A treatise on the implementation of an appropriate and feasible framework for ABP to cope with unanticipated inflation risk

Master Thesis Financial Economics

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Abstract

The aim of this thesis is to empirically assess the underlying relationship between unanticipated inflation risk and asset class returns to guide policy recommendations concerning the practical implementation of an inflation risk framework at ABP. Johansen's Multivariate Cointegration Model and Multivariate Vector Error Correction Models shall be utilized to establish the long-run cointegrating equilibrium of short-term and long-term unanticipated inflation. The VECM inherently assumes that a deviation from the long-run pathway affects short-run dynamics. Thus the speed of adjustment (α˚) shall be assessed via the Vector Error Correction Terms, whilst the persistence of a σ innovation under Cholesky Decomposition shall be assessed through the medium of Impulse Response Functions. The aforementioned helps establish whether specific asset classes mitigate or promulgate unanticipated inflation risk, ergo serve as a natural hedge. Furthermore, if there is a high degree of asymmetry between unexpected inflation betas over different inflation regimes, i.e. inflation betas are highly susceptible/sensitive to whether inflation expectations are rising or falling, then the assumption of time-invariance no longer holds. If so, one must take into account the time-varying nature of the estimated parameters ere a decision can be made regarding the efficacy of specific asset classes as a natural hedge. To verify the time-invariance assumption the rolling Dynamic Ordinary Least Squares Method shall be employed. In conclusion, Commodities and Private Equity are strongly concurrent with STUI and LTUI respectively in the long run. Short-run inflation risk insulation is provided by Commodities and Real Estate despite over-/undershooting phenomena. Under time-varying short-run inflation betas, Gold and Hedge Funds are "defensive", whilst Commodities is equivalent to a "positively skewed, but risky bet" as it exacerbates the magnitude of STUI.

Keywords: *Unanticipated Inflation risk, VECM, Johansen Multivariate Cointegration, Time-Varying Inflation Betas, Impulse Response Functions, Rolling Dynamic Ordinary Least Squares.*

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Acknowledgment

This master thesis was produced during an internship at the 'Stichting Pensioenfonds Algemeen Burgerlijk Pensioenfonds' (ABP) and the All Pensions Group (APG) in Amsterdam. The experience has taught me to cope with a steep learning curve and to immerse myself in the enchanting world of pension funds. Knowledge garnered during this period is of incalculable value and has become a treasured asset that will endure for the remainder of my life.

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1. Introduction

On the 9th of March 2015, the European Central Bank [ECB] commenced its 'no-holds-barred' bond-purchase program (Expanded Asset Purchase Program [EAPP]) to fulfil their ascribed price stability mandate. The program is a structured extension of the Asset-Backed Securities Purchase Program [ABSPP] and the Covered Bond Purchase Program [CBPP3], the latter of which was launched in 2014[4]. The ECBs Quantitative Easing program is currently expected to culminate by March 2017 or at least until the ECBs Governing Council witnesses a period of sustained inflation consistent with the target rate of inflation, i.e. just below 2 percent, expected to endure over the medium term. By September 2016, up to €1.1 trillion in securities will have been purchased of European institutions that in turn can acquire other assets and ensure widespread credit availability in the real economy[5]. Ad nauseam, the notion that yields' natural floor is at the zero percent mark was considered an aphorism, a universally accepted truth. Nevertheless, recent events have indicated that holding on to negative-yielding bonds is acceptable provided that the yield is expected to fall further, and thus provide the bond holder with capital gains. Currently, the natural floor of bond yields within the Euro area has been set equal to the ECBs negative deposit rate of -0.40 percent[6]. At the time, the ECB's (and other Central Banks') flirting with negative interest rates was an unconventional that complemented the provision of additional term funding to banks via Targeted Long-Term Refinancing Operations [TLTROs] and the aforementioned ABSPP. Nevertheless, the potentially debilitating impact of persistently ultra-low interest rates on banks' resilience has become a significant constraining factor that crucially undermines the profitability (and in turn stability) of the banking sector in the Eurozone as profit margins are squeezed. Profit margins between lending and deposit rates are narrowing as thus far retail deposit rates have remained partially insulated due to the banks' reluctance to pass on negative deposit rates to consumers. Concisely, uncertainty continues to plague investors as the behaviour of individuals and institutions remains ambiguous and might venture into the erratic if rates stray further into negative territory. Despite the fact that the counterfactual is difficult to pinpoint, the negative interest rate policy [NIRP] has failed to boost future growth- and inflation expectations. Case in point is that the lower nominal yields have spilled over from real yield components to the inflation

[4] https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html
[5] http://www.bloomberg.com/news/articles/2015-01-22/draghi-commits-ecb-to-trillion-euro-qe-plan-in-deflation-fight
[6] Key ECB Interest Rates, ECB.

expectations component, thus suppressing the latter. Furthermore, the NIRP may increase risk aversion and high grade investment bonds, i.e. AAA/sovereign bonds, become riskier. Holding these high quality bonds to maturity translates to a guaranteed loss of purchasing power. Indeed, the NIRP has already contributed to financial market volatility and has proven to be a catalytic agent in light of tightening global financial conditions. One of the consequences of the NIRP is the stockpiling of nearly $13 trillion of negative yielding sovereign bonds, recently fed by the flight to safety by global investors in the wake of Brexit. Furthermore, as of the 6th of September 2016 two corporations, Henkel and Sanofi, have issued negative yielding Eurobonds at a yield of -0.05pp. Finally, as the CBPP outstanding has grown to €213bn, ABSPP to €20bn and the Public Sector Purchase Programme to approximately €991bn concerns have been raised regarding the ECBs ability to give impetus to economic growth and stability in the euro area, particularly in light of potential deadlocks and the ubiquity of negative deposit rates and negative yields that may entrench the public's expectations for deflation due to unintended signalling by the ECB.

The protracted period of macroeconomic volatility has fed into investors' risk aversion whom no longer feel insulated from financial upheavals. Currently, unprecedented policy stances and a slew of economic reforms (particularly pertaining to the banking system and the pension fund sector) have accentuated, rather attenuated, the aforementioned imbroglio. Normally, Gesell taxes or expansionary fiscal policy measures can ensure debt deflation does not turn into a liquidity trap. Debt deflation occurs when risk of default surges as asset-backed securities' collateral declines in value. Subsequent margin calls and insolvencies spur on deleveraging, which may develop into a full-fledged 'fire sale' of assets[7] leading to a downward spiral. A liquidity trap occurs when monetary policy is rendered ineffective as short-term nominal interest rates are set to zero. To escape from a liquidity trap one can then utilize fiscal policy or set negative rates for the ECB deposit facility[8]. Conversely, some investors feel that a number of Eurozone member states are nearing their fiscal limit, i.e. unsustainable debt levels, despite the pre-Credit Crisis[9] notion that the rapid expansion and diversification of global FOREX reserves and increased market depth[10] of sovereign Eurobond markets ensured that sovereign bond demand was infinite. Thus

[7] A. Shleifer and R. Vishny, (2011).
[8] S. Gesell, (1916).
[9] Credit Crunch occurred between 2007 and 2009.
[10] The depth of market refers to a security's ability to withstand swift execution of large market orders without creating large swings in a security's price.

only negative deposit rates remain, one of Gesell's postulations, which is meant to ensure a negative effective return on currency in order to cope with excess reserves in the wake of the 'nuclear' option that is quantitative easing (QE).

Sovereign bonds are of particular interest to pension funds and the wider economy for several reasons. First off, government bonds are medium-term financing vehicles that form the basis of the monetary policy transmission mechanism via four channels; the interest rate channel, banks' balance sheet, wealth channel and the collateral channel. Long-term sovereign bond yields influenced bank lending rates, municipal and corporate bond yields via the process of arbitrage and bond pricing approximations, and can serve as a hedge in investors' portfolios against interest rate risk and stock market deterioration. Secondly, sovereign bonds allow pension funds to mitigate mismatch risk[11] as they can be bought in sufficient quantities and have extensive maturity structures that lend themselves well to matching pension fund liabilities size and maturities. Finally, Dutch pension funds have to contend with the Ultimate Forward Rate (UFR) method for European insurance companies and pension funds that determines the yield curve utilized to discount liabilities. The UFR was an initiative embedded in the Solvency II framework to extrapolate the ultra-long liability discounting curve (i.e. beyond traded maturities) and make amendments to shorter maturities (between 20 and 30 years) to partially resemble the market value approach. The discount curve is equal to the Euro swap curve for all maturities up to 20 years, the last tradable maturity. The lower the average pension liability discount rate, the higher the value of pension liabilities. Thus the ECB's insistence on engaging in Asset Purchasing Programmes has distorted the fixed income securities markets. The ECB apparently considers funded pension systems as "collateral damage" in light of the extended EAPP.

Academic relevance of this thesis includes a dissection of inflation risk components, their associated impact on the Dutch Pension Funds Sector and an indication of whether recent nuclear options utilized by the ECB have altered the 'rules of the game'. Furthermore, an elucidation of the level of (a)symmetry between inflation and deflation shocks can provide an important guideline with respect to potential coping mechanisms designed to guarantee the pension fund's nominal liabilities with a particular degree of certainty, depending on the economic environment and institutional setting. Also, most research in this field has pertained to the relationship between inflation and real stock returns, foregoing the impact of inflation on the returns of other asset

[11] Mismatch occurs where pension fund liabilities and balance sheet assets do not match.

classes, e.g. bonds, commodities, real estate. Furthermore, this paper will venture into the less chartered territory of inflation risk under time-varying parameters, their propagation in terms of short-run deviations from long-run equilibria and the expected length of deviation in time units. Economic relevance includes the rigorous scrutiny of inflation risk components and their dynamic relationship with different asset classes in the short-run and their implied convergence to long-run equilibria. Furthermore, by assessing the underlying fundamental relationship between (un-)expected inflation risk, asset class returns and time-varying inflation betas, one ought to be more capable of mitigating risk exposure and attenuating the associated adverse effects of prolonged periods of (excessive) (dis-)inflation. Recent upheavals in financial markets such as the effect of QE measures taken by the ECB, i.e. the one trillion euro rescue package to counter the 'European malaise' and the ECBs further measures to combat the deflationary spiral that rendered more than €3.6 trillion of the Euro zone's sovereign bonds in the negative yield spectrum in September 2016, can have a lasting effect on Dutch DB pension funds in terms of investment opportunities and the potential persistence of funding shortages. To understand the behaviour exhibited by inflation risk components during periods of financial distress is imperative, for pension funds form one of the bedrocks of investment and one of the cornerstones of civilization in (advanced) economies. Thus, one of the pivotal questions that ABP (and APG) are wrestling with concerns the practical implementation of a coherent framework for inflation risk. Economic inflation erodes the value of the asset side of ABPs balance sheet, whilst simultaneously increasing the liability-side of ABPs balance sheet. In order to ensure the two sides retain their matching targets and ABPs business plan retains its viability, one necessarily has to take into account inflation risk as inflation is an uncompensated risk factor, it affects both sides of the balance sheet and the impact of inflation is determined by several underlying factors that cannot be directly observed (particularly where it concerns unanticipated inflation). Concisely, an understanding of how rapidly the influence of an inflation shock dissipates over time, enables one to bolster and partially insulate the pension fund's overall portfolio so that we need not engage in 'gambling for redemption' to attain the benefit level promised to beneficiaries. In light of the aforementioned, the main research question pertains to the implications of inflation risk for Defined Benefit pension funds within the Dutch pension funds sector, which shall be emulated via a case study at ABP/APG. Furthermore, besides studying the inflation-hedging properties of traditional financial instruments, e.g. equity, bonds, commodities; the alternative asset classes, e.g. private equity, listed real estate and inflation-linked sovereign bonds; shall also be assessed. To gauge the implications of recent developments and the run-up to the Financial Crisis and the subsequent Sovereign Debt Crisis, time-varying parameters will be estimated to gauge whether unanticipated inflation betas exhibit time-invariance. Thus, in order to assess the evidence underlining (unanticipated) inflation (and deflation) risk and guide policy recommendations concerning the practical implementation of such a framework, the following main research quandary was developed:

"A treatise on the implementation of an appropriate and feasible framework for ABP to cope with unanticipated inflation risk."

The first part of this thesis is concerned with a quantitative analysis of the underlying relationship between unanticipated inflation risk components and asset returns in the long run and the dynamic adjustment to deviations from long run equilibrium in the short-run, i.e. their propagation pathways. Thus I can ascertain whether an asset class lends itself as a natural hedge against unexpected inflation either in the short run or in the long run. I anticipate at least one cointegrating relationship for each asset class under consideration.

The second part of this thesis is concerned with the (time-varying) inflation betas and the level of (a)symmetry based on whether we are faced with rising or falling inflation expectations. If unexpected inflation betas are highly sensitive to different inflation regimes, then depending on their sign and magnitude, the asset class in question might either insulate from or promulgate inflation risk.

In order to provide critical inflation risk policy recommendations I have devised several hypotheses that will guide the thesis-writing process. The first is concerned with the underlying short-run dynamic relationship between two types of unanticipated inflation and asset class returns. If asset class returns perfectly incorporate the inflation risk, then there will be no asset value erosion in case of unanticipated inflation. Thus the first hypothesis is as follows:

Hypothesis 1: Asset class returns will fully incorporate changes in unanticipated inflation in the short-run, thus combining asset classes will provide a natural hedge against inflation risk.

Time horizon tends to play a pivotal role in the approach taken towards inflation risk and the type of inflation one attempts to hedge. If unanticipated inflation is matched one-for-one by assets in the short-run, then it has little effect on the real portfolio level and the cumulative effect can be rendered negligible. Similarly, to gauge whether a cointegrating relationship exists that results in a long-run equilibrium between asset class returns and the unanticipated inflation rate, I shall utilize several econometric models including Johansen's Multivariate Cointegration Analysis, Vector Error Correction Models and several Impulse Response Functions in order to verify the statistical significance of the prior- and the following hypothesis:

Hypothesis 2: Asset class returns will converge towards their equilibrium level in the long-run, which is dominated by long-run inflation and fully insulates investors from unanticipated inflation.

To answer the first two hypotheses one must turn to the realm of econometrics in order to account for potential interaction effects betwixt variables that regular models fail to capture. The JMC shall determine the cointegrating rank of each asset class, i.e. the number of cointegrating vectors present that form the long-run equilibrium level. The VECM then enables one to estimate the sign and magnitude of the coefficients that indicate the long-run equilibria, whereby particular attention is given to the coefficients of the unanticipated inflation components. Furthermore, the Error Correction Terms indicate the coefficients of short-run "corrections" resulting from any deviation from the long-run equilibrium. If the short-run coefficient of the ECT is of the same magnitude and opposing sign, then deviations do not have a long-term impact as equilibrium is swiftly re-established. Finally, the IRFs shall gauge the impact of a one standard deviation shock in inflation on the asset classes under investigation. The IRFs also indicate the duration of an unanticipated inflation shock and thus tells us whether the impact of such a shock is permanent or only temporary.

Traditionally, investors tended to resort to Equities, TIPS/ILBs, Real Estate, Gold and Commodities as a hedge against inflation. The very long-term inflation hedging properties of gold are indisputable according to many academic papers, hence earning gold the nickname 'Holy Grail' of value[12]. Nevertheless, gold has also been used as a speculative vehicle during times of

[12] N. Dempster and J.C. Artigas, (2010).

economic turmoil and thus may render it unsuitable as a hedge against purchasing power erosion, particularly if one has to contend with a finite time horizon. Similarly, commodities may serve as an effective hedge as they can be the key root of inflationary pressure. Furthermore, demand for commodities can also be sustained by foreign countries, e.g. export-driven China, and thus could be seen as a partial hedge against national deflation. Indeed, research provides strong evidence that commodities provide effective short-run inflation protection. However, whilst Fama and Schwert (1977) found that residential property provided a complete hedge against expected and unexpected inflationary pressures for the period 1953-1971, Bond and Seiler (1998) conclude that commercial and residential real estate serves only as a partial hedge against inflation since the 1960s. Whilst long-term, high quality (or foreign) bonds serve as the go-to solution during periods of deflation, they tend to perform extremely poorly during extreme inflationary periods. Thus if one anticipates short-run deflation/disinflation followed by subsequent inflation in the long-run, fixed income securities may underperform in the long-run. Particularly as the bond and equity markets' business cycles have recently seem to have become more synchronized[13]. Defensive stocks[14] and dividend-paying stocks may partially insulate the portfolio from deflation, but do not form a panacea during periods of protracted periods of deflation, e.g. due to an increase in bankruptcies. Nevertheless, the aforementioned traditional conjectures may not hold water in the real world due to failure of standard economic models to capture inter-variable effects and long-run cointegration. Furthermore, little evidence has pertained to the short-run error correction inherent in asset equilibrium models, though current consensus according to Mehra (1994) is that the bond rate does not adjust one-for-one with actual inflation even in the long-run.

Presumably, the higher the degree of substitutability between inflation and deflation time-varying betas (i.e., assumption of homogeneity in absolute terms), the greater the absolute symmetry of their impact on the de facto asset class returns in light of altering fundamentals. Thus the third hypothesis was devised:

Hypothesis 3: There exists perfect symmetry between disinflation- and inflation-based betas for unanticipated inflation over the entire time period studied, ergo inflation betas are time-invariant.

[13] Similar to the McClintock Effect.

[14] Necessities tend to have inelastic demand.

As certain inflation cycles tend to be relatively short-lived only the short-run unanticipated inflation (STUI) variable shall be utilized for testing hypothesis 3. Evidence for or against shall be supplied by a set of rolling Dynamic Ordinary Least Squares estimates of the unexpected inflation betas over different time periods. The rolling DOLS method takes into account the underlying inter-variable relationships and enables one to gauge the time-(in)variant nature of inflation- and disinflation betas respectively. If it turns out that inflation betas have a time-variant nature, then this would have implications for the investment beliefs and ABPs ambition attainment strategy.

Prudent investing is a legal requirement for Dutch pension funds and remains a component of integrated risk management. Pension fund members expect the trustees of ABP to take precautions to steer clear of foreseeable dangers. The majority of Dutch DB pension funds, ABP included, pursue the following primary objectives:

1. Guarantee a nominal level of retirement income (Fundamental).
2. Increase the nominal level of retirement income in line with a (wage-)inflation index, conditional upon the financial position of the pension fund (Indexation Ambition).

Interest rate risk is the main source of risk for the first primary objective as they determine the price of acquiring deferred annuities. Hedging occurs either via cash flow matching (of asset and liabilities) or via a (partial) duration match. The second primary objective is mainly liable to high inflation risk due to its impact on the liability side. Nominal asset class returns may provide a partial hedge against expected inflation, but all too often fail to capture unanticipated inflation risk. To amend for this ABP also invests in real asset classes, e.g. ILD (Inflation Linked Debt), including Inflation Linked Bonds (ILBs). Though ILBs provide a closer inflation risk match, they also entail a tradeoff due to their lower expected returns, as over-reliance on ILBs reduces the indexation potential.[15] Despite the fact that certain asset class returns, e.g. real estate, commodities and infrastructure, are expected to run parallel to inflation in the long run, statistical evidence remains elusive. Thus, answering the above hypotheses enables me to formulate sound policy implications pertaining to inflation risk for ABP/APG. The final policy recommendations can be found in Section 9, Conclusions.

[15] Secondary objectives of ABP include socially responsible investing and sustainability (as a prerequisite). Indeed, regulatory requirements regarding the abovementioned issues are currently being implemented in the Netherlands.

The remainder of the paper is structured as follows. Section 2 elucidates the theoretical framework. The structure of the Dutch pension system shall be illuminated in Section 3 followed suit by the literature review in Section 4. Subsequently, the different inflation measures shall be elucidated in Section 5. Section 6 concerns the data sources, variables under consideration and descriptive statistics. Then Section 7 states the methodological methods and econometric techniques employed. Section 8 contains the results and associated explications, intermingled with robustness tests. Section 9 concludes.

2. Theoretical Framework

In this section I shall endeavour to elucidate the theoretical considerations underlying institutional investor behaviour, the inflation risk components and their respective propagation pathways. The theoretical construct underlying the functions of demand for and supply of money (and in turn illustrates the notion of inflation), is governed by Allais' Hereditary, Relative and Logistic (HRL) theory. The hereditary concept refers to the determination of the present that is solely based on past occurrences. Allais postulates that the dependence between past and present is invariant regardless of whether chronological time or psychological time is applied. Thus, relativism holds that an economic agent's rate of forgetfulness and the rate of interest are an invariant function of prior global expenditure fluctuations. Concisely, the past is forgotten identically to the way the future is discounted, hence the propagation of monetary events will gradually weaken à la the concept of contiguity. The perceived inflation rate will converge asymptotically on the instantaneous rate of inflation as the rate of memory decay grows exponentially and the elasticity of perceived inflation nears unity. The coefficient of psychological expansion reflects the average assessment of the current and future (macro)economic state by all economic agents.

From a financial economics perspective, plan sponsors ought to ensure a significant portion of their portfolio contains fixed income securities, mainly because the pay-out structure of pension benefits enables pension funds to (cash flow) match liability streams directly. Furthermore, as plan assets are invested in matching fixed income security portfolios, then actuarial assumptions become increasingly invariant and thus capital markets' transparency and efficiency is improved. In light of the importance of fixed income securities with respect to the pension fund sector I shall now expound the theoretical framework utilized for bonds. For investors whom trade in bonds to achieve capital-gains we assume they adhere to a term structure theory called the Preferred Habitat

Theorem[16] (PHT), which postulates that different bond investors have a specific maturity preference and can only be induced to deviate from their preferred maturity range if the yield deviation sufficiently compensates them. The PHT is a synthesis of the pure expectations theory[17] (ET) and the Market Segmentation Theory[18] (MST). ET purports that long-term yields are naught but a close approximation of future short-term yields. Thus bond investors are solely concerned with yield and have no maturity preference. This is indicative of a flat term structure, where nominal interest rates are not expected to rise. Conversely, MST postulates that bonds characterized by different maturities are not perfect substitutable, hence short-run interest rates are determined separately from long-term interest rates. Bond prices and thus yields are determined by the forces of supply and demand in separate market segments, and 'never the twain shall meet'[19]. If current interest rates are high we anticipate a future decline in interest rates, which feeds demand for long-term bonds (anticipated future capital gains) whilst limiting its supply (bond issuers do not wish to lock-in at high interest rates). Vice versa would be the case if investors anticipate a future increase in interest rates.

Furthermore, Dynamic Asset Allocation Theory[20] (DAAT) assumptions will apply to pension fund investors whom attain bonds that are held-for-collection. DAAT is a portfolio investment strategy whereby an investor enters into a long-term investment of asset classes or securities and periodically actively rebalances the positions via purchasing and selling of securities (active rebalancing) to ensure the asset mix remains in line with its long-term target. DAAT involves the use of Constant Proportion Portfolio Insurance[21] (CPPI). CPPI is a 'convex' strategy that relies on a capital guarantee against downside risk whilst retaining exposure to upside potential (capital gains). The capital guarantee is based on a position in sovereign bonds, e.g., the floor; the position in the risky asset is usually highly leveraged.

Further assumptions that accentuate the findings in this thesis are concerned with the relationship between asset returns and macroeconomic fundamentals, whereby we assume that they adhere to the principles explicated by New Keynesianism. Concisely, financial markets are segmented based on investors' risk preferences and both price- and wage-adjustments exhibit

[16] F. Modigliani and R. Sutch, (1966).
[17] F.A. Lutz, (1940).
[18] J.M. Culbertson, (1957).
[19] *The Ballad of East and West*, Rudyard Kipling, (1889); published as part of Stedman's A Victorian Anthology, (1895)
[20] J. Picerno, (2010).
[21] G. Kingston, (1989).

sluggishness, thus allowing for (short-term) economic fluctuations. These nominal deviations can amplify existing macroeconomic perturbations, particularly if the latter are structural by nature. The factotum of central banking policy is the interest rate transmission mechanism that indirectly affects aggregate demand, though it is imperative that the money market rate and the long-term (sovereign) bond yield are treated as separate entities. ECB policy vacillation may give rise to Euribor fluctuations that do not seamlessly match monetary shocks and thus credit market disturbances may partly reflect forecasts of expected future monetary policy choice.

3. Dutch Pension System

This section shall explicate the structure of the Dutch pension system, which consists of a three-pillar interconnected system.

