing the natural rate of interest. Whenever monetary policy interest rates reach the ZLB, unconventional monetary policies − such as QE − remain a possible instrument for lowering the real interest rate. Alternatively, increasing investment demand and lowering savings supply results in a higher natural rate of interest. To this end, structural policies aimed at increasing labor supply growth or expansionary fiscal policies are possibilities.

Turning to balance sheet recessions, Koo (2014b) claims that monetary policy becomes ineffective. As the private sector is unwilling to invest at any interest rate, lowering the interest rate via conventional or unconventional instruments does not result in an increase in aggregate demand. As the private sector is not borrowing any money, the government should step in and play this role. Specifically, the government must borrow the funds from households and corporations paying off debt, and invest these funds elsewhere. These fiscal expenditures are required until the private sector repairs its balance sheets. Concluding, the major difference in policy effectiveness between both theories is concerned with monetary policy. In a balance sheet recession monetary policy is ineffective, whilst a situation of secular stagnation might call for expansionary unconventional monetary policy.

2.7 Hypotheses

After introducing the secular stagnation and balance sheet recession theories, we are in the position to form several hypotheses to be tested in the empirical section. We develop the following subset of hypotheses:

- H1: Sluggish post-crisis investment growth within the Eurozone is mainly the result of demographic, as opposed to deleveraging forces,
- H2: Sluggish post-crisis GDP growth within the Eurozone is mainly the result of demographic, as opposed to deleveraging forces,
- H3: An increase in broad money supply growth does not result in an increase in GDP growth in the long-run,
- H4: A decline in the real interest rate does not result in GDP growth returning to potential in the long-run,

We test H1 and H2 by observing how GDP and investment growth responds to shocks − so called 'impulse responses' − in variables underlying the secular stagnation and balance sheet recession theories. By observing the impact of the post-crisis movement of these underlying variables on GDP and investment growth, we are able to infer whether forces behind secular stagnation or a balance sheet recession are important in explaining sluggish post-crisis economic growth. When we observe that the impact of a negative shock in demographics on investment and GDP growth outweighs the impact of a negative shock in the debt level, we confirm H1 and H2. We take into account the movement of these variables during 10 quarters (2.5 years).

In order to answer H3 and H4, we again rely on impulse responses. Observing a positive response of the GDP growth rate to a shock in the broad money supply growth in the long-run (after 20 quarters) results in a rejection of H3. H4 is rejected in case we find a return of GDP growth to its potential after lowering the real interest rate towards the prevailing natural rate of interest in the Eurozone. In addition to the impulse responses, we make use of Granger causality tests. These tests do not lead us to confirm or reject a hypothesis, but do provide insights into the short-run causality between money supply growth and GDP growth on the one hand and a change in the real interest rate and GDP growth on the other. This provides further evidence on the (short-run) effectiveness of monetary policy shocks in the Eurozone.

By answering H1:H4, we aim to answer the main research question of this paper: *is the Eurozone in secular stagnation, or is the area suffering from a balance sheet recession?* Firstly, H1 and H2 indicate whether the slack in economic growth following the outbreak of the GFC is caused by forces underlying secular stagnation or a balance sheet recession. Confirming H1 and H2 strengthens the secular stagnation theory in the Eurozone. Secondly, the current effectiveness of monetary policy in the Eurozone is determined after answering H3. H3 gives insights in the broad impact of money supply growth on the economy. As the ECB alters the money supply via its monetary policy tools, answering this hypothesis gives some insights in the effectiveness of monetary policy (as well as QE) in the Eurozone. As monetary policy is ineffective in a balance sheet recession, confirming H3 strengthens the case for a balance sheet recession. H4 focuses on the impact of a shock to the real interest rate. In case of secular stagnation, lowering the real interest rate to the natural rate of interest results in a rate of GDP growth returning to its potential. Confirming H4 − an irresponsiveness of long-run GDP growth to the real interest rate − thus supports the balance sheet recession theory.

3 Data

3.1 Timespan and Geographical Area

To effectively make a distinction between the secular stagnation and balance sheet recession theories in the Eurozone, we analyze the period 1999Q1:2015Q4. By using this time period, we aim to capture both pre-crisis forces on the basis of secular stagnation as well as post-crisis forces underlying a balance sheet recession. The geographical area taken into consideration is the Eurozone, consisting of 19 countries. We thus take the admission of 8 countries since 1999 into account, and focus this research on the Eurozone as it is formed today. We use quarterly data.

3.2 Relevant Variables

This section provides an analysis of the variables used in the empirical section of this paper. The first part of this section describes the main economic aggregates used in the analysis. Afterwards, variables depicted as most important drivers of secular stagnation and balance sheet recessions are portrayed. This section concludes with the selection of monetary policy and interest rate variables.

3.2.1 Aggregate Variables

As discussed in section 2, a deficiency in demand is possibly the result of both a balance sheet recession and secular stagnation. As we are interested in economic growth, the most evident variable to include is GDP growth. We use quarterly chain-linked data of the GDP level, originating from the Eurostat database. By chain-linking these GDP figures, the price level of the previous year is taken into account. In other words, the GDP variable is corrected for the inflation level and is thus observed in real terms. We transform this real GDP variable into its natural logarithm and refer to this variable as *GDP*. This variable is measured in millions of Euros. We use the natural logarithm as our empirical methodology relies on the first-differenced value of the *GDP* variable. First-differencing of a variable denoted in its natural logarithm results in values approximately equal to percentage changes. As we are interested in growth rates, we rely on this methodology. For similar reasons, we transform several additional variables in their natural logarithmic form.

Another variable of interest concerns the level of aggregate investments within the Eurozone. A potentially important driver of sluggish GDP growth is a lack of private sector investments. As noted in section 2, both secular stagnation and a balance sheet recession result in a decline in investment-demand. We capture the level of investments by using Eurostat data on gross fixed capital formation. We observe investments in real terms and refer to this variable as *investments.* We transform this variable into its natural logarithm, and this variable is measured in millions of Euros.

3.2.2 Variables relevant for Secular Stagnation

As Hansen (1939) argues, changing demographics are considered as the major driver of secular stagnation. Summers (2014a), among others, states the largest threat to the Eurozone concerns demographic change. For this reason, we exclusively take into account demographic variables when focusing on secular stagnation. As observed in the European Commission report (2015), the Eurozone's main forecasts show lower labor supply growth and an increasing old-age dependency ratio. We use Eurostat population data of two age categories to create a dependency ratio. This dependency ratio is calculated as:

$$Dependency\ ratio = \frac{Individuals\ >\ 65\ years\ old}{Individuals\ 15 - 64\ years\ old} * 100\ \% \quad (3)$$

As this data is only available annually, we use linear interpolation to transform the ratio into quarterly data. Linear interpolation is most appropriate in this case, as the ratio follows a linear path. After this exercise, we obtain the quarterly *dependency ratio*. We expect a negative impact of this variable on the *GDP* and *investment* variables. As shown in section 2.2, the Eurozone shift in the dependency ratio originates from a decline in labor supply growth. Following Keynes (1937), a decline in the labor force results in lower investment-demand and lower output growth. We therefore expect a negative impact of the *dependency ratio* variable on the *GDP* and *investment* variables. In contrast, assuming consumption-smoothing over the life-cycle, the *dependency ratio* may have an alternative impact. As the numerator consist of net consumers and the denominator consists of net savers, an increase in the *dependency ratio* may result in an increase in the relative level of consumption. However, as the large shift in the Eurozone dependency ratio originates from a lower labor supply, we expect a negative impact on our economic aggregates measures. In order to only include this labor supply shift, we include the labor supply growth rate as an important variable underlying secular stagnation. The labor supply consists of individuals between 15 and 64 years old. We manually transform the labor supply into its growth rate via $(new - old)/old * 100\%$. Again, we make use of linear interpolation in order to find the quarterly growth rate. We refer to this variable as *labor supply*. Again, following Keynes (1937), we expect a positive impact of the *labor supply* variable on *GDP* and *investments*.

3.2.3 Variables relevant for Balance Sheet Recession

Koo (2003) states that a balance sheet recession occurs whenever both households and corporations are paying off debt. The relevant variables are thus household and (non-financial) corporate sector deleveraging. We take into account household and non-financial corporate debt levels. Household debt consists of total loans towards the household sector, whereas corporate debt consists of loans, debt securities and currency and deposits held by non-financial corporations. We combine this data to create total private sector debt and refer to this variable as *debt*. This variable is measured in millions of

Euros. We expect a positive impact of this variable on the *investments* and *GDP* variables. We use non-consolidated quarterly financial balance sheet data, retrieved from the European Sector Accounts 2010 database on Eurostat. The data is transformed into its natural logarithm. For a representation of the household and non-financial corporate debt-to-equity ratio's in isolation, see figure 13 in Appendix A. Furthermore, figure 14 in Appendix A shows the total private sector debt/GDP ratio. This data is obtained from the BIS series on total credit to the non-financial sector. As this figure relies on the financial transactions account instead of the balance sheet data, we observe a deviation between this ratio and our *debt* and *GDP* data. As we are solely interested in a change in absolute debt levels via deleveraging, we rely on our measure of indebtedness. Furthermore, the decision to include the total private sector debt level as opposed to the private sector debt/equity or debt/GDP ratio originates from data-related issues. Specifically, the regression results of both the debt/equity and debt/GDP ratios were counterintuitive. This is potentially the result of an inability to effectively distinguish between movements in these variables caused by changes in the term in the numerator on the one hand or the term in the denominator on the other.

3.2.4 Monetary Policy and Interest Rate Variables

As our research focuses on the Eurozone, we are able to take into account several monetary variables. With the main outcome variables being GDP and Investment growth, we must control for confounding forces that impact these variables. A monetary variable that impacts these outcome variables is the money supply. This variable, indicating the stock of money flowing into the real economy, is a measure of aggregate demand. Furthermore, the goal of monetary policy is often to alter the money supply. By altering the money supply, interest and inflation rates respond. We take into account the broadest measure of money supply. This variable will be referred to as *M3* and is transformed into its natural logarithm. *M3* is measured in millions of Euros. We retrieve this monetary variable from the ECB Statistical Data Warehouse. We expect a positive impact of *M3* on *investments* and *GDP*.

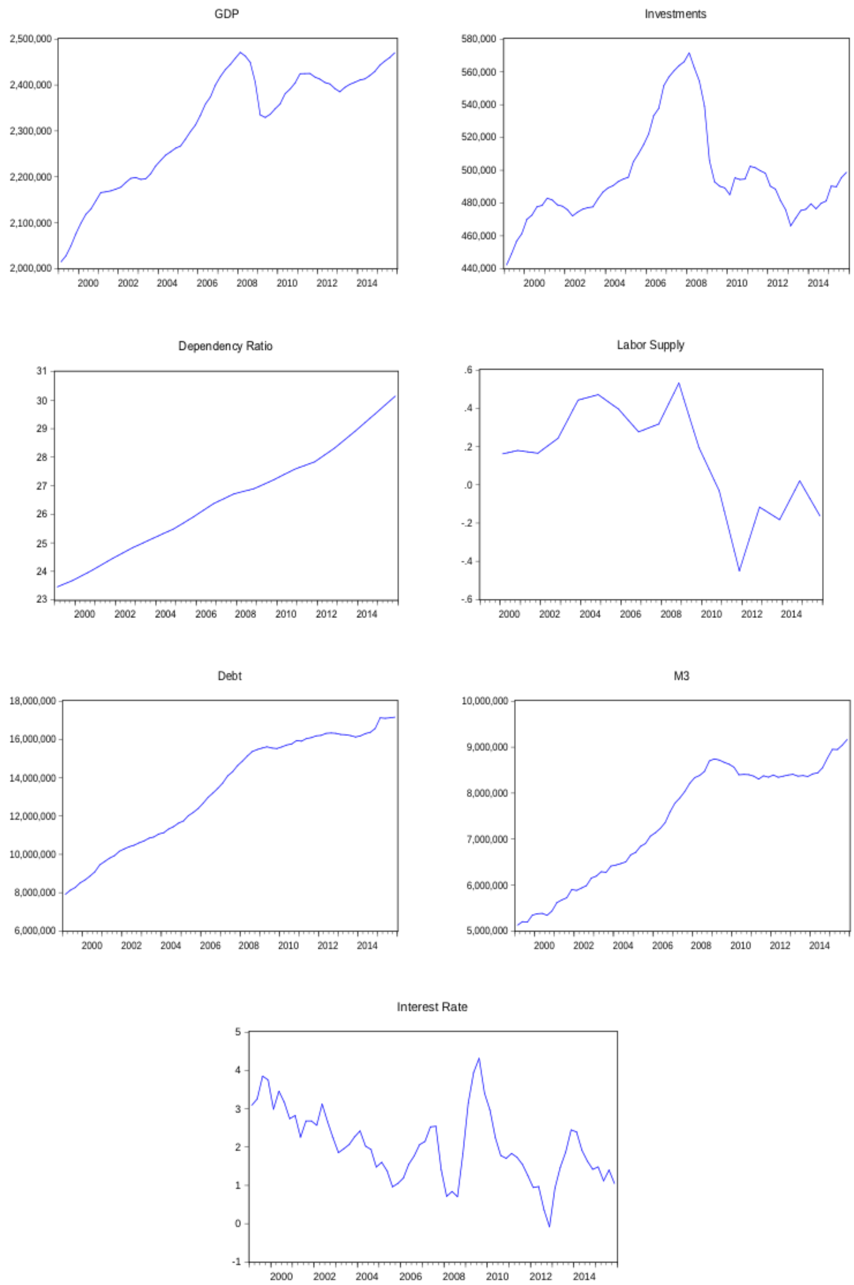
An important additional variable, relevant for both the secular stagnation and balance sheet recession theories, is the long-term interest rate. The interest rate plays an important role in the secular stagnation theory due to its relationship with the natural rate of interest. The secular stagnation theory states that a decline of the real interest rate towards the natural interest rate results in a recovery in economic growth towards its potential. In determining which interest rate to use, we decide to focus on the 10 year Eurozone government bond yield. This data is retrieved from the ECB Statistical Data Warehouse, and calculated by weighing the government bond yields of all 19 Eurozone Member States. We deduct the inflation rate (shown in figure 15 of Appendix A) from the nominal interest rate to obtain the long-term real interest rate. We obtain this inflation rate from the Eurostat database. We refer to this variable as *interest rate*. As this interest rate represents the cost-of-capital of investments for firms and households, we expect a negative impact of this variable on the *investments* and *GDP* variables. An alternative to this long-term interest rate is the 10-year commercial interest rate.

However, figure 16 in Appendix A shows that this commercial rate on long-term loans for households and businesses largely moves in line with the 10-year government bond yield. Therefore, we rely on our initial *interest rate* variable.

3.3 Graphical Representation Variables

Figures 1 and 2 provide insights in the movement of our main variables of interest over the period 1999Q1:2015Q4. Figure 1 illustrates the variables in levels, whilst figure 2 shows the variables in first-differences. We observe that both GDP and Investments showed a large decline at the onset of the GFC. The private sector debt level grew less rapidly following the onset of the crisis. The dependency ratio increases throughout the entire sample period, whereas labor supply growth shows a sharp decline around 2009. The interest rate shows a large decline following the trough around 2009. By observing the variables in first-differences, we are able to determine stationarity of our variables. We observe that the majority of the variables tend to oscillate around zero, suggesting stationarity. However, due to linear interpolation, the old-age dependency ratio and labor supply shows a different path. Chapter 4 further elaborates on the importance of stationarity within this paper.

Figure 1: Variables in Levels



Note: The time period taken into consideration is 1999Q1:2015Q4. Variables *GDP, Investments Debt* and *M3* measured in millions (Euros). *Dependency Ratio* and *Interest Rate* are percentages and *Labor Supply* is a growth rate.

Figure 2: Variables in First-Differences

Note: The time period taken into consideration is 1999Q1:2015Q4. Figures include differenced values, that is ($variable_t - \ variable_{t-1}$).

4 Methodology

This section focuses on the empirical strategy underlying our results. To this end, section 4.1 introduces the main model used in the paper. Section 4.2 turns to the relevance of stationarity of our time-series variables. In section 4.3, we turn to the importance of determining the correct lag length, after which section 4.4 presents the concept of cointegration. Finally, sections 4.5 and 4.6 present the main applications of our models. Herein we focus on Granger Causality and Impulse Response Functions (IRFs).

4.1 Vector Autoregressive Model

On the basis of the empirical analysis is a Vector Autoregressive (VAR) model, introduced by Sims (1980). This VAR-model describes the evolution of a set of variables from only their common history. Generally, a p-lag VAR (p) model for a k-dimensional vector Y_t is depicted as (Verbeek, 2008):

$$\bar{Y}_t = \delta + \Theta_1 \bar{Y}_{t-1} + ... + \Theta_p \bar{Y}_{t-p} + \bar{\varepsilon}_t \tag{4}$$

where $\bar{Y}_t$ is a vector of endogenous variables, δ is the intercept vector and Θ_p the number of coefficients. $\bar{\varepsilon}_t$ indicates the vector of unpredictable white noise components and p refers to the number of lags. This white noise term is assumed to have a mean of zero and a constant variance (Verbeek, 2008). Within the VAR-model, endogenous and exogenous variables do not have to be defined *a priori*. Every variable within the $\bar{Y}_t$ vector thus enters the VAR model in the same (endogenous) manner.

For this reason, VAR-models are useful when demographic variables are taken into consideration. This is the case as population growth is unlikely to be truly exogenous with respect to GDP growth in the long run. An increase in population growth results in GDP growth, and GDP growth is generally found to be positively related to fertility rates. This reverse causality issue results in bias of the coefficient on the demographic variable. To circumvent this problem, VAR-models are often used in determining the impact of demographics on economic aggregates (Aksoy et al., 2016; Eckstein et al., 1984; Nicolini, 2007; Kim and Lee 2008). As all variables are treated as endogenous in the VAR, the largest issues with respect to endogeneity are evaded. For similar reasons, the impact of deleveraging on economic aggregates is also regularly determined by making use of the VAR strategy (Kumar, 2014).

Before estimating the VAR-model, determining the stationarity of the various time-series within the model is vital. Whenever certain variables are not stationary, estimating a VAR in levels − as in equation 4 − is no longer advisable, as the short-run dynamics between variables may not be well captured. As a result of differences between the rules of convergence towards the 'true' estimator for stationary and non-stationary variables, interpreting regression coefficients in a model including non-stationary variables becomes difficult (Granger and Newbold, 1974). The following section further describes the intuition behind stationarity.

4.2 Stationarity

In order to describe the notion of stationarity, consider the following first-order autoregressive, AR (1), process (Verbeek, 2008):

$$Y_t = \delta + \theta Y_{t-1} + \varepsilon_t \tag{5}$$

In this process, the current value Y_t is explained by a constant δ plus θ times the value of Y in period $t-1$. An error-term is added to act as an unpredictable $-$ white noise $-$ component. Stationarity of Y_t occurs when shocks to this variable die out over time, and the series converges back to the origin after such a shock. In this situation, the variances of Y_t and auto-covariances of $(Y_t - Y_{t-p})$ are independent of time. In terms of the AR process in equation 5, stationarity is observed when $-1 < \theta < 1$. If we make p tend to infinity in this situation, the expected value of Y_t, $E[Y_t]$, becomes zero. In this situation, a random shock to the system gradually dies out over time. The mean of Y_t is thus independent of time. Furthermore, using similar reasoning, the variance of Y_t becomes finite.

In contrast, the process in equation 5 shows non-stationarity when $\theta = 1$. By forward substitution of equation 5, we can show that $E[Y_{t+p}] = Y_t$. Thus, in the long-run, there is no tendency to return to zero. Rather, a 'random walk' outcome is observed. This random walk states that we are unable to find a clear path of the series, every movement of the series is completely random. Furthermore, we are able to show that the variance of the series grows linearly in time. In essence, the variance is thus infinite. When $\theta = 1$, the series is non-stationary, or contains a 'unit root'. Additionally, a value of $|\theta| > 1$ results in non-stationarity. In this situation, convergence to a mean does not occur either: a random shock results in an increasing divergence of the time-series over time.

In addition to equation 5, it is possible that the series is non-stationary due to the presence of a time trend. This is the case whenever a time trend t is added to equation 5 (Verbeek, 2008):

$$Y_t = \delta + \theta Y_{t-1} + \gamma t + \varepsilon_t \tag{6}$$

where $-1 < \theta < 1$ and $\gamma \neq 0$. In this case, the process for Y_t is 'trend stationary'. As in regular stationary processes, a shock to the system in equation 6 results in mean-reversion. In this situation, the series reverts to its trend in the long-run.

In general, regressions including non-stationary variables are at risk of being 'spurious'. The danger of estimating a spurious regression is mainly concerned with causality. A regression of two non-stationary variables may indicate causality between the variables, while in reality a mere correlation is present. Granger and Newbold (1974) indicate that these 'nonsense' regressions result in an inability to interpret the resulting regression coefficients. Thus, we are only able to make proper use of the VAR-model when all variables are stationary. If we find a series to be stationary in levels, we say that this series is integrated of order zero: I (0). However, Nelson and Plosser (1982) indicate that most economic time-series are non-stationary. One solution to non-stationary time-series is transforming the data into first-differences. When the series become stationary after transformation into first-differences, this series is integrated of order 1: I (1). Series that become stationary after differencing twice are integrated of order 2: I (2), and so forth. Section 4.2.1 focuses on empirical tests used in order to identify stationarity.

4.2.1 Stationarity Tests

In order to successfully determine the order of integration of our variables, we rely on three different stationarity tests. We use the Augmented Dickey Fuller Test (ADF-Test) (Dickey and Fuller, 1979), Phillips-Perron test (PP-Test) (Phillips and Perron, 1988) and the Kwiatowski, Phillips, Schmidt and Shin test (KPSS-Test) (Kwiatowski et al., 1992) We briefly explain the theory behind these tests in this section.

The ADF-Test is used to reveal stationarity within a higher-order AR process (Dickey and Fuller, 1979). The Dickey-Fuller test estimates whether $\theta = 1$ in equation 5. This test only takes into account an AR (1) process. However, in the ADF-Test an AR (p) process is assumed. This ADF-regression, including the possible presence of a deterministic time trend, is shown as (Verbeek, 2008):

$$\Delta Y_t = \delta + \pi Y_{t-1} + \beta_p \Delta Y_{t-p} + \gamma t + \varepsilon_t \tag{7}$$

This augmented regression is used to test the hypotheses (Verbeek, 2008):

$$H_0 : \pi = 0, H_A : \pi < 0 \tag{8}$$

H_0 indicates presence of a unit root and thus a non-stationary time series, H_A indicates the series is (trend) stationary. When performing the ADF-Test, we have the possibility to include an intercept (constant), both a linear trend and an intercept, or neither. We determine whether inclusion of these terms is necessary by relying on economic theory. For instance, a constant is included whenever the mean of a variable is larger than zero by definition. The graphical representations of the variables of interest in section 3.3 give insights in inclusion of a constant when testing for stationarity. For instance, the *investment* variable should include a constant. Furthermore, economic theory suggests that the real GDP level follows a certain trend. We therefore test this variable for stationarity by including a constant and a linear trend. H_A now indicates that the variable is stationary around a deterministic trend.

Kwiatowski et al. (1992) develop an alternative method of testing for the presence of a unit root. The KPSS-Test applies slightly different assumptions than the ADF-test when determining whether a variable is stationary or not. Specifically, the hypotheses are the mirror image of the ones in the ADF-test. With the KPSS-Test, the null hypothesis indicates the time series is (trend) stationary, whereas the alternative hypothesis indicates non-stationarity. As in the ADF-test, we use economic theory to determine whether a trend is required in this test.

Finally, we consider a test created in Phillips and Perron (1988). The PP-Test is comparable to the ADF-test but differs in the method used to incorporate lags. Where the ADF-test directly incorporates the lags in its regression − as in equation 7 − the PP-test accounts for lags by adjusting the test statistics. Under the PP-Test, the null hypothesis refers to non-stationarity and the alternative hypothesis states the series is stationary. Again, we decide to include a constant, a linear time trend or neither.

4.3 Lag Length Selection

After identifying whether our variables are stationary or not, we are able to run the VAR model in levels (in case the variables are I(0)) or in differences (whenever the variables are I(1)). However, before estimating this VAR, we have to determine the optimal number of lags to incorporate in the model. That is, the p in equation 4. Lütkepohl (1993) states that including a longer lag length than the 'true' one results in an increase in the mean square error forecast of the VAR model, biasing the estimates of this model. On the other hand, a lag length shorter than optimal results in residual autocorrelation (Gonzalo, 1994). Furthermore, Braun and Mittnik (1993) find that impulse responses and variance decompositions are incorrectly specified from a VAR with a lag length that differs from its true value. Deciding on the appropriate lag length stems from statistical methods and economic arguments.

Several statistical tests are available for determining the optimal lag length in a VAR model. Besides the SC, created in Schwarz (1978), and the HQ created in Hannan and Quin (1979), we make use of the Akaike Information Criterion (AIC) developed in Akaike (1998) and several other means of model selection (Log Likelihood and Final prediction error). Ivanov and Kilian (2005) argue that in quarterly VAR models with less than 120 observations, the SC statistic provides the best results. We thus attach relatively more weight to the results found when performing the SC test. We determine the lag length by observing the outcome of the statistical tests, and assess whether the suggested lag length makes economic sense.

To this end, we must assess how persistent the effects of shocks to both the debt level and demographic variables are on economic aggregates. In the VAR model in Aksoy et al. (2016), determining the impact of demographic shocks on economic aggregates, estimation occurs by using both 1 and 2 lags. However, the demographic data in this paper is gathered annually, indicating 4-8 lags in our quarterly model. In the VAR of Nicolini (2007), a data-oriented strategy is used. Using annual data, the Bayesian Information Criteria (BIC) and Hannan Quin (HQ) information criterion find that it is optimal to use either 1 or 2 lags. However, Nicolini (2007) takes into account the birth rate as demographic variable, and therefore differs from our approach. Concerning the impact of deleveraging forces on economic aggregates, Kumar (2014) makes use of quarterly data in a SVAR model and estimates that 4 lags are appropriately taking into account the dynamic impact of deleveraging.

4.4 Cointegration

If our variables are integrated of order 1, we are forced to run the VAR-model in first-differences. Although first-differencing removes the risk of running a spurious regression, it has a drawback. The first-difference estimation only reveals the short-run relationship between variables, and removes any long-run information existing in the level representation of the data. Thereby, information on long-run relationships between variables is lost by relying on this method.

Engle and Granger (1987) provide a solution to this problem. The authors find that a linear combination of two or more non-stationary time series may be stationary. If this combination exists, these non-stationary time series are 'cointegrated'. In other words, cointegration is observed whenever within a set of non-stationary variables, one or more linear relationships exist that are I(0). These variables are nonstationary in isolation (and in levels) and become stationary when combined. Imagine, for instance, the following estimated regression model (Verbeek, 2008):

$$Y_t = \alpha + bX_t + \varepsilon_t \tag{9}$$

In this regression, we assume that both variables Y_t and X_t are I (1). In case we observe that $Y_t - bX_t - \alpha = I(0)$, the series is cointegrated. This cointegrating relationship can be interpreted as a long-run equilibrium equation. In this series, the OLS estimator $\hat{b}$ is said to be 'super-consistent' for its true value β (Engle and Granger, 1987). This super-consistency indicates that the OLS estimator $\hat{b}$ converges to its true value at a much faster pace compared to an estimation without a cointegrated series.

Engle and Granger (1987) state that whenever this cointegrated relationship is found, a valid 'error correction' representation of the data exists. In general, when both Y_t and X_t are I (1), but have a long-run relationship which is I (0), there must be some force that pulls deviations from its equilibrium back towards zero. This force thus corrects for these deviations. To this end, consider the simple regression model in equation 9, written in first-differences:

$$\Delta Y_t = \alpha + \phi \Delta X_t + \varepsilon_t \tag{10}$$

This model accounts for a spurious relationship between Y_t and X_t, but does not yet incorporate the long-run equilibrium that underlies the relationship. Therefore, we have to alter equation 10, and include the $Y_t - bX_t - \alpha$ term, found to be I (0). In fact, this term is equal to the residual of equation 9: ε_t. In order to effectively incorporate the long-run term in equation 10, we add the lagged value of this residual term: ε_{t-1}. This lagged value can be thought of as an equilibrium error that occurred in the previous period. Furthermore, instead of the current difference term of X_t, we include its lagged difference term. After altering equation 10, we obtain the following (Verbeek, 2008):

$$\Delta Y_t = \alpha + \phi \Delta X_{t-1} - \gamma (Y_{t-1} - \alpha - bX_{t-1}) + \mu_t \tag{11}$$

Engle and Granger (1987) refer to a model of this kind as the Error Correction Model (ECM). The ϕ coefficient captures the short-run dynamics of the model, where the γ coefficient determines how quickly the Y_t variable reverts to its long-term equilibrium. That is, if past values of Y_t deviate from its equilibrium value, the γ coefficient corrects this deviation downwards. To this end, the γ coefficient has to be negative. If this coefficient is positive, deviations would be corrected upwards. This does not result to a reversion to equilibrium, rather an increasing deviation from its equilibrium occurs. This regression does not include any nonstationary variables, as ΔY_t, ΔX_{t-1} and $(Y_{t-1} - \alpha - bX_{t-1})$ are I (0). Therefore, the regression is not spurious.

The ECM created in equation 11 can be extended to a model including more than two variables, as is required in our VAR strategy. Starting from the simple VAR model in equation 4, we can determine whether multiple cointegrating relationships are present. Johansen (1988) develops a test for finding multiple cointegrating relationships in such a multivariate framework. Imagine all variables in equation 4 are I (1). For similar reasons as in the two-variable system, we do not want to throw away information in the variables long-run relationships. In case of r cointegrating relationships within the VAR, we can alter equation 4 in order to include the long-run mechanics in the following manner (Verbeek, 2008):

$$\Delta \bar{Y_t} = \delta + \Theta 1 \Delta \bar{Y}_{t-1} + ... + \Theta p \Delta \bar{Y}_{t-p} + \gamma \beta^{'} \bar{Y}_{t-1} + \bar{\varepsilon}_t \tag{12}$$

This regression is called a Vector Error Correction Model (VECM). The coefficients in γ measure the error correction terms. This VECM includes the error correction term in the original VAR model. Hereby, both short- and long-run dynamics of the model are taken into account. The first-differenced variables in equation 12 represent short-run dynamics, the $\gamma \beta^{'} \bar{Y}_{t-1}$ includes the cointegrating relationships and thereby takes into account long-run dynamics.

Before using the VECM, we have to establish whether cointegrating relationships exist between our variables. We focus on two main methods of testing for the presence of a cointegrating relationship. We make use of the single-equation Engle and Granger (1987) residual based method and the multi-equation Johansen (1988) method. Sections 4.4.1 and 4.4.2 explain the intuition behind both tests.

4.4.1 Engle-Granger Method

The Engle and Granger (1987) residual method tests whether the residuals of a long-run equation are stationary. A two-step procedure underlies the Engle and Granger method. The first step of the Engle and Granger method requires estimation − using OLS − of a simple (long-run) relationship, as in equation 9. This two-variable equation can easily be extended to include multiple variables, as required in our analysis. From this equation, we capture the OLS residuals:

$$\varepsilon_t = Y_t - \alpha - bX_t \tag{13}$$

The residuals are used to determine whether a cointegrating relationship between Y_t and X_t is present. In order to test for this relationship, the residuals must be stationary. Testing for stationarity of these residuals occurs via the provided stationarity tests in section 4.2.1. Rejection of the null hypothesis of no stationarity indicates a cointegrated relationship is present.

After finding this cointegrating relationship between our variables, the second step requires estimation of the ECM. Generally, the ECM provides a manner of combining both short- and long-run dynamics between variables. The cointegrating term plays the role of this error correction term, and corrects any deviation from a long-run equilibrium through short-term adjustments. After establishing that the error term is stationary, we estimate an equation including its lagged value as in equation 11.