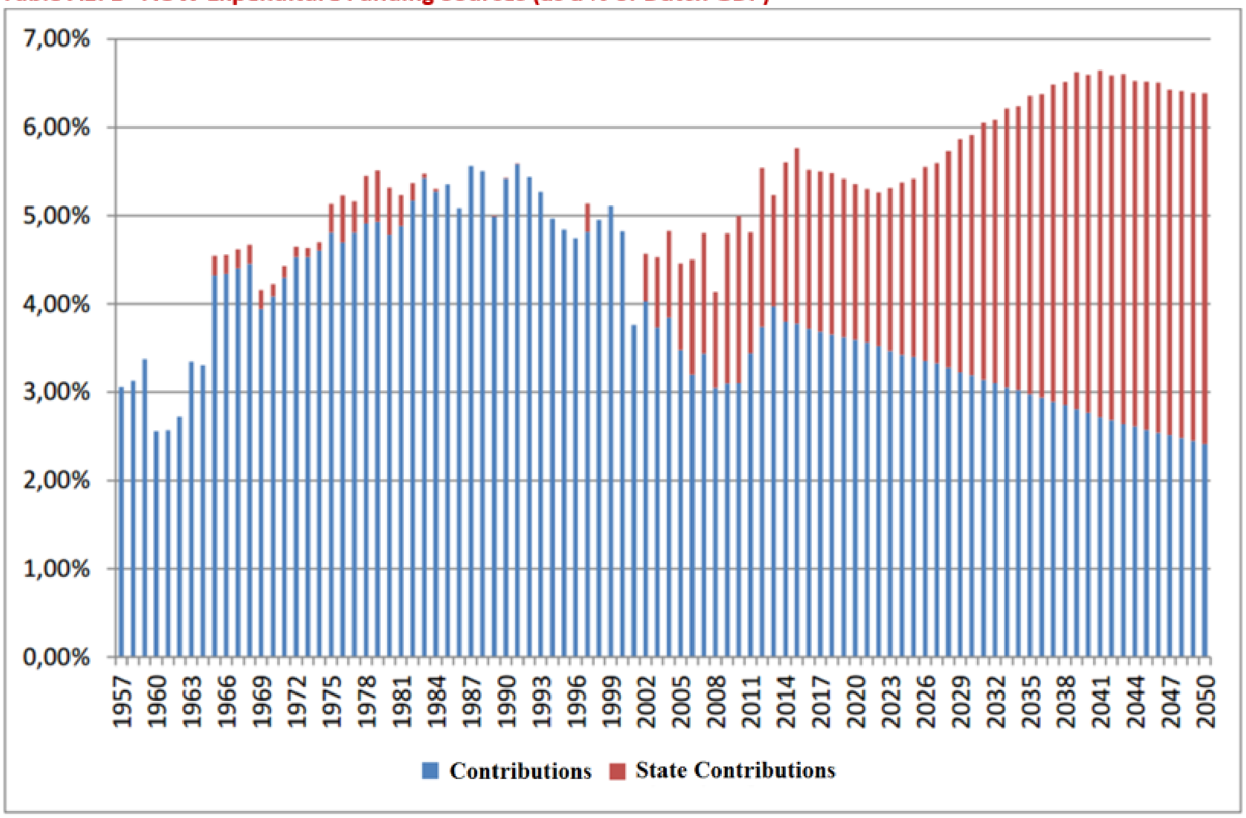
The three pillars of the Dutch pension system are comprised of a state pension (AOW), supplementary quasi-mandatory collective occupational pensions and voluntary private individual pension arrangements. In Europe, pension system formats tend to vary immensely across countries. At one end of the spectrum countries adhere to the pay-as-you-go system (PAYG) which entails pension benefits that are fully sponsored by the working population (employees below the age of 65 years and 6 months as of 1st of January 2016). At the opposite end of the spectrum we find individual pension plans (IPP) where the eventual pension benefit level largely depends on investment returns. Currently, most European countries adhere to an amalgamation of these two opposites. The Dutch pension system in particular is typified by the reliance on mandatory participation, capital funding as a means of financing and the triangular relation between pension providers, employees and employers.

3.1 First Pillar

The first pillar is a standardized state-run pension that ensures basic coverage and endeavours to eliminate elderly poverty. The public pension is provided by the state at minimal wage level and functions as a general old age pensions act, i.e. in the Netherlands it is referred to as the Algemene Ouderdoms Wet (AOW). The AOW is a direct continuation of the ‘Noodwet

Ouderdomsvoorziening' (NO) implemented in 1947 by Willem Drees[22]. The amended version of the NO, i.e. AOW, was ratified in 1956 under Drees' tutelage when he became the Dutch Prime Minister. The compulsory insurance plan is financed on a PAYG basis via employees' social contributions tax and the general government budget. The level of the state pension provided is concomitant with the statutory minimum wage and until 2028 is guaranteed to rise with inflation.

Table A1. 1 **AOW Expenditure Funding Sources (as a % of Dutch GDP)**[19]



Furthermore, pension benefits are also adjusted relative to minimum wage adjustments and are liable to income taxation. The AOW Savings Fund is expected to grow to €135bn in 2020 in order to cope with rising public pension expenditures.

Those who have resided in the Netherlands for fifty years (between the ages of 15 and 65) are entitled to a full old-age pension, thus the annual accruement rate amounts to 2pp of the total savings. As of the 1st of July 2016, an individual living alone may receive a gross monthly AOW of €1.144,72.

Table A1. 2 **Income Taxation Brackets**

Income Tax Brackets	Earnings (per annum)	Income Tax Rate
Bracket 1	€0 - €19.922	36.55%
Bracket 2	€19.923 - €33.715	40.15%
Bracket 3	€33.716 - €66.421	40.15%
Bracket 4	≥ €66.422	52.00%

[22] Willem Drees was the Dutch minister of Social Affairs when he devised and implemented the 'Noodwet Ouderdomsvoorziening'.

A pensioner in a common household (either through marriage or cohabitation) is entitled to receive 50pp of the minimum wage resulting in a gross monthly AOW of €788,81. For early retirees and those who have not lived in the Netherlands, the pension entitlement will be reduced by 2pp per year either spend in early retirement or as an expatriate. Due to an ageing population, the pension eligibility age has been increased to 65 years and 6 months in July 2016 and is expected to rise to 67 years by 2025. In May 2016, over 3.34 million people received (at least partially) the Dutch state pension benefits[23]. In 2013 the Dutch government spent approximately €32.72 billion on provision of AOW and this figure is expected to rise to 6.5pp of Dutch GDP by 2040. Similarly, an increasing proportion of the total AOW expenditures will be financed via the general government budget (see Table A1.1), which in turn is mainly sponsored by the third and fourth income tax brackets (see Table A1.2). Thus, the AOW is designed to create a more egalitarian society due to its inherently 'progressive' structure, e.g. those with higher incomes bear the brunt of the income tax burden.

3.2 Second Pillar

The Dutch second pillar is one of the best developed occupational pension systems in the world and has approximately 5.5 million active participants. There are three main types of second pillar pension fund, to wit: industry-wide (mandatory for all firms operating in the sector with stringent opt-out conditions), corporate (mandatory participation and governed by collective labour agreements) and professional group funds (participation requires adherence to a particular profession/vocation). Dutch pension funds differ from those in other European Union member states in terms of their absolute size, accumulated assets vis-à-vis own GDP and in terms of their intermediate position between high-risk (Anglo-Saxon countries) and conservative (Continental Europe) risk profiles. Currently the ratio of total pension assets under the second pillar over GDP is equivalent to 183.6pp[24]. The Dutch Central Bank (DNB) acts as supervisor and has encouraged the consolidation of pension funds via regulatory requirements that allow for economies of scale, e.g. reporting requirements and new governance structures to increase expertise and veracity via pension fund board composition changes. Since the end of 2005 the total number of Dutch pension funds has been reduced from 800 to 365, particularly amongst company pension funds. The Dutch

[23] Centraal Bureau voor de Statistiek (CBS).
[24] Figure established in 2015 in Global Pension Assets Study 2016, Willis Towers Watson.

pension fund has thus become profoundly concentrated as the two main pension funds (ABP and PFZW) account for 45 percent of total pension fund assets under management[25].

Occupational pension provision is not mandatory, though sector-wide pension schemes often stipulate compulsory membership upon approval by the government. Approximately 80pp of all occupational scheme members are covered by these quasi-mandatory sector-wide pension schemes. Opting-out of the sector-wide pension scheme(s) is only allowed if the employer can provide a company pension plan that ensures at least an equivalent level of pension benefits. Note that occupational pension agreements entail an outsourcing obligation, whereby an administration agreement must be forged with an external pension provider. The outsourcing obligation was instated to ensure that the employees' rights are protected in case a firm files for bankruptcy.

The prevailing occupational pension scheme utilizes the average salary as computation basis with valorisation to average earnings, though a few final salary schemes have remained, i.e. where annual pension benefits are equivalent to a fixed percentage of your final salary. The move from final to average salary negates the 'back-service', i.e. requirement to increase pension benefits over all the participant's pensionable years as the result of wage increases when a participant changes jobs. Furthermore, fiscal legislature necessitates the inclusion of the right to AOW prior to establishing the annual pension amount.

The Dutch government proactively encourages pension accruement by omitting pension claims from taxation. Conversely, the final benefit is liable to taxation, a practice oft referred to as the 'reverse rule' ('omkeerregel'). Fiscal treatment of pension accrual in the Netherlands thus ensures that pensions savings contributions are tax-free (up to a certain premium level), whilst pension benefits are taxable.

As of January 2016, the Financial Assessment Framework for Pension Funds reforms (nFTK) have reduced the maximum per annum accrual rate for Defined Benefit pension schemes from 1.9pp to 1.657pp of the pensionable wage under the final salary schemes, and from 2.15pp to 1.875pp for average salary pension schemes. The aforementioned FTK reforms have been agreed upon in the Coalition Agreement and were incorporated in the Witteveen Framework legislative proposal of 2015. The fiscal legislation has placed a cap on the favourable tax treatment

[25] Investment & Pensions Europe, March 2015, "Best hands on deck: The consolidation of Dutch pension funds."

for incomes exceeding €100.000,- and the pensionable salary must remain within the statutory limits of €101.519,-[26].

3.2.1 Defined Benefit and Defined Contribution Schemes

A Defined Benefit (DB) pension plan is based on the premise that the employer or pension plan sponsor promises a specified monthly benefit based on the employee's earnings history, tenure and age (ergo participant's entitlement). Thus the formula used for computing the ultimate pension benefit is known in advance. In an average pay scheme, pension accumulation recurs annually as per annum accruals critically depend on the salary earned that year. As mentioned prior, there is no 'back-service' requirement if a salary increases. The total accrual (pension entitlement) is the amalgamation of each annual accrual, which is liable to conditional indexation[27]. Under conditional indexation the pension liabilities are only fully indexed to inflation conditional upon the policy funding ratio (PFR)[28] being above 110pp and provided that it is expected that full indexation can also be granted in all future years. Depending on the maturity of the fund, the indexation ambition and the prevailing interest rate, this usually occurs only if the policy funding ratio is near 130pp.

As of 2015, the maximum percentage for tax purposes is 1.875pp of the pensionable base per year. In the past pension benefit accruement was strongly tied to earnings in the final years of employment and to the tenure at a particular firm, thus 'accrual' risk was exceptionally high. Also, DB schemes are currently under tremendous pressure due to longer than anticipated life expectancy increases, an ageing workforce (greying population), exceptionally low interest rates and pernicious yields. Funding shortfalls are becoming increasingly prevalent as pension obligations exceed asset-side funds. As pension funds fall under the jurisdiction of the Dutch central bank (De Nederlandsche Bank, DNB), they are obligated to submit a recovery plan within three months if [sic] "the pension fund no longer holds the required own funds based on the policy funding ratio." Required own funds (ROF) refers to the ancillary own funds that are maintained by the pension fund to absorb potential losses in a going concern situation. Quantity and quality

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[26] Stipulations were effective as of the 1st of January 2016.

[27] Conditional indexation can be regarded as an embedded barrier call option (down-and-out option where the value of an option is 'knocked out' as the underlying asset's price reaches the barrier level) that the pension fund offers its plan participants.

[28] Policy funding ratio is calculated as the 12-month moving average of the actual funding ratio (value of assets/value of pension liabilities).

of own funds must be up to par and in accordance with applicable European legislation. Ancillary own funds can only be classified as Tiers 2 or 3 items under the Solvency II Directive. The lower limit of the ROF is indicated by the minimum required own funds (MROF) which depends on the investment risk assumed by the pension fund and whether administration costs are fixed pursuant to the Institutions for Occupational Retirement Provision Directive (IORP). The funding ratio is then the ratio between the assets utilized to cover pension liabilities and the pension liabilities alongside technical reserves. Any special purpose funds (SPFs) are excluded from the funding ratio calculation. The policy funding ratio is equivalent to the average funding ratio over the past year based on daily market data. Concisely, the recovery plan must contain at least one of the following recovery measures: higher contributions, pension benefit curtailment or foregoing indexation. Pension funds tend to prefer increasing the contribution rate over foregoing indexation. Pension benefit curtailment is seen as a last resort in dire situations (ergo severe underfunding)[29].

A Defined Contribution (DC) scheme is an occupational pension plan where the employee and employer both make a fixed periodic contribution that is invested. The formula for computing the required contribution rate is known in advance, the pension benefit level remains unknown until the pension capital is converted into either a lump-sum or an annuity at the retirement date. DC individual accounts administered by the plan sponsor, tend to exhibit smoother asset accumulation than the backloading (postponement) of the accrual of vested pension benefits under a DB scheme. Despite the fact that DC schemes circumvents the longevity risk of the DB scheme, the substantial variation in DC plan design, regulation, fiscal limits and legislation; ensures that the DC scheme is riven with a plethora of risks faced by employees. Furthermore, the wide array of options and built-in decision-making nodes during the accumulation and decumulation phase may serve as deterrent in the form of an 'encysting bias'[30]. During the accumulation phase, decisions must be made regarding the participation (default option is often not to enrol, which is problematic due to inertia[31]), expected salary replacement level, contribution rate, portfolio allocations (oft constrained by plan sponsor) and periodical portfolio rebalancing. During the decumulation phase, choices are made regarding the pay-out (type of annuity) and timing of

[29] L. De Haan, (2015).

[30] Encysting bias refers to the 'can't-see-the-forest-for-the-trees' adage. People feel overwhelmed by the number of options under consideration and thus engage in procrastination.

[31] Inertia bias (also referred to as status quo bias) concerns a tendency to prefer the current wealth position over alternatives, not because it is superior, but rather because it is our current reference point.

withdrawals (frequency and size). The encysting bias discourages timely decision-making and thus people postpone pension accruement.

The only risk that employers and/or sponsors retain in a regular DC scheme is the potential fiduciary or legal risk. Fiduciary risk occurs when funds are not used for their intended purposes, recording and accounting is inconsistent and suboptimal asset/portfolio allocation. Note that fiduciary risk does not necessarily imply unsavoury practices or fraudulent behaviour on the part of the asset manager.

3.2.2 Demographic Shift

Occupational pension schemes in the Netherlands are still predominantly DB as the DB/DC split in 2015 amounted to 95 percent vs. 5 percent. Similarly, the preponderance of pension assets are held by countries with mature pension systems, particularly with respect to funded occupational schemes. Approximately 92 percentage of occupational pension sector assets within the OECD, equivalent to approximately $14.4 trillion, were held by just six countries – the Netherlands, Canada, United Kingdom, Japan, Australia and the United States[32].

Nevertheless, the recent shift towards a preference for DC schemes seems to have arisen due to an amalgamation of factors and circumstances. Historically, most of these factors concern an industrial composition change and workforce demographics[33]. For example, one paradigmatic shift occurred when the female labour force participation rate in the Netherlands rose from 30 percent in 1975 to 70 percent in 2011 (above the OECD average of 59.9 percent)[34]. As a direct result, the share of dual-earner households increased necessitating joint decision-making that could either foster greater mobility, i.e. change in employment situation of a spouse requires a change in employment of the other; or could hamper labour force mobility, i.e. joint decision-making implies greater constraints. The inherent accrual risk of DB plans would then persuade dual-earner households to prefer portable accrued pension benefits and pension schemes that do not penalize above average job turnover, thus resulting in a predilection for DC schemes. Similarly, as production technology evolved, the return to general human capital (skills that are transferable across firms) grew faster than the return to firm-specific human capital[35]. Finally, the general

[32] J. Broadbent, M. Palumbo and E. Woodman, (2006).
[33] S. Aaronson and J. Coronado, (2005).
[34] OECD, (2012).
[35] J.M. Abowd, P.A. Lengermann and K.L. McKinney, (2002).

increase in longevity of the population at large combined with regulatory constraints with respect to any alterations made to plan provisions, may persuade some employers to turn to DC schemes instead. The democratization of financial markets may also have instilled a greater need in economic agents to feel that they can exert control over their own portfolio allocations.

In years to come, private pension schemes (e.g. Individual Defined Contribution [IDC] schemes) that safeguard purchasing power via embedded guarantees, may well take centre stage in countries without an entrenched funded DB pension system. Economic agents will have to adjust to the rapidly changing symbiotic relationship between the financial- and demographic landscape.

Regardless, by combining the flat-rate first pillar PAYG public scheme and the second pillar (DB) occupational pension fund schemes, old-age poverty has been neigh on eradicated in the Netherlands. Retirement income chiefly hails from the second pillar occupational pension schemes funded by tax-deductible contributions made by the employee which are 'quasi-matched' by the employer. Generous replacement rates are prevalent in the Netherlands with gross replacement rates standing at 90.7pp for the average earner and 94.4pp for the low earner (whom earns 50pp of the average). The net replacement rate of current disposable income for the majority of households is equivalent to 84pp[36], which includes AOW and accounts for an approximate replacement rate of 30pp of the average wage. Nevertheless, with a dwindling workforce, mounting demographic pressures and a rising share of self-employed (i.e. ZZP workers, 'zelfstandig zonder personeel'/'self-employed without personnel') whom are not covered by the second pillar, the third pillar has garnered more attention over the past few years.

3.3 Third Pillar

The third pillar comprises individual pension provisions (IPP) that are issued by an insurance company or a bank[37]. These individual pension provisions come in two flavours, either in the form of an annuity insurance or as an endowment insurance, e.g. lump sum provision. The third pillar is relatively small in the Netherlands despite its advantageous, albeit limited, tax treatment. Nevertheless, the self-employed and employees without a collective pension scheme tend to resort to these IPP options in order to supplement their first pillar pension benefits, particularly if there

[36] Knoef et al., (2014).
[37] J.M. Kremers, (2002).

exists a pension accrual gap. For the self-employed there exists a special tax clause whereby a percentage of their company's profit will be taken into account in the tax return and will become a deferred tax item. Furthermore, the Bank Savings Act 2008 ("Wet Banksparen") offers similar tax relief on asset accumulations schemes provided by banks or investment firms that were hitherto only provided by insurance firms in a de facto monopoly. Under the Act, the tax-relieved capital formation composite market has come under sustained, competitive pressure due to an influx of banks and investment firms wresting away market share from traditional insurance firms. As a direct result new policies have been developed to encourage private retirement saving via tax-relieved asset accumulation. The profitability of the life insurance industry has thus come under sustained strain, necessitating a restructuring process. Consequently, under the emblem of 'tax-relieved capital formation', bank saving schemes (mainly saving accounts or investment rights with a bank) and life insurance policies now operate in a single composite market.

Furthermore, until January 2012 the Dutch could also opt for a salary savings scheme ("spaarloonregeling") where an employer could pay part of an employee's gross annual salary into a separate account with a vesting period of four years. This amount would not be liable to income taxation provided that the amount remained below a fixed limit. These savings could potentially be used to buy an annuity or serve as self-imposed contribution for supplemental third pillar pension saving.

4. Literature Review

What follows in this section is the illumination of the current body of evidence pertaining to the economic analysis of the different types of inflation risk and its components faced by Dutch pension funds as well as several studies highlighting the potential of several asset classes in hedging said inflation risk.

In the late 1970s, Volcker's anti-inflationary measures took effect (i.e. monetary tightening) and the Great Inflation era[38] had drawn to a close by 1984. Interestingly, the current widespread deflation appears to be a global counterpart to the rampant inflation of the 1970s. Nevertheless, the pivotal question remains whether a period of prolonged deflation can be benign.

[38] A.H. Metzler, (2005).

The leading factor in deciding whether 'lowflation'[39] or even deflation is relatively benign or malign depends on the rate of deflation and the nature of its underlying cause.

Benign deflation occurs due to favourable international shocks to prices, e.g. fall in commodity prices, high rates of innovation in technology-intensive industries feeding into a loop of lower costs (which are passed on to consumers due to price-cutting practices), an increase in aggregate supply or other productivity-increasing factors that drive down prices. It is considered benign due to its productivity-driven nature, particularly if it does not affect overall economic activity and increases the purchasing power of consumers via higher real wages. Conversely, pernicious deflation occurs when general (rather than relative) price declines ensue concurrent with prevalent expectations of further price declines. According to Beckworth (2008), deficient aggregate demand and thus weak economic activity can develop into a self-perpetuating and vicious, downward spiral. Potential causes of harmful deflation tend to consists of an amalgamation of specific market conditions and consumer behaviour. Examples include rigid market structures, inappropriate government policies and severe monetary shocks. Even a temporary adjustment-process following the bursting of an asset pricing bubble can have prolonged adverse effects from a macroeconomic perspective.

Furthermore, widespread levels of excessive (sovereign) indebtedness and impaired debt sustainability[40], downward-drifting inflation (even deflation), deferred consumer spending (protracted marginal propensity to consume)[41] and waning consumer confidence are all hampering economic recovery in the Euro Area and amplify macroeconomic instability. Under present circumstances, a deflationary spiral would be particularly detrimental in conjunction with policy rates that are at the zero mark and extremely low bond yields.

Demographic ageing in advanced economies may transform cyclical lowflation into a structural phenomenon due to "a negative wealth effect from falling asset prices and changes in relative prices reflecting different consumption preferences"[42], and hence reduce the effectiveness of monetary policy tools. Indeed, despite unconventional monetary policy pursuits, e.g. QE, there is no evidence of sustained inflationary pressure.

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[39] Ultra-low inflation which may lead to higher real debt stocks and real interest rates, less relative price adjustments and greater unemployment. Financially (di)stressed countries in particular would experience a process of painful adjustment in case of a prolonged period of lower than expected inflation.

[40] Particularly if real interest rates increase.

[41] May give rise to a 'paradox of aggregation', i.e. downward spiral.

[42] P. Imam, (2013).

For pension schemes, the impact of a prolonged period of lowflation on cash flows and funding (ratios) critically depends on a number of underlying assumptions. Funding and cash flow considerations with respect to the wider inflationary (or deflationary) pressures depend critically on the degree of indexation (i.e. unconditional or conditional), nature of inflation index tracked (e.g. CPI, RPI, PPI or wage-price index), level of inflation hedging and the inflation measure utilized for funding ratio purposes. Furthermore, many pension schemes have statutes that explicitly state that pension rights shall not be curtailed in the event of prolonged deflation, thus implying asymmetric treatment.

4.1 Abridged Inflation: From History to Present

Over the past decade, the underlying drivers of headline inflation indices have experienced a rollercoaster ride[43], whilst core inflation has been virtually flat fluctuating around the 1pp mark for every advanced economy[44]. Concisely, inflation has more faces than Janus[45]. The Credit Crunch (2009-2012) has led to a plethora of alterations made to the way in which pension funds insulate or guard against inflation risk. The plunging funding ratios have put excessive pressure on pension funds' ability to pursue their indexation policies. Falling returns on the equities markets twinned with artificially depressed (sovereign) bond yields due to continued QE measures by the ECB, has adumbrated a turning of the tide. As a direct consequence, guaranteeing the unconditional nominal liabilities has taken centre stage. Lacklustre economic growth and inflation expectations are common malaises that plague many of the developed economies. Inflation uncertainty is on the rise and average expected inflation has dropped significantly over the past few years. Investors' opinion on the broad monetary policy of CBs, e.g. ECB, FED and BOE, remain diametrically opposed and the uncertainty with respect to the future direction of inflation rates is cause for concern. The level of inflation uncertainty and its consequences is felt keenly in the pension fund sector and can be observed from divergent measures taken by the aforementioned. Many within the pension fund sector have resorted to strategic divestiture of inflation-related products and hedges (particularly inflation swaps) in response to the funding ratio free fall. An understandable, though bold move, chiefly undertaken by funds that adhere to a dynamic portfolio-

[43] O.J. Blanchard and J. Gali, (2007).
[44] P. V.d. Noord and C. Andre, (2007); T. Sinai and S.H. Shore, (2010).
[45] In Roman mythology the God Janus presided over beginnings and periods of transition whether abstract or concrete. He was often depicted as a two-headed image to reflect his divalent nature.

matching policy that was hitherto geared towards the safeguarding and provision of sustainable, conditionally index-linked pension benefits to participants. Amid curtailment of pension benefit rights and more stringent indexation requirements, purchased inflation risk protection has (partially) disappeared from the matching portfolios. Conversely, other pension funds have amalgamated inflation-protected securities and hedges as expected inflation took a nosedive. It is not a strategic inflation hedge aimed at the preservation of pension obligations per se, but rather the pursuit of a tactical absolute return investment highlighted by the comprehensive purchase of ILDs. Furthermore, the tactical asset allocation to inflation-sensitive investments has substantially increased under the ALM method. Extreme adverse events during the recent financial crises have led pension funds to utilize bad weather scenarios and ascribe greater significance to the ‘tails’ of risk distributions. Thus, scenarios marked by higher inflation(-fluctuations) under the ALM model, are likely to induce a preference for increased allocation to inflation-sensitive products in the investment mix. Inflation protection could well be enhanced via TAA by tilting towards commodities and away from bonds in the wake of a positive inflation shock, only to be reversed once commodity returns shrink.