4.4.2 Johansen Method

A drawback of the Engle and Granger (1987) method is that it only allows for testing of a single cointegrating relationship between several variables. The method created in Johansen (1988) circumvents this problem, and allows testing for multiple cointegrating relationships within a subset of variables. The Johansen method does not require an OLS regression as in the Engle and Granger framework, but rather relies on Maximum Likelihood (ML) estimation. As a starting point, the Johansen test considers a VECM, similar to the one in equation 12 (Verbeek, 2008):

$$\Delta \bar{Y}_t = \delta + \Pi \bar{Y}_{t-p} + \sum_{i=1}^{p-1} \Gamma_i \Delta \bar{Y}_{t-i} + \bar{\varepsilon}_t \tag{14}$$

In this equation, we again assume that $\bar{Y}_t$ is a vector of I(1) variables. For this reason, all $\Delta\bar{Y}_{t-i}$ values will be zero in equilibrium. Furthermore, due to their assumed normal distribution, the expected value of the error terms will also be equal to zero. We also assume that the expected value of δ is equal to zero. The remaining $\Pi\bar{Y}_{t-p}$ term provides the foundation of the cointegration test. The Π matrix is assumed to take into account the long-run dynamics of the model. In order to observe whether long-run relationships exist, hypotheses on the long-run matrix Π have to be tested. To this end, the matrix Π can be written as a function including a vector of adjustment parameters γ and a matrix of − hypothetical − cointegrating vectors β (Verbeek, 2008):

$$\Pi = \gamma \beta' \tag{15}$$

The coefficients in the cointegrating vector β' act as the long-run estimation (similar to b in equation 9), and provide a linear combination of variables that are stationary. The γ coefficients represent the pace of adjustment, and determines how quickly the variables respond to deviations from a long-run equilibrium. Again, we thus expect negative values for γ. On the other hand, when no cointegrating relationships are present, the matrix Π is equal to zero.

Thus, the Johansen test determines whether $\Pi = 0$. Specifically, the rank, r, of the matrix has to be determined. This rank corresponds to the number of cointegrating relationships. The Johansen tests are based on 'eigenvalues'. These values are − after transformation of the original data − estimated by means of likelihood ratio tests, and are displayed in a descending order: $\hat{\lambda}_1 > \hat{\lambda}_2 > .... > \hat{\lambda}_k$ (Dwyer, 2014). For a cointegrating relationship to be present, the largest eigenvalue must be significantly larger than zero, where the other values must not significantly differ from zero. When the second largest eigenvalue also differs from zero, and the rest of the eigenvalues do not, we observe two cointegrating relationships. We thus test the null hypothesis of no cointegration versus the alternative of one (or more) cointegrating relationships. In mathematical terms, the hypothesis $H_0 : r \leq r_0$ versus the alternative of $H_A : r_0 < r \leq k$ is tested by making use of the following statistic (Verbeek, 2008):

$$\lambda_{trace}(r_0) = -\tau \sum_{j=r_0+1}^{k} log(1 - \hat{\lambda}_j) \tag{16}$$

This test is called the trace-test. The alternative hypothesis represents a number of cointegrating relationships smaller than or equal to the maximum number of relationships possible. A more restrictive test estimates whether $H_0 : r \leq r_0$ versus $H_A : r = r_0 + 1$ by means of the following statistic (Verbeek, 2008):

$$\lambda_{max}(r_0) = -\tau log(1 - \hat{\lambda}_{r_0+1}) \tag{17}$$

This alternative test is referred to as the maximum eigenvalue test. In our analysis, we solely rely on the trace test. This decision is based on a study of Lütkepohl et al. (2001), who compare the properties of both tests. The authors find the trace test to sometimes be superior than the maximum eigenvalue test, especially concerning the power of both tests.

Before relying on the trace test, the Johansen test requires an assumption regarding the trend underlying the data. Precisely, we have to decide on − as in the ADF-test − whether to include an intercept and linear trend in the cointegrating relationship and in the general time series data. By making use of economic theory and observing graphical representations of our variables, we determine which specification fits our data best. The inclusion of intercept terms and linear trends in the series data can be derived from observing figure 1 in section 3.3. Furthermore, we determine whether a linear relationship between cointegrated variables exists by relying on graphical representations of the data. Additionally, lag length selection is important when performing the Johansen cointegration test. We make use of the lag length as specified as optimal in the estimated VAR model via the specification tests as shown in section 4.3.

4.5 Granger Causality

In case we do not find any cointegrated relationships via the previously mentioned approaches, we estimate a VAR model. If we do find evidence for these relationships, we estimate a VEC model. After creating this optimal VAR or VEC model, we are in the position to use the coefficients created in the model. We use the Granger causality test. This test, developed in Granger (1969), indicates whether short-run causality is present between several variables. The test examines whether lagged values of one variable in the VAR or VEC help to predict another variable. A time series X_t 'Granger causes' Y_t if lagged values of X_t are significant in explaining Y_t. It is also possible that Y_t causes X_t. In this situation, bi-directional causality is present.

In our analysis, we use Granger causality to test whether short-run causality between several variables is present. However, the Granger Causality test differs when using a VAR or VEC-Model. As the Granger method only measures short-run dynamics, the Granger test is incapable of determining whether the error correction term in a VEC-model Granger causes other variables in the system. The Granger causality test does provide an additional basis for the short-run relationship between one variable and the other in the VECM. In case we use a VECM, and our variables are I (1), we must denominate our variables in first-differences when performing the Granger causality test to make proper inferences. We do not rely on the results of the Granger causality tests to provide answers to the hypotheses as laid down in section 2.7.

4.6 Impulse Response Functions

In addition to the Granger Causality test, we use Impulse Response Functions (IRF). These IRFs trace the effect of a one-time shock to one of the endogenous variables on current and future values of all the other endogenous variables in the model. The shocks, or 'innovations', are in fact impulses to the error terms of these endogenous variables. The impact of this impulse on other endogenous variables is easily interpretable whenever error terms in the vector of endogenous variables are uncorrelated. However, in macroeconomic modelling, it is often the case that various variables share a common component. In this case, correlation between variables exists and inferences from impulse responses cannot be made in a straightforward manner. An impulse to one of the variables cannot be measured in isolation, as other variables automatically respond. In order to circumvent this issue, we apply a transformation to the innovations, such that they become uncorrelated. Several transformation methods are available, including: Cholesky ordering, Generalized Impulses and unit and standard deviation residual impulses. As explained in Durlauf and Blume (2016) interpretation of impulse response functions differ from VAR- to VEC models. The impulses in a stationary VAR system do not have to tend to zero in the long-run, whereas impulses for systems including cointegrating relationships do tend to zero. We decide to make use of generalized impulse responses. Generalized impulses − originating from Pesaran and Shin (1998) − do not demand the variables in a VAR or VEC model to be ordered in a specific manner. Furthermore, 'orthogonalization' of impulses occurs. This orthogonalization process ensures that impulses (and error terms) become uncorrelated.

In addition to the generalized impulse responses, we rely on user specified impulse responses. We base the magnitude of these impulses on movements of our variables as depicted in section 3.3. In order to successfully distinguish between the impact of private sector deleveraging and the demographic transition, we have to ensure the innovations are uncorrelated and of a similar magnitude. We determine the magnitude of our shocks by observing the actual changes in several variables over the period 2008Q4:2015Q4. By creating a matrix including these changes on its diagonal, we create user specified impulse responses.

5 Results

This section presents the main results of our empirical analyses. We follow the steps laid out in the methodological section. Section 5.1 determines the level of stationarity of our variables of interest. Section 5.2 introduces the models, and determines their optimal lag lengths. Afterwards, section 5.3 analyzes whether cointegrating relationships are present within the specified models. We test the robustness of our models in section 5.4, after which section 5.5 provides the main results of the Granger causality analysis. Section 5.6 shows the results of the impulse responses.

5.1 Stationarity Tests

The results of the ADF, PP and KPSS-tests for the subset of variables as laid down in section 3 is provided in tables 1:3.

Table 1: Augmented Dickey Fuller Test

Variable	Exogenous variables	Lag length	Test statistic
GDP	Constant, Linear Trend	1	-2.137195
Investments	Constant	2	-2.324051
Dependency Ratio	Constant	1	1.214528
Labor Supply	Constant, Linear Trend	0	-2.116326
Debt	Constant	2	-2.488208
M3	Constant	5	-1.772097
Interest Rate	Constant	1	-3.278418**
ΔGDP	None	0	-3.144040***
ΔInvestments	None	0	-4.358104***
ΔDependency Ratio	None	0	0.456942
$2^{nd}\Delta$Dependency Ratio	None	0	-8.000000***
ΔLabor Supply	None	0	-8.061458***
ΔDebt	None	0	-1.711861*
ΔM3	Constant	4	-2.843232*

Note: * denotes the significance level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The Δ denotes first-differencing of the variable.

Table 2: Phillips-Perron Test

Variable	Exogenous variables	Bandwidth	Test statistic
GDP	Constant	4	-2.441912
Investments	Constant	5	-2.207782
Dependency Ratio	Constant, Linear Trend	6	0.828770
Labor Supply	Constant, Linear Trend	2	-2.174206
Debt	Constant, Linear Trend	5	-1.127691
M3	Constant	4	-1.884747
Interest Rate	None	1	-1.411787
ΔGDP	None	0	-3.144040***
ΔInvestments	None	4	-4.448695***
ΔDependency Ratio	None	1	0.464035
2^{nd}ΔDependency Ratio	None	0	-8.000000***
ΔLabor Supply	None	0	-8.061458***
ΔDebt	None	6	-2.500224**
ΔM3	Constant	3	-5.885229***
ΔInterest Rate	None	1	-5.735589***

Note: * denotes the significance level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The Δ denotes first-differencing of the variable.

Table 3: Kwiatowski, Phillips, Schmidt and Schin Test

Variable	Exogenous variables	Bandwidth	LM test statistic
GDP	Constant, Linear Trend	6	0.223148***
Investment	Constant, Linear Trend	6	0.204944**
Dependency Ratio	Constant, Linear Trend	6	0.139451*
Labor Supply	Constant, Linear Trend	6	0.167849**
Debt	Constant, Linear Trend	6	0.251542***
M3	Constant, Linear Trend	6	0.234079***
Interest Rate	Constant, Linear Trend	5	0.513353**
ΔGDP	Constant, Linear Trend	4	0.061161
ΔInvestments	Constant	5	0.188325
ΔDependency Ratio	Constant, Linear Trend	6	0.170794**
2^{nd}ΔDependency Ratio	Constant	1	0.100681
ΔLabor Supply	Constant	0	0.108272
ΔDebt	Constant, Linear Trend	5	0.068024
ΔM3	Constant, Linear Trend	4	0.112510
ΔInterest Rate	Constant	1	0.032140

Note: * denotes the significance level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The Δ denotes first-differencing of the variable.

Table 4: Order of Integration

Variable	ADF-Test	PP-Test	KPSS-Test
GDP	I (1)	I (1)	I (1)
Investments	I (1)	I (1)	I (1)
Dependency Ratio	I (2)	I (2)	I (2)
Labor Supply	I (1)	I (1)	I (1)
Debt	I (1)	I (1)	I (1)
M3	I (1)	I (1)	I (1)
Interest Rate	I (0)	I (1)	I (1)

Note: I(X) indicates that the variable is integrated of order X. That is, the variable has to be differenced X times in order to become stationary.

We observe that the majority of our variables are integrated of order one. The following five variables are I (1) in the ADF, PP and KPSS-tests: *GDP*, *Investments*, *Labor Supply*, *Debt* and *M3*. We observe a different outcome for the *Interest Rate* and *Dependency Ratio*. The PP- and KPSS-tests state the *Interest Rate* is integrated of order one, whilst the ADF-test finds that the variable is I (0). Stationarity of real interest rates has been studied in depth, the variable is usually found to be stationary after first-differencing (I (1)) (Rose, 1988; Coppock and Poitras, 2000). Furthermore, the graphical representation of the interest rate variable in section 3.3 shows that this variable tends to oscillate around zero after first-differencing. For these reasons, we treat the *Interest Rate* as I (1).

An odd outcome is observed for the *dependency ratio* variable. The test results indicate that this variable is I (2). After differencing twice, this variable becomes stationary. However, we believe this may be the result of the required manual linear interpolation practices on original annual data. Dezhbakhsh and Levy (1994) find that linear interpolation affects the 'true' outcome of stationarity tests. Focusing on related literature, we are inclined to believe that the true order of integration for the *Dependency Ratio* variable is I (1) (Aydin, 2010; Hondroyiannis, 2006). To this end, we proceed with our analysis by assuming that the *Dependency Ratio* variable is I (1).

5.2 Lag Length Selection

In order to analyze the appropriate lag length for our model, we create the following groups including our main variables of interest:

<u>Models</u>

1a *(GDP, Debt, Dependency Ratio, M3, Interest Rate)*

1b *(GDP, Debt, Labor Supply, M3, Interest Rate)*

2a *(Investments, Debt, Dependency Ratio, M3, Interest Rate)*

2b *(Investments, Debt, Labor Supply, M3, Interest Rate)*

These variables represent the $\bar{Y}_t$ endogenous variables (as in equation 4) in our system of preference. Throughout this paper, we refer to these models as models 1a, 1b, 2a and 2b. By estimating these models as a VAR in levels, we compare different lag lengths via the criteria laid down in section 4.3. The results of the lag length selection tests are found in tables 5 to 8.

Table 5: Lag Length Selection Model 1a

Lag	LogL	LR	FPE	AIC	SC	HQ
0	229.6055	NA	4.91e-10	-7.245339	-7.073796	-7.177987
1	823.1532	1072.215	5.34e-18	-25.58559	-24.55633	-25.18147
2	882.0206	96.84638	1.82e-18	-26.67808	-24.79111*	-25.93721*
3	897.5536	23.04902	2.57e-18	-26.37270	-23.62801	-25.29506
4	925.8714	37.45254	2.50e-18	-26.47972	-22.87732	-25.06533
5	966.4339	47.10481*	1.73e-18	-26.98174	-22.52162	-25.23058
6	1003.485	37.05088	1.46e-18*	-27.37048*	-22.05264	-25.28256

Note: * Indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error. AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion.

Table 6: Lag Length Selection Model 1b

Lag	LogL	LR	FPE	AIC	SC	HQ
0	401.3120	NA	1.93e-12	-12.78426	-12.61271	-12.71690
1	797.1278	715.0222	1.24e-17	-24.74606	-23.71680*	-24.34194*
2	831.1741	56.01168	9.38e-18	-25.03787	-23.15090	-24.29700
3	853.7862	33.55344	1.05e-17	-24.96085	-22.21616	-23.88321
4	877.9299	31.93204	1.17e-17	-24.93322	-21.33082	-23.51883
5	914.7817	42.79555*	9.18e-18*	-25.31554	-20.85542	-23.56438
6	945.1060	30.32432	9.61e-18	-25.48729*	-20.16945	-23.39937

Note: * Indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error. AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion.

Table 7: Lag Length Selection Model 2a

Lag	LogL	LR	FPE	AIC	SC	HQ
0	171.2978	NA	3.22e-09	-5.364444	-5.192901	-5.297092
1	772.9305	1086.820	2.70e-17	-23.96550	-22.93624	-23.56139
2	824.8259	85.37635	1.15e-17	-24.83309	-22.94612*	-24.09222*
3	842.9599	26.90841	1.50e-17	-24.61161	-21.86692	-23.53397
4	867.1735	32.02454	1.66e-17	-24.58624	-20.98384	-23.17185
5	911.6852	51.69094*	1.01e-17	-25.21565	-20.75553	-23.46449
6	943.4933	31.80808	1.01e-17*	-25.43527*	-20.11743	-23.34735

Note: * Indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error. AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion.

Table 8: Lag Length Selection Model 2b

Lag	LogL	LR	FPE	AIC	SC	HQ
0	337.4408	NA	1.51e-11	-10.72390	-10.55235	-10.65654
1	742.1597	731.1052	7.28e-17*	-22.97289	-21.94364*	-22.56878*
2	766.6943	40.36343	7.51e-17	-22.95788	-21.07091	-22.21701
3	788.5957	32.49882	8.64e-17	-22.85793	-20.11324	-21.78029
4	809.1509	27.18581	1.08e-16	-22.71454	-19.11214	-21.30015
5	848.7748	46.01487*	7.72e-17	-23.18628	-18.72616	-21.43513
6	878.0579	29.28315	8.36e-17	-23.32445*	-18.00661	-21.23653

Note: * Indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error. AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion.

For models 1a and 2a, the SC and HQ criteria indicate that including 2 lags is optimal. However − in both models − the FPE and AIC criteria select 6 lags. Ivanov and Kilian (2005) argue that in quarterly VAR models with less than 120 observations, the SC test provides the best results. The authors also argue that this criterion performs well when using a VEC model. Furthermore, models 1a and 2a both include the dependency ratio variable. We believe that including 2 lags in these models rather than 6 makes economic sense. The impact of a change in the dependency ratio on GDP and Investment growth is more likely to occur after half a year than after 1.5 years (Hondroyiannis and Papapetrou, 2001). For this reason, we decide to include 2 lags in models 1a and 2a.