From an equity perspective, Hagmann and Lenz (2004) examine the empirical relation between real stock returns and different inflation components, i.e. ex post inflation, expected inflation, changes in expected inflation and unexpected inflation. According to the Fisherian world view, stocks represent ownership of physical capital assets and thus should offer protection against inflation as they form a perfect hedge. Concisely, real asset values and inflation rates ought to be wholly independent. Nevertheless, Fama (1981) postulates that the correlation between real stock returns and inflation is spurious due to the presence of confounding variables. Indeed, several theoretical studies with respect to real stock returns and inflation components as conducted by Danthine and Donaldson (1986) have purported that the viability of stocks as a long-run hedge against inflation depends on the nature of the economic shock that induced inflation. A real output shock will render the relation between real stock returns and inflation negative, whereas a pure monetary shock means stocks lend themselves well as long-run inflation hedges. These results are echoed by Marshall’s equilibrium monetary asset pricing model (1992) which predicts that the correlation between ex-post measures of real stock returns and inflation is negative when induced by real shocks and vice versa for monetary shocks. Furthermore, the magnitude of the shock’s impact is greater for real economic shocks, i.e. asymmetrical effect propagation. Several papers have forayed into the area of non-structural vector autoregressive models to explicate the negative relation between real stock returns and inflation (Lee, 1992; Balduzzi, 1995). However, some argue that structural VARs are required in order to incorporate the effect of the nature of the stock and its effect on different components of inflation. Hess and Lee (1999) decompose real stock returns and inflation utilizing a bivariate structural VAR and find that the negative relation between real stock returns and ex-post inflation is induced by aggregate supply shocks, whilst a positive relation emerges

$$\hat{\beta}_{\pi} = \beta_{\pi} + \beta_{ip} \frac{\text{cov}(\text{inflation}, \text{ip})}{\text{var}(\text{inflation})}$$

in the case of aggregate demand shocks. Gallagher and Taylor (2002) use the Hess-Lee model, but replace real stock returns for real output growth.

Bekaert and Wang (2010) found that the inflation betas[46] of government bonds (indicators of the viability of an asset class as an inflation hedge) were close to 0.31 for the developed countries, despite inclusion of a negative industrial production growth beta which may be indicative of a world state of stagflation[47]. The low inflation beta of sovereign bonds suggests that ‘plain vanilla’ nominal bonds serve as poor inflationary hedges.

The viability of other asset classes as adequate inflation hedges were investigated by several authors, whose general consensus was that many asset classes were imperfect at best and that time horizon under consideration plays a pivotal role in the inflation protection granted. The effectiveness of REITs as an inflation hedge remains inconclusive. Nevertheless, on average their average hedging characteristics seem to mirror those of developed equities, largely due to their inherent equity component. As inflation rises, the distinction between indirect and direct real estate becomes crucial.

Attié and Roache (2009) found that commodities are an effective short-term hedge (less than 12 months), but in the long-run prices tend to fall gradually rendering the hedge ineffective. This long-run reversal was explicated by Frankel (2006) whom purported that real interest rates and commodity prices tend to be inversely correlated. Thus as real interest rates gradually increase after an inflation shock, commodity prices will fall with a lag.

Commodity futures on the other hand seem to exhibit a positive correlation with consumer prices[48]. Nevertheless, the correlation exhibits substantial time variation when utilizing a rolling

[46] If inflation beta is equal to one it forms a perfect inflation hedge (in theory).
[47] Stagflation = stagnating/slow economic growth concurrent with high inflation.
[48] L. Spierdijk and Z. Umar, (2013).

window method to estimate the correlation. Nevertheless, the correlation is predominantly positive and thus could potentially be used as an effective partial hedge.

Gold has withstood the test of time and to this day remains unique in its ability to prevent the erosion of real value due to inflationary pressures. Despite the fact that gold is not immune to business cycles. The very long-term inflation hedging properties are indisputable, hence earning gold the nickname 'Holy Grail' of value[49]. Conversely, gold tends to be utilized as a speculative vehicle during times of economic turmoil and hence renders it unsuitable as a hedge against purchasing power erosion, particularly if one has to contend with a finite time horizon.

Pension funds with an integrated approach vis-à-vis inflation hedging can press their advantage by exploiting the valuation difference between ILDs and inflation swaps to construct an optimal portfolio. By foregoing the separation of the swap-overlay and the fixed income securities portfolios, pension funds can more readily identify and profit from (momentary) market inefficiencies. As the prospect of stable inflation oscillating around the 2pp mark is growing dimmer, at least for the next decade or so, the need for inflation-linked bond issues and high levels of inflation hedging may fade also. Nevertheless, the growing level of unhedged inflation risk could prove dire in the event of an unanticipated positive inflation shock. Particularly if inflation rates remain close to zero during 'normal' economic scenarios, as it enhances deflationary momentum in the case of an unexpected negative inflation shock or discombobulated central banking policies that ultimately go pear-shaped. One proposal to optimize the portfolio from a risk perspective involves the replacement of traditional nominal-interest bonds with linkers (id est inflation-linked bonds). Linkers and nominal bonds have similar returns, yet the former generally entails lower volatility. According to Illeditsch (2009), the combination of stocks, real assets and inflation-indexed bonds optimize a (pension) funds asset allocation. Particularly as linkers tend to outperform when growth rates decline and inflation is rising, whilst stocks outperform when growth rates are climbing and inflation is declining.

5. Inflation Measures

This section shall explicate the two main flavours of inflation that are viable choices for the purpose of this thesis. The two types of inflation considered are price inflation and wage inflation respectively. This section also contains an explication of the pivotal role inflation plays during

[49] N. Dempster and J.C. Artigas, (2010).

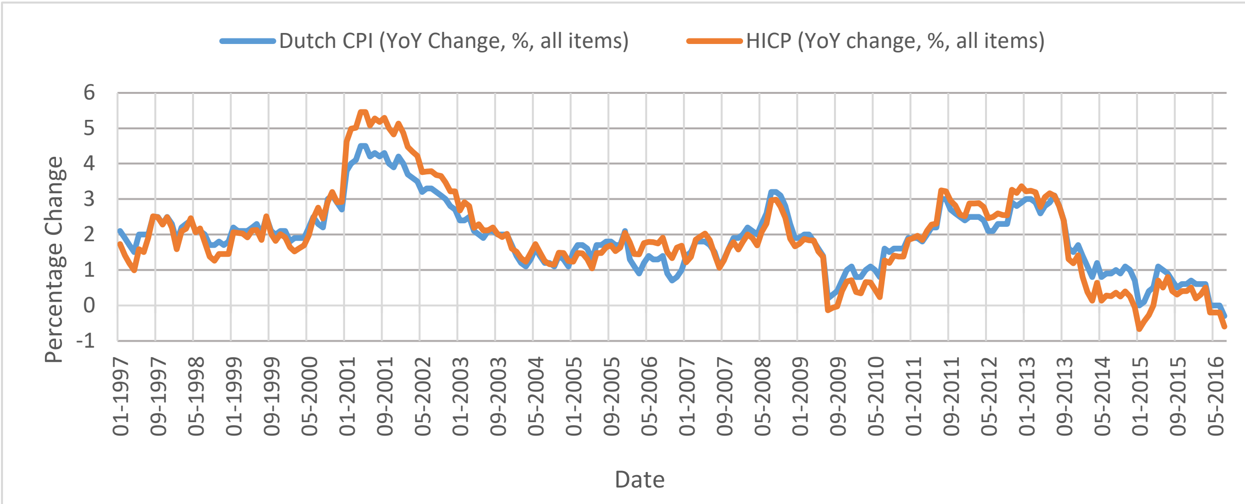
the formulation of pension indexation policies. Inflation risk (and deflation risk) remain pivotal factors for (DB) pension funds, particularly as it concerns an unrewarded risk factor.

5.1 Price Inflation

There exists a plethora of price indices in the Netherlands, though the two price indices most commonly cited are the Dutch Consumer Price Index as published by the Central Bureau of Statistics (CBS) and the Harmonised Index of Consumer Prices (HICP) as published by the European Central Bank (ECB). The former concerns the measure of the weighted average of prices of a predetermined basket of consumer goods and services in the Netherlands. Private household price changes as indicated by the CPI are utilized to assess the cost of living, thus private consumption includes consumption-related taxes and owner-occupied housing[50]. The HICP is a Laspeyre index[51] that is produced by each EU member state, the aggregate HICP is the weighted average of HICPS of the Eurozone member states. The HICP is the core measure of inflation in the Economic and Monetary Union (EMU) according to the ECB. Note that whilst the ECB utilizes HICP as an to ‘anchor’ to guide the monetary policy formulation process, the Dutch government and many Dutch institutions reference the Dutch CPI for the purpose of indexation of contracts or tariff adjustments. HICP weighting differs per country, though regulatory measures and macroeconomic-, fiscal- and political convergence across the Eurozone ought to have mitigated the level of divergent weights used. The aforementioned expected convergence has been tentatively supported by Henning and Mariagnese (2005). Nevertheless, the European Classification of Individual Consumption by Purpose (ECOICOP) will be introduced as part of the revised HICP and national CPI measures of EU member states over the course of 2016 and 2017 to aid in convergence between the HICP and national CPIs[52]. ECOICOP shall also provide greater detail, facilitate greater international comparability and enhances production efficiency. Nevertheless, some differences remain as the composition of the underlying basket of goods the respective indices reference are not identical.

[50] Form of imputed rent.
[51] The Laspeyre index divides the current expense on the current period’s basket of goods by the cost of the same basket in the base period at base period prices.
[52] J. Walschots, (2016).

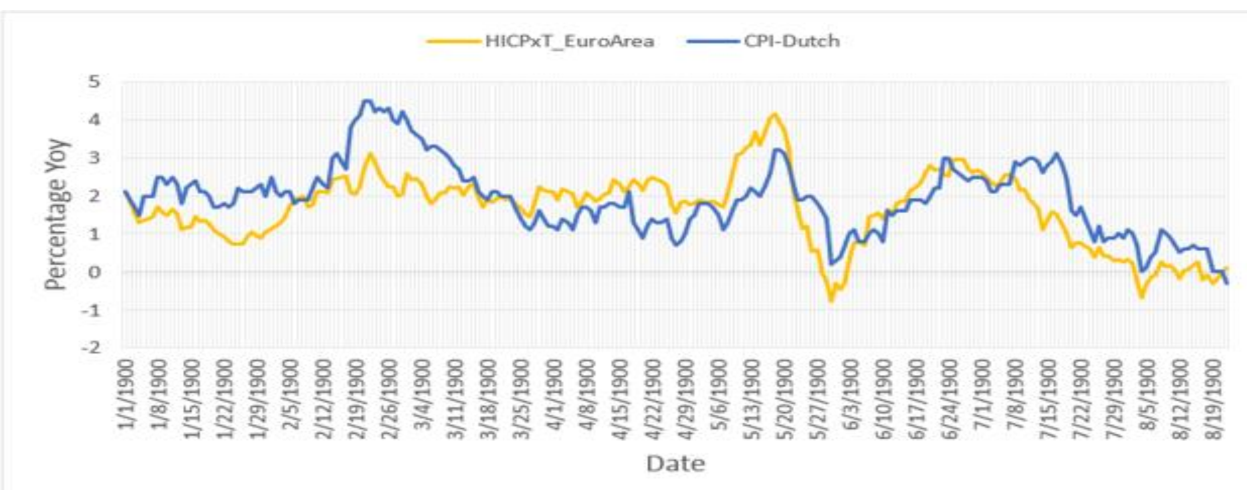
Graph A5.1 **Y-o-Y Change Dutch CPI and HICP-Dutch**



One of the most notable differences is that whilst the Dutch CPI excludes certain health care costs, the HICP explicitly excludes imputed rent (owner occupied housing) and consumption-related taxes. Concisely, the year-on-year monthly changes in national CPI and Dutch HICP indicate a high degree of convergence between January 1997 and May 2016 as can be seen in graph A5.1. The 'HICP excluding tobacco' (HICPxT) measure has no economic rationale, despite this it has become a well-established market convention. The HICPxT index from

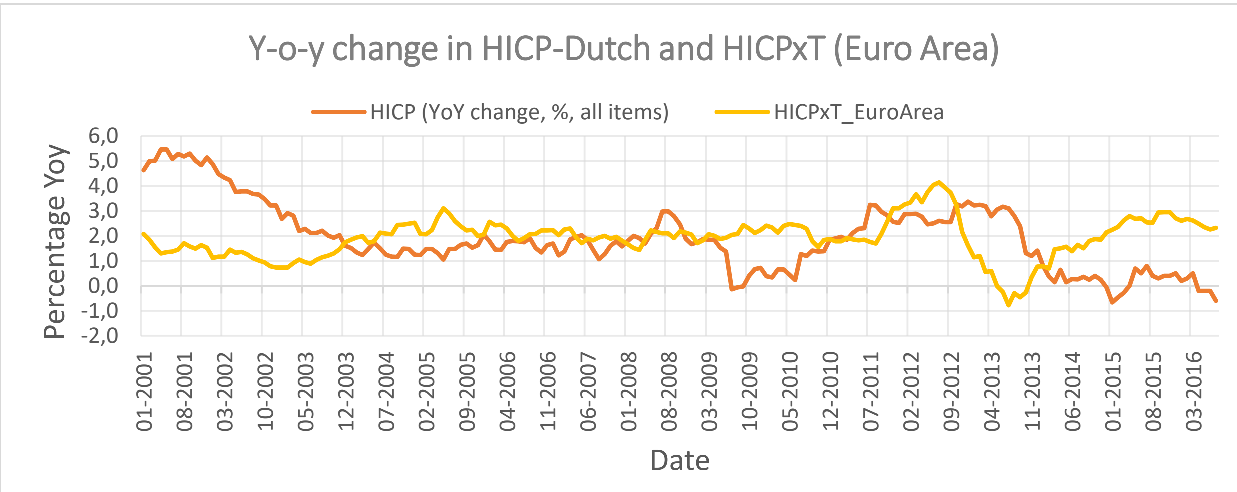
Eurostat is still utilized as the underlying for inflation-linked derivatives in the European market,

Graph A5.2 **Y-o-Y Change Dutch CPI and HICPxT (Euro Area)**



except for France whom references the FRCPI index from INSEE[53] and the UK market that focuses on the Retail Price Index from National Statistics.[54] Concisely, graph A5.2 indicates that the y-o-y changes in CPI-Dutch and HICPxT (Euro Area) exhibit a strong tendency to oscillate periodically (quasi-sinusoid nature). Graph A5.3 reflects different propagations of the HICP-Dutch and the HICPxT. Both graphs indicate that the HICPxT is more prone to large swings and that its evolution runs contrary to that of the HICP-Dutch and the CPI-Dutch. The ECBs macroeconomic policies, e.g. price stability, are based on the HICP and the difference between the national CPI and HICP-Dutch is negligible, thus our preference goes out to the Dutch CPI measure.

Graph A5.3 **Y-o-Y Change HICP-Dutch and HICPxt (Euro Area)**



As many pension funds in the Netherlands have increasingly opted to utilize wage inflation for indexation purposes, the next section shall illuminate the measures used to proxy wage inflation.

5.2 Wage Inflation

In the Netherlands the system of wage formation is relatively stable. Collective bargaining arrangements exist between employers/employers' federation and trade unions, e.g. collectively referred to as the Social Partners, that are either reached at industry- or at company level. These Collective Labour Agreements (CAOs) stipulate wages and working conditions that are legally binding on the membership of the employers' organisations and trade unions that signed the CAO[55]. Employers whom have signed a CAO must offer the same terms to non-unionized

[53] FRCPI refers to the French Consumer Price Index (ex. Tobacco) and INSEE stands for Institut National de la statistique et des études économiques (National Institute of statistics and economic studies).
[54] J. Kerkhof, (2005).
[55] CAO agreements 2013, (2014).

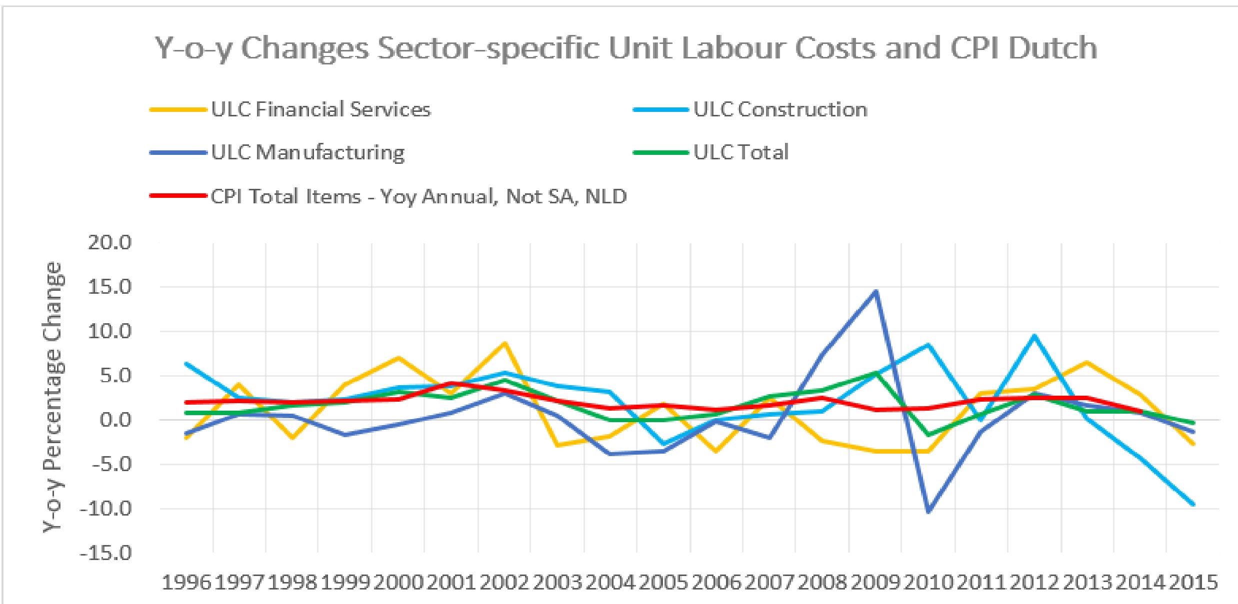
members. Nevertheless, unauthorised downwards wage flexibility (e.g. wage freezes or wage increases below inflation) can be condoned under specific circumstances as most CAOs contain dispensation clauses, though they are rarely if ever utilized. In 2013 approximately 84pp of the labour force in the Netherlands was covered by such an agreement, i.e. 5.895.000 out of 7.018.000 employees.[56] The Social Partners and independent experts negotiate at the Social and Economic Council (SER[57]), a statutory/consultative body that provides the parliament with advice on economic and social issues. Derogation from the CAO norms is contingent on approval by the Ministry of Social Affairs and Employment.

Young and future participants can earn an inflation risk premium if they compensate elderly participants for unexpected inflation increases. The younger generations are oft better able to bear inflation risk as their human capital provides a partial hedge against inflation risk. Conversely, the main problem with tying conditional indexation policies to wage inflation is that there exists no centralized approach to incorporating or measuring wage inflation. Furthermore, the wage inflation rate displays vast dissimilarity between different sectors and industries in the Netherlands. Nevertheless, intergenerational risk sharing, one of the hallmarks of the DB pension system, ensures that younger generations share in the (financial) risks that would otherwise be concentrated amongst the elderly. When conditional indexation is tied to wages there exists reciprocity, i.e. retirees share in the employees' productivity risk[58]. Wage inflation proxies that have gained traction are the Unit Labour Cost (ULC) measures and the Labour Cost Indices (LCI). The latter is a Laspeyres index of labour costs per hour worked, chain-linked annually and based on the statistical classification of economic activities in the European Community (NACE[59]). If wages rise whilst productivity rises faster, then ULC will fall. Thus the ULC method indicates the combined effect of productivity changes and wage changes on the production cost. It measures the average cost of labour per unit of real output and can be displayed at a specific sector level and as an aggregate. The LCI measure too has both a sector specific and an aggregate form. The LCI is a Euro indicator that quantifies the average hourly cost pressure arising from the labour production factor. LCI is still vulnerable to compositional effects from occupational- and human capital shifts.

[56] Central Bureau of Statistics, (2014).
[57] Sociaal-Economische Raad.
[58] H. Bohn, (2006); R.M.W.J. Beetsma and A.L. Bovenberg, (2009).
[59] NACE refers to the French term *Nomenclature statistique des Activités économiques dans la Communauté Européenne.*

Preliminary results regarding wage inflation measures in the Netherlands were as follows. As one can observe in graph A5.4 the ULC in the manufacturing and construction sector exhibits a high level of amplitude, thus rendering it unsuitable as a yardstick for conditional indexation. The ULC total is comparatively similar to the Dutch CPI, both in levels and in terms of its degree of change. The results of the alternative sector specific labour cost measures, LCI, are displayed in graph AA5.5 [Appendix]. The LCI measures are prone to larger increases and display less negative y-o-y changes vis-à-vis their counterparts (ULC).

Graph A5.4 **Y-o-Y Changes Sector-Specific ULC and CPI Dutch**



In conclusion, the LCI-total and ULC-total seem to be the only viable option as a wage inflation proxy for indexation purposes.

To verify the evolution of labour cost vis-à-vis price inflation these measures were plotted against each other in graph AA5.6. The ULC provides the closest fit with respect to the respective price inflation indices.

5.3 Pension Fund Indexation and Inflation

Compendiously, pension fund liabilities in the Netherlands are indexed to either wage inflation or price inflation. Accumulated pension rights may be liable to indexation to compensate for either the past rate of price inflation, hence protecting the purchasing power of pension benefits, or wage inflation, where pension benefits track the general increase in welfare. Indexation is conditional on the funding ratio and overall health of the pension fund in question. Price inflation indexation occurs at a general or national level, whereas wage inflation indexation tends to be sector specific. Nevertheless, wage inflation tends to exhibit 'sluggishness' vis-à-vis price inflation developments. Furthermore, there is no reliable wage inflation index that could function as the underlying for indexation purposes. The evolution of wage inflation as proxied by sector specific ULC and LCI measures is too erratic to be utilized for pension benefit indexation. This is particularly problematic as a predominance of Dutch second pillar pension funds offer sector specific pension schemes.

Also, current collective contracts may share non-traded risk factors such as inflation- and longevity risk more effectively than any individual contracts. If the current collective contracts utilize the nominal interest rate for discounting purposes (rather than the real interest rate), then temporary inflation shocks will be partially absorbed. Nevertheless, pension benefits remain vulnerable towards a permanent inflation shock. One of the solutions, e.g. inflation-linked debt (ILD), is not a feasible panacea for detrimental inflationary pressures due to lack of fit and lack of market depth. Similarly, 10y HICP swaps have shown limited correlation with contemporaneous inflation patterns in the Euro area, whilst the size of the market for inflation-linked bonds in the Euro area has grown to approximately $650bn by June 2014 representing more than 20pp of the total outstanding global ILD market. Regrettably, the total accumulated pension assets in the Netherlands alone amount to roughly $1.457 trillion, which easily outstrips the total supply of Eurozone ILDs. Nevertheless, the unique features of the Eurozone ILD market include its low correlation with other risk assets, the broadening of funding options and further risk diversification opportunities due to investor diversification. The redemption value of a linker at maturity may be less than its par value after a sustained period of persistent deflation. A deflation floor guarantee is an integrated capital protection measure that ensures that the redemption value at maturity will never be below par. Conversely, a drawback of the deflation floor is that the premium charged for it rises fast with the likelihood of persistent deflation.

6. Data

In this section I shall elucidate the data sources that will be utilized in the writing of this thesis. Furthermore, the main variables' construction shall be briefly highlighted alongside a number of independent variables and control-/proxy variables. Sub-section 6.1 contains a clarification of the data sources and variables used, including an elucidation of the risk proxy variables constructed for the purpose of this thesis. Programs used include Eviews, Excel and JMulti.

6.1 Data Sources

The research in this thesis is concerned with empirical analysis. Data utilized will be procured via ABP/APG, Datastream (Thomson Reuters), Bloomberg, Organisation for Economic Co-operation and Development (OECD) database, CRSP, Federal Reserve Economic Data (FRED), World Bank DataBank, De Nederlandsche Bank, Central Bureau of Statistics (CBS), Deutsche Bundesbank, CRSP and Eurostat. The exact data source of each variable is listed alongside its construction method (where applicable) in Section II of the Appendix. The time period under consideration concerns the 1st of January 1990 till the 1st of September 2016 for the majority of this thesis.

The country under consideration will be the Netherlands, which has one of the best pension systems in the world in terms of adequacy, sustainability and (incremental) innovation. Nevertheless, the call for alterations to the system to maintain its prime position eventually translated into a new version of the regulatory framework entitled nFTK (Financial Assessment Framework), which has potentially altered the inflation risk attitude of DB pension funds, increased regulatory solvency/capital buffers and altered discount rates based on the amended UFR method. An overview of the databases/sources utilized for the procurement of data can be found in Section II of the Appendix. A quick explanation of the risk proxies will be interposed prior to the descriptive statistics.

The first constructed risk proxy is the credit spread, i.e. Moody's seasoned Baa 10 year corporate bond yield relative to the 10 year maturity government bond yield. It serves as a measure of the prevailing credit default risk. The narrower the credit spread, the lower is the perceived credit default risk. Naturally, credit spreads tend to be larger for debt issued by EM, for lower quality corporate issues and for bonds with longer maturities.

The market spread risk factor proxy is constructed by subtracting the seasoned BBB corporate bond yield from the seasoned AAA bond yield. Prior to the end of 2013, the market convention was to proxy market risk as the spread between the "risk-free" US t-bill and BBB-rated corporate bonds. Conversely, Egan-Jones has consistently downgraded US t-bill ratings since July 2011 amidst ongoing concerns regarding the unsustainable rise in the debt-to-GDP ratio and the US government's lacklustre attempt to resolve the situation and alleviate economic strain. Fitch has also expressed dire concerns regarding the continued strife over the de facto federal debt ceiling, whilst Dagong Global Credit Ratings had downgraded US treasury bonds from A to A- by October 2013. The alternative market risk proxy utilized in this thesis is an acceptable route according to Codogno et al. (2003) and Bernoth and Erdogan (2010).

The ΔVIX serves as a "catch-all" aggregate risk proxy and is oft colloquialistically referred to as the "Investor Fear Gauge". It is a key measure of implied near-term volatility derives from a wide range of options whose underlying is the S&P500 stock index. Concisely, the VIX is tantamount to the market's prediction of short-term price volatility for as option premiums increase, then ceteris paribus, the market adopts an expectation of increased future volatility.

The TED spread, the 3M t-bill minus the 3M Euribor, shall serve as a liquidity proxy. Liquidity directly refers to the depth of a market, whilst it implicitly concerns the ability to maintain or unwind positions without contracting severe transaction costs or cause excessive market impact. Euribor refers to the European interbank offered rate. As the TED spread widens one can anticipate lower prevailing liquidity.

Term spread is modulated to gauge the slope for the bond yield curve as it indicates the differential between long-term interest rates and short-term interest rates on debt securities, i.e. coupon rates differential for two bonds of equivalent quality but with different maturities. As the term spread rises the yield curve steepens and, provided that the term spread is positive, a normal spread prevails. If the term spread turns negative we are faced with an inverted yield curve. Monetary policy expansion causes both short- and long-term interest rates to fall, though the former by more than their long-term counterparts. Note that he term spread morphs into a more accurate predictor if monetary authorities do not solely focus on controlling inflation.

Finally, dividend yield is added as an economic variable that pertains to the equity markets. Variance decomposition has indicated that the majority of positive covariance between the dividend yield and expected inflation is due to in-tandem movement of expected inflation and the equity risk premium. As dividend yields increase, then average stock prices are falling. In the search for yield, particularly against the backdrop of miserly bond yields, dividend yields can seem like an attractive alternative. Nevertheless, the speed and magnitude of dividend yield changes are pivotal in understanding whether rising dividend yields provide an economic opportunity or are indicative of gloomy times ahead.

As an addendum, break-even inflation rate assesses the prevailing inflation expectations of market participants. Break-even inflation is equivalent to the difference between the nominal yield on a vanilla bond and the real yield on an inflation-indexed bond of the same maturity and credit rating. As long as break-even inflation rates for longer maturities remain above that of shorter maturities, the market anticipates higher long-term inflation than in the short- to intermediate term.

6.2 Descriptive Statistics

This section shall briefly elucidate the preliminary findings of the standard application of statistics, e.g. mean, standard deviation, distribution and cross-correlations. For a detailed overview of the descriptive statistics of each group variable, e.g. rates, asset class returns and risk proxies, see Section III of the Appendix. The arithmetic and geometric version of the means and standard deviations have been calculated. The harmonic mean (HM), which is often used in case of extreme outliers as it concerns a Schur-concave function, was omitted as it did not add significant value to the discussion. Suffice it to say that the nature of equivalence between the three measures can be explicated in special cases as follows: $AM \times HM = GM^2$. The geometric mean (GM) is often utilized when data is inter-related, e.g. in case of returns or interest rates. For GM the additive structure is based on the logarithms of the original data points. The mathematical structures of the three means are displayed to the right. An overview of the geometric mean and standard deviation can be found in the Appendix, Section III – Part 6.

Figure A6.1 **Arithmetic-Geometric-Harmonic Relationship**

Arithmetic Mean of n numbers	$\frac{\sum_{i=1}^{n} x_i}{n}$
Geometric Mean of n numbers	$\sqrt[n]{x_1 x_2 \cdots x_n}$
Harmonic Mean of n numbers	$\frac{n}{\sum_{i=1}^{n} \frac{1}{x_i}}$

6.2.1 Mean Returns, Standard Deviations and Distributional Inference

This part has been split up into three parts, i.e. inflation rates, asset classes and risk proxies. Cross-correlations and ex-post Sharpe ratios shall be elucidated in Section 6.2.2 and Section 6.2.4.

Associated tables and graphs can be found in Section III and Section V: Part 10 of the Appendix, though references will be made explicitly where appropriate.

Inflation Rates

As can be seen in the Inflation Rate Propagation graph of Section III – Part 1 in the Appendix, the average of current and short-term expected inflation are neigh on identical (note: logical as short-term expected inflation is derived from the 3 month moving average of actual inflation) and just over 2pp for the entire period. However, both have large standard deviations of 7.67pp and 7.37pp respectively. Their maxima are close to 5pp, whilst the minima just dip below the zero mark at -0.2pp. Conversely, short term unexpected inflation is negligible at close to zero. These results are also reflected in Table A6.2 below containing the most important descriptive statistics regarding inflation rates.

Table A6.2 **Main Descriptive Statistics Inflation Rates**

Descriptive:	NL CPI	ST EXP INFL	LT EXP INFL	LT UNEXP INFL	ST UNEXP INFL
Monthly Arithmetic Mean	0,180%	0,181%	0,270%	-0,128%	-0,001%
Annual Arithmetic Mean	2,161%	2,168%	3,245%	-1,539%	-0,008%
Monthly Geometric Mean	0,178%	0,179%	0,265%	-0,105%	-0,001%
Annual Geometric Mean	2,135%	2,143%	3,180%	-1,265%	-0,008%
Periods	320	320	320	319	320
Monthly Standard Deviation					
Arithmetic	1,010%	0,981%	1,244%	1,200%	0,349%
Geometric	2,214%	2,127%	3,593%	1,798%	0,350%
Annual Standard Deviation					
Arithmetic	3,500%	3,399%	4,309%	4,156%	1,209%
Geometric	7,670%	7,367%	12,447%	6,230%	1,212%
Median	2,100%	2,133%	3,395%	-1,756%	-0,033%
Maximum	4,900%	4,800%	4,798%	1,302%	1,267%
Minimum	-0,200%	-0,067%	-0,973%	-4,096%	-1,400%
Skewness	0,504	0,570	-1,578	0,357	0,095
Kurtosis	0,452	0,424	2,880	-0,730	2,082
Jarque-Bera	15,86	19,27	23,65	11,35	55,45
Probability	0.000361	0.000066	0.000000	0.003439	0.000000

On an annual basis, unexpected short term inflation may grow to 1.2pp or fall to -1.4pp accordingly. These results indicate that short term expected inflations forecasts already incorporate sufficient information to mitigate the emergence of unanticipated short-term inflation fluctuations due to their 3 month MA character. Long-term unexpected inflation has a geometric mean of -1.27pp per annum indicating a tendency to overestimate the level of future inflation five years a priori. The geometric standard deviation of LT unexpected inflation is equal to -1.265pp.

Nevertheless, long term expected inflation took a nosedive in March 2015 as the ECB commenced its (then) €66.3 billion purchasing programme of euro-denominated public sector securities in the secondary market whilst maintaining their ABSPP and CBPP3 agenda. On average, LT expected inflation lies close to 3pp, though with a geometric standard deviation of 12.45pp per annum.

Inflation rates, interest rates and the assortment of sovereign bond yields all exhibit a non-normal distribution. Only the 10-year government bond yield seems to adhere to the normal distribution as indicated by the Jarque-Bera normality test. Note that the Chi-distribution used for the JB test has 2 degrees of freedom, i.e. the third and fourth moments known as skewness and kurtosis.

Asset Classes

An overview of the descriptive statistics pertaining to the Asset Classes can be found in the Appendix, Section III – Part 3. Section III – Part 5 concerns table that indicate the arithmetic and geometric means per annum of various asset classes in both nominal and real terms. Descriptive statistics are based on nominal returns, unless mentioned otherwise. The main results are highlighted in Table A6.3 below.

For equities, the arithmetic means of the Emerging Market (EM) and the S&P500 were equivalent to 7.8pp p.a. between 1990 and 2016. Nevertheless, the geometric means indicate a marked difference between the two markets of approximately 1.1pp with EM lagging behind. The global equities market proved to be the underdog for the period studied with an annual geometric mean of 3.9pp on average, though it had the lowest standard deviation of the equity classes. The S&P500 had the tightest range of annual returns. EM equity had the largest range [-26pp to +26pp] per annum and also had the largest standard deviation. All equity classes showed negative skew (implying a long tail the left), and positive excess kurtosis ($k > 3$) indicating significant "peakedness" ergo leptokurtic. Thus, equities do not adhere to a normal distribution.

Table A6.3 **Main Descriptive Statistics Equity and Fixed Income Securities**

	S&P500	STOXX EUROPE 600	MSCI EM	MSCI WORLD	EMU 20-30Y GOV	ML EMU Corporate	Barc EM AGG	BOFA ML ILB 10Y GOV EURO
Descriptive:	Developed	Developed	Emerging	Global	Sovereign	Corporate	Emerging	Inflation-Linked
Monthly Arithmetic Mean	0.653%	0.468%	0.653%	0.379%	0.529%	0.409%	0.885%	0.414%
Annual Arithmetic Mean	7.840%	5.620%	7.840%	4.551%	6.349%	4.911%	10.621%	4.972%
Monthly Geometric Mean	0.564%	0.370%	0.471%	0.327%	0.513%	0.410%	0.510%	0.405%
Annual Geometric Mean	6.769%	4.442%	5.650%	3.925%	6.161%	4.920%	6.120%	4.857%
Periods	312	320	320	320	168	248	283	215
Monthly Standard Deviation:								
Arithmetic	4.205%	4.779%	6.616%	3.541%	1.499%	0.969%	1.081%	1.384%
Geometric	4.334%	4.979%	6.942%	3.669%	5.979%	0.971%	1.140%	1.394%
Annual Standard Deviation:								
Arithmetic	14.565%	16.553%	22.917%	12.267%	5.192%	3.358%	3.745%	4.795%
Geometric	15.013%	17.247%	24.046%	12.711%	20.713%	3.365%	3.947%	4.827%
Median	1.049%	0.969%	1.275%	0.762%	6.025%	0.479%	0.671%	0.437%
Maximum	11.159%	13.263%	26.637%	11.478%	9.210%	3.114%	4.048%	4.147%
Minimum	-16.943%	-21.682%	-26.524%	-20.328%	3.870%	-4.356%	-2.666%	-5.308%
Skewness	-0.587	-0.715	-0.378	-0.984	0.378	-0.711	-0.225	-0.523
Kurtosis	1.197	1.525	1.497	4.275	-1.063	2.111	0.247	1.498
Jarque-Bera	35.224	56.268	35.779	285.219	11.903	64.521	2452.216	28.123
Probability	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000

For the fixed income category I differentiated between sovereign, corporate, EM and inflation-linked bonds, though some overlap is inevitable. In terms of sovereign bonds, the longest EMU sovereign bonds (20-30 years) had the highest geometric mean return and the largest geometric standard deviation, i.e. 20pp per annum. Geometric standard deviations indicate that sovereign bonds are not as risk-free as they appear when one only looks at the arithmetic standard deviations, i.e. between 5pp and 9pp on an annual basis, which falls well below that of the equity markets. Conversely, sovereign bonds rarely yield a negative return. In fact, between 1990 and 2016 only the EMU 10Y government bonds experienced a sub-zero monthly minimum return. European Corporate High Yield markets have strong alternating performance cycles. Nevertheless, their geometric standard deviation was not significantly higher than that of some other EU (corporate) bonds. Nevertheless, growing exposure to EM-based issues in the HY markets (historically below 5%, though liable to exceed 14% by 2017) and largely sentiment-driven market corrections can give rise to geometric standard deviations between 3pp and 13pp per annum. Though in light of unremitting ECB market intervention that will continue to depress yields into the near future, the HY sector may offer superior returns provided that HY firm fundamentals show no sign of deterioration.

For EM fixed income securities, both the aggregate and investment grade had comparatively attractive geometric returns between 6.1pp and 8.5pp annually. Their standard deviations however were also comparatively higher than that of European bond markets, i.e. between 3.9pp (aggregate) and 12.2pp (investment grade) per annum. Meanwhile, the aggregate corporate European bond market attained an annual return just short of 5pp. Nevertheless, their annual standard deviations amounted to approximately 3.5pp.

Inflation-linked bonds had a geometric annual return fluctuating around the 4.7pp mark with a geometric annual standard deviation between 4.8pp and 5.6pp on average in European and US markets.

It must be noted that ILBs made their entrance into the market relatively recent, i.e. end of the 90s, a point at which inflation was comparatively lower than pre-1998 (difference of 0.68pp on average). European ILBs (either 10 maturity or composite) have achieved slightly lower returns paired with lower standard deviations than their American counterparts, the US 10Y Treasury Inflation-Protected Securities (TIPS). The downside is that EU ILBs tend to exhibit a larger absolute minimum vis-à-vis EU corporate bonds. In terms of their distribution, the fixed income securities markets all exhibit negative skew for corporate, emerging and inflation-linked bonds. Virtually all exhibit positive excess kurtosis which implies a leptokurtic distribution, i.e. fat tails and peakedness, except for US 10Y TIPS which exhibits negative kurtosis. Sovereign bonds exhibit a platykurtic distribution due to negative excess kurtosis, the only caveat is that they are not significant. Similarly, their positive skew is marginal at best. Nevertheless, the Jarque-Bera test indicates that all bond sector returns have a non-normal distribution, except for the EM Investment Grade and Dutch 10y Sovereign bond sectors. Finally, European ILBs display a greater propensity for attaining sub-zero returns vis-à-vis their US counterparts as indicated by their range.

Finally, the Alternatives Asset Class contains Hedge Funds (HF), Private Equity (PE), Real Estate (RE) and Commodities (COM). Main results are displayed in Table A6.4 below. HF Barclays Index attained the highest geometric return, i.e. 13pp, though the Credit Suisse HF Index indicated a lower geometric annual mean return of 7.6pp. The geometric annual standard deviations (between 5.5pp and 7.5pp) are above that of EU corporate bonds sector, but lower compared to the EU High Yield bonds sector. Geometric mean returns for PE are markedly lower than one would expect based on arithmetic means. The top 20 PE firms in the Eurozone (STOXX PE 20) attained geometric annual returns of nearly 7pp with a relatively lower (vis-à-vis COM and

RE) geometric standard deviations of 12.8pp. In the PE sector it is imperative to invest in the upper echelon of PE-specialized firms in order to attain excess returns particularly in light of the absolute range of annual returns, i.e. -26.6pp versus 36.5pp. Similarly, the PE Buyout sector achieved higher geometric returns of 10.6pp, though with a standard deviation of 29.4pp per annum. The absolute range of returns fluctuated between 44.3pp and -33.6pp. Ignoring the importance of diversification that the Alternatives provide for the overall pension fund portfolio and the potential downside loss risk, the corporate social responsibility angle might take precedence.

Table A6.4 **Main Descriptive Statistics Alternative Assets**

	CS HF	STOXX EU PE	FTSE NAREIT REAL ESTATE Composite	Gold Spot	GSCI Commodity
Descriptive:	Hedge Funds	Private Equity	Real Estate	Commodities	Commodities
Monthly Arithmetic Mean	0.648%	0.863%	0.980%	0.468%	0.281%
Annual Arithmetic Mean	7.772%	10.351%	11.764%	5.611%	3.368%
Monthly Geometric Mean	0.634%	0.582%	1.017%	0.063%	0.408%
Annual Geometric Mean	7.610%	6.985%	12.207%	0.750%	4.899%
Periods	272	239	320	319	304
Monthly Standard Deviation:					
Arithmetic	2.017%	6.527%	5.161%	3.662%	6.211%
Geometric	2.181%	3.679%	5.274%	5.812%	8.183%
Annual Standard Deviation:					
Arithmetic	6.987%	22.610%	17.878%	12.686%	21.515%
Geometric	7.554%	12.745%	18.271%	20.135%	28.347%
Median	0.688%	1.134%	1.346%	0.352%	0.548%
Maximum	8.528%	36.521%	27.975%	15.284%	17.831%
Minimum	-7.549%	-26.641%	-30.226%	-10.916%	-21.818%
Skewness	-0.119	-0.126	-0.849	0.469	-0.357
Kurtosis	3.108	5.683	7.702	1.534	0.745
Jarque-Bera	104.655	306.190	800.823	41.115	12.826
Probability	0.000	0.000	0.000	0.000	0.002

PE Buyout firms in particular have been vilified, their reputation has been tarnished and colloquialistically referred to as “sprinkhanen” (English: locusts). From an Orwellian perspective, PE Buyout firms have ramped up leverage in acquired firms thereby disrupting the internal capital structure resulting in severe reductions in the company’s equity in order to profit in the intermediate term. Nevertheless, the merits of the PE market are undeniable. Furthermore, non-buyout PE firms may have a positive impact on the acquired firms, though one would have to invest in the top decile or top quantile of PE firms in order to secure a relatively consistent excess return. The opacity of the PE market and self-reporting prerogative has led to a skewed view of the overall market, in particular as many PE firms are unlisted.

The RE sector has one of the highest geometric returns, i.e. 8.2pp to 11.2pp per annum, and relatively high standard deviations of 18.2pp and 21.2pp for FTSE NAREIT and MSCI EU RE respectively. The absolute range of attained returns since 1990 is from 28pp and -30.2pp annually.

Finally, as for the COM sector Crude Oil has the highest annual standard deviation (σ = 31.4pp) vis-à-vis that of gold (σ = 20.1pp). All constituents of the COM market sector are marked by standard deviations above the average for all markets, despite their comparatively low annual returns. Composite Commodity Indices vary significantly in terms of returns and standard deviations. Finally, all Alternatives returns display negative skew with the exception of PE Buyout and Gold, though none are significant. Nevertheless, all exhibit a significantly leptokurtic distribution that renders the probability distribution of the Alternatives' returns non-normal.

Risk Proxies

As can be gleaned from the table in Section III – Preliminary Statistics Part 2, the arithmetic mean of the risk spreads does not differ significantly from the geometric mean, except for the VIX. Note that results are also displayed in Table A6.5 below.

The average term spread (yield differential of a 10 year Eurozone government bond relative to the euro area one-month EURIBOR rate) is approximately 1.66pp and proxies the ECBs monetary stance derived from the term structure of interest rates.[60] Market spread and dividend yield seem to be the most stable and fluctuate around the 0.96pp and 2.77pp respectively. The TED spread has a negative mean of -0.857pp and has one of the highest standard deviations, i.e. 1,838pp, giving rise to a confidence interval of [-1.059pp ; -0.655pp] for $\alpha = 0.05$. This indicates that the 3M Euribor on average exceeds the 3M T-bill implying a higher degree of liquidity risk in the European market.

[60] J.C. Wu and F.D. Xia, (2015).

Table A6.5 **Main Descriptive Statistics Risk Proxies**

Descriptive:	Term Spread	Credit Spread	Market Spread	TED Spread	DIVIDEND YIELD	ΔVIX S&P500
Arithmetic Mean	1.663%	1.830%	0.962%	-0.857%	2.766%	1.583%
Geometric Mean	1.659%	1.821%	0.961%	-0.874%	2.764%	-0.199%
Periods	320	313	313	320	206	319
Monthly Standard Deviation:						
Arithmetic	0.972%	1.409%	0.407%	1.838%	0.595%	20.230%
Geometric	0.961%	1.400%	0.402%	1.889%	0.580%	20.417%
Median	1.603%	2.233%	0.880%	-0.663%	2.770%	-1.193%
Maximum	3.752%	5.014%	3.380%	2.025%	5.270%	134.571%
Minimum	-0.430%	-1.451%	0.550%	-6.690%	1.500%	-38.490%
Skewness	0.076	-0.646	3.099	-0.953	0.457	1.651
Kurtosis	2.239	3.239	4.239	5.239	6.239	7.239
Jarque-Bera	8.032	25.119	26.350	56.211	52.337	72.210
Probability	0.018	0.000	0.000	0.000	0.000	0.000
Observations	320	313	313	320	206	319

The ▲VIX arithmetic mean is 1.58pp, whilst its geometric counterpart is equivalent to -0.2pp. A logical finding as the VIX is an avatar of aggregate risk and is colloquialistically referred to as the 'Investor Fear Gauge', thus it stands to reason that volatility is excessive and must be accounted for as financial markets tend to swing between bull- and bear-like prevailing market conditions. The credit spread has the penultimate highest standard deviation (not counting the VIX for obvious reasons) at 1.4pp and with a CI between 1.67pp and 1,99pp.

The Jarque-Bera test rejects the null hypothesis of a normal distribution for all risk proxies. Note that the confidence intervals (Section III – Rates, Appendix) were calculated by assuming a Student t-distribution to ensure results were more robust in lieu of a normal distribution.

6.2.2 Cross-Correlations

The cross-correlation table for all chosen asset classes and inflation rates are displayed in Section III – Part 4 – Compendium Cross Correlation of the Appendix. Our focus will be on the highest levels of inter-correlation (above 0.70) and in particular the correlation betwixt the inflation variables and the returns of the asset classes.

For STEI, the highest positive correlation is with the LTUI, possibly due to the inherent failure of economic agents to incorporate short-term expectations into long-term components resulting in higher levels of LTUI. Mayhap myopia or the mistaken believe that STEI changes constitute a temporary effect that will decay over time can elucidate this phenomenon. Further indications shall be given in the Results section.

STUI correlates nigh on one-for-one (0.989) with COM, thus rendering it a potential hedge for STUI only due to the COMs capricious nature. Similarly, the LTEI and has a strong negative correlation with the term spread. Hence another indication the term spread might be a good indicator of the ECBs stance as they directly endeavour to intervene in the (financial) markets to alter future economic growth and utilize the interest rate mechanism to influence the level of prevailing inflation in the future.

Compendiously, no conclusions can be drawn from the cross-correlation table alone due to inherent non-stationarity of variables and the fact that correlation only measures linear relationships. Nevertheless, the cross-correlation table was included for illustrative purposes.

6.2.3 Structural Breaks

In order to get an initial impression of inflation rate fluctuations and/or time-variance, multiple structural breaks tests were conducted with respect to the inflation rates to check for 'regime switching'. First off, I utilized Ordinary Least Squares method to estimate three univariate equations with a constant for the STEI, LTEI and current inflation (CPI-Dutch) variables. As serial correlations in the errors are a prerequisite for structural break analyses, the coefficient covariance matrix was set to the HAC Newey-West method with prewhitened residuals.[61] The quadratic spectral kernel was selected alongside the Andrews bandwidth prior to conducting the multiple break point tests. When conducting the multiple break point test, I allowed for heterogeneous error distributions across breaks and the significance level was set to $\alpha = 0.01$.

The current inflation rate did not have any significant breaks at either the global level or when computed sequentially. Nevertheless, LTEI did have one significant break in January 2009. STEI had three breaks, i.e. February to March of 2001, February to March of 2003 and April to May of 2014. More extensive results of the multiple breaks tests can be found in Section III – Descriptive Statistics, Part 7, of the Appendix.

[61] Lags selected automatically based on Akaike Information Criterion.