In model 1b, the SC and HQ criterion indicate that including 1 lag is optimal whilst the LR and FPE tests find 5 lags to be optimal. The difference between this model and models 1a and 2a has to do with the demographic variable. In this model, labor supply is used as opposed to the dependency ratio. We believe that the labor supply has a more direct impact on GDP than the dependency ratio. The dependency ratio incorporates both changes in labor supply growth as well as changes in life expectancy. Compared to labor supply growth, a change in life expectancy has a delayed impact on economic aggregates. After a change in life expectancy, individuals make decisions on consumption and investments after a certain period of time. For this reason, it makes sense that the model that includes the labor supply variable finds a shorter lag length to be optimal. We thus decide to include 1 lag in model 1b. The same lag length is found by the FPE, SC and HQ tests for model 2b. For the same reason as with model 1b, we decide to include 1 lag in this model. A summary of the different lag lengths for the models 1a:2b is found in table 9 below.

Table 9: Lag Selection

Model	**Optimal number of lags**
1a	2
1b	1
2a	2
2b	1

Note: Optimal number of lags based on specification tests and economic arguments.

5.3 Cointegration Tests

After observing the level of integration of our variables and the optimal lag length of our models, we are in the position to determine whether using a VAR- or VEC-Model is optimal in our analysis. In making this decision, we have to assess whether cointegrating relationships are present in our models. As shown in section 4.4, two methods exist in identifying a cointegrated relationship. The following sections provide the results of the Engle-Granger and Johansen tests for cointegration.

5.3.1 Engle-Granger Test

As explained in section 4.4.1, the approach created in Engle and Granger (1987) requires a first-stage OLS regression of the possible long-run relationship in levels. In order to test this long-run relationship for cointegration, all variables have to be integrated of order 1. Section 5.1 established that this is the case in our models. We estimate the following long-run relationships, corresponding to models 1a, 1b, 2a and 2b:

$$GDP = c + \alpha_1\, Debt - \alpha_2\, Dep.\, Ratio + \alpha_3\, M3 - \alpha_4\, Interest\, Rate + \varepsilon_t \qquad (18)$$

$$GDP = c + \alpha_1\, Debt + \alpha_2\, Labor\, Supply + \alpha_3\, M3 - \alpha_4\, Interest\, Rate + \varepsilon_t \qquad (19)$$

$$Investments = c + \alpha_1\, Debt - \alpha_2\, Dep.\, Ratio + \alpha_3\, M3 - \alpha_4\, Interest\, Rate + \varepsilon_t \qquad (20)$$

$$Investments = c + \alpha_1\, Debt + \alpha_2\, Labor\, Supply + \alpha_3\, M3 - \alpha_4\, Interest\, Rate + \varepsilon_t \quad (21)$$

We expect the signs of the coefficients to be as portrayed in equations 18:21 in the long-run. Where all $\alpha_i \geq 0$ and the postulated signs have been inserted. The Engle-Granger two-step approach requires estimation of these long-run relationships, and subsequent stationarity testing of the residuals from the equations. Table 10 shows the results of the regressions in levels. Appendix B.1 shows the entire individual estimation output of the 4 models.

Table 10: OLS Regressions

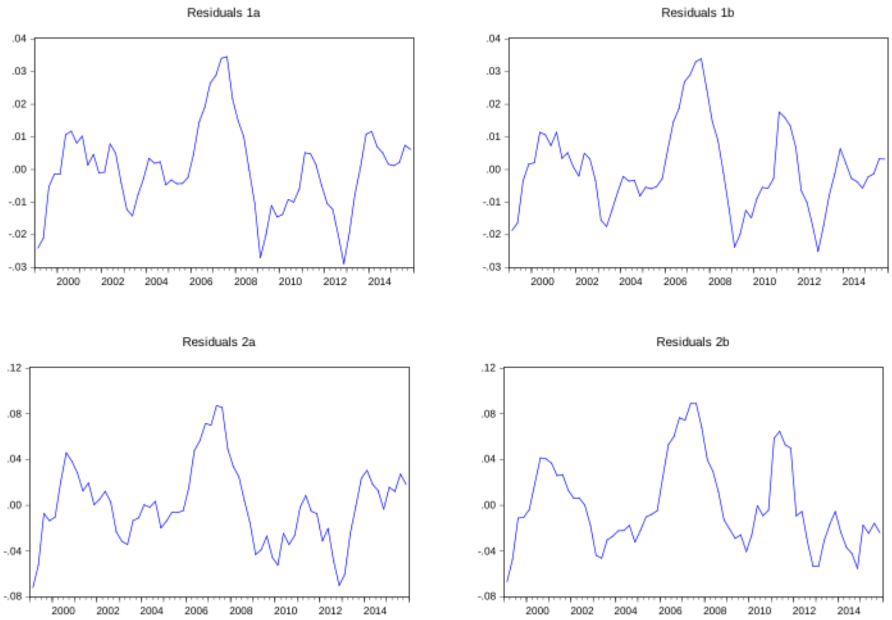
	GDP (1a)	GDP (1b)	Investments (2a)	Investments (2b)
Constant	10.1443***	10.7768***	5.0585***	8.9933***
	(0.333)	(0.250)	(0.869)	(0.736)
Debt	0.1206*	0.1696**	-0.4239**	-0.4461*
	(0.072)	(0.077)	(0.189)	(0.227)
Dependency Ratio	-0.0064**		-0.0439***	
	(0.003)		(0.008)	
Labor Supply		0.0982***		0.4134***
		(0.036)		(0.106)
M3	0.1725**	0.0703	1.0266***	0.7246***
	(0.078)	(0.092)	(0.204)	(0.270)
Interest Rate	0.0111***	-0.0086***	-0.0272***	-0.0170**
	(0.002)	(0.002)	(0.006)	(0.007)
Observations	68	68	68	68
R-Squared	0.9430	0.9452	0.6413	0.5632
Adj. R-Squared	0.9394	0.9418	0.6186	0.5355
Log Likelihood	197.9033	199.2674	132.5731	125.8730
F-Statistic	260.5687	271.8800	28.1636	20.3092
Prob. (F-statistic)	0.0000	0.0000	0.0000	0.0000
Durbin-Watson stat.	0.2486	0.2498	0.2536	0.2319

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard Deviations are shown in parantheses.

We observe that the majority of the regression coefficients are significant. Furthermore, we find the expected signs on the majority of our variables. The signs on the *Debt* variable in models 2a and 2b and on the *Interest Rate* variable in model 1a are exceptions. Nonetheless, making inferences from this model is unwise. As most of our variables are I (1), the regressions are probably spurious. The high R-squared values and low Durbin-Watson statistics reveal this is most likely the case (Granger and Newbold, 1974). The regressions are at risk of being serially correlated, and may suffer from omitted variable bias.

The main purpose of running these regressions is to find cointegrating relationships. The Engle-Granger approach involves statistical testing of the estimated residuals. To this end, we capture the residuals from the table 10 regressions and test them for stationarity. A graphical representation of these residuals is found in figure 3.

Figure 3: Residuals OLS Regressions



Note: Residuals of the OLS regressions as shown in Table 10.

These figures already indicate that the series tend to revert around zero. To test for stationarity more formally, we make use of the three stationarity tests as in section 5.1. Table 11 shows the results of the ADF, PP and KPSS tests on the residuals of the four models.

Table 11: Unit Root Tests on Residuals

Model	Test	Exogenous Variables	Lag Length / Bandwidth	Test Statistic
	ADF-Test	None	1	-3.6122***
1a	PP-Test	None	4	-3.0651***
	KPSS-Test	Constant	5	0.0817
	ADF-Test	None	1	-3.5859***
1b	PP-Test	None	4	-3.0194***
	KPSS-Test	Constant	5	0.0733
	ADF-Test	None	1	-3.1117***
2a	PP-Test	None	3	-3.0448***
	KPSS-Test	Constant	5	0.0854
	ADF-Test	None	1	-2.8032***
2b	PP-Test	None	4	-2.9104***
	KPSS-Test	Constant	5	0.1271

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. ADF-test: Augmented Dickey Fuller Test. PP-test: Phillips-Perron test. KPSS-test: Kwiatowski, Phillips, Schmidt and Shin-test.

Every test indicates that the residuals of the models are stationary in levels. Long-run relationships for all of the estimated models thus exist according to the Engle and Granger method.

We are now in the position to create the Error Correction representation of the models. For this second-stage of the Engle-Granger (1987) approach, the OLS regressions in table 10 have to be altered in a certain manner. As shown in equation 11 in section 4.4, we include first-differences of the dependent variables and lagged (1 period) first-differences of the independent variables. Furthermore, we include the lagged residuals found in the first-stage regressions. Table 12 shows the outcomes of these ECMs for models 1a:2b. The entire output per individual model is found in Appendix B.2.

Table 12: Error Correction Representations

	ΔGDP (1a)	ΔGDP (1b)	ΔInvestments (2a)	ΔInvestments (2b)
Constant	-0.0078***	0.0009	-0.0248***	-0.0033
	(0.003)	(0.001)	(0.006)	(0.003)
$\Delta Debt_{t-1}$	0.3809***	0.2912***	0.6315***	0.4896**
	(0.094)	(0.099)	(0.213)	(0.227)
$\Delta Dependency\ Ratio_{t-1}$	0.0831***		0.2099***	
	(0.024)		(0.053)	
$\Delta Labor\ Supply_{t-1}$		-0.0238		-0.0512
		(0.032)		(0.071)
$\Delta M3_{t-1}$	-0.2193***	-0.1703**	-0.2175	-0.1127
	(0.074)	(0.081)	(0.162)	(0.1791)
$\Delta Interest\ Rate_{t-1}$	-0.0009	-0.0012	-0.0027	-0.0034
	(0.001)	(0.002)	(0.003)	(0.004)
$Error\ Correction\ Term_{t-1}$	0.0246	0.0251	-0.0032	-0.0480
	(0.059)	(0.063)	(0.052)	(0.049)
Observations	66	66	66	66
R-Squared	0.3119	0.1779	0.2729	0.1027
Adj. R-Squared	0.2546	0.1094	0.2124	0.0279
Log Likelihood	252.6380	246.7616	200.7551	193.8102
F-Statistic	5.4414	2.5964	4.5061	1.3735
Prob. (F-statistic)	0.0003	0.0343	0.0015	0.2470
Durbin-Watson stat.	0.8265	0.6962	1.2248	1.0519

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard deviations are shown in parantheses.

The regression output for models 1a:2b in table 12 shows that the coefficients on the error terms are positive for models 1a and 1b. This indicates that the model corrects deviations from the long-run path upwards. This is counterintuitive, and would lead to an 'explosive' model. Any deviation from the equilibrium is corrected upwards. The coefficients on the error correction terms in models 2a and 2b are negative. However, these coefficients are not significant. Looking at the remaining coefficients on the variables in table 12, we observe that the majority of the values are insignificant. Additionally, the signs of several coefficients do not correspond with the theories laid down in this paper.

For instance, the demographic variables show the wrong sign. On the other hand, the *debt* variable is significant in every regression and shows the expected positive sign.

The Engle and Granger framework merely tests for a single cointegrating equation. In fact, multiple cointegrating equations may be present in our models. For this reason, we do not rely on the results of the regressions shown in table 12, and proceed with the Johansen test for multiple cointegrating relationships.

5.3.2 Johansen Test

To perform the Johansen test, we have to determine whether to include an intercept and/or linear time trend in the error correction term and in the regular time series data. We choose to include a time trend in the general series data only, and include intercepts in both the cointegrating terms and the general data. We believe that the majority of our variables follow a certain trend, but no relationship in this trend exists between the variables. Observing the variables in section 3.3 matches this belief. We include intercepts in both the cointegrating relationships as well as the data in levels as our variables have a mean which is above zero. We use the lag lengths for the different models as specified in section 5.2. The results of the Johansen tests are found in tables 13:16.

Table 13: Johansen Test Model 1a

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.410123	81.20104	69.81889	0.0047
At most 1	0.291058	46.89135	47.85613	0.0614
At most 2	0.214618	24.53254	29.79707	0.1788
At most 3	0.120548	8.829487	15.49471	0.3814
At most 4	0.007355	0.479830	3.841466	0.4885

Note: * denotes rejection of the hypothesis at the 0.05 level. ** are the Mackinnon-Haug -Michelis (1999) p-values.

Table 14: Johansen Test Model 1b

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.489864	94.22836	69.81889	0.0002
At most 1 *	0.297961	49.80528	47.85613	0.0324
At most 2	0.220541	26.45672	29.79707	0.1156
At most 3	0.108303	10.01250	15.49471	0.2798
At most 4	0.036397	2.446989	3.841466	0.1177

Note: * denotes rejection of the hypothesis at the 0.05 level. ** are the Mackinnon-Haug -Michelis (1999) p-values.

Table 15: Johansen Test Model 2a

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.387966	84.53784	69.81889	0.0021
At most 1 *	0.341448	52.62499	47.85613	0.0167
At most 2	0.233768	25.47373	29.79707	0.1452
At most 3	0.114582	8.166163	15.49471	0.4478
At most 4	0.003930	0.255969	3.841466	0.6129

Note: * denotes rejection of the hypothesis at the 0.05 level. ** are the Mackinnon-Haug -Michelis (1999) p-values.

Table 16: Johansen Test Model 2b

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.380390	82.32245	69.81889	0.0036
At most 1 *	0.284059	50.73058	47.85613	0.0262
At most 2	0.242129	28.67620	29.79707	0.0669
At most 3	0.100999	10.37821	15.49471	0.2528
At most 4	0.049507	3.351136	3.841466	0.0672

Note: * denotes rejection of the hypothesis at the 0.05 level. ** are the Mackinnon-Haug -Michelis (1999) p-values.

The Johansen output indicates that a cointegrating relationship is present in every model. For model 1a in table 13, the output rejects no cointegrating equations but is unable to reject at most 1 cointegrated relationship. For this reason, model 1a has 1 cointegrated relationship. Models 1b:2b in tables 14:16 indicate that a rejection of at most 1 cointegrated relationship occurs, but a rejection of at most 2 relationships does not occur. To this end, models 1b:2b cointain 2 cointegrated relationships.

As we find cointegrated relationships, we proceed our analysis by relying on VEC models. After specifying the correct lag lengths and the correct number of cointegrating relationships, we estimate our VEC models. This output is shown in Appendix B.3. The coefficients in the cointegrating equations provide some insights into the long-run impact of the variables underlying the secular stagnation (i.e. labor supply and dependency ratio) and balance sheet recession (i.e. debt) theories on GDP and investments. The results show that no long-run relationships between the labor supply and GDP variables exist in models 1b and 2b. This thus does not hold with the secular stagnation theory, stating that a long run positive relationship exists. A potential reason is concerned with the life-cycle consumption smoothing hypothesis (Eggertson and Mehrothra, 2014). In this model, individuals are net savers during their active years on the labor market. In contrast, the secular stagnation theory states that labor supply growth results in an increase in production and investments. Both factors may potentially shape the insignificant long-run relationship between labor supply growth and investment and GDP growth. Furthermore, the coefficient on the debt variable in model 1a shows a significant and positive sign. Over the long-run, an increase in the debt level thus results in GDP growth. This holds with the balance sheet recession theory. In line with the secular stagnation theory, the dependency ratio variable has a negative and significant impact on investments in model 2a. Finally, M3 has a significantly positive impact on GDP and Investments in models 1b:2b and the interest rate variable has a significantly negative impact on GDP in model 1b. In order to test the formulated hypotheses, we take into account both short-run and long-run dynamics between our variables of interest. To this end, we focus on estimating the IRFs.

5.4 Model Robustness

Before turning to the Granger causality and impulse response analyses, we have to determine whether our VEC models are robust to several specification checks. Lütkepohl and Krätzig (2004) provide several tests for adequacy of VAR and VEC models. The authors focus on tests concerned with residual autocorrelation and normality of residuals. In addition to these model adequacy tests, we focus on stability of our models (Lütkepohl, 1993).

In case of autocorrelation in the residuals, the estimated parameters of the VEC model may become biased. Gonzalo (1994) further states that underspecifying the number of lags in a VEC model can lead to serial correlation in the residuals. Concerning tests for residual autocorrelation, Brüggemann et al. (2006) state that the Breusch-Godfrey autocorrelation test by Breusch (1978) and Godfrey (1978) provide good properties for VEC-Models. We provide the results of these residual autocorrelation tests for our models in Appendix C.1. We observe that model serial correlation is present in the second lag of model 2a. However, as shown in section 5.2, both statistical lag length tests and economic reasoning indicate that the optimal lag length for model 2a is 2. Furthermore, appendix C.3 indicates that model 2a is stable when including two lags. Therefore, we decide to not alter the number of lags in this model.