6.2.4 Ex-Post Sharpe Ratios

The Sharpe ratio is a metric designed for comparing risk-adjusted performance. Though there exists no de facto cardinal scale that determines investment worthiness according to the Sharpe Ratio, the following rule of thumb is applicable: the higher the Sharpe ratio, the better the result.

The ex-post version accounts for the average differential return and the associated variability. The historic Sharpe Ratio is equivalent to: $S_h \equiv \frac{\bar{D}}{\sigma_D}$ where $\bar{D} = \frac{1}{T}\sum_1^T(D_t)$ and

$$\sigma_D = \sqrt{\frac{\sum_1^T(D_t - \bar{D})^2}{T-1}}.$$

The 1 year US T-bill rate was taken as the semi-risk free benchmark. The de facto Sharpe Ratios were calculated in both real and nominal terms. Results can be found in Section V, Part 10 of the Appendix. In Table A6.6 and Table A6.7 below however, a selection of primary ex-post Sharpe Ratio results are displayed.

Table A6.6 **Primary Nominal Ex-Post Sharpe Ratio Results**

	Number of Periods	319						
Risk free								
Arithmetic	**Monthly**	0.26%						
	Yearly	3.20%						
Geometric	**Monthly**	0.26%						
	Yearly	3.18%						
Sharpe ratio		S&P500	STOXX EUROPE 600	MSCI EM	MSCI WORLD	ML EMU Corporate	Barc EM AGG	BOFA ML ILB 10Y GOV EURO
Arithmetic	**Monthly**	0.093	0.043	0.059	0.033	0.150	0.575	0.109
	Yearly	0.319	0.146	0.203	0.110	0.510	1.982	0.370
Geometric	**Monthly**	0.070	0.022	0.030	0.018	0.153	0.218	0.103
	Yearly	0.239	0.073	0.103	0.059	0.517	0.745	0.348
T-statistics	**Annual arithmetic**	5.629	2.616	3.623	1.972	8.031	33.334	5.421
	Annual geometric	4.223	1.309	1.838	1.049	8.144	12.531	5.096
Downside Standard Deviation	**Annual Arithmetic**	10.55%	12.49%	15.93%	10.08%	2.38%	2.04%	3.38%

***Table A6.6* Primary Nominal Ex-Post Sharpe Ratio Results (continuation)**

Sharpe ratio		CS HF	STOXX EU PE	FTSE NAREIT REAL	Gold Spot	GSCI Commodity
Arithmetic	**Monthly**	0.190	0.092	0.139	0.056	0.003
	Yearly	0.654	0.316	0.479	0.190	0.008
Geometric	**Monthly**	0.171	0.087	0.143	-0.034	0.018
	Yearly	0.586	0.299	0.494	-0.121	0.061
T-statistics	**Annual arithmetic**	10.794	4.890	8.570	3.396	0.137
	Annual geometric	9.672	4.616	8.839	-2.155	1.058
Downside Standard Deviation	**Annual Arithmetic**	5.27%	18.14%	15.10%	7.01%	15.05%

In terms of the nominal Sharpe ratios, t-statistics ($S_h * \sqrt{T}$) indicate that virtually all Sharpe ratios are significant at α = 0.05 either in geometric or arithmetic terms. The only exception concerns the GSCI Commodity Index. The top five of nominal arithmetic Sharpe ratios are found in the HY EU, EM aggregate, HF and LBO PE sectors. However, only the Sharpe's of the fixed income securities markets are above 1 on an annual basis. Real Estate and Commodities were amongst the worst performers as indicated by their respective Sharpe's. Conversely, in geometric terms the best performers still included HF and EM aggregate, but also indicated that EU corporate bond markets ranked amongst the highest in terms of risk-adjusted returns. The worst performing geometric Sharpe's were found in the Commodities sector, though many were not significant at the 5% significance level. If one were to focus only on the significant Sharpe's then the worst performers can be found in the Equities and Real Estate sector.

***Table A6.7* Primary Real Ex-Post Sharpe Ratio Results**

	Number of Periods	319
Risk free		
Arithmetic	**Monthly**	0.263%
	Yearly	3.199%
Geometric	**Monthly**	0.261%
	Yearly	3.180%

Ex-Post Sharpe ratio		S&P500	STOXX EUROPE 600	MSCI EM	MSCI WORLD	ML EMU Corporate	Barc EM AGG	BOFA ML ILB 10Y GOV EURO
Arithmetic	**Monthly**	0.082	0.034	0.121	0.053	0.151	0.087	0.161
	Yearly	0.280	0.115	0.417	0.180	0.513	0.297	0.547
Geometric	**Monthly**	0.070	0.025	0.030	0.018	0.153	0.319	0.103
	Yearly	0.239	0.085	0.103	0.059	0.517	1.092	0.348
T-statistics	**Annual arithmetic**	4.953	2.060	7.463	3.219	8.082	5.002	8.022
	Annual geometric	4.222	1.518	1.838	1.049	8.143	18.378	5.096
Downside Standard Deviation	**Annual Arithmetic**	10.55%	12.49%	15.93%	10.08%	2.38%	2.04%	2.45%

Table A6.7 **Primary Real Ex-Post Sharpe Ratio Results (continuation)**

Sharpe ratio		CS HF	STOXX EU PE	FTSE NAREIT REAL	Gold Spot	GSCI Commodity
Arithmetic	**Monthly**	0.059	0.077	0.112	0.050	0.004
	Yearly	0.203	0.265	0.386	0.169	0.011
Geometric	**Monthly**	0.181	0.057	0.106	0.042	-0.027
	Yearly	0.621	0.194	0.366	0.141	-0.096
T-statistics	**Annual arithmetic**	3.346	4.101	6.908	3.022	0.186
	Annual geometric	10.240	3.004	6.542	2.523	-1.671
Downside Standard Deviation	**Annual Arithmetic**	11.31%	2.04%	3.76%	0.81%	18.14%

In terms of real Sharpe ratios, t-statistics indicate that the majority of Sharpe ratios are significant both in arithmetic and geometric terms. The best performers in terms of real Sharpe ratios are still found in the fixed income securities markets, HF and LBO PE in arithmetic terms. The worst performers belong to the equity and commodities markets. In geometric terms, the best performers belong to the HF and fixed income securities markets. The worst performers according to the geometric annual Sharpe's are found in the commodities, real estate and global equity categories. Conversely, if one only takes significant Sharpe's into consideration, then the worst performers belong to the equities, PE and Gold Spot categories. Concisely, whilst these measures are not absolute indicators, they do emphasize the importance of gauging returns in conjunction with standard deviations, rather than on a standalone basis.

7. Methodology

In this Section I shall elucidate the econometric and statistical models that will be utilized to answer the central hypotheses of this thesis. Furthermore, this section shall also justify the methodological stance taken and the econometric techniques employed. Supplementary information can be found in Section IV of the Appendix.

7.1 Johansen's Multivariate Cointegration Analysis, ADF test and Information Criterion

Standard regression models containing non-stationary variables tend to exhibit spurious relationships, e.g. confounding or lurking variables that lead to misconstruction of causal relationship(s) betwixt two or more variables. Stationarity of residuals can be achieved by finding a linear combination of dependent and independent variables that eradicates the stochastic trend.

The number of k independent cointegrating vectors is referred to as cointegration of order k, indicating a long-run relationship between these variables. The JMC test is designed to gauge the number of independent linear combinations (k) that would yield a stationary relationship, whilst allowing for the complex structures and causal connections that remain the hallmark of any mature securities market. Thus, the long-term equilibrium of the linear combination of endogenous variables contains a reduced rank matrix [$\prod_{RR} = \alpha\beta'$][62] whose rank determines the cointegration rank. As the reduced rank matrix is not uniquely identified, further restrictions are introduced via the imposition of an identity matrix.

Prior to employing the JMC, the Augmented Dicky-Fuller (ADF) test will be employed to ascertain whether variables contain a unit root ~I(1) or ~I(2). The lag order (m) of the autoregressive relation is selected based on evidence form the Information Criteria, e.g. Akaike and Hannan-Quinn. The ADF is run to prevent inclusion of stationary variables that would render the JMC's cointegrated eigenvectors too restrictive. For the augmented DF test, the test equation is as follows:

$$\Delta y_t = \alpha + \gamma Y_{t-1} + \sum_{i=1}^{m} a_i \Delta y_{t-1} + \upsilon_t.$$

As $H_0: \gamma = 0$ $(\rho = 1)$ and $H_a: \gamma < 0$ $(\rho < 1)$; if H_0 is rejected then we conclude that the series is stationary.

The JMC consists of two likelihood ratio test statistics; the trace test statistic and the maximum eigenvalue statistic. Under the trace test the null hypothesis states that there is no cointegration, the alternative hypothesis states that there is at least one cointegration relationship, i.e. H_0: $K = 0$ (no cointegration)

H_a: $K > 0$ (at least one cointegrating relationship)

There are two test statistics that can be utilized to determine the cointegrating rank of underlying variables in the JMC. The trace test statistic assumes an asymptotic distribution that 'traces' a Brownian motion or standard Wiener process matrix, whilst the maximum eigenvalue test is essentially a likelihood ratio test and does not adhere to the usual asymptotic χ^2 distribution. Note

[62] α represents the speed of adjustment/reversion to the long-run equilibrium.

that for high orders of cross-unit cointegration, the unit root null hypothesis is rejected too often[63], rendering correct interpretation of the augmented unit root tests pivotal.

7.2 VAR-Granger Causality/Block Exogeneity Wald Test

Essentially, Granger causality indicates the extent to which past values of variable X_t can help predict the current value of variable Y, whilst incorporating the impact of past values of Y_{t-i} may have on the current level, and vice versa. The GCBEW test was conducted to establish ex ante whether a variable under consideration is exogenous or endogenous ere we conduct the VECM. An explanation of the GCBEW test is illustrated in Section IV – Supplementary Information – Part 2: Granger Causality/Block Exogeneity Wald, in the Appendix.

7.3 Multivariate Vector Error Correction (VEC) Models

The Vector Error Correction Model (VECM) is a multivariate dynamic model that incorporates at least one long-run cointegrating relationship between the regressors and assumes that a deviation from the dependent variable's long-run pathway will affect the model's short run dynamics. A VECM enables one to estimate the speed of adjustment, i.e. convergence towards long-run equilibrium, in the wake of a deviation in one of the underlying variables. The VEC is analogous to a VAR model of non-orthogonal variables with error corrections and operates much like a multivariate VAR(*m*) model. Under the multivariate VAR(*m*) model with *n* endogenous variables, the following equation holds:

$$\boldsymbol{y}_t = \sum_{i=1}^{m} (\boldsymbol{\Phi}_i \boldsymbol{y}_{t-i}) + \boldsymbol{v}_t$$

Let $\boldsymbol{y}_t$ be the n-dimensional vector of endogenous variables, $\boldsymbol{\Phi}_i$ the coefficient matrices for i [1,...,m] and $\boldsymbol{v}_t$ as the error vector that is typified as 'white noise', e.g., time invariant definite covariance matrix as $E(\boldsymbol{v}_t) = 0$ and $E(\boldsymbol{v}_t \boldsymbol{v}'_t) = \sum \boldsymbol{v}$. White noise essentially indicates the presence of serially uncorrelated variables where $\mu=0$ and σ^2=finite. The VECM differs from the multivariate VAR via its incorporation of error correction

[63] Banerjee et al., (2005)

terms, which depend on its cointegration rank (*k*). The multivariate VEC(*m*) for cointegrating rank (*k*) can be written as follows:

$$\Delta \boldsymbol{y}_t = \boldsymbol{\Pi} \boldsymbol{y}_{t-1} + \sum_{i=1}^{m-1} (\boldsymbol{\Phi}_i^* \Delta \boldsymbol{y}_{t-i}) + \boldsymbol{v}_t$$

Here let $\Delta \boldsymbol{y}_t$ be equal to vector of first differences of variables, i.e., $\Delta \boldsymbol{y}_t = \boldsymbol{y}_t - \boldsymbol{y}_{t-1}$. The error-correction matrix $\boldsymbol{\Pi} = \mathbf{AB}' = \mathbf{AB}^{\mathbf{T}}$ is thus equal to the matrix of **A** (loading matrix, e.g., weighting factor) multiplied by the transpose of matrix **B** (LR coefficient matrix).[64] Under the VEC(*m*) model, $\boldsymbol{\Phi}_i^*$ has been transformed into the matrix of cumulative long-run momentum. VECM can only be utilized if the dependent variables are not covariance stationary in levels, whilst their first differences are. The resulting short-run parameters under the VECM can be interpreted as respective short-run elasticities[65].

7.4 VEC Impulse Response Functions

As Granger Causality is insufficient to accurately trace the variable interactions within a dynamic higher order system we resort to the VEC Impulse Response Function (IRF). IRFs can identify the marginal dynamic effects of an exogenous shock of a single variable on the pathway of at least one of the other variables. According to Engle and Granger (1987), IRF will often yield better results compared to more traditional models. Structural knowledge could have been incorporated to utilize a RRR-Model (Reduced Rank Regression). Conversely, interpretation becomes skewed and in the presence of certain ‘near’ unit roots both the VAR and RRR-Model provide misleading inference about long-run impulse responses[66]. In the IRF we first use the one standard deviation shock (σ) in order to overcome measurement issues inherent in a unitary shock. IRFs are equivalent to the $(n \times n)$ matrix of marginal effects of a one-standard deviation shock to one variable (*q*) on itself or on another variable (*r*): $\varphi_t^{rq} = \frac{\partial y_{t+s}^r}{\partial \varepsilon_t^q}$. Thus, as time (*t*) increases by increments of s, then the IRF should converge to zero as long as the function is stationary. Also, singular shocks

[64] H.T. Nguyen, (2011).
[65] A. Masih and R. Masih, (1996).
[66] P.C.B. Phillips, (1998).

ought not to have a permanent effect under normal circumstances and thus will decay to zero as *s* progresses, i.e., $\lim_{s\to\infty}\left(\frac{\partial y^{r}_{t+s}}{\partial \varepsilon^{q}_{t}}\right) = 0$.

Compendiously, the IRF impact is indicated by φ^{rq}_{t}, whilst the marginal effects of the system innovation are contained within the matrix $\Psi_s = \frac{\partial Y^{r}_{t+s}}{\partial \varepsilon'_{t}}$. The variables are first difference stationary (see Section 7.1 on the ADF), the transitory nature of the IRF is typified by the decay to zero over time. Note that for orthogonalized (Cholesky) IRFs the identification assumption, i.e., 'ordering' of variables, ensures that shocks to variables that are 'near-the-bottom' will have no current-period effect on variables that enjoy a higher-order ranking. Concisely, IRFs constitutes an expedient method of determining the momentum of the shock at impact and its dissipation rate whilst allowing for variable interdependencies (e.g., dynamic cointegration). Nevertheless, orthogonalized IRFs require a set of unambiguous criteria for choosing an optimal variable order, which is lacking. In order to negate the role of ordering, i.e. the sequence of elements within vector of variables, Pesaran and Shin (1998) developed the Generalised Impulse Response Functions (GIRF). The cumulative effect of a σ shock on vector $\boldsymbol{X_{tk}}$ is given by:

$$\boldsymbol{\Psi^{G}_{x,j}(k) = \frac{\sum_{j=0}^{k}(\Sigma_u * e_j)}{\sqrt{\sigma_{jj}}}}$$

Here the Σ_u is the variance-covariance matrix, σ_{jj} is one of its diagonal elements and $\boldsymbol{\upsilon_t}$ is the vector of shock variables. IRF error bands can be quantified either by asymptotic bands or Monte Carlo bands.

7.5 Dynamic Ordinary Least Squares

The Dynamic Ordinary Least Squares (DOLS) method has been formulated by Saikkonen (1991) and Stock and Watson (1993) to estimate long-run equilibria coefficients in cointegrated systems of higher orders. The DOLS approach copes well with small-sample bias and simultaneity bias within regressors due to the inclusion of lagged and leading first differences of regressors, in turn resolving potential endogeneity issues. According to Chen, McCoskey and Koa (1999), the DOLS parametric approach is computationally convenient and is preferred over the Fully Modified OLS

(FMOLS)[67] method and the bias-correction technique for t-statistics and OLS estimators[68] in order to estimate the LR cointegrating vectors. Contrary to the Johansen method, which uses the Maximum Likelihood estimation method and constitutes a full information technique, the DOLS is not liable to the propagation of parameter misspecification in underlying equations. According to Saikkonen (1991), the DOLS is equivalent to an asymptotic optimality model that unearths the cointegrating vectors inherent in the data. The DOLS lag-lead model can be specified as follows:

$$y_t = \varphi_0 + \varphi_1 x_t + \sum_{-m}^{n} (d\Delta x_{t+m} + \varepsilon_t)$$

In the above formula the length of the leads are indicated by *n* and the lags are indicated by *m*. The vector(s) φ contain the long-run impact of a change in the x_t variables on y_t. According to Baba et al. (1992) the DOLS render the stochastic error terms independent of all past innovations in stochastic regressors. Concisely, the DOLS method shall be utilized to gauge the difference in inflation beta of unexpected inflation over different time periods. The Principal Component Analysis method is an alternative to the DOLS method and is briefly alluded to in Section IV, Supplementary Information, Part 5.

8. Results

This Section provides a compendium of the results of the econometric/statistical analyses that were conducted. Graphs and tables alluding to the results can be found in Section V of the Appendix. All the same, direct references to the Appendix will be given wherever appropriate. The first section indicates the Group ADF, VAR Lag Order Selection and JMC results. Section 8.2 is concerned with the Granger Causality Block Exogeneity Wald test, whilst 8.3 elucidates the results from the VEC Models. Section 8.4 describes the VEC's associated Impulse Response Functions and their implications with respect to inflation risk. Section 8.5 concerns itself with the results from the Rolling Dynamic Ordinary Least Square estimation method.

8.1 Johansen's Multivariate Cointegration Analysis

Prior to starting the JMC analyses one must first employ a plethora of unit root tests and infer the appropriate number of lags to set up an unrestricted VAR. The results of the group ADF unit root

[67] P. Pedroni, (1997); H.R. Moon and P. Perron, (2002).
[68] Note that results have only been gauged in finite samples.

tests and the VAR lag order selection method are explicated in the following sub-section 8.1.1, whilst sub-section 8.1.2 elucidates the JMC results.

8.1.1 Group ADF Unit Root Tests and VAR Lag Order Selection

Unit root tests are a prerequisite ere various cointegration methods can be utilized. There are two main types of unit root processes that will be considered, e.g. common unit root and individual unit roots. The former occurs when there are persistence parameters that are common across the board. The test statistics for a common unit root are derived from the Levin, Lin and Chu method and the Breitung t-stat test, both of whom assume the presence of a common deterministic trend. Individual unit roots are parameters that propagate themselves freely and do not share a common element. Furthermore, the Modified Akaike Information Criterion was used as it treats the error variance term (sigma) as an estimated coefficient and thus includes it in the calculation of the correct lag order (k) to use during the unit root estimations. For the purpose of cointegration it is imperative that a common unit root exists in the level specification. The null hypothesis states that there is a unit root present. As can be gleaned from the Group ADF tables in the Appendix Section V, a common unit root (non-stationarity) was detected for each asset class in the levels specification, whilst the null hypothesis of a unit root was rejected for each asset class in the first difference specification. Thus we can conclude that the variables are integrated of order one ~I(1) and possess a common deterministic trend or constant. The only exception to the rule was the first difference probability under the Breitung t-stat test for the SEPE variable. Conversely, the Levin, Li and Chu method did reject it and as the latter is leading, thus the SEPE variable can be utilized without reservation.

Next an unrestricted VAR system was devised for all asset classes involved, i.e. 12 in total. Subsequently the VAR Lag Order Selection Criteria method was used to establish the best number of lags to use in our estimations. Further serial correlation charts provided by the Adjusted Q-Stat and Lagrange Multiplier tests indicated that the lag structure of the data is erratic partly due to the inclusion of the long-term expected and/or unexpected inflation variables leading to serial correlation that persists for several years. Nevertheless, the AIC and Final Prediction Error critical tests all indicated the correct lag that was highly significant and thus these two critical values indicated the specified lag order per variable. Supplementary information on the Information Criterion and Lag Order Selection methods can be found in Section IV of the Appendix.

8.1.2 Johansen's Multivariate Cointegration Rank Order

The JMC Method was utilized to establish the cointegrating rank of the system of variables at our disposal. The lag order for differenced endogenous variables, i.e. the asset class returns, was set at 12 for each asset class variable based on the prior VAR lag order test. The deterministic trend assumption was set to a possible linear trend and intercept, whilst the critical value size was set at the 0.01 significance level. Table A8.0 describes the summary of JMC Test Results under the Max Eigenvalue (MEV) Test Method.

Table A8.0 ***JMC Test Results Summary (MEV Method)***

Johansen's Multiple Cointegration Test Results			
Asset Class	Method	Order Cointegration Rank	Probability
COM	Maximum Eigenvalue Test	3	0.0017
CSHF	Maximum Eigenvalue Test	2	0.0017
EMBAG	Maximum Eigenvalue Test	2	0.0038
FTNA	Maximum Eigenvalue Test	2	0.0003
G	Maximum Eigenvalue Test	3	0.0047
GCEU30	Maximum Eigenvalue Test	2	0.0001
INF10	Maximum Eigenvalue Test	4	0.0015
ML_CEU	Maximum Eigenvalue Test	3	0.0022
MSEM	Maximum Eigenvalue Test	2	0.0004
MSW	Maximum Eigenvalue Test	3	0.0005
SE6	Maximum Eigenvalue Test	4	0.0036
SEPE	Maximum Eigenvalue Test	2	0.0000

As indicated by the compendium of results, both the Trace test and the Max Eigenvalue statistic indicate the presence of multiple cointegrating relationships for each asset class. The latter test statistic was guiding in the decision of the cointegrating rank order as the Trace test statistic tends to overstate the cointegrating rank in the case of a multivariate structure. Concisely, the Max Eigenvalue statistic retains higher degree of power for multivariate analyses and thus was taken to be the correct estimate of the number of cointegrating equations present. The lowest number of cointegrating equations was 2, whilst the highest was equal to 4 for the INF10 and SE6 dependent variables. These cointegrating rank orders will be utilized during the estimation of several VECMs in the next section.

8.2 VAR Granger Causality/Block Exogeneity Wald Test

The VAR GCBEW analysis is performed separately for each asset class variable (dependent) and results are given in Section V of the appendix. The main focus of the directionality and significance of inter-variable relationships shall be on the dependent variables and their relationship vis-à-vis short-term unexpected inflation and long-term unexpected inflation to gauge whether the asset classes are viable natural hedges in the portfolio, i.e. protection against unanticipated inflation. As the GCBEW was merely an indication it shall not be further discussed here. For results and the associated elucidation see Appendix Section V, Part 5.

8.3 Vector Error Correction Models

Many have advocated the use of SVAR models in the field of financial economics. Structural Vector Auto-Regressions (SVAR) is a multivariate, linear representation of a vector of independent variables on its own lags, with a trend or constant. Economic theory indicates whether short-run restrictions are placed on the contemporaneous covariances between shocks or whether the long-run accumulated impact of the shock is constrained. SVAR makes explicit identifying assumptions that are placed directly on the orthogonalization matrix **P**. Besides omitted variable bias, the SVAR model also tends to be sensitive to the specific identification assumptions. Thus a priori bias might be rife amongst modellers under the guise of statistical inference. One can conduct a sensitivity analysis to detect the impact of ordering effects by computing an LM test statistic to verify whether the residual covariance matrix is close to diagonal (e.g. where the ordering of variables has no effect). The LM statistic is equivalent to: $LM = T\,\hat{\rho}^2$, which has an asymptotic χ^2 distribution with df=1 and the null hypothesis: $\boldsymbol{\Omega}$ is diagonal. Nevertheless, SVAR model results are still too rigid and exceedingly reliant upon the initial a priori assumptions and parameters. Thus, I opted for the use of a Multivariate VEC Model instead. Added benefits of the VECM vis-à-vis (S)VAR is that it solves potential problems of multicollinearity and spurious correlations without information loss that would result from taking the first difference approach under VAR. Sub-section 8.3.1 shall explicate the long-run relationships uncovered via the VECM method, whilst sub-section 8.3.2 gives a detailed account of the (short-term) error correction terms and their implications. Utilized terminology for graph descriptions can be found in Section IV, Part 3 of the Appendix.

8.3.1 VECM Long-Run Equilibria

The compendium of results regarding the long-run equilibria can be found in Section V, Part 3. To ensure that the rank condition for identification is met, I imposed the 'just identifying' restrictions, i.e. set r-1[69] zero restrictions on the beta coefficients of the cointegrating vector to ensure that the VECM model solution is unique. Note that only significant endogenous variables are considered in the discussion that follows. Furthermore, the main results will be displayed throughout the main body of this Section.