The second model adequacy test concerns normality of the VEC models' residuals. We assess whether these residuals are normally distributed by means of Choleski decomposition of the residual covariance matrix. Results of the normality tests are found in Appendix C.2. We conclude that all of our models show signs of non-normality. However, non-normality of residuals does not have to impose significant problems to our estimation exercise (Lütkepohl, 1993. pp. 174-181). We therefore decide to not alter the models.

Finally, we focus on stability of our models. In case of instability, specification errors following VEC estimations may result (Lütkepohl, 1993). As shown in Lütkepohl (1993), we determine stability by focusing on the inverse roots of the AR lag polynomial. Appendix C.3 shows the results of these exercises. We determine that all of our models are stable.

5.5 Granger Causality

As explained in section 4.5, Granger causality merely measures short-run dynamics between variables. We use the Granger causality test to get further insights the short-run relationships among our variables. The variables are denoted in first-differences. We focus our analysis on model 1b, including GDP growth as well as labor supply growth.

Table 17: Granger Causality Model 1b

Dependent variable: ΔGDP			
Excluded	Chi-sq	df	Prob.
ΔDebt*	3.483408	1	0.0620
ΔLabor Supply	1.112635	1	0.2915
ΔM3*	2.771432	1	0.0960
ΔInterest Rate	1.540733	1	0.2145
All*	8.971431	4	0.0618

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. df: degrees of freedom. Chi-sq: Chi-squared test-statistic. Δ denotes first-differences.

The test results indicate that Granger causality runs between M3 and GDP, and between Debt and GDP. Furthermore, no Granger causality is found between the real interest rate and GDP. Short-run causality between M3 and GDP but not between the interest rate and GDP provides some insights in the (short-run) impact of monetary policy. Furthermore, no Granger causality between labor supply and GDP is found. Granger causality does exist between a combination of all variables and the GDP variable. However, in order to effectively answer our hypotheses, we exploit the long-run information in the VECM and rely on impulse response analysis.

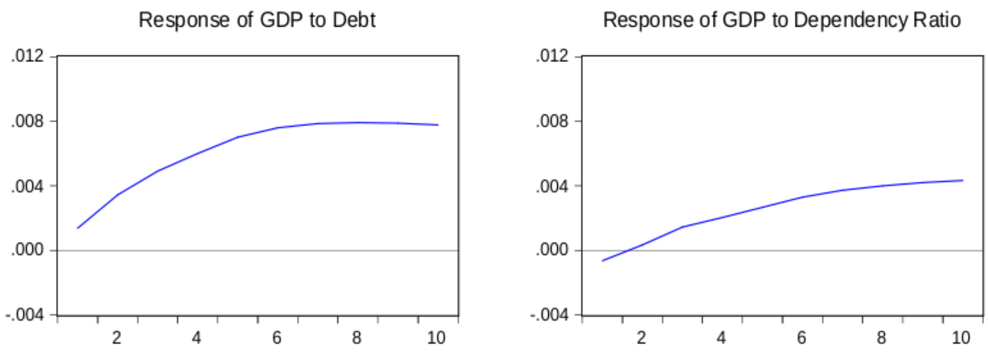
5.6 Impulse Response Functions

Having generated the proper models, we are in the position to apply shocks and observe how certain variables respond to a shock in another variable. In order to determine whether the Eurozone has suffered from forces behind secular stagnation or a balance sheet recession after the GFC, we shock the demographic variables and the debt variable and observe their impact on GDP and Investment growth. Furthermore, in order to determine the effectiveness of monetary policy in the Eurozone, we shock M3 and the interest rate variables. We use of two types of shocks: generalized Impulses (section 5.6.1) and User Specified Impulses (section 5.6.2).

5.6.1 Generalized Impulse Responses

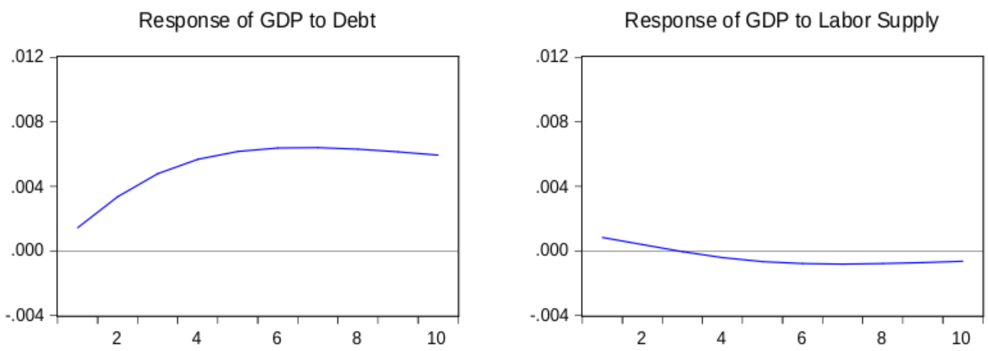
This section shows the impact of the generalized impulse responses in our models. The size of the shocks are equal to a positive one standard deviation change in the variable underlying the balance sheet recession and secular stagnation theories. The response of the shocks to our GDP and Investment variables for models 1a:2b is found in figures 4:7.

Figure 4: Generalized IRF Model 1a



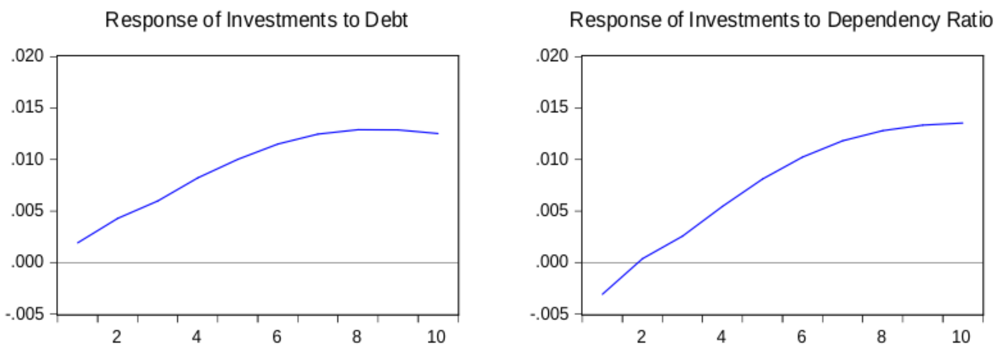
Notes: Response of GDP to a shock (equal to one standard deviation) in the debt and dependency ratio variables. Duration of the response is 2.5 years (10 quarters).

Figure 5: Generalized IRF Model 1b



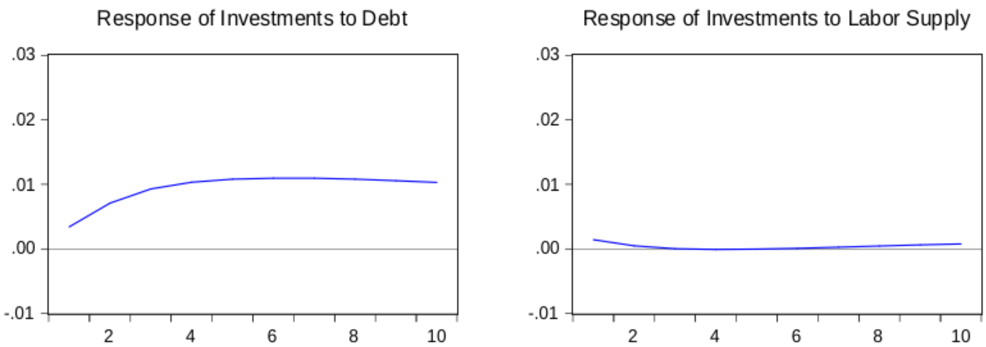
Notes: Response of GDP to a shock (equal to one standard deviation) in the debt and labor supply variables. Duration of the response is 2.5 years (10 quarters).

Figure 6: Generalized IRF Model 2a



Notes: Response of Investments to a shock (equal to one standard deviation) in the debt and dependency ratio variables. Duration of the response is 2.5 years (10 quarters).

Figure 7: Generalized IRF Model 2b



Notes: Response of Investments to a shock (equal to one standard deviation) in the debt and labor supply variables. Duration of the response is 2.5 years (10 quarters).

In every model, GDP and Investments positively react to a positive one standard deviation impulse to *Debt*. This result corresponds with the theory laid down in Koo (2003). An increase in debt accumulation results in a positive shock in investment and GDP growth. However, the impact of the demographic variables on GDP and Investments is less intuitive. An increase in the dependency ratio results in an increase in economic activity. In models 1a and 2a, an increase in the dependency ratio results in an immediate decline of GDP growth, turning positive after 2 quarters. A possible explanation for this finding has to do with the fact that the elderly might increase spending after retirement. This is in line with the life-cycle consumption smoothing hypothesis (Eggertson and

Mehrothra, 2014). The impact of a change in the numerator of the dependency ratio now outweighs the impact of the change in the denominator. The immediate decline in GDP and investment growth originates from the impact of a lower labor supply on economic aggregates. After 2 quarters, the true impact of the dependency ratio occurs. An increase in spending of the elderly population is observed.

The impact of a shock in the labor supply variable results in an immediate (yet small) increase in GDP growth in models 1b and 2b. However, in model 1b, GDP growth turns negative after 3 quarters. This does not correspond with the theory laid down in the literature review, which states that an increase in labor supply growth results in a positive shock in GDP. A possible explanation for this has to do with labor productivity. When the number of workers increases, but productivity falls, a decline in GDP results. In contrast, model 2b shows a positive (yet, negligible) impact of labor supply on investment growth. The insignificant coefficients in the VEC output in appendix B.3 may provide an additional reason for the observed outcomes. As no short or long-run dynamics are found in this output, coefficients may deviate from the theory laid down in the literature review.

These generalized impulse response functions may not fully capture the dynamics of GDP and Investment growth in the period following the GFC. For this reason, we create shocks by observing the post-crisis movements of several variables in section 5.6.2.

5.6.2 User Specified Impulse Responses

In order to determine the impact of demographic and deleveraging forces − and provide answers to H1:H3 − we use user specified impulse response functions. We explicitly focus on the change in the variables *debt*, *dependency ratio*, *labor supply* and *M3*. We estimate user specified impulse responses by taking into account changes in our variables over the post-GFC period 2008Q4:2015Q4. This period corresponds with the onset of the GFC − triggered by the collapse of Lehman Brothers in September 2008 − and the post-crisis period thereafter. As shown in figure 1 in section 3.3, the *debt* variable does not show a decline after the onset of the GFC. However, it does show a slowdown in its growth rate after 2008Q4. As we are interested in the impact of deleveraging on *GDP* and *investments*, we focus on the change in the yearly growth rate of debt in 2008Q4 and its yearly growth rate in 2015Q4. The difference between these growth rates is used as a proxy for post-crisis deleveraging, and used in the impulse response functions. Table 18 shows the movements of our variables of interest during this time period.

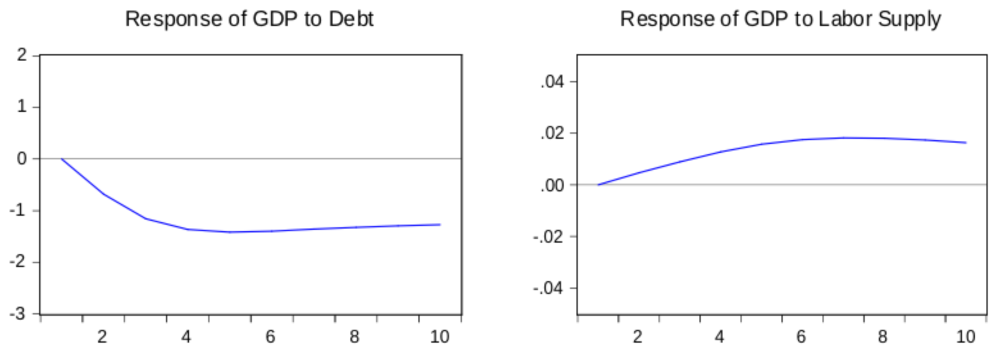
Table 18: Changes in variables of interest

	Debt	Dependency Ratio	Labor Supply	M3
2008Q4:	7.0%	26.89%	0.133%	8701.3
2015Q4:	3.0%	30.14%	-0.041%	9166
Change:	-4.0%	3.25%	-0.17%	5.34%

Note: We estimate the change in the debt variable by observing the difference in its yearly growth rate in 2008Q4 (7%) and its yearly growth rate in 2015Q4 (3%). M3 is measured in billion Euros.

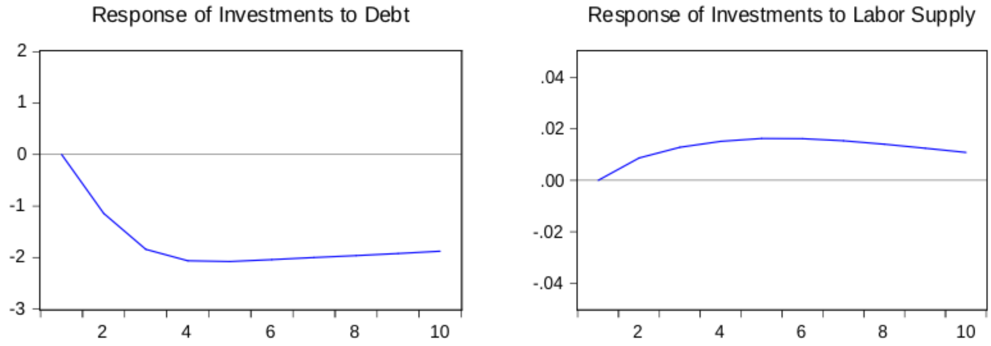
In order to incorporate these changes, we create a matrix with on its diagonal the changes in the variables as observed in table 18. As the largest demographic transition following the GFC in the Eurozone occured in the labor supply growth rate, we decide to focus our analysis on models including this demographic variable (1b and 2b). Concerning the secular stagnation theory, labor supply growth is the most relevant variable to incorporate. Both Hansen (1939) and Summers (2014a) stress the importance of this variable in the secular stagnation theory. The responses of the GDP and investment variables to the shocks in models 1b and 2b are found below. For completeness, the results of the shocks in models 1a and 2a are found in figures 18 and 19 of Appendix A.

Figure 8: User specified IRF Model 1b



Notes: Response of GDP to shocks (size debt shock: -4% and size labor supply growth: -0.17%) in the debt and labor supply variables. Duration of the response is 2.5 years (10 quarters).

Figure 9: User specified IRF Model 2b



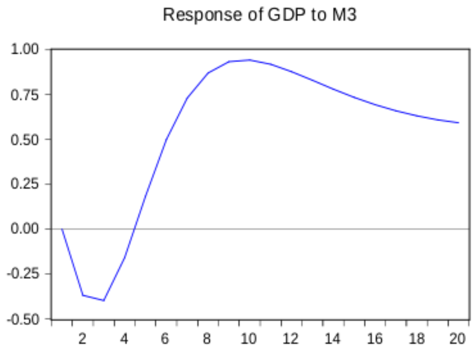
Notes: Response of investments to shocks (size debt shock: -4% and size labor supply growth: -0.17%) in the debt and labor supply variables. Duration of the response is 2.5 years (10 quarters).

We observe similar outcomes as in section 5.6.1. Models 1b and 2b show that the deleveraging that took place in the period 2008Q4:2015Q4 resulted in a large drop in GDP and Investment growth. In both cases, the peak of the impact occurred after approximately 3 quarters. GDP and investment growth falls with around 2% following the large negative impulse in the debt level. As in section 5.6.1, we observe a counterintuitive impact of the labor supply variable on GDP and investment growth. Investment and GDP growth are not affected largely by the observed decline in labor supply. The small magnitude of the labor supply shock (observe table 18) may be the driver for this result. Furthermore, as in section 5.6.1, the insignificant coefficients on the labor supply variable in the VEC output in appendix B.3 may drive the results.

In order to answer H1 and H2, we do have to observe which shock had the largest negative impact on Investment growth. It is clear from figures 8 and 9 that the force underlying the balance sheet recession theory (i.e. debt) had the largest impact on GDP and investment growth. We therefore *reject* H1 and H2.

In order to answer H3, we implement a shock to the *M3* variable. Monetary policy is stated to be largely ineffective in case of a balance sheet recession, whereas it is effective whenever the economy suffers from secular stagnation. By observing how GDP responds to a one-time shock in money supply growth, we obtain insights in the current level of responsiveness of the economy to monetary policy. We focus on model 1b, as we are only interested in the response to GDP. We use the change in money supply growth as observed in table 18.

Figure 10: User specified IRF Model 1b

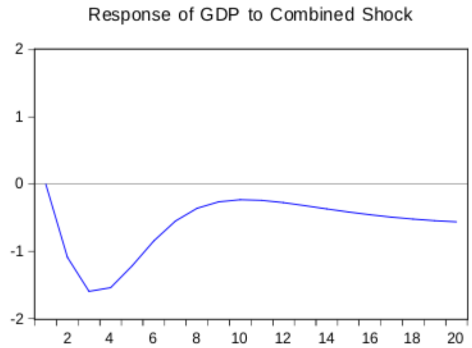


Notes: Response of GDP to a shock in the M3 variable (size shock: 5.34%)
Duration of the response is 5 years (20 quarters).

A delayed impact of a one-time money supply shock on GDP growth is found. The long-run impact – equal to 20 quarters, or 5 years – is an increase in GDP growth. After 4 quarters – equal to 1 year – we observe a positive impact of the money supply on GDP growth. That is, as its peak, we observe an increase in GDP growth close to 1%. We therefore *reject* H3. This finding supports the secular stagnation theory, an increase in the money supply has a positive impact on GDP growth in the long-run. Thus, the results suggest that monetary policy – in terms of the money supply – effectively spurs GDP growth. However, an increase in the money supply generally has a large impact on GDP growth. This does not directly mean that monetary policy is the reason behind its impact. The transmission channel of monetary policy may not work optimally in case of economic stagnation, for example in case of a balance sheet recession. Koo (2011, pp. 20-21) argues that the large liquidity injections – via QE – did not result in an increase in money supply in the U.K., the U.S. or in Japan. Furthermore, figure 17 in Appendix A shows the movements of an increase in assets on the ECB balance sheet (i.e. via QE) and the movements of M3. The figure shows that M3 does not increase following QE, corresponding to Koo (2011).

To gain further insights in the actual movements in GDP growth, and determine the actual effectiveness of M3 growth in the post-crisis period, we perform a combined shock in both the debt and M3 variables. Thus, incorporating deleveraging forces. Again, the shock equals the actual changes in the variables as depicted in table 18.

Figure 11: User specified IRF Model 1b

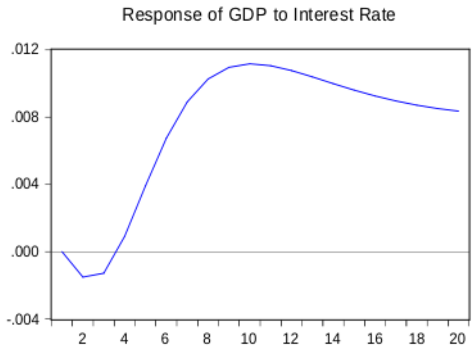


Notes: Response of GDP to a combined shock in the M3 and debt variables (size debt shock: -4% and size M3 shock: 5.34%) Duration of the response is 5 years (20 quarters).

Despite the large increase in M3, we still observe a negative impact on GDP growth in the long-run. However, compared to the debt shock in isolation in figure 9, we see that the negative impact on GDP is smaller due to the incorporation of M3. The result in figure 11 shows the impact of the deleveraging shock. Although M3 increased during the post-crisis period, the negative impact of debt outweighed the positive impact of the money supply on GDP growth. The net impact of the shock thus remains negative. Nonetheless, as the M3 shock in isolation (shown in figure 10) results in an increase in GDP growth, we *reject* H3.

In order to answer H4, we turn to a shock in the *interest rate* variable. In theory – in a period of secular stagnation – the economy returns to its potential GDP growth trend when the real interest rate is equal to the natural rate of interest. We thus require an estimation of the natural rate of interest in the Eurozone, as well as an approximation of potential GDP growth in the Eurozone. Concerning the natural rate of interest, the studies of Kleczka (2015) and Rawdanowicz (2014) imply the Eurozone rate lies between 0.5 and -0.5%. We decide to focus on an NRI of -0.5%, as Summers (2014a) argues a negative NRI is a requirement for secular stagnation to occur. The real interest rate in the Eurozone in 2015Q4 is 1.1%. Thus, we determine the impact of a negative shock to this interest rate of 1.6%. Figure 12 shows the response of GDP in the long-run.

Figure 12: User specified IRF Model 1b



Notes: Response of GDP to a shock in the interest rate variable (size shock: -1.6%). Duration of the response is 5 years (20 quarters).

We observe a small impact of GDP growth following a decline in the real interest rate towards the natural rate of interest. We believe potential output growth to be around 1% (Anderton et al., 2014). Thus, we do not observe a return to the long-run growth trend in GDP and for this reason *confirm* H4.

Confirming hypotheses 1 and 2 would provide evidence for the secular stagnation theory and confirmation of hypotheses 3 and 4 was in line with the balance sheet recession theory. We reject H1:3 and confirm H4. Our rejection of H1:H2 and confirmation of H4 thus corresponds with the balance sheet recession theory. Sluggish post-crisis investment and GDP growth in the Eurozone was mainly the result of deleveraging, as opposed to demographic forces. Furthermore, lowering the real interest rate towards the (estimated) natural rate of interest does not result in GDP growth returning to its potential rate in the long-run. The rejection of hypothesis 3 states that an increase in broad money supply growth results in an increase in GDP growth in the long-run. This is in line with the secular stagnation theory, but solely due to the relationship between (unconventional) monetary policy and M3. However, as argued in Koo (2011) and shown in figure 17 in Appendix A, large liquidity injections by the central bank via QE may not result in large changes in M3. All-in-all, we state that the Eurozone is, *at the time of writing*, suffering from a balance sheet recession.

6 Discussion

By taking into account changes in demographic and financial variables over the period 1999Q1:2015Q4, and making use of a VEC methodology, we determine that the current state of the Eurozone economy is depicted by cyclical as opposed to permanent sluggishness. However, as put forward in the European Commission (2015) report, the demographic transition has only just started in the Eurozone. Labor supply growth is projected to decline rapidly and the old-age dependency ratio will increase substantially over the coming 40 years. Our findings suggest that, *at the time of writing*, the economic state of the Eurozone fits the balance sheet recession theory better than the secular stagnation theory. However, this does not imply that the Eurozone is immune to secular stagnation. Taking into account the future demographic transition is important when determining whether the Eurozone will slide into secular stagnation in the coming decades. Future research may take this phenomenon into account. On the other hand, we must assess whether deleveraging forces have in fact subsided in the Eurozone. It is often claimed that many Eurozone Member States' private sectors remained highly indebted following the GFC, and deleveraging needs remain large in various Eurozone economies (Bornhorst and Ruiz-Arranz, 2013; Pontuch, 2014). In order to investigate to what extent this debt overhang has an impact on future economic growth in the Eurozone, this factor has to be taken into consideration.

This paper solely focuses on the Eurozone economy, consisting of its 19 Member States. A potential drawback of this exercise is the fact that large differences in the economic performance between various Member States may exist. Southern European countries may be facing larger deleveraging needs than Northern European countries. Furthermore, differences in the timing and magnitude of the demographic transition between countries might exist as well. For this reason, in the short-run, within Eurozone heterogeneity concerning the secular stagnation versus balance sheet recession theories may exist. That is, one country may suffer from forces underlying secular stagnation whilst the other country faces strong deleveraging needs. Providing a general statement on the economic state of the Eurozone is therefore difficult. Furthermore, we claim − as in Koo (2003) − that the optimal response in case of a balance sheet recession is expansionary fiscal policy. We thus advocate fiscal planning at the Eurozone level. In practice, this is hard to accomplish. As the Eurozone is far from a fiscal union, government expenditure decisions cannot be made at the supra-national level.

A possible limitation of our findings is concerned with the use of a single variable with regards to private sector indebtedness. We use this variable as we want to determine the impact of total private sector deleveraging on economic growth in the Eurozone. Distinguishing between household and non-financial corporate debt might improve the precision of our results. Furthemore, we use linear interpolation in order to create quarterly demographic data. We revert to this technique due to the unavailability of quarterly demographic data for the Eurozone for our time period. Using original quarterly data might improve the fit of the model.

In order to determine whether the Eurozone has been suffering from secular stagnation following the GFC, we shock the structural demographic factors underlying the secular stagnation theory. This exercise is in fact reduced-form. Firstly, a decline in labor supply growth results in a structural decline in investment demand and thereby lowers the natural rate of interest into negative territory. Secondly, the interest rate gap between the natural rate of interest and the real interest rate results in a decline in investment and GDP growth. A path for future research is to directly incorporate a measure of the natural rate of interest in the model.

7 Conclusion

The post-GFC economic performance of the Eurozone is characterized by its sluggishness. Almost a decade following the fall of Lehman Brothers, GDP and investment growth has still not returned to its 'normal' pre-crisis trend. The long duration of the economic recovery in the Eurozone spurred a debate among economists. This debate has to do with the views of the economy being in a state of secular stagnation, as developed in Summers (2014a), versus the balance sheet recession theory, originating from Koo (2003). Where structural economic forces such as a change in demographics lead to secular stagnation, cyclical forces such as deleveraging needs by the private sector result in a balance sheet recession. A major difference between both theories has to do with the speed of economic recovery. In case of secular stagnation, sluggishness in economic growth is observed for an indefinite period of time. In contrast, a balance sheet recession is depicted by cyclical sluggishness.

This paper distinguishes between these two forms of 'sluggishness'. By using a VEC methodology − taking into account the period 1999Q1:2015Q4 − we investigate the case of the Eurozone. By using impulse responses, we determine that sluggish post-crisis economic growth is to a large extent driven by forces underlying the balance sheet recession theory. Furthermore, we determine that an increase in M3 results in a rise in GDP in the Eurozone. However, as in Koo (2003), this is not necessarily the direct result of expansionary monetary policy. In case of a balance sheet recession, monetary policy is unable to effectively spur the aggregate money supply. To further distinguish between the secular stagnation and balance sheet recession theories, we implement a shock to the real interest rate. After lowering this interest rate towards its hypothetical natural rate, we do not find a large response in terms of GDP growth. All-in-all, we determine that, *at the time of writing*, the economic state of the Eurozone fits the balance sheet recession theory better than the secular stagnation theory.

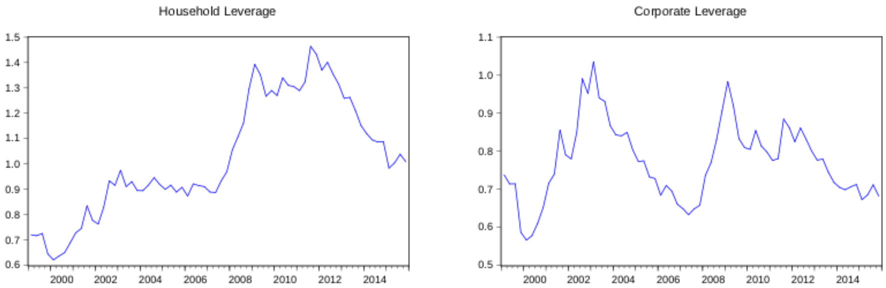
Our findings are relevant concerning economic policies in the Eurozone. In case of a balance sheet recession, monetary policy is ineffective (Koo, 2014b). As the private sector is unwilling to invest at any interest rate, monetary policy (altering private sector investments via changes in interest rates) becomes unable to effectively spur aggregate demand. For this reason, the QE policy of the ECB is ineffective in a balance sheet recession. Koo (2003) argues that expansionary fiscal policy is the true cure for a balance sheet recession. As the private sector is unwilling to spend, the public sector should fill the gap in aggregate demand. We thus argue that, at this point in time, increasing government expenditures in the Eurozone is an optimal policy response. However, future demographic and deleveraging trends must be taken into account.

Our results do not imply that the Eurozone is immune from entering a period of secular stagnation in the future. As shown in the European Commission (2015) report, the demographic transition is still underway in the Eurozone. Further research on the impact of future demographic changes on the Eurozone economy is required. Furthermore, the fact that many Eurozone Member States may still be in need of debt repayments gives rise to future research.

Appendix

A. Figures

Figure 13: Household and Non-financial Corporate Leverage Ratios



Note: Measured as: Eurozone household or non-financial corporate debt divided by Eurozone household or non-financial corporate equity. Data obtained from the BIS.

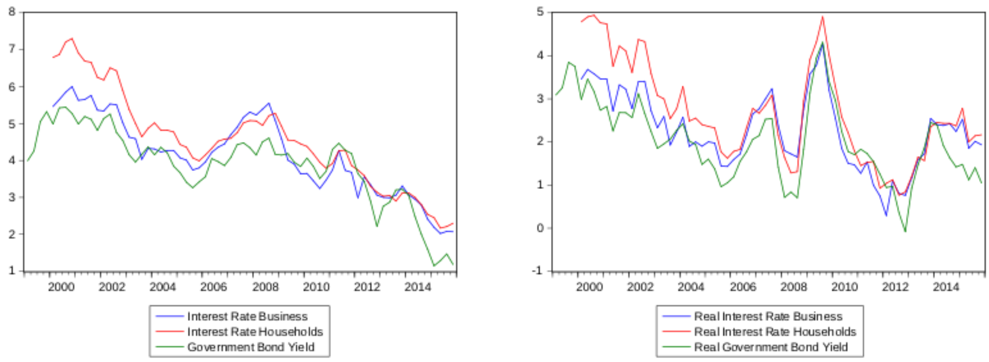
Figure 14: Private Sector Debt

Note: BIS measure of Eurozone private sector (household and non-financial corporate) debt (as stated on the financial account) divided by total Eurozone GDP

Figure 15: Inflation Rate Eurozone

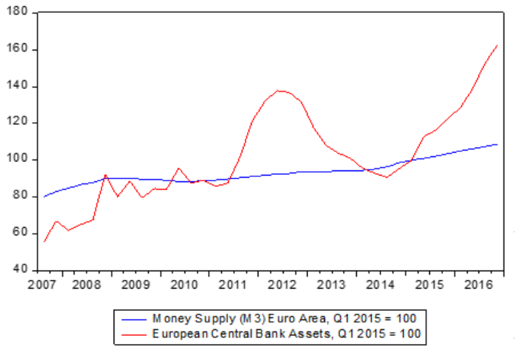
Note: Inflation rate obtained from Eurostat database. Measures the yearly change in all items HICP.

Figure 16: Interest Rates Eurozone



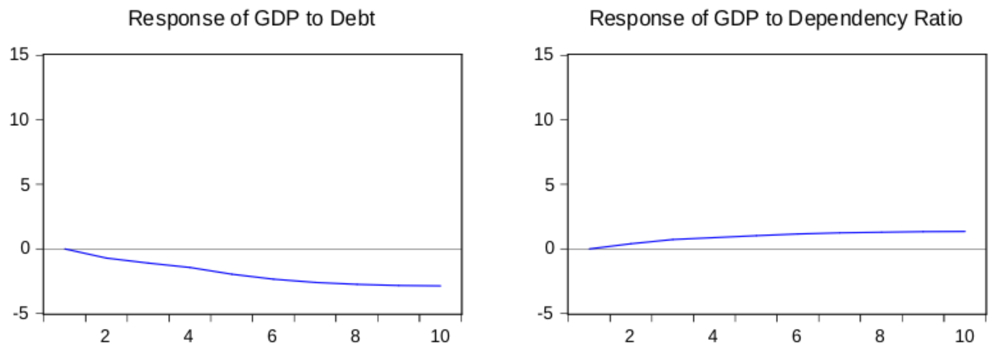
Note: Figure on LHS depicts nominal interest rates (obtained from Eurostat), RHS figure calculated by deducting inflation rate (Figure 15) from nominal interest rates.

Figure 17: ECB Assets and Money Supply Euro Area



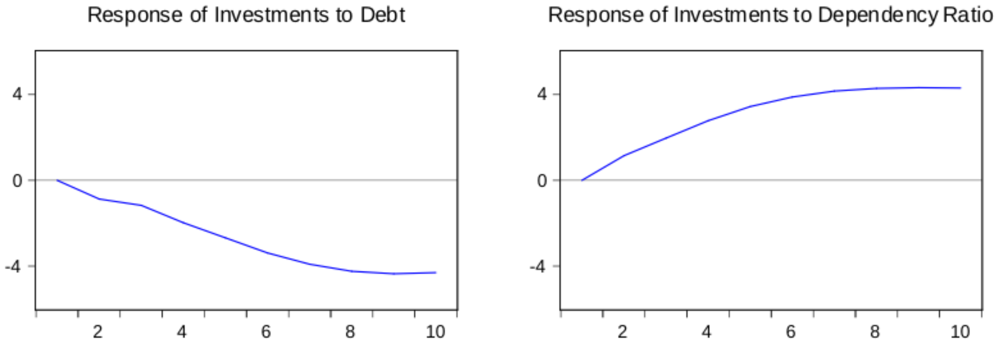
Note: Data obtained from St. Louis Fed Database.