In order to facilitate interpretation I normalized the long-run equations, though I omitted the trend terms from the formulas displayed below as they were extraneous and of little illustration. Nevertheless, the trend term in the long-run is relatively small and not significant at α=0.01 and α=0.05 for all asset classes. At the α=0.05 level only the trend terms for COM, CSHF and INF10 are significant. Each of these variables had a long-run trend term of 0.009, 0.004 and 0.01 respectively. The term spread is significant at the 1pp significance level for three sub-asset classes, i.e. COM, FTNA and SE6. For COM, a 1pp increase in the term spread induces a fall in COM of 0.548pp vis-à-vis an increase of 0.829pp for FTNA.

Table A8.1 ***Long-Run Normalized Cointegration Equations***

NORMALIZED LONG-RUN COINTEGRATION EQUATIONS	
COM	= 3.466 - 0.548*TERM + 2.066*MSPREAD + 74.115*STUI + 0.769*LTUI
CSHF	= 2.607 - 0.252*CSPREAD - 0.875*MSPREAD - 0.064*STUI - 17.513*LTUI
EMBAG	= 0.89 + 0.101*STUI + 0.269*LTUI
FTNA	= - 0.45 + 0.829*TERM + 0.271*STUI
G	= - 0.356 - 3.923*STUI - 420.204*LTUI
GCEU30	= 0.866 + 0.112*LTUI
INF10	= 0.473 - 0.311*STUI
ML_CEU	= - 0.146 + 0.992*MSPREAD + 0.09*STUI + 0.20*LTUI
MSEM	= - 9.416 - 2.06*VIX - 2.993*STUI - 383.508*LTUI
MSW	= 1.128 + 0.241*STUI
SE6	= 33.765 - 10.97*TERM - 13.769*LTUI
SEPE	= 9.049 + 1.489*CSPREAD + 1.098*LTUI

Note that the asset class returns and variables are in percentages. Furthermore, the calculated return that results is the annualized return.

A 1pp increase in the term spread leads to a 10.97pp fall in SE6. Concisely, commodities (COM) and European stock markets (SE6) are negatively related to the term spread. As the yield curve

[69] R = rank order.

steepens, only the returns on European Real Estate (FTNA) rise accordingly. The TED spread was not a significant contributor in the long-run for any asset class.

The market spread was only significant for COM, CSHF and ML_CEU with coefficients of 2.066pp, -0.875pp and 0.992pp respectively. Market events may temporarily rattle the corporate bond markets, hence the spread widens between prime and lower medium grade fixed income securities. For example in the case of commodities, if prices of oil and industrial metals take a nosedive then there will be lower cash flows at commodity-sensitive firms resulting in increased default risk. In the LR, the trend reverses and returns of COM and ML_CEU increase. Hedge fund returns are largely dependent on the fund strategy followed, e.g. convertible arbitrage, market neutral, corporate life cycle, long/short or global macro. Hedge funds obtain economic leverage via the use of repo agreements, short positions and derivative contracts and are thus constrained by and/or sensitive to liquidity risk. As market spreads rise, then liquidity diminishes and initial margin calls may arise whilst collateral value declines, thus imposing an effective trading/credit limit on hedge funds and resulting in lower returns. A similar analogy can be drawn with respect to widening credit spreads, i.e. a negative long-run coefficient of -0.252pp for CSHF. This may seem counterintuitive as widening credit spreads tend to be countercyclical and signal deteriorating economic conditions. Conversely, during economic downturns and recessions, PE funds can secure high returns by scooping up distressed corporate debt at a steep discount and by extending credit to sub-par borrowers as evidenced by the long-run coefficient of the credit spread is 1.489pp for SEPE.

As the term spread increases and the interest rate differential grows, returns on real estate (FTNA) will increase by less than 1pp, thus staying true to the maxim that REITs are less interest-rate sensitive and more dependent on overall economic growth. Caution must be taken here as markets have fully recapitalized since the Credit Crunch (2009-2012) and growth in demand for new real estate may decelerate in light of concerns over EM Real Estate prospects and sluggish key economic drivers.

Table A8.1.1 ***Long-Run Equilibrium VECM***

LONG-RUN EQUILIBRIUM MULTIVARIATE VECTOR ERROR CORRECTION MODEL						
	COM	CSHF	EMBAG	FTNA	G	GCEU30
Asset Class Returns	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
TED(-1)		-0.030263 (0.07529) [-0.40197]				0.0772 (0.059) [1.31551]
TERM(-1)	0.547823 (0.18891) [2.89996]	-0.007722 (0.08835) [-0.08740]	0.000000	-0.828828 (0.29658) [-2.79466]	0.000000	
CSPREAD(-1)		0.252457 (0.13656) [1.84872]	-0.00222 (0.181) [-1.22961]	-0.572684 (0.56950) [-1.00560]	0.419035 (3.72709) [0.11243]	
MSPREAD(-1)	-2.0656 (0.50373) [-4.10056]	0.875388 (0.25378) [3.44945]				
STUI(-1)	-74.1146 (13.5375) [-5.47478]	0.063816 (0.02343) [2.72313]	-0.10110 (0.020) [-5.01383]	-0.270899 (0.06036) [-4.48786]	3.922580 (0.44042) [8.90639]	-0.02220 (0.015) [-1.45589]
LTUI(-1)	-0.7688 (0.06126) [-12.5490]	17.51373 (6.15543) [2.84525]	-0.26890 (0.086) [-3.12656]	-29.772890 (25.8704) [-1.15085]	378.3436 (187.762) [2.01502]	-0.11180 (0.068) [-1.64839]
@TREND(90M01)	0.008769 (0.00264) [3.32430]	0.003977 (0.00124) [3.20396]	0.19600 (0.0021) [0.94238]	0.002455 (0.00644) [0.38094]	0.052270 (0.03548) [1.47315]	0.00984 (0.001) [0.96028]
C	-3.46588	-2.606504	-0.89030	0.450152	0.355934	-0.86630

* Any t-statistic above |2.7|, |2| and |1.684| is significant at the 1%, 5% and 10% level respectively.

* [] refers to a t-statistic, whilst () refers to the standard error.

Operating fundamentals will remain low in the public and private real estate market unless a surge in demand revitalizes the market. It is imperative to understand that bond markets and real estate are not direct substitutes, though an increase in bond yields alters investors' expectations regarding real estate investments. As yields are already historically low and pockets of supply have sprung up in historically lean-supply markets, returns on real estate are expected to be lower than their historic estimate.

For COM, the long-run equilibrium of endogenous variables indicates that ΔSTUI has the largest impact on COM, i.e. every 1pp increase in STUI can induce a fall in COM of 74.115pp. However, STUI tends to be historically low and negative, i.e. arithmetic mean of -0.001pp, thus explicating the large coefficient of STUI. If STUI is negative it implies that current inflation is lower than our short-term expectation [$\pi < \pi_{st}^{e}$], in which case COM returns tend to fall. Conversely, if STUI is positive [$\pi > \pi_{st}^{e}$] the current inflation rate exceeds our expectations and

COM rises. In the long run, COM and LTUI are cointegrated with a coefficient of 0.769, hence if $\pi < \pi_{lt}^{e}$ then LTUI is negative and COM returns fall. If actual inflation exceeds our long-term expectation [$\pi > \pi_{lt}^{e}$] then COM rises by 0.769pp for every 1pp increase in LTUI.

For CSHF, in the case of unanticipated inflation hikes (STUI, LTUI > 0), the returns on HF are significantly lower as indicated by their negative LR coefficients. LTUI has a significantly higher impact on HFs than does STUI, for example if both STUI and LTUI rise by 0.1pp then COM will face a decrease in returns of 0.0064pp for the former and 1.75pp per annum for the latter.

EMBAG has a relatively mild negative coefficient for STUI and thus can serve only as a minimal/partial hedge against (unanticipated) inflation risk. High degrees of trade linkage and integrated banking systems have increased the likelihood of unexpected inflation in the Eurozone spreading to EM. In return EM domestic interest rates rise and concurrently bond returns will fall.

Listed real estate (FTNA) provides a partial hedge against inflation risk due to its positive coefficient for STUI. Nevertheless, the magnitude of this coefficient was relatively low at 0.271. Naturally, the real estate market tends to be far more illiquid than stock or bond markets and thus has little to offer in terms of co-movement with inflationary pressures. The LTUI coefficient was rendered insignificant for the same reason despite its longer horizon. Nevertheless, private real estate may serve as a better LTUI hedge due to its appraisal-based portfolio indices that are liable to appraisal smoothing[70]. Furthermore, one of the hallmarks of the private real estate sector is its illiquidity which also mitigates the ease of transmission of inflationary pressures.

The findings for the Gold Spot (G) prove that one cannot always rely on conventional wisdom as apparently gold is not much of an unanticipated inflation hedge[71]. Gold prices do not rise during times of inflation, as theory dictates, but rather tend to exhibit ‘positive price elasticity’. Concisely, momentum drives gold prices and past returns drive momentum in turn. For the past 15 years gold and inflation have had a correlation of approximately 0.85, though gold and inflation have exhibited an average correlation of only 0.30 over the past 80 years.

[70] Riddiough et al., (2005).
[71] “Gold: not much good for anything, unless you’re a Centurion.”

Table A8.1.2 *Long-Run Equilibrium VECM (continuation)*

LONG-RUN EQUILIBRIUM MULTIVARIATE VECTOR ERROR CORRECTION MODEL	INF10	ML_CEU	MSEM	MSW	SE6	SEPE
Asset Class Returns	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
VIX(-1)			2.060009		0.000000	
			(0.21160)			
			[9.73532]			
TED(-1)	0.000000	0.000000	0.452831	0.000000	0.000000	
			(1.79821)			
			[0.25182]			
TERM(-1)		0.000000		-0.222304	10.97002	4.613559
				(0.24507)	(2.82339)	(3.52340)
				[-0.90708]	[3.88541]	[1.30941]
CSPREAD(-1)			0.412742			-1.48858
			(3.14638)			(0.27526)
			[0.13118]			[-5.40796]
MSPREAD(-1)	0.000000	-0.9919				-1.168186
		(0.288)				(1.10666)
		[-3.44778]				[-1.05560]
STUI(-1)	0.3106	-0.0902	2.993295	-0.2405	1.501738	-0.7075
	(0.00065)	(0.017)	(0.50702)	(0.06193)	(1.76980)	(1.15569)
	[4.75811]	[-5.18517]	[5.90376]	[-3.88292]	[0.84854]	[-0.61217]
LTUI(-1)	0.1880	-0.2004	383.5083	3.666879	13.69354	-1.0980
	(0.00163)	(0.0693)	(149.315)	(15.6751)	(3.55925)	(0.11634)
	[1.15530]	[-2.88315]	[2.56846]	[0.23393]	[3.84731]	[-9.43801]
@TREND(90M01)	0.0045	0.0054	-0.0140	-0.0061	0.076837	0.006516
	(3.7E-05)	(0.00185)	(0.02992)	(0.00331)	(0.04047)	(0.01921)
	[1.21566]	[0.08517]	[-0.46955]	[-1.83259]	[1.89860]	[0.33926]
C	-0.4726	0.1461	9.415931	1.127596	-33.7653	-9.0485

* Any t-statistic above |2.7|, |2| and |1.684| is significant at the 1%, 5% and 10% level respectively.
* [] refers to a t-statistic, whilst () refers to the standard error.

Thus, the recent market correction may spell the end of the current time trend correlation as the gold-inflation pairing reverses back to its mean. Gold fails to hedge against LTUI in particular with a negative coefficient of 420.204 in the LR, thus as LTUI rises by 0.01pp then gold falls by 4.2pp.

INF10 also has a negative coefficient for STUI (-0.311) implying it is unsuitable as a hedge against unexpected inflationary pressures. A logical observation, as returns are directly tied to actual inflation, i.e. underlying Consumer Price Index. For the GCEU30, as expected inflation rises vis-à-vis the current inflation rate then interest rates and bond yields necessarily rise too, resulting in a fall in price to compensate for the erosion of purchasing power of future CFs. However, the longer the time horizon of the bond allows for a reversal of the trend and thus results in a positive loading of the LTUI coefficient for central European government bonds.

Corporate debt in Europe (ML_CEU) has an interesting effect. It appears that in the long-run, ML_CEU provides a partial hedge against unanticipated inflation, i.e. 0.09 for STUI and 0.20 for LTUI. Unexpected inflation reduces firms' real leverage and thus lowers default risk, leading to partial reversal of the adverse effect of expected interest rate increases under sustained inflation. In the long-run, corporate bond returns, aided by higher yields and stable prices, begin to outperform inflation and thus positively impact corporate bond returns in the EMU. In terms of portfolio insulation this implies that in the short-run one could tilt the portfolio away from bonds immediately following a positive inflationary shock as a precaution, though at some point reversal sets in and the portfolio tilt switches back towards corporate bonds.

EM stock market returns tend to decrease as VIX increases, a logical trajectory as implied volatility is indicative of a potential downturn in the market resulting in an end to the buoyancy of stock markets. As the absolute change in VIX can be significant, the coefficient indicated here can have a severe impact on the risk-return profile of EM-designated stocks. One explanation is that the effect of a change in VIX is exacerbated in EME as it builds on baseline risk that remains substantially and structurally higher in EM than in the more economically developed markets. Case in point, the coefficients of STUI and LTUI are noteworthy as it implies that rather than hedging unanticipated inflation by investing in EME, it apparently exacerbates it. One possible explanation is that if LTUI and/or STUI increase in the EU, inflation expectations will become de-anchored and an interest rate rise becomes more likely. With the "taper tantrum" of 2013 fresh in mind, it is not inconceivable that a sudden hike would wreak havoc amongst EM governments and institutions as their domestic interest rates are pushed higher, increasing debt-service costs on large stocks of (euro-denominated) debt. As the risk of default increases for firms and governments alike operating inside the EM, local stock markets will endure turbulent times. As a caveat, severe financial strains in EM tend to be self-inflicted, e.g. unsustainable fiscal deficits, tolerating high inflation, sluggish implementation of required structural reforms and domestic political uncertainty. Vice versa, the EUs current regime of quantitative easing may still have unintended consequences for EME as excess liquidity disrupts export channels, inflation levels and spending patterns. One major feature of the world's financial markets is rapidly increasing globalization via trade ties, capital flows and the banking channel. Excess liquidity flow into EM following Central

Bank stimulus by leading economies and has a disruptive effect on their domestic economies. Over the long-term and on risk-adjusted basis, EM generates higher yields than in the developed world, thus attracting excess liquidity. The pivotal question is whether these developing economies can absorb foreign capital flows to feed the growth engine without jeopardizing their financial viability. Unlike the developed economies, widespread credit availability has led to a surge in credit and lending to private borrowers in developing economies. Nevertheless, a surge in aggregate demand in EM puts upward pressure on commodity prices and the banking system's lending capacity can become strained. As crude oil and agricultural commodities are imperative to many developing countries, a surge in price would lead to the rapid development of inflation and thus interest rates would rise. Due to higher debt service and squeezed profit margins, the expected future CFs would fall under the DCF method and EM stock prices decline in turn.

Global stock markets on the whole appear to be only slightly more resilient and serve as a partial hedge only against short-term inflation, if and only if, the global trend is divergent from the domestic inflation trend. Exchange rates moderate inflation differentials and international stocks are a perverse hedge in the long-run due to the unexpected inflation component. Increasingly synchronized changes in global financial conditions are largely the result of globally-active banks, key propagators of cross-border financial conditions. In the case of a nominal shock, e.g. foreign CB, then exchange rates can either dampen or reinforce (dis-)inflationary impulses. Nevertheless, the pass-through of exchange rate changes through supply chains into CPI tends to be a protracted process due to inherent pricing frictions within developed markets.

European stock markets are particularly liable to LTUI as evidenced by the long-run coefficient. As LTUI rises, corporate profits tend to be squeezed through higher input costs that cannot immediately be passed on to consumers and thus stock prices fall. Unexpected inflation may contain new information about future prices and generates enhanced volatility of stock market returns. During inflationary periods, prevailing conditions and future expectations are more opaque and prudent investment decision-making become harder. Still, during periods of inflation value stocks tend to outperform most other equities, whilst growth stocks outperform during deflationary periods. Dividend-yielding stock falls out of favour in light of inflationary impulses as nominal dividends tend to be stable over time and their value is eroded away.

Finally, private equity in Europe serves as a partial hedge against LTUI, partly due to its inherently lower liquidity. Conversely, the downside is that a prolonged period of deflationary pressure will wreak havoc on the PE industry. As PE utilizes leverage to enhance returns and maximize the company valuation, a bout of deflation would disrupt the core of its model by making existing debts dearer in real terms. Concisely, PE is not a panacea against inflation risk and may prove to be a double-edged sword once inflationary pressure mounts in the future. Furthermore, a more specific type of inflation may be on the horizon, i.e. private equity inflation. Investors put pressure on private equity houses to make new investments. PE funds may be suffering from winner's curse at auctions as investors have put pressure on PE houses to make new investments whilst the number of PE houses has steadily risen for years, thus inducing bidding wars. Both venture capital and leveraged buyout-styled transactions are affected by changing interest rates and inflation. Low or declining interest rates lead to an abundance of fund-raising activities and PE houses can lock-in low interest rates to reduce periodic outflows, thus IRR is enhanced. Nevertheless, the other side of the coin entails the aforementioned winner's curse in response to the bidding-up process. Exiting PE firms still benefit as IPO activity tends to flourish in a low interest rate environment. If inflation returns with a vengeance, then investors turn to fixed income securities once more and asset valuations necessarily decrease. Smart PE firms will then become more active on the buy-side[72], i.e. predominance of undervalued assets. Long-term institutional investors, chiefly pension funds, will continue to invest in PE for its diversification benefits. This ensures a steady base of demand for PE. Finally, every asset class and sub-category has unique inflation-cycle sensitivities. Furthermore, black swan events[73] like asset bubbles, severe bear markets and credit crunches, drive asset returns in erratic and oft ex ante inexplicable ways.

8.3.2 VECM Error Correction Terms

The Vector Error Correction Terms [ECT] indicate the short-run adjustment parameters of the cointegrated system under consideration. To discover the error correction pathways we utilize the following formula to normalize: $\alpha° = -(1 - \alpha)$, where α is equal to the ECT.

The table below explicates the meaning of the sign and adjustment speed indicated by $\alpha°$. The compendium of results regarding the VECM ECT can be found in Section V: Results, Part 4 of the Appendix. Table A8.2.1 and Table A8.2.2 indicate the summary results for LTUI and STUI.

[72] Reversal of capital accumulation.
[73] T.N. Nicholas, (2007).

Table A8.2 *$\alpha°$ adjustment pathways*

$\alpha°$	Meaning
< -2	Overshooting of economic equilibrium
[-1.5,-0.5]	A large percentage of disequilibrium disappears in each period
[-0.5,0]	Adjustment towards equilibrium is slow
> 0	Divergence from LR equilibrium pathway

For COM, any disequilibria due to ΔCOM or ΔSTUI leads to an overzealous correction by the market the following period as $\alpha°$ by far exceeds -2. Concisely, the overshooting phenomenon ensues, which over time dissipates as we converge on the long-run equilibrium. The speed of adjustment indicated by the $\alpha°$ of ΔMSPREAD, ΔDY and ΔLTUI is close to -1, thus a large proportion of the disequilibrium is corrected for within the first period.

For CSHF, overshooting occurs based on a deviation from its own equilibrium, i.e. ECT of ΔCSHF = -2.456. Other significant error correction terms include those for ΔDY, ΔTERM and ΔMSPREAD. All of these had $\alpha°$ close to -1 and thus rapidly corrected for disequilibria within approximately a month. Short-term adjustments for STUI and LTUI were insignificant, though with negative signs implying a reversal of the effect of unanticipated inflation in the short-run.

EMBAG also suffered from an overshooting element based on its own propagation (i.e. ΔEMBAG), ΔTERM and particularly for ΔSTUI. All three had an $\alpha° < -2$, though the latter ECT was insignificant. The ΔCSPREAD indicates that a deviation is corrected for nearly within a month. Finally, the ECT of ΔLTUI was positive and thus propagates the original deviation from equilibrium. If ΔLTUI > 0, it would have a positive effect on EMBAG that would endure for some time. Unfortunately, this ECT was insignificant even at the 10% significance level.

For FTNA, its own price propagation was insignificant in the short-run. Nevertheless, the aggregate risk proxy ΔVIX indicates overshooting in the short-run should disequilibrium occur. Similarly, ΔLTUI is neigh on -1 and thus almost entirely corrects itself within a month following the disequilibrium. However, the ΔSTUI adjusts slowly back to the long-run equilibrium as evidenced by its negative, but small, $\alpha°$. Thus, if ΔSTUI > 0, then FTNA returns should experience short-term growth.

For G, a ΔCSPREAD is corrected for in less than two months, whilst ΔG elicits a small overshooting effect. For GCEU30, its own propagation leads to overshooting, whilst the ΔLTUI is nearly one-for-one in terms of the short-term correction, i.e. converges on LR equilibrium within a month. For INF10, the ΔINF10 causes overshooting of its LR equilibrium along with the ΔMSPREAD. Similar findings for ML_CEU, whose significant ECTs, i.e. ΔTERM, ΔMSPREAD and its own propagation, all exhibit an overshooting effect.

Table A8.2.1 ***ECT Results Part* 1**

VECTOR ERROR CORRECTION TERMS			
Asset Class	**Variable Considered**	**Error Correction Term**	**α˚= - (1 - α)**
COM	D(LTUI) D(STUI)	-0.003 -3.628	-1.003 -4.628
CSHF	D(STUI) D(LTUI)	0.201 0.0001	-0.799 -1.000
EMBAG	D(STUI) D(LTUI)	-65.951 2.159	-66.951 1.159
FTNA	D(STUI) D(LTUI)	0.475 0.0003	-0.525 -1.000
G	D(STUI) D(LTUI)	-0.056 0.00002	-1.056 -1.000
GCEU30	D(STUI) D(LTUI)	-33.246 2.029	-34.246 1.029

ΔLTUI and ΔSTUI have positive, but insignificant α˚.

Table A8.2.2 ***ECT Results Part* 2**

VECTOR ERROR CORRECTION TERMS			
Asset Class	**Variable Considered**	**Error Correction Term**	**α˚= - (1 - α)**
INF10	D(STUI) D(LTUI)	111.8169 5.3136	110.8169 4.3136
ML_CEU	D(STUI) D(LTUI)	26.0347 3.2087	25.0347 2.2087
MSEM	D(STUI) D(LTUI)	-0.1265 0.0000	-1.1265 -1.0000
MSW	D(STUI) D(LTUI)	-1.0051 -0.0004	-2.0051 -1.0004
SE6	D(STUI) D(LTUI)	-0.0040 0.0155	-1.0040 -0.9845
SEPE	D(STUI) D(LTUI)	-0.2707 0.0031	-1.2707 -0.9969

ΔMSEM does not have any short-run adjustments with respect to its own propagation pathway. ΔDY and ΔSTUI are close to unity, though the Δ(ΔVIX) slightly overreaches its target, i.e. the LR equilibrium. Conversely, global equity markets are typified in the short-run by overshooting based on ΔSTUI and ΔMSW. The ΔDY has an adjustment process that is close to unity, thus any disequilibrium based on the ΔDY is quickly accounted for. Conversely, European stock markets do not adjust to changes in STUI or LTUI in the short-run and are thus the short-run elasticity of unanticipated inflation for SE6 is exceedingly low.

Finally, SEPE disequilibria based on its own return propagation is significant and below -2, i.e. overshooting results. Interestingly, SEPE is the only asset class with a significant positive

$\alpha°$ this indicates that as the VIX rises, it will not lead to short-run reversion to its long-run equilibrium, but rather exacerbates the divergence from its long-run equilibrium.

Prior to engaging in VEC Impulse Response Functions, one must ascertain whether variables in the VAR are covariance stationary. One method of performing such a stability test is the 'Inverse Roots of AR Characteristic Polynomial" technique. If coefficient $|\lambda_i| > 1$, the time series exhibits an element of explosiveness and IRF pathways following a 'shock' will be guided by an unbounded mean and variance. As we are employing a VECM with at least one unit root for each asset class, not all points can lie inside the circle. The unit roots of the system must coincide with that of the circle at the value of 1, indicating a permanent shock under IRF. Note that $\prod(z)$ is non-invertible regardless because of this unit root condition. The horizontal axis indicates real numbers, whilst the vertical axis indicates the imaginary numbers (typical requirement for complex, high-order integrated systems. If all roots that are not unit roots $|\lambda_i| < 1$, i.e. both imaginary and real roots have modulus less than 1, then the estimated model is stable and IRF standard errors remain valid. Results indicated that all models had unit roots that intersected the unit circle, whilst all other inverse roots fell inside the unit circle. Thus one can only conclude that the model is stable and IRFs either converge either on their original value or converge on their new long-run value for temporal and permanent shocks respectively. A graphical representation of results based on the inverse root characteristic polynomial method can be found in Section V, part 7 of the Appendix. Furthermore, as I converted the estimated VECM back into a VAR for the purpose of IRF analysis, optimal predictions and consistent IRFs should result.