Figure 18: User Specified Impulse Responses Model 1a



Notes: Response of GDP to shocks (size debt shock: -4% and size dependency ratio shock: 3.24%) in debt and dependency ratio variables. Duration of the response is 2.5 years (10 quarters).

Figure 19: User Specified Impulse Responses Model 2a



Notes: Response of investments to shocks (size debt shock: -4% and size dependency ratio shock: 3.24%) in debt and dependency ratio variables. Duration of the response is 2.5 years (10 quarters).

B. Regression Output

B.1 OLS Output

This section provides the full output of the OLS regressions, originating from Eviews statistical software. The variables *GDP, Investments, Debt* and *M3* are transformed into their natural logarithms.

Table 19: OLS Model 1a

Dependent Variable: GDP				
Indep. Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	10.14434	0.332619	30.49837	0.0000
Debt	0.120563	0.072184	1.670233	0.0998
Dependency Ratio	−0.006385	0.002959	−2.157592	0.0348
M3	0.172476	0.078119	2.207858	0.0309
Interest Rate	−0.011081	0.002295	−4.829053	0.0000
R-squared	0.943001	Mean dependent var		14.65301
Adjusted R-squared	0.939382	S.D. dependent var		0.055603
S.E. of regression	0.013690	Akaike info criterion		−5.673626
Sum squared resid	0.011807	Schwarz criterion		−5.510427
Log likelihood	197.9033	Hannan-Quinn criter.		−5.608961
F-statistic	260.5687	Durbin-Watson stat		0.248626
Prob(F-statistic)	0.000000			

Table 20: OLS Model 1b

Dependent Variable: GDP				
Indep. Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	10.77680	0.250053	43.09807	0.0000
Debt	0.169647	0.077050	2.201769	0.0314
Labor Supply	0.098214	0.036044	2.724834	0.0083
M3	0.070289	0.091794	0.765727	0.4467
Interest Rate	−0.008606	0.002440	−3.526923	0.0008
R-squared	0.945242	Mean dependent var		14.65301
Adjusted R-squared	0.941765	S.D. dependent var		0.055603
S.E. of regression	0.013418	Akaike info criterion		−5.713746
Sum squared resid	0.011343	Schwarz criterion		−5.550547
Log likelihood	199.2674	Hannan-Quinn criter.		−5.649081
F-statistic	271.8800	Durbin-Watson stat		0.249825
Prob(F-statistic)	0.000000			

Table 21: OLS Model 2a

Dependent Variable: Investments				
Indep. Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	5.058462	0.869341	5.818729	0.0000
Debt	−0.423917	0.188661	−2.246979	0.0282
Dependency Ratio	−0.043906	0.007735	−5.676284	0.0000
M3	1.026556	0.204174	5.027853	0.0000
Interest Rate	−0.027157	0.005997	−4.528165	0.0000
R-squared	0.641341	Mean dependent var		13.11275
Adjusted R-squared	0.618569	S.D. dependent var		0.057934
S.E. of regression	0.035780	Akaike info criterion		−3.752150
Sum squared resid	0.080655	Schwarz criterion		−3.588951
Log likelihood	132.5731	Hannan-Quinn criter.		−3.687486
F-statistic	28.16355	Durbin-Watson stat		0.253604
Prob(F-statistic)	0.000000			

Table 22: OLS Model 2b

Dependent Variable: Investments				
Indep. Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	8.993327	0.735832	12.22199	0.0000
Debt	−0.446089	0.226736	−1.967436	0.0535
Labor Supply	0.413379	0.106067	3.897327	0.0002
M3	0.724608	0.270122	2.682522	0.0093
Interest Rate	−0.017030	0.007181	−2.371608	0.0208
R-squared	0.563218	Mean dependent var		13.11275
Adjusted R-squared	0.535486	S.D. dependent var		0.057934
S.E. of regression	0.039485	Akaike info criterion		−3.555089
Sum squared resid	0.098223	Schwarz criterion		−3.391890
Log likelihood	125.8730	Hannan-Quinn criter.		−3.490424
F-statistic	20.30919	Durbin-Watson stat		0.231930
Prob(F-statistic)	0.000000			

B.2 Error Correction Models

This section provides the results of the Eviews estimation of the Engle-Granger Error Correction representations of our models.

Table 23: Error Correction Model 1a

Dependent Variable: ΔGDP				
Indep. Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	−0.007839	0.002859	−2.741439	0.0080
$\Delta Debt_{t-1}$	0.380985	0.093573	4.071520	0.0001
$\Delta Dep.\,Ratio_{t-1}$	0.083138	0.024170	3.439654	0.0011
$\Delta M3_{t-1}$	−0.219293	0.074322	−2.950557	0.0045
$\Delta Interest\,Rate_{t-1}$	−0.000862	0.001472	−0.585869	0.5602
$Residuals_{t-1}$	0.024564	0.058803	0.417731	0.6776
R-squared	0.311983	Mean dependent var		0.002989
Adjusted R-squared	0.254649	S.D. dependent var		0.006395
S.E. of regression	0.005521	Akaike info criterion		−7.473880
Sum squared resid	0.001829	Schwarz criterion		−7.274820
Log likelihood	252.6380	Hannan-Quinn criter.		−7.395222
F-statistic	5.441440	Durbin-Watson stat		0.826483
Prob(F-statistic)	0.000341			

Table 24: Error Correction Model 1b

Dependent Variable: ΔGDP				
Indep. Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.000980	0.001239	0.790494	0.4324
$\Delta Debt_{t-1}$	0.291173	0.099114	2.937756	0.0047
$\Delta Labor\,Supply_{t-1}$	−0.023827	0.031665	−0.752479	0.4547
$\Delta M3_{t-1}$	−0.170289	0.080500	−2.115402	0.0386
$\Delta Interest\,Rate_{t-1}$	−0.001241	0.001687	−0.735397	0.4650
$Residuals\,1b_{t-1}$	0.025062	0.063437	0.395062	0.6942
R-squared	0.177879	Mean dependent var		0.002989
Adjusted R-squared	0.109369	S.D. dependent var		0.006395
S.E. of regression	0.006036	Akaike info criterion		−7.295806
Sum squared resid	0.002186	Schwarz criterion		−7.096746
Log likelihood	246.7616	Hannan-Quinn criter.		−7.217148
F-statistic	2.596398	Durbin-Watson stat		0.696242
Prob(F-statistic)	0.034267			

Table 25: Error Correction Model 2a

Dependent Variable: $\Delta Investments$

Indep. Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	−0.024773	0.006407	−3.866676	0.0003
$\Delta Debt_{t-1}$	0.631500	0.213283	2.960859	0.0044
$\Delta Dep.\,Ratio_{t-1}$	0.209963	0.053490	3.925249	0.0002
$\Delta M3_{t-1}$	−0.217534	0.162155	−1.341514	0.1848
$\Delta Interest\,Rate_{t-1}$	−0.002672	0.003237	−0.825429	0.4124
$Residuals\,2a_{t-1}$	−0.003198	0.051745	−0.061803	0.9509
R-squared	0.272996	Mean dependent var		0.001587
Adjusted R-squared	0.212412	S.D. dependent var		0.013655
S.E. of regression	0.012118	Akaike info criterion		−5.901670
Sum squared resid	0.008811	Schwarz criterion		−5.702610
Log likelihood	200.7551	Hannan-Quinn criter.		−5.823012
F-statistic	4.506102	Durbin-Watson stat		1.224785
Prob(F-statistic)	0.001491			

Table 26: Error Correction Model 2b

Dependent Variable: $\Delta Investments$

Indep. Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	−0.003256	0.002755	−1.181971	0.2419
$\Delta Debt_{t-1}$	0.489614	0.226625	2.160455	0.0347
$\Delta Labor\,Supply_{t-1}$	−0.051243	0.070718	−0.724608	0.4715
$\Delta M3_{t-1}$	−0.112742	0.179143	−0.629340	0.5315
$\Delta Interest\,Rate_{t-1}$	−0.003411	0.003761	−0.906968	0.3681
$Residuals\,2b_{t-1}$	−0.048017	0.048634	−0.987312	0.3275
R-squared	0.102706	Mean dependent var		0.001587
Adjusted R-squared	0.027931	S.D. dependent var		0.013655
S.E. of regression	0.013463	Akaike info criterion		−5.691218
Sum squared resid	0.010875	Schwarz criterion		−5.492158
Log likelihood	193.8102	Hannan-Quinn criter.		−5.612560
F-statistic	1.373540	Durbin-Watson stat		1.051997
Prob(F-statistic)	0.247029			

B.3 VEC Output

This section provides the results of the Eviews estimation of the VEC models 1a:2b. Here, * indicates $p < 0.10$, ** states $p < 0.05$ and *** states $p < 0.01$. The standard errors are provided in parantheses.

Table 27: VEC Model 1a

Cointegrating Eq:	CointEq1				
LOG(GDP(-1))	1.000000				
LOG(DEBT(-1))	-0.320314***				
	(0.07710)				
OLD_DEP(-1)	0.005357				
	(0.00399)				
LOG(M3(-1))	0.029067				
	(0.08413)				
INTEREST_RATE_REAL(-1)	0.005859**				
	(0.00224)				
C	−10.01771				
Error Correction:	D(LOG(GDP))	D(LOG(DEBT))	D(OLD_DEP)	D(LOG(M3))	D(INTEREST_RATE_REAL)
CointEq1	−0.033262	0.354154***	-0.483745**	0.559847***	−11.01076
	(0.07309)	(0.11186)	(0.20916)	(0.15820)	(7.43931)
D(LOG(GDP(-1)))	0.808328***	0.020214	−0.495922	-0.587956**	−21.63906
	(0.13838)	(0.21179)	(0.39601)	(0.29952)	(14.0850)
D(LOG(GDP(-2)))	−0.004818	0.080516	0.778247**	−0.358739	6.448560
	(0.14621)	(0.22377)	(0.41840)	(0.31645)	(14.8814)
D(LOG(DEBT(-1)))	0.169636**	0.117315	0.142528	0.019785	1.394469
	(0.08676)	(0.13279)	(0.24829)	(0.18779)	(8.83106)
D(LOG(DEBT(-2)))	−0.116654	0.112258	0.227324	0.378219**	10.07486
	(0.08849)	(0.13543)	(0.25322)	(0.19152)	(9.00642)
D(OLD_DEP(-1))	0.124750**	0.101730	0.786327***	0.045463	−5.091256
	(0.04775)	(0.07308)	(0.13665)	(0.10336)	(4.86038)
D(OLD_DEP(-2))	-0.101157**	−0.095127	0.122928	0.117008	5.057096
	(0.04933)	(0.07550)	(0.14117)	(0.10677)	(5.02096)
D(LOG(M3(-1)))	-0.127718**	−0.096797	0.116630	−0.138447	3.980629
	(0.06276)	(0.09605)	(0.17960)	(0.13584)	(6.38800)
D(LOG(M3(-2)))	0.129016**	0.025363	−0.071104	−0.208422	10.49013
	(0.06432)	(0.09845)	(0.18408)	(0.13923)	(6.54719)
D(INTEREST_RATE_REAL(-1))	0.001119	$9.88E-05$	0.003136	−0.003194	0.232093*
	(0.00132)	(0.00202)	(0.00377)	(0.00285)	(0.13426)
D(INTEREST_RATE_REAL(-2))	0.001489	−0.001534	0.001335	0.000121	−0.018245
	(0.00129)	(0.00197)	(0.00368)	(0.00278)	(0.13080)
C	−0.002494	-0.008038*	0.004999	−0.006260	−0.241437
	(0.00249)	(0.00382)	(0.00713)	(0.00540)	(0.25373)
R-squared	0.638546	0.629844	0.869125	0.471479	0.311103
Adj. R-squared	0.563527	0.553019	0.841962	0.361786	0.168124
Sum sq. resids	0.000940	0.002201	0.007694	0.004401	9.733366
S.E. equation	0.004210	0.006444	0.012049	0.009113	0.428542
F-statistic	8.511818	8.198434	31.99694	4.298162	2.175867
Log likelihood	269.9657	242.3033	201.6232	219.7758	−30.51911
Akaike AIC	−7.937406	−7.086256	−5.834560	−6.393102	1.308280
Schwarz SC	−7.535981	−6.684831	−5.433134	−5.991676	1.709706
Mean dependent	0.002872	0.011234	0.100639	0.008737	−0.043075
S.D. dependent	0.006373	0.009638	0.030309	0.011407	0.469855
Determinant resid covariance (dof adj.)		$1.17E-18$			
Determinant resid covariance		$4.20E-19$			
Log likelihood		914.0490			
Akaike information criterion		−26.12458			
Schwarz criterion		−23.95020			

Table 28: VEC Model 1b

Cointegrating Eq:	CointEq1	CointEq2			
LOG(GDP(-1))	1.000000	0.000000			
LOG(DEBT(-1))	0.000000	1.000000			
LABOR_SUPPLY(-1)	0.026705	0.289389***			
	(0.03484)	(0.07336)			
LOG(M3(-1))	-0.303943***	-1.076571***			
	(0.01492)	(0.03143)			
INTEREST_RATE_REAL(-1)	0.007896***	0.023615***			
	(0.00252)	(0.00530)			
C	−9.868443	0.563822			
Error Correction:	D(LOG(GDP))	D(LOG(DEBT))	D(LABOR_SUPPLY)	D(LOG(M3))	D(INTEREST_RATE_REAL)
CointEq1	-0.090307**	0.296733***	0.552272**	0.420780***	−2.293399
	(0.04953)	(0.07227)	(0.28031)	(0.10651)	(4.63122)
CointEq2	0.001227	-0.143556***	−0.132924	0.010816	-6.527348**
	(0.02797)	(0.04081)	(0.15831)	(0.06016)	(2.61558)
D(LOG(GDP(-1)))	0.766313***	0.087188	−0.245100	−0.186871	-27.766603**
	(0.10751)	(0.15685)	(0.60839)	(0.23118)	(10.0517)
D(LOG(DEBT(-1)))	0.169235*	0.133370	−0.441555	0.056167	−0.766803
	(0.09068)	(0.13229)	(0.51313)	(0.19498)	(8.47795)
D(LABOR_SUPPLY(-1))	−0.025415	0.006027	−0.084186	0.027307	2.687355
	(0.02409)	(0.03515)	(0.13635)	(0.05181)	(2.25276)
D(LOG(M3(-1)))	-0.102386*	−0.068200	−0.213249	0.054280	−0.227982
	(0.06150)	(0.08973)	(0.34804)	(0.13225)	(5.75032)
D(INTEREST_RATE_REAL(-1))	0.001627	0.000916	−0.006147	0.000179	0.250090**
	(0.00131)	(0.00191)	(0.00742)	(0.00282)	(0.12253)
C	−0.000417	0.010121***	0.006273	0.008060***	0.071100
	(0.00119)	(0.00174)	(0.00676)	(0.00257)	(0.11165)
R-squared	0.565567	0.589127	0.082225	0.366692	0.305016
Adj. R-squared	0.513135	0.539539	−0.028540	0.290258	0.221139
Sum sq. resids	0.001155	0.002458	0.036987	0.005341	10.09652
S.E. equation	0.004462	0.006510	0.025253	0.009596	0.417226
F-statistic	10.78676	11.88041	0.742335	4.797508	3.636457
Log likelihood	267.8105	242.8814	153.4156	217.2785	−31.69362
Akaike AIC	−7.873045	−7.117619	−4.406534	−6.341773	1.202837
Schwarz SC	−7.607632	−6.852206	−4.141121	−6.076361	1.468250
Mean dependent	0.002989	0.011328	−0.001209	0.008581	−0.033434
S.D. dependent	0.006395	0.009594	0.024900	0.011390	0.472761
Determinant resid covariance (dof adj.)		$5.05E-18$			
Determinant resid covariance		$2.65E-18$			
Log likelihood		867.3755			
Akaike information criterion		−24.76895			
Schwarz criterion		−23.11012			

Table 29: VEC Model 2a

Cointegrating Eq:	CointEq1	CointEq2			
LOG(INVESTMENTS(-1))	1.000000	0.000000			
LOG(DEBT(-1))	0.000000	1.000000			
OLD_DEP(-1)	0.060209***	0.428304*			
	(0.01189)	(0.23697)			
LOG(M3(-1))	-0.780238***	-5.243666**			
	(0.10042)	(2.00171)			
INTEREST_RATE_REAL(-1)	0.001047	-0.505471***			
	(0.00594)	(0.11840)			
C	−2.382895	56.14444			
Error Correction:	D(LOG(INVESTMENTS))	D(LOG(DEBT))	D(OLD_DEP)	D(LOG(M3))	D(INTEREST_RATE_REAL)
CointEq1	−0.040833	0.122332**	−0.123293	0.239616***	−4.410773
	(0.07101)	(0.04398)	(0.08563)	(0.06003)	(2.77454)
CointEq2	-0.007231**	-0.007271***	0.010082**	−0.000237	0.526304***
	(0.00373)	(0.00231)	(0.00449)	(0.00315)	(0.14563)
D(LOG(INVESTMENTS(-1)))	0.398904**	0.031331	−0.061684	−0.084132	−6.629728
	(0.14144)	(0.08760)	(0.17056)	(0.11956)	(5.52644)
D(LOG(INVESTMENTS(-2)))	0.342714**	0.109728	0.121398	−0.147255	2.032873
	(0.13872)	(0.08592)	(0.16728)	(0.11727)	(5.42035)
D(LOG(DEBT(-1)))	0.226436	0.039632	0.146537	−0.127278	5.102228
	(0.22423)	(0.13888)	(0.27040)	(0.18955)	(8.76145)
D(LOG(DEBT(-2)))	−0.086529	0.068501	0.181214	0.217495	10.68641
	(0.22445)	(0.13902)	(0.27066)	(0.18974)	(8.77001)
D(OLD_DEP(-1))	0.361125***	0.105205	0.795901***	0.009261	−7.512258
	(0.11879)	(0.07358)	(0.14325)	(0.10042)	(4.64156)
D(OLD_DEP(-2))	−0.148777	−0.094545	0.060920	−0.008631	3.237512
	(0.12854)	(0.07962)	(0.15501)	(0.10866)	(5.02246)
D(LOG(M3(-1)))	−0.116596	−0.038707	0.013267	−0.055744	1.860228
	(0.14393)	(0.08915)	(0.17357)	(0.12167)	(5.62390)
D(LOG(M3(-2)))	0.007526	0.048606	−0.075024	−0.122952	11.601353**
	(0.14497)	(0.08979)	(0.17481)	(0.12255)	(5.66433)
D(INTEREST_RATE_REAL(-1))	−0.000275	−0.000844	0.004224	−0.001206	0.344036**
	(0.00322)	(0.00200)	(0.00389)	(0.00273)	(0.12597)
D(INTEREST_RATE_REAL(-2))	−0.000673	−0.003193	0.002996	0.002234	0.172842
	(0.00342)	(0.00212)	(0.00413)	(0.00289)	(0.13370)
C	-0.021753**	0.008358*	0.012403	0.009464	0.107264
	(0.00786)	(0.00487)	(0.00947)	(0.00664)	(0.30699)
R-squared	0.533822	0.642659	0.863022	0.524813	0.401597
Adj. R-squared	0.426242	0.560196	0.831412	0.415154	0.263504
Sum sq. resids	0.005538	0.002125	0.008053	0.003957	8.454775
S.E. equation	0.010320	0.006392	0.012445	0.008724	0.403227
F-statistic	4.962113	7.793288	27.30192	4.785878	2.908168
Log likelihood	212.3117	243.4485	200.1419	223.2330	−25.94219
Akaike AIC	−6.132667	−7.090723	−5.758214	−6.468707	1.198221
Schwarz SC	−5.697789	−6.655845	−5.323336	−6.033829	1.633099
Mean dependent	0.001350	0.011234	0.100639	0.008737	−0.043075
S.D. dependent	0.013624	0.009638	0.030309	0.011407	0.469855
Determinant resid covariance (dof adj.)		$6.02E-18$			
Determinant resid covariance		$1.97E-18$			
Log likelihood		863.7849			
Akaike information criterion		−24.27031			
Schwarz criterion		−21.76140			

Table 30: VEC Model 2b

Cointegrating Eq:	CointEq1	CointEq2			
LOG(INVESTMENTS(-1))	1.000000	0.000000			
LOG(DEBT(-1))	0.000000	1.000000			
LABOR_SUPPLY(-1)	−0.215148	0.272365***			
	(0.13217)	(0.07613)			
LOG(M3(-1))	-0.395653***	-1.066677***			
	(0.05673)	(0.03267)			
INTEREST_RATE_REAL(-1)	−0.000733	0.030971***			
	(0.00946)	(0.00545)			
C	−6.852987	0.393116			
Error Correction:	**D(LOG(INVESTMENTS))**	**D(LOG(DEBT))**	**D(LABOR_SUPPLY)**	**D(LOG(M3))**	**D(INTEREST_RATE_REAL)**
CointEq1	−0.043332	0.083790***	0.137384	0.098910***	−1.497772
	(0.03964)	(0.02303)	(0.08632)	(0.03407)	(1.39947)
CointEq2	−0.015519	−0.028341	0.058114	0.100348	-9.350697***
	(0.07314)	(0.04249)	(0.15928)	(0.06286)	(2.58229)
D(LOG(INVESTMENTS(-1)))	0.569269***	0.102962	0.141070	0.108120	-9.702890**
	(0.12070)	(0.07013)	(0.26286)	(0.10375)	(4.26167)
D(LOG(DEBT(-1)))	0.301129	0.129685	−0.492664	−0.030457	−1.411773
	(0.24910)	(0.14472)	(0.54249)	(0.21411)	(8.79499)
D(LABOR_SUPPLY(-1))	−0.056015	0.008711	−0.074720	0.042172	2.658195
	(0.06263)	(0.03639)	(0.13640)	(0.05383)	(2.21135)
D(LOG(M3(-1)))	−0.090816	−0.017982	−0.077176	0.151529	−0.982030
	(0.15895)	(0.09235)	(0.34617)	(0.13662)	(5.61217)
D(INTEREST_RATE_REAL(-1))	0.001171	0.000485	−0.006004	0.000319	0.335837**
	(0.00345)	(0.00200)	(0.00750)	(0.00296)	(0.12166)
C	−0.002173	0.009811***	0.004732	0.007508**	0.020041
	(0.00305)	(0.00177)	(0.00665)	(0.00263)	(0.10786)
R-squared	0.345241	0.552312	0.066084	0.304766	0.319039
Adj. R-squared	0.266218	0.498280	−0.046630	0.220858	0.236854
Sum sq. resids	0.007936	0.002679	0.037638	0.005863	9.892793
S.E. equation	0.011697	0.006796	0.025474	0.010054	0.412996
F-statistic	4.368889	10.22205	0.586296	3.632160	3.881970
Log likelihood	204.2090	240.0496	152.8403	214.1999	−31.02095
Akaike AIC	−5.945728	−7.031805	−4.389099	−6.248482	1.182453
Schwarz SC	−5.680316	−6.766393	−4.123686	−5.983069	1.447866
Mean dependent	0.001587	0.011328	−0.001209	0.008581	−0.033434
S.D. dependent	0.013655	0.009594	0.024900	0.011390	0.472761
Determinant resid covariance (dof adj.)		$4.36E-17$			
Determinant resid covariance		$2.29E-17$			
Log likelihood		796.2040			
Akaike information criterion		−22.61224			
Schwarz criterion		−20.95341			

C. Model Adequacy

C.1 Residual Autocorrelation

We make use of the LM residual autocorrelation test. This test indicates whether autocorrelation is present within our models. We ascertain that autocorrelation is present whenever the Prob. value is lower than 0.05. As shown in table 9 in section 5.2, we estimate models 1b and 2b using 1 lag and models 1a and 2a using 2 lags. The results indicate that autocorrelation is detected in the second lag in model 2a. However, we decide to not alter the number of lags in model 2a as both the specification test and economic reasoning do not provide reasons to do so.

Table 31: LM Autocorrelation Test Output

	Model 1a		Model 1b		Model 2a		Model 2b	
Lags	LM-Stat	Prob.	LM-Stat	Prob.	LM-Stat	Prob.	LM-Stat	Prob.
1	22.3612	0.6148	18.6002	0.8159	25.4707	0.4363	17.6753	0.8559
2	28.8473	0.2703	22.6664	0.5970	37.9965	0.0463	16.5415	0.8977
3	19.9544	0.7492	29.6354	0.2382	25.0444	0.4599	22.5366	0.6046
4	43.8015	0.0114	36.8975	0.0590	31.1605	0.1838	34.9756	0.0886
5	24.2274	0.5063	28.1878	0.2993	21.0135	0.6919	33.2430	0.1251
6	14.1992	0.9581	20.9028	0.6980	20.6764	0.7105	26.6604	0.3731
7	19.8982	0.7521	25.7000	0.4237	15.2137	0.9362	23.4805	0.5495
8	23.8527	0.5279	36.3773	0.0661	25.7273	0.4223	31.0923	0.1860
9	30.1036	0.2204	27.6263	0.3253	29.4367	0.2461	30.1616	0.2183
10	27.6581	0.3238	22.3286	0.6167	26.9146	0.3602	19.6649	0.7642
11	25.6770	0.4250	23.3369	0.5579	21.1151	0.6862	22.445	0.6099
12	2,551,468	0.4338	39.5609	0.0323	29.5739	0.2406	44.4008	0.0098
13	30.3939	0.2099	36.9018	0.0590	23.7675	0.5328	38.7609	0.0389
14	16.6667	0.8935	16.8019	0.8889	31.7615	0.1650	20.0664	0.7433
15	21.2459	0.6788	25.1116	0.4561	18.6261	0.8147	32.8998	0.1336

C.2 Normality Tests

The normality tests give insights into the manner of distribution of the residuals. The test output shows skewness, kurtosis and Jarque-Bera results. The null hypothesis indicates that the residuals are multivariate normal. Our results indicate that non-normality is found in models 1a:2b. We do not alter our model, as non-normality of residuals does not have to impose significant problems to our estimation exercise (Lütkepohl, 1993).

Table 32: Normality Test Model 1a

Component	Skewness	Chi-sq	df	Prob.
1	−0.546838	3.239507	1	0.0719
2	1.715080	31.86623	1	0.0000
3	1.176363	14.99150	1	0.0001
4	−0.091853	0.091401	1	0.7624
5	−0.286610	0.889907	1	0.3455
Joint		51.07855	5	0.0000

Component	Kurtosis	Chi-sq	df	Prob.
1	6.002790	24.42036	1	0.0000
2	9.220497	104.7978	1	0.0000
3	9.489951	114.0735	1	0.0000
4	3.424690	0.488480	1	0.4846
5	2.997681	$1.5e-05$	1	0.9970
Joint		243.7802	5	0.0000

Component	Jarque-Bera	df	Prob.
1	27.65987	2	0.0000
2	136.6641	2	0.0000
3	129.0650	2	0.0000
4	0.579881	2	0.7483
5	0.889922	2	0.6408
Joint	294.8588	10	0.0000

Table 33: Normality Test Model 1b

Component	Skewness	Chi-sq	df	Prob.
1	−1.364361	20.47628	1	0.0000
2	1.873785	38.62176	1	0.0000
3	−1.134871	14.16726	1	0.0002
4	0.170737	0.320663	1	0.5712
5	−0.218003	0.522779	1	0.4697
Joint		74.10875	5	0.0000

Component	Kurtosis	Chi-sq	df	Prob.
1	8.939277	97.00628	1	0.0000
2	9.214523	106.2058	1	0.0000
3	12.13392	229.4285	1	0.0000
4	3.040579	0.004528	1	0.9463
5	2.669584	0.300230	1	0.5837
Joint		432.9453	5	0.0000

Component	Jarque-Bera	df	Prob.
1	117.4826	2	0.0000
2	144.8276	2	0.0000
3	243.5957	2	0.0000
4	0.325192	2	0.8499
5	0.823009	2	0.6627
Joint	507.0541	10	0.0000

Table 34: Normality Test Model 2a

Component	Skewness	Chi-sq	df	Prob.
1	−0.992136	10.66361	1	0.0011
2	1.598917	27.69580	1	0.0000
3	0.956266	9.906474	1	0.0016
4	−0.005732	0.000356	1	0.9849
5	−0.313966	1.067892	1	0.3014
Joint		49.33413	5	0.0000

Component	Kurtosis	Chi-sq	df	Prob.
1	5.797679	21.19814	1	0.0000
2	8.594691	84.77237	1	0.0000
3	8.398770	78.93903	1	0.0000
4	2.773606	0.138814	1	0.7095
5	2.979412	0.001148	1	0.9730
Joint		185.0495	5	0.0000

Component	Jarque-Bera	df	Prob.
1	31.86175	2	0.0000
2	112.4682	2	0.0000
3	88.84551	2	0.0000
4	0.139170	2	0.9328
5	1.069040	2	0.5860
Joint	234.3836	10	0.0000

Table 35: Normality Test Model 2b

Component	Skewness	Chi-sq	df	Prob.
1	−1.203926	15.94383	1	0.0001
2	1.868478	38.40329	1	0.0000
3	−0.956156	10.05658	1	0.0015
4	0.116372	0.148968	1	0.6995
5	−0.305957	1.029704	1	0.3102
Joint		65.58237	5	0.0000

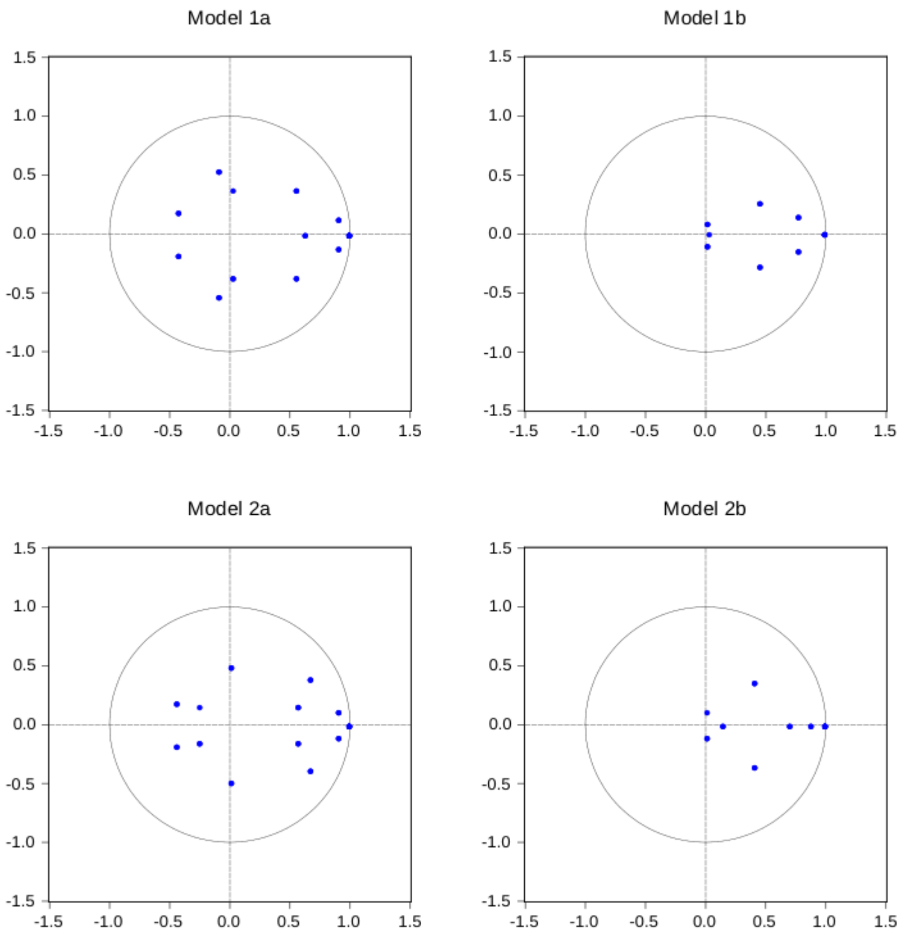
Component	Kurtosis	Chi-sq	df	Prob.
1	6.871551	41.21949	1	0.0000
2	8.777196	91.78398	1	0.0000
3	11.90343	217.9954	1	0.0000
4	2.863922	0.050922	1	0.8215
5	2.706578	0.236766	1	0.6266
Joint		351.2865	5	0.0000

Component	Jarque-Bera	df	Prob.
1	57.16331	2	0.0000
2	130.1873	2	0.0000
3	228.0519	2	0.0000
4	0.199890	2	0.9049
5	1.266470	2	0.5309
Joint	416.8689	10	0.0000

C.3 Stability Test

This section shows the results of the stability tests performed on our models. The circles indicate the AR Root polynomials of our models. A dot inside this circle indicates stability of the model. As all of the dots lay within this circle in models 1a:2b, we conclude that every model is considered stable.

Figure 20: AR Polynomial Root Stability Tests



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