8.4 VEC Impulse Response Functions

The IRF model is typified by the innovation of independent and identically distributed random variables that give rise to either permanent or transitory shocks based on the underlying system of cointegrated variables. An ordinary IRF has a serious flaw in that it operates from a ceteris paribus condition, i.e. a one standard increase for one independent variable holding all else constant. Due to contemporaneous correlation the ordinary IRF renders causal interpretation tenuous at best. Orthogonalization of innovations is a solution to the aforementioned problem and Sims (1980) purports that the orthogonalization matrix **P** can be written via Cholesky decomposition. Thus we transform the contemporaneous impact matrix $\mathbf{\Phi_i}$ into a lower triangular matrix whose diagonals are the standard deviations. The ordering of the variables then guides the propagation of the dynamic multipliers. Furthermore, no long-run restrictions were employed despite their prevalence in contemporary research. The reason for this is that long-run restrictions lead to imprecise estimation of the long-run effect of shocks due to serious bias even with large samples[74]. The compendium of IRF results can be found in Section V: Results, Part 6 of the Appendix and in Tables A8.3.1-A8.3.3 in this Section.

Compendiously, the IRFs by and large reinforce the results found under the VECM. A one σ shock in STUI and LTUI, which implies that actual inflation exceeded expectations, results in new stable equilibrium for COM at a higher level than before. Thus unexpected inflation, both short-term and long-term, are partially incorporated into the returns in COM. Between the two, LTUI leads to the highest new equilibrium, though it also exhibits the greatest overshooting during the first 6 months. STUI initially exhibits similar overshooting of a lower magnitude, prior to reversal and eventual undershooting in month 5/6. Eventually STUI settles at its new equilibrium level just below LTUI. Nevertheless, the magnitude of the equilibrium increase remains relatively low, i.e. 0.10 (LTUI) and 0.06 (STUI). Interestingly, the new COM equilibrium level for the neg_dum*LTUI, i.e. when long-term inflation expectations are falling, leads to the highest gain in COM returns, i.e. close to the 0.70 mark. Thus if unexpected inflation were to suddenly arise in a period of low or falling inflation expectations, COM would serve as relatively strong hedge. The new plateaus are reached after around 18 months.

For CSHF, following a σ shock LTUI and STUI display pre-transition overshoot followed by reversal and severe post-transition undershooting ere finding their new equilibrium level. Both STUI and LTUI end up in the negative domain and thus do not serve as a hedge against unexpected inflation. LTUI and STUI settle after approximately 24 months at -0.10 and -0.03 respectively. Interestingly, the neg_dum*LTUI experiences pre-transition overshoot and complete reversal post-transition prior to settling at its new equilibrium level of 0.08 after 14 months. Thus, CSHF serves as a minor hedge against sudden inflation during periods of low-/falling inflation expectations.

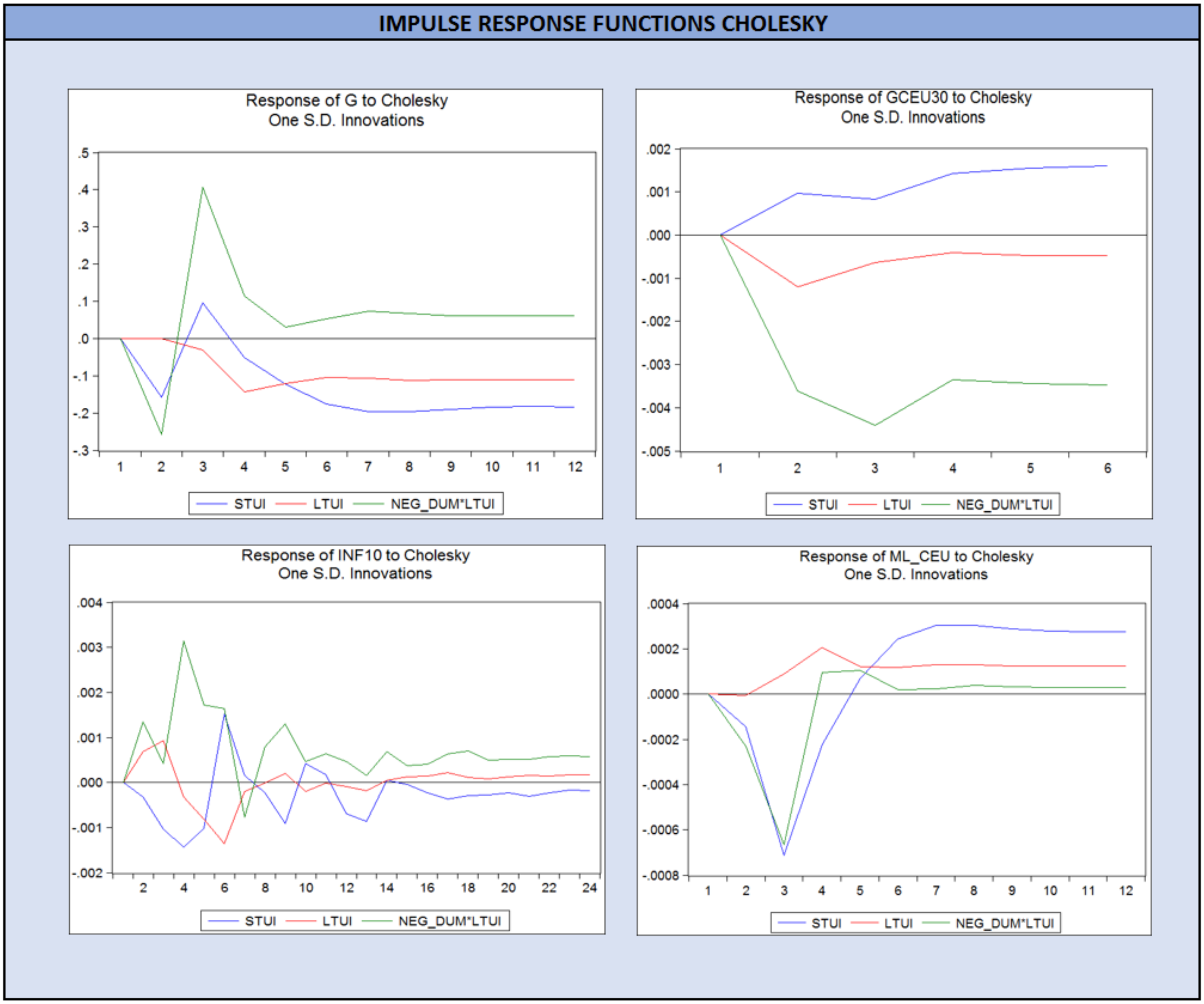
[74] J. Faust and E.M. Leeper, (2005).

Table A8.3.1 ***Impulse Response Functions A***

IMPULSE RESPONSE FUNCTIONS CHOLESKY

Both EMBAG and FTNA settle rapidly at their new equilibrium subsequent to a σ shock, i.e. after 4-5 months. STUI and LTUI both settle at a higher post-transition level, though the magnitude for EMBAG is negligible, i.e. 0.001 and 0.0007 respectively. For FTNA, STUI has a strong positive impact on the returns as it settles at a new equilibrium of 1.3 following slight post-transition overshoot. Unfortunately, the response to a shock in LTUI leads to an adverse impact on the returns level of FTNA as it settles rapidly at a new equilibrium level of -1.4. Similarly, for both categories the neg_dum*LTUI propagation occurs exclusively in the negative domain. The magnitude of the adverse impact is equivalent to -0.5 for FTNA and -0.0034 for EMBAG. In conclusion, the effect of EMBAG following a shock is negligible.

Table A8.3.2 ***Impulse Response Functions B***



For G, a σ shock gives rise to a fall in the return on G for both LTUI and STUI, the latter effect being more pronounced. The transition for LTUI is relatively smooth and it attains its new equilibrium state after 5-6 months at the -0.11 mark. The effect of a shock in STUI is more erratic as it briefly breaches the zero floor during the mid-transition overshoot during the third month, however it eventually falls to approximately -0.18. Dum_neg*LTUI encounters significant pre-transition undershoot and post-transition overshoot, prior to settling at its new equilibrium of 0.06.

Thus G serves as a minor hedge against long-term unexpected inflation during periods of falling inflation expectations.

GCEU30 displays a persistent, positive effect for STUI and remains inside the negative domain for LTUI and dum_neg*LTUI. Exact opposite effects have been found for INF10, though it displays several pre-transition and post-transition overshooting and undershooting moments prior to settling at new equilibria. For INF10 the LTUI and neg_dum*LTUI settle in the positive domain, whilst STUI settles in the negative domain. Conversely, for both G and INF10 the magnitude of the prevailing impact is negligible.

ML_CEU exhibits severe pre-transition undershoot for both neg_dum*LTUI and STUI, though both eventually reverse and breach the zero boundary. The effect of a shock in LTUI has a positive impact on the ML_CEU returns. Stable states have been attained after 6-7 months, though magnitude of impacts is essentially negligible.

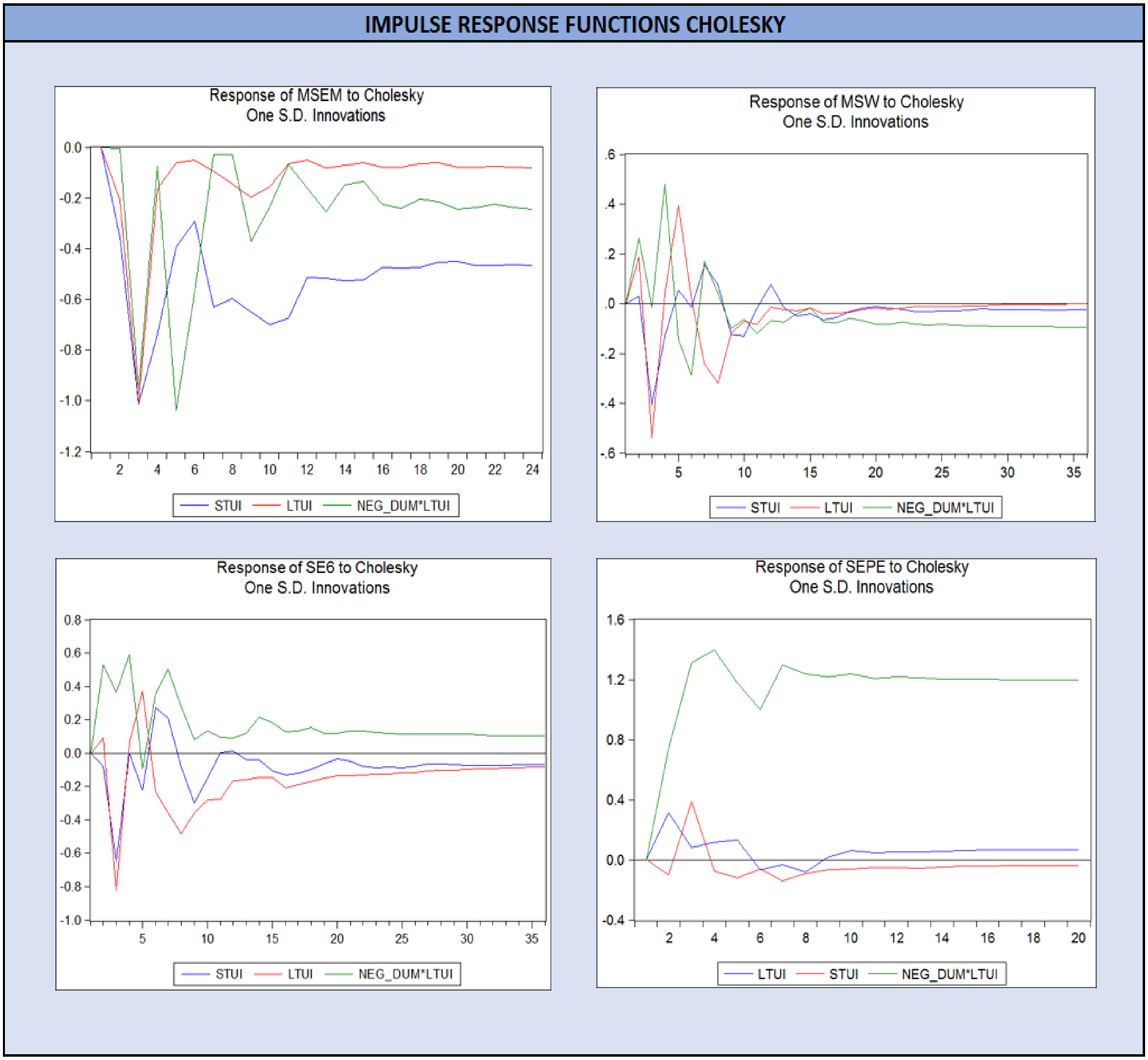
The effect on the MSEM returns following a σ shock is strictly negative for all three variables. Thus, MSEM does not serve as an appropriate hedge in light of unanticipated inflation. The negative effect is particularly prominent for following a STUI shock. New steady states are achieve after approximately 12 months at -0.08 (LTUI), -0.47 (STUI) and -0.24 (neg_dum*LTUI).

MSW displays severe post-transition undershooting and overshooting for both LTUI and STUI in the short-run, though the effect following a σ shock in LTUI dissipates after approximately 18 months. STUI settles at a slightly lower post-transition equilibrium at -0.02, whilst neg_dum*LTUI settles at -0.09 despite severe pre-transition double-dip overshooting. In conclusion, MSW does not lend itself well as a natural hedge against unanticipated inflation.

For SE6, LTUI and STUI shocks give rise to post-transition undershoot followed by overshoot ere they settle at their new equilibria just below the zero boundary at -0.08 and -0.07 respectively. Neg_dum*LTUI displays double dip post-transition overshoot and experiences severe undershoot in the aberration region, though it settles at its new steady state after 8 months at a level of 0.10. Thus if long-term inflation suddenly increases during a period of falling inflation expectations, SE6 provides a measure of protection in terms of value preservation.

Finally, SEPE reacts positively to a σ shock in LTUI and neg_dum*LTUI. LTUI experiences initial post-transition overshoot followed by undershoot and settles at 0.07. Meanwhile, a STUI shock briefly gives rise to a positive impact around the 3-month mark prior to turning negative and settling -0.04. Nevertheless, the strongest effect is reserved for a shock in neg_dum*LTUI, which remains strictly in the positive domain and swiftly settles at its new steady state after less than 6 months at a level of 1.20. Thus, SEPE is an excellent hedge against unanticipated inflation during periods of low-/falling inflation expectations.

Table A8.3.3 *Impulse Response Functions C*



8.5 Rolling Dynamic Ordinary Least Squares

This section expounds the results from the rolling DOLS for STUI alongside appropriate risk proxies as indicated by the results from the previous sections. The compendium of results pertaining to the rolling DOLS can be found in Section V, Part 8 of the Appendix. P-values of STUI coefficients can be found at the end of Section V, Part 8 of the Appendix.

STUI tends to be negative whenever the actual inflation rate is falling and positive if the actual inflation rate is rising if one ignores the slight lag. This implies that short-term expectations of inflation do not adjust instantaneously to inflationary changes.

For COM, the STUI coefficient is significant and positive for the entire period studied. STUI effects tend to persist for a longer time than the peak of inflation, thus implying that negative STUI fully impacts the returns on of COM. Nevertheless, during times of excessive inflation, i.e. above 2%, the STUI coefficient is close to 1 implying a one-for-one change with unexpected short-term inflation. During periods of sustained deflation, the STUI remains positive implying a severe fall in COM and thus it does not serve as a good hedge against the adverse effects of deflation. The deflationary dummy is not significant between January 2003 and July 2011. During periods where inflation falls below its trend-level, any negative STUI exacerbates the fall in COM returns, whilst positive STUI magnifies the return structure of COM. Overall, COM seems to be most effective and significant during times of inflationary pressures, unfortunately the downside is COM returns responsiveness to deflationary trends.

For CSHF, prior to 2013 the STUI coefficient had the correct signs during periods of negative and positive STUI, i.e. negative and positive sign respectively. Despite the fact that the coefficient for negative STUI during 2013 and 2015 was lower than its positive counterpart, the difference is indistinct. For during times of inflation trend undershooting and negative STUI the coefficients were negative, thus ensuring significant value strengthening. Unfortunately, the negative coefficient of dum_def*stui has fallen in recent years. Similarly, positive STUI during times of inflation trend undershooting dampens the positive impact on the CSHF returns. Between 2010 and the present, the CSHF has proven to be a significant and positive hedge against unexpected inflation. However, as inflation falls, the overall coefficient remains slightly positive indicating a worsening of the return on CSHF. Nevertheless, the adverse effect of deflation on CSHF returns is less severe than for COM.

Under EMBAG, the STUI coefficients indicate a worsening of returns regardless of whether inflationary or deflationary pressures are present, i.e. positive coefficients for negative STUI and vice versa. The coefficient of STUI is positive following a fall in inflation with a lag longer than 12 months prior to 2010, however the trend seems to have reversed as the STUI coefficient has been severely negative since 2011. Furthermore, the magnitude of the coefficients of STUI and dum_def*STUI are negligible. Thus, EMBAG does not serve as a reliable hedge against unanticipated inflation or deflationary pressures.

FTNA has a promising track record of highly positive and significant coefficients for STUI, particularly between 2010 and 2013, which coincides with a rise in actual inflation and where STUI coefficients were between 0.45 and 0.78. Nevertheless, recent negative STUI during a period of lowflation has led to a steady deterioration of FTNA value as evidenced by the significantly positive dum_def*STUI coefficient. During periods of severe market upheaval, FTNA is more resilient in the short-run, which is indicative of sluggish downward adjustment to falling prices (higher level of inelasticity in the short-run).

G only responds to STUI sporadically, i.e. between 1997 and 1998 and between 2015 and 2016 though with a positive coefficient approaching 0.12 and 0.20 respectively. For the latter period, the sign and magnitude for positive STUI are acceptable. The former period led to a positive overall impact during times of negative STUI if one takes into account the dum_def*stui coefficient which completely reverses the adverse impact of the STUI coefficient on a standalone basis, i.e. reverse the sign of the STUI coefficient, and partially insulate gold returns from deflationary pressures. Conversely, during times of excessive inflation, the STUI coefficients are insignificant.

The results of GCEU30, INF10 and ML_CEU were negligible due to their magnitude, i.e. STUI and dum_def*STUI coefficients had a range of 0.002 to -0.0017. Overall, the dummy coefficients seem to offer some protection against inflation and deflation for GCEU30, and only a partial hedge against negative STUI for INF10 and ML_CEU. Concisely, none serve as a natural hedge against unanticipated inflation.

For MSEM, the positive coefficient for STUI>0 is slightly mitigated if it occurs during a period of low-/falling inflation. The adverse impact of falling inflation was reversed entirely in the 90s. However since the 2000s the coefficient of the deflationary dummy has been positive during periods of negative STUI. The abovementioned is cause for concern if one wishes to utilize the asset class as a natural hedge against unanticipated inflation.

For MSW, the coefficients of positive STUI are of the right sign. However, for negative STUI they tend to be positive implying an erosion of MSW value, particularly during periods of financial turmoil. The deflation dummy coefficients were insignificant for the majority of the period under study.

Positive STUI is incorporated quickly into the returns of SE6 as evidenced by the positive coefficient for STUI. Prior to the Tech Bubble, negative STUIs adverse effects were eradicated, though this trend seems to have reversed since 2003. Furthermore, dummy coefficients indicate that adverse impact of deflation was not mitigated during periods of falling inflation and that deflationary pressures exacerbated losses in terms of SE6.

SEPE only offered a measure of protection during the Credit Crunch of 2009, where negative STUI impact was mitigated. Nevertheless, during recent years the coefficient for STUI has been stable and close to 0.5 regardless of the sign of STUI.

9. Conclusion

This section functions as a compendium of the results section and contains final remarks. To complement the results of this thesis I also conducted a naïve α analysis based on Jensen's Alpha method. The compendium of results can be found in Section V, Part 9 and Part 10 of the Appendix. Section 9.1 contains the main conclusions and Section 9.2 the policy implications for ABP based on the outcomes of this thesis.

9.1 Main Conclusions

For nominal returns, α's that are significant are all positive. EM aggregate and investment grade have positive significant alphas of 0.47% p.a. and 3.84% p.a. respectively, whilst HFs have positive and significant alphas of 2.59% and 1.73% per annum. However, the highest alphas are reserved for the LBO PE at 12.59% p.a. and for NAREIT at 4.13% p.a.

Comparatively, the alphas for real returns are lower than their nominal counterparts though still positive and significant, except for EM aggregate. In real terms, the latter has a significant and negative alpha. LBO PE, NAREIT and HF have real positive alphas of 1.44%, 0.39%, 11.94% and 3.51% per annum respectively. The EM investment grade sector has a positive alpha of 2.86%, however in real terms EM aggregate now has a negative alpha of -1.56% per annum. One sample t-tests were conducted to derive the associated p-values. The beta coefficients were calculated via the Cov/Var method and via the Slope method. Both methods tended to yield similar market βs.

As the Sharpe ratio is biased due to its inherent structure, i.e. penalizes for positive/upside volatility, the Sortino ratio can be utilized to gauge results when only downside risk is considered. The Sharpe ratio cannot differentiate

Table A9.1a Comprehensive Summary Real Ex-Post Sortino Ratios

Real Ex-Post Sortino Ratios				
Asset Class	σ downside per annum	Sortino Ratio	Score	Notes
SEPE	2.04%	3.51	++	Sorted from highest to lowest Sortino Ratio.
G	0.81%	3.16	++	
FTNA	3.76%	2.26	++	
EMBAG	2.04%	1.74	++	
ML_CEU	2.38%	0.75	+	
INF10	2.45%	0.72	+	
CSHF	11.31%	0.41	0	
MSEM	15.93%	0.32	0	
SE6	12.49%	0.21	-	
MSW	10.08%	0.15	-	
COM	18.14%	0.01	-	

between upside- and downside volatility in an investment even though the former is oft considered beneficial, thus not all volatility is malignant. Concisely the Sortino ratio only penalizes downside volatility below a specified return, whereas Sharpe penalizes all volatility swings. The Sortino ratio can be expressed as: $= \frac{R_p - R_f}{\sigma_{down}}$. The results of the Sortino ratio analysis can be found in Section V, Part 11 of the Appendix.

Table A9.1b Comprehensive Summary Ex-Post Sortino Ratios

Ex-Post Sortino Ratios				
Asset Class	σ downside	Sortino Ratio	Score	Notes
EMBAG	2.04%	3.64	++	Sorted from highest to lowest Sortino Ratio.
FTNA	15.10%	2.26	++	
GCEU30	2.08%	1.38	++	
CSHF	5.27%	0.99	+	
ML_CEU	2.38%	0.72	+	
INF10	3.38%	0.52	+	
COM	15.05%	0.43	0	
G	7.01%	0.42	0	
MSEM	15.93%	0.29	-	
SEPE	18.14%	0.25	-	
SE6	12.49%	0.19	-	
MSW	10.08%	0.13	-	

Table A9.2 Scoring System

Scoring System	
Level	Meaning
++	Mitigates Unexpected Inflation Risk
+	Temporary/Minor Respite From Inflation Risk
0	Neutral
-	Temporary/Minor Aggravation of Inflation Risk
--	Exacerbates Unexpected Inflation Risk

For equities the highest Sortino ratio is for the S&P500 at 0.44. For the fixed income securities, EMBAG and GCEU30 attain the highest ex-post Sortino ratios. A comprehensive summary of ex-post Sortino Ratios can be found in Graph A9.1a/b. FTNA and CSHF attain relatively high ex-post Sortino ratios at 2.26 and 0.99. Conversely, MSEM, SEPE, SE6 and MSW proved to be the underdogs as they lagged behind with Sortino ratios < 0.30. Concisely, only some of the alternative categories attain excess returns that by far outweigh the increased downside volatility. In real terms, EMBAG and FTNA still score highly, though SEPE and G now attain the highest Sortino ratios. Note that the Score Scale is explicated in Table A9.2. Finally, the hypotheses of this thesis can be answered in full. The first hypothesis stated that:

Hypothesis 1: Asset class returns will fully incorporate changes in unanticipated inflation in the short-run, thus combining asset classes will provide a natural hedge against inflation risk.

As the IRFs and Vector ECTs indicated, disequilibria tend to persist for most asset classes to some extent. According to the short-run ETCs, COM and FTNA return to their long-run positive equilibrium rapidly following a change in LTUI. In terms of the STUI, COM displays severe over-/undershooting in the SR, whilst FTNA returns relatively slowly to its LR equilibrium. Thus, if STUI is positive than FTNA is preferred. If STUI is negative then the adverse impact on FTNA will persist for a protracted period of time.

Table A9.3 ***VECM Error Correction Terms Summary***

Short-Run Error Correction Terms			
Asset Class	**Type of Unexpected Inflation [SR, LR]**	**Score**	**Notes**
COM	SR	**+/0**	*For STUI: positive LR equilbrium, but severe over-/undershooting in SR.*
		++	*For LTUI: quickly returns to LR positive equilbrium.*
CSHF	SR	**0**	
EMBAG	SR	**0**	
FTNA	SR	**++**	*For STUI: slow adjustment to LR equilibrium, though strongly positive.*
		+/0	*For LTUI: quickly returns to LR positive equilbrium, though latter is*
G	SR	**0**	
GCEU30	SR	**0**	
INF10	SR	**0**	
ML_CEU	SR	**0**	
MSEM	SR	**--**	
MSW	SR	**+**	*For STUI: overshooting in the SR, thus market entry and exit are imperative.*
		0	*For LTUI: not signficant.*
SE6	SR	**0**	
SEPE	SR	**0**	

According to Table A9.4, COM is the asset class par exemple in terms of inflation risk insulation. Generally, subsequent to a standard deviation shock in STUI, FTNA and COM are preferred. Unfortunately, when it comes to FTNA, a standard deviation shock in LTUI leads to a permanently lower equilibrium return compared to the a priori situation. G, CSHF and SE6 provide a semblance of protection during a period of low-/deflation as indicated by dum_neg*LTUI. Finally, SEPE provides a measure of protection in case of a standard deviation shock in LTUI and during a sudden bout of deflationary pressure. Other effects are either adverse with respect to unanticipated inflation or negligible. Compendiously, the level of insulation from unanticipated inflation in the SR depends strongly on the asset class under consideration. A few asset classes fluidly incorporate changes in unanticipated inflation, whilst others promulgate the adverse impact of a standard deviation shock in underlying inflationary measures. Asset classes do not respond to sudden changes in short-run and long-run unanticipated inflation and incorporation of such shocks oft contains large errors and gives rise to severe under-/overshooting. Thus the second hypothesis is soundly rejected in general terms, though it may hold true for particular asset classes depending on the unexpected inflation measure used and time under consideration. Note that the IRF Summary is displayed in Table A9.4 below.

Table A9.4 *Impulse Response Functions Summary*

Persistence of σ Shock - *Impulse Response Functions* -			
Asset Class	**Type of Unexpected Inflation [SR, LR]**	**Score**	**Notes**
COM	STUI	+	
	LTUI	+	
	dum_neg*LTUI	++	
CSHF	STUI	-	
	LTUI	-	
	dum_neg*LTUI	+	
EMBAG	STUI	0	Negligible
	LTUI	0	
	dum_neg*LTUI	0	
FTNA	STUI	++	
	LTUI	--	
	dum_neg*LTUI	-	
G	STUI	-	
	LTUI	-	
	dum_neg*LTUI	+	
GCEU30	STUI	0	Negligible
	LTUI	0	
	dum_neg*LTUI	0	
INF10	STUI	0	Negligible
	LTUI	0	
	dum_neg*LTUI	0	
ML_CEU	STUI	0	Negligible
	LTUI	0	
	dum_neg*LTUI	0	
MSEM	STUI	--	
	LTUI	--	
	dum_neg*LTUI	--	
MSW	STUI	-	
	LTUI	0	Effect dissipates entirely
	dum_neg*LTUI	-	
SE6	STUI	-	
	LTUI	-	
	dum_neg*LTUI	+	
SEPE	STUI	-	
	LTUI	+	
	dum_neg*LTUI	++	

As evidenced by Table A9.3 and Table A9.4, only Commodities and Listed Real Estate show promising (and relatively consistent) results with respect to insulation against unanticipated short-run inflation. Other asset classes either propagate contrary to short-run unexpected inflation pathways or the effects are rendered statistically negligible. Thus, the first hypothesis is rejected for most asset classes.

The second hypothesis stated that:

Hypothesis 2: Asset class returns will converge towards their equilibrium level in the long-run, which is dominated by long-run inflation and fully insulates investors from unanticipated inflation.

As can be gleaned from Table A9.5, certain asset classes display severe negative covariance in the long-run vis-à-vis unanticipated inflation. The asset classes that exacerbate inflation risk in the long-run have been marked with a score of '--', i.e. that includes CSHF, G, MSEM and SE6. Conversely, COM and SEPE seem to provide the best natural hedges in the long-run both for STUI and LTUI. FTNA and MSW display a positive equilibrium in relation to STUI and thus only provide temporary relief if the effect persists for a protracted period.

For GCEU30, only LTUI has a cointegrating relationship with inflation risk in the long-run. EMBAG and ML_CEU exhibit positive long-run cointegration with both STUI and LTUI, though the magnitude of their covariance is slightly lower than for some of the other asset classes.

Table A9.5 ***VECM Long-Run Equilibria Summary***

Long-Run Equilibria			
Asset Class	Type of Unexpected Inflation [SR, LR]	Score	Notes
COM	LR	++	
CSHF	LR	--	
EMBAG	LR	+	
FTNA	LR	+	*Positive for both STUI and LTUI in the LR, though only the former is signficant.*
G	LR	--	
GCEU30	LR	+	*Positive for both STUI and LTUI in the LR, though only the latter is signficant.*
INF10	LR	-	*Negative for both STUI and LTUI in the LR, though only the former is signficant.*
ML_CEU	LR	+	
MSEM	LR	--	
MSW	LR	+	*Negative LTUI and positive STUI in the LR, though only the latter is signficant.*
SE6	LR	--	*Strong negative LTUI and STUI in the LR, though only the former is significant.*
SEPE	LR	++	*Positive coefficients for STUI and LTUI, though only the latter is signficant.*

In conclusion, long-run equilibria are not all dominated by long-run inflation risk. Indeed, the sensitivity and level of cointegration seems largely dependent on the asset class studied. Thus, by taking these propagation pathways into account when making an investment decision, one can partially hedge against unanticipated inflation in the long-run by tilting the portfolio towards particular asset classes. Nevertheless, based on the results in Table A9.5, one can ascertain that the long-run equilibrium level does not converge on long-run inflation and hence does not fully insulate investors from unanticipated inflation. In the wake of these results the second hypothesis was partially rejected. COM and SEPE provide the best insulation from unanticipated long-run inflation according to the VECM long-run equilibria summary.

The final hypothesis states that:

Hypothesis 3: There exists perfect symmetry between disinflation- and inflation-based betas for unanticipated inflation over the entire time period studied, ergo inflation betas are time-invariant.

Concisely, the hypothesis postulates that unanticipated inflation betas are time-invariant by nature. Table A9.6 on the next page summarizes findings based on the Rolling DOLS Method that pertains to the question of unanticipated inflation beta time-invariance. Section V, Part 8 of the Appendix contains graph-based rolling DOLS results, whilst Table AA8.39 depicts STUI between January 1990 and September 2016. Together they illustrate the time-based propagation of unanticipated inflation betas and prove that the time-invariance assumption does not hold water. Indeed, asset classes appear to respond in dissimilar ways to periods of inflation and disinflation. Furthermore, for most asset classes inflation betas are only significant for particular time periods. As one can observe, for certain asset classes the magnitudes of the STUI and/or disinflationary dummy variable*STUI coefficients are negligible. Only G and CSHF provide a measure of protection against short-term unexpected disinflation.

Based on the results I can ascertain that it is imperative to know in advance whether we are likely to face disinflation or inflation over the medium term. Similarly, one must know whether to (partially) hedge against inflation or disinflation in combination with the expected inflation regime in order to gauge the likely effect of a change in unanticipated inflation. The sign of the dummy-based STUI coefficients largely hinge upon the current inflation regime, i.e. intermediate inflation expectations. Furthermore, coefficients of any type of unanticipated inflation/disinflation are only significant when strong, contrary movements occur, i.e. when inflation exhibits a prolonged movement contrary to expectations. Furthermore, with the exception of COM, all asset classes have shown increased sensitivity to unanticipated inflation ever since the Credit Crisis (and thus retained their relevance during the Sovereign Debt Crisis).

Table A9.6 ***Rolling DOLS Summary***

Rolling DOLS			
Asset Class	**Type of Unexpected Inflation**	**Score**	**Notes**
COM	STUI	**+/-**	
	dum_def*STUI	**-**	
CSHF	STUI	**+/-**	*STUI<0 worsened in recent years.*
	dum_def*STUI	**+/-**	*Good during STUI<0, though declining in recent years. Bad during STUI>0.*
EMBAG	STUI	**0**	*Negligible*
	dum_def*STUI		
FTNA	STUI	**+**	*During the Credit Crunch, a strong negative dum_def*stui coefficient mitigated the adverse impact. Beware of adverse impact propagation.*
	dum_def*STUI	**-**	
G	STUI	**0/-**	*Sporadic signficance.*
	dum_def*STUI	**+**	*Completely reverses impact of negative STUI, though dampens postive STUI effect.*
GCEU30	STUI	**0**	*Negligible*
	dum_def*STUI		
INF10	STUI	**0**	*Negligible*
	dum_def*STUI		
ML_CEU	STUI	**0**	*Negligible*
	dum_def*STUI		
MSEM	STUI	**+**	
	dum_def*STUI	**-**	
MSW	STUI	**+**	
	dum_def*STUI	**-**	
SE6	STUI	**+/-**	
	dum_def*STUI	**-**	
SEPE	STUI	**+/-**	
	dum_def*STUI	**-**	

As evidenced by the Rolling DOLS Summary and Graphs pertaining to the DOLS in Section V of the Appendix, disinflation and inflation betas pertaining to unanticipated inflation do not exhibit consistency over time. They exhibit wild fluctuations and are oft only statistically significant during periods of severe economic turmoil (sporadic significance of unanticipated (dis-)inflation betas). Thus the third hypothesis pertaining to the theoretical time-invariant nature of inflation betas was soundly rejected. Concisely, only COM, G and CSHF provide a reliable measure of protection against short-term unexpected (dis-)inflation according to the rolling DOLS results.

Compendiously, the three main conclusions are:

1. Commodities and Real Estate provide relatively consistent results in terms of insulation from unanticipated inflation risk in the short run. Nevertheless, beware of the over-/undershooting phenomenon ere the new equilibrium level is attained.
2. The long-run equilibrium levels of Commodities and Private Equity are largely dominated by their positive relationship with unanticipated inflation. Private Equity has a near 1-for-1 relationship with LTUI and a high degree of covariance with STUI in the long run. Commodities has a strong, positive relationship with STUI that persists into the long-run.
3. Only Gold, Commodities and Hedge Funds provide a measure of protection against short run (dis-)inflation when one allows for time-varying inflation betas. Gold dampens the effect of negative STUI, though also hampers upside potential in the wake of positive STUI. Similarly, CSHF performs well during periods of sub-zero STUI and underperforms during periods of positive STUI. Commodities exhibits a relatively time-invariant unanticipated inflation beta that is close to one-for-one with STUI. Thus, COM returns rise concurringly with positive unanticipated inflation in the short run, but also fall during times of deflation.

Section 9.2 shall explicate the current inflation risk policy ABP adheres to, prior to establishing the overarching conclusion of this thesis and its implications wrt. policy recommendations.

9.2 Policy Implications

The provision of insurance against wage- or price inflation based on intergenerational risk sharing is one of the raison d'êtres of DB pension funds[75]. A supervision framework called the nFTK (Financial Assessment Framework) focuses on market valuation of investments and liabilities and endeavours to secure the Dutch pension fund system by adopting risk-based solvency

[75] Ponds, E.H.M., (2003).

requirements, increased regulatory capital buffers, utilizing the Ultimate Forward Rate (UFR) method for market funding ratios and a separate policy coverage ratio[76] for determining indexation and benefit curtailment. Nevertheless, many pension funds have deemed these market-/risk-based requirements too strict as chronic underfunding results in light of the protracted period of extremely low interest rates. The nFTK essentially induces pension fund sponsors to alter the pension contract, i.e. reduce guarantees or switch to DC schemes.

Currently, ABP does not adhere to an explicit (strategic) inflation-hedging policy. The inflation duration reduction is measured and reported, though it does not function as a direct target. If the investment portfolio does not adhere to the desired inflation sensitivity, this is amended via an inflation overlay, i.e. primarily inflation swaps (OTC linear form of an inflation derivative). Conversely, inflation-related investments tend to mitigate inflation risk, but increase the mismatch risk vis-à-vis nominal pension liabilities. Furthermore, inflation risk mitigation is also costly due to the inflation risk premium, though it remains difficult to quantify. Nevertheless, as interest rate sensitivity/risk grew, inflation hedging levels were reduced to 8%, which is well below the previous STIPs (Strategic Investment Plan, ABP) indicated intention.[77] However, another method of inflation risk mitigation that ABP adheres to is via investing in both nominal and real asset classes, the former tends to be a (partial) natural hedge against expected inflation only, whilst the latter tends to exhibit concurrent positive movements with inflation pathways in the long run. Supposedly, real asset classes partially insulate the pension fund from unanticipated inflation risk. Currently, this form of protection derived from asset class selection is not explicitly accounted for under ABPs inflation protection measurements.

The following paragraphs contain the main conclusion of this thesis as well as an explanation of the policy implications for ABP. Based on the conclusions in Section 9.1, the overarching conclusion is that:

> Commodities and Private Equity are strongly concurrent with STUI and LTUI respectively in the long-run. Short-run inflation risk insulation is provided by Commodities and Real Estate, despite over-/undershooting. Under time-varying short-run inflation betas, Gold

[76] Policy coverage ratio is based on the average funding over the previous 12 months.
[77] ABP Strategic Investment Plan 2016-2018, (2015).

and Hedge Funds are “defensive”[78], whilst Commodities is equivalent to a “positively skewed, but risky bet”[79] as it exacerbates the magnitude of STUI.

Concisely, the general policy recommendations for the implementation of a coping mechanism for unanticipated inflation risk by ABP can be summarized as follows. Firstly, if one wishes to establish an unanticipated inflation risk framework at ABP then one must accurately trace the dynamic interactions betwixt selected asset classes and unanticipated inflation variables in order to capture the inherent long-run cointegration and short-run error corrections that can serve as model inputs. Secondly, due to the time-varying nature of unanticipated inflation betas and the persistence of short-run effects of unanticipated inflation changes into the medium-term, periodically verify the changes in short-run (dis-)inflation betas that hinge upon the inflation regime, i.e. negative or positive STUI. Thus, time-invariance cannot be used as an (implicit) model assumption when coping with unanticipated inflation. I can firmly ascertain that whilst unanticipated inflation does play a major role in determining the equilibrium level of asset classes, an important distinction must be made between short-term and long-term unanticipated inflation. Furthermore, whilst virtually all asset classes do converge towards long-run equilibria dominated by unanticipated inflation, not all (real) asset class returns exhibit a positive concurrent movement with inflation. For example, Hedge Funds, Gold and Emerging Equity all seem to have negative long-run relations vis-à-vis long-term unexpected inflation. Thus one policy implication is that the sign and magnitude of the long-run cointegrating relationship between the asset class in question and (unanticipated) inflation propagation must be taken into account.

Furthermore, certain asset classes implicitly carry insulation from unanticipated inflation in the short run, e.g. Commodities, Emerging Markets Equity (STUI only), Global Equity (STUI only) and Listed Real Estate (adjusts to ΔSTUI equilibrium slowly). Nevertheless, the overshooting phenomena is widespread amongst the asset classes, for STUI in particular. If LTUI rises suddenly during a period of falling long run inflation expectations (portrayed by neg_dum*LTUI), then the best asset classes to invest in with respect to short-run inflation risk insulation are Commodities, Private Equity and Global Equity in the very short-run as it the latter

[78] Outperform during periods of negative STUI and underperform during periods of positive STUI.

[79] Neigh on 1-for-1 positive relationship with positive STUI, though also a relatively positive relationship with negative STUI, i.e. coefficient between 0.14 and -0.01.

dips into negative territory after only 4 months. Minor inflation hedges following an inflation shock are provided by Gold, Hedge Funds and European Stock Markets. Negative impact of unanticipated inflation during a period of falling inflation expectations is exacerbated by Emerging Markets Equity, Global Equity (after the 4th month marker) and Real Estate. Thus one must take into account the altered relationship between asset class returns and unanticipated inflation in the wake of sudden inflation spikes (or inflation regime switches). Conversely, Commodities and Private Equity appear to be excellent natural hedges against unanticipated inflation of any kind.

A third policy implication is derived from the fact that disinflation and inflation betas are neither perfectly symmetric nor identical. Rather, they tend to exhibit wildly fluctuating coefficients over time and are only sporadically significant. Nevertheless, disinflation and inflation betas that display the highest degree of symmetry are found in the following asset classes: Listed Real Estate and Emerging Markets Equity. Thus regardless of whether the economy faces inflation or disinflation, these two asset classes insulate the pension portfolio best. The following asset classes also displayed relative symmetry, though the magnitude of (dis-)inflation betas was negligible, i.e. Emerging Markets Bonds, 10 year Inflation Linked EU Government Bonds and 20-30 year EMU Government Bonds. Thus the policy implication is that one cannot operate from the assumption that inflation betas are static for any length of time, their time-invariant nature makes them a mercurial hedge against unanticipated short-term inflation. Nevertheless, keep in mind that short-run unanticipated inflation betas have shown greater statistical significance since 2006 and may continue to play a part for as long as market uncertainty remains.

As a last thought, despite the fact that protracted lowflation or even mild deflation can be relatively benign in the short-run (positive supply-side shock)[80], the paradox of aggregation and the uncertainty that arises due to continually missing inflation targets and/or expectations can drive a wedge between asset class return propagation pathways and their underlying fundamentals. In that situation a disinflationary self-fulfilling prophecy wreaks havoc on the economy via a cascading series of debt defaults and anaemic economic growth. Continued QE stimulation by the ECB indirectly fuels speculative bubbles in the equities domain as short- and long-term interest rates remain artificially depressed. Furthermore, current ECB actions have led to an agentic shift whereby governments in the EU no longer feel responsible for implementing structural reforms, i.e. diffusion of responsibility paired with what is reminiscent of a legal strategy referred to as the

[80] Exempli gratia, falling commodity prices, oil in particular, can stimulate economic growth.

Nuremberg defence. Similarly, excess liquidity that has been pumped into the market is not a panacea for weaker euro countries as producers, investors and consumers alike have remained on the fence and refuse to invest and/or spend. Concisely, unless internal demand is strengthened and confidence is restored in the markets, the European 'malaise' remains a self-perpetuating phenomenon that puts institutional investors, like large pension funds, into a proverbial deadlock.

10. Suggestions for Future Research

This final section contains suggestions for future research. The first subsection, 10.1, concerns the adaptation of the Monte Carlo Simulation Method. The second subsection, 10.2, explicates the use of Adaptive Wave Models and 'wave packets' to help forecast/emulate inflation risk propagation pathways whilst accounting for the dynamic interaction with asset classes.

10.1 Monte Carlo Simulation

Monte Carlo Simulations draw samples from a predetermined probability distribution for each regressor in order to produce a surfeit of potential outcomes. One could keep certain (risk factor) assumptions fixed, e.g. interest rates, projected time, returns on cash and other securities etc., except for the inflation rate assumption. In this case, each type of inflation and associated set of economic scenarios can be paired with a different type of indexation ambition, e.g. real, nominal or hybrid. Hybrid indexation ambition is henceforth referred to as Defined Ambition, which consists of Defined Benefit elements like conditional indexation targets, whilst it also allows for individual benefits adjustments (e.g. Defined Contribution plan element). As the MCS is based on the generation of manifold 'trials' to determine the expected value of a 'random walk' variable, the Cov/Var Matrix can be amended to reflect long-run equilibrium relationships uncovered by the research conducted in this thesis. However, as MCS oft fails to capture tail risk events a supplemental Tail Value at Risk model would have to be utilized to trace potential impact of so-called 'bad weather' scenarios.

10.2 Adaptive Wave Models/Infinite Quantum Wells

Personally I would like to opt for a method based on the consilience between two disciplines, i.e. financial economics and quantum physics. This method lends itself well if one wishes to incorporate the effect of financial derivatives as it concerns a financial contract whose value is based on the performance of an underlying entity, e.g. asset, index, interest rates etc. However, I daresay one could potentially incorporate (unexpected) inflation risk as the underlying driver of value so that asset returns resemble financial derivatives based on underlying inflation risk. The line of inquiry (with respect to derivatives) has thus far been limited to time-invariant models based on Schrödinger's and Hamilton's equations. As most models of quantum physics involve temporally-fixed potential fields, the assumption of time-independence is a natural starting point.

To illustrate I shall start with a familiar subject, the Black-Scholes Model (BSM). The Black-Scholes model (BSM) was devised to describe the time-evolution of European-style call and put options. European options may only be exercised at a pre-specified maturity date, unlike American-style options which may be exercised at any time up to and including maturity. American and Asian options must be ignored as there is no specific formula that leads to a closed-end solution, only price approximations including the Roll-Geske-Whaley model and the Black approximation. The BSM works for path-independent options whereby the payoff structure solely depends on the underlying security's value at its expiration date. The BSM also adheres to the following conditions:

Black-Scholes Conditions

- No arbitrage opportunities
- Borrowing and lending occur at the same risk-free rate (R_f)
- No transactions costs
- No restrictions placed on buying, selling or short-selling
- Constant implied volatility (σ)
- Non-negativity constraints/terminal conditions: $C(S,t) \to 0 \ \ if \ \ S \to 0$
  $C(S,t) \to \infty \ \ if \ S \to \infty$
  $C(S,T) = \max[0, S - K]$
- Put-Call Parity Condition
- No dividends
- Geometric Brownian Motion (explicated below)

The starting point of the BS model is the following partial differential equation(PDE):

$$\underbrace{\frac{\partial V}{\partial t}}_{\text{I}} = \underbrace{rV}_{\text{II}} - \underbrace{rS\frac{\partial V}{\partial S}}_{\text{III}} - \underbrace{\frac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2}}_{\text{IV}}$$

I. Time decay; change in derivative value due to the passage of time.

II. Risk-free return from a long position in the financial derivative.

III. Return on a short position consisting of $V's$ shares (of the underlying).

IV. Second spatial derivative that denotes the level of convexity with respect to the value of the underlying asset, essentially the gain of holding the derivative.

Essentially the BS PDE is analogous to the diffusion equation of atoms, i.e. density dynamics based on the net movement of a particle from high to lower regions of concentration. The difference is that we assume that the underlying asset of the derivative follows a geometric Brownian motion based on the drift (μ) and volatility (σ). Geometric Brownian motion (GBM) was originally postulated by Einstein (1905) to explicate the apparent randomness of small particles suspended in a solute. It follows a Wiener-process[81] with drift, which is based on the continuous-time stochastic process of Levy, whereby the probability distribution is standard normal. According to a plethora of research papers, the percentage drift (μ) captures deterministic trends aptly. The GBM can be expressed as follows:

$$dS(t) = \mu S(t)dt + \sigma S(t)dW(t)$$

By employing either the Itö's Lemma method or the Fokker-Planck and Langevin equations one can derive the Black-Scholes partial differential equations. The formula for the price of a European call option then becomes:

$$C(S,t) = SN(d1) - Ke^{-r(T-t)}N(d2)$$

$$d1 = \frac{1}{\sigma\sqrt{T-t}}[\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)(T-t)]$$

$$d2 = d1 - (\sigma\sqrt{T-t})$$

Whereby the normal distribution is given by:

$$N(x) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{x} e^{-\frac{z^2}{2}}\,dz$$

Where $z = \frac{(x-\mu)}{\sigma}$; this holds for any further notation of z.

In order to transform the standard normal distribution into a generic cumulative normal distribution with $\mu \neq 0$ and constant σ, we may utilize the Cumulative Density Function (CDF) usually denoted by Φ.

$$\Phi(z) = \frac{1}{2}(1 + \mathrm{erf}\left(\frac{z}{\sqrt{2}}\right))$$

The CDF is a good indicator of the probability that a random sample from the population in question will take a value of equal to or less than z. The erf-term is a Gauss error function which indicates the probability that any given measurement is less than x-distance away from μ. If we

[81] Wiener process: continuous-time stochastic Lévy process that forms the basis of Feynman's path independent integrals. Certain Schrödinger Equation solutions can also be modulated as a wiener process with drift.

assume that $erf(y) = \mathrm{erf}\left(\frac{z}{\sqrt{2}}\right)$ then we know that $(y) = \frac{2}{\sqrt{\pi}}\int_0^y e^{-t^2}\,dt$. The integration of the Gaussian kernel is imperative for later proof of orthonormality[82] of quantum states under a one-dimensional wave function in an infinite square well, as we will be required to use the Dirac-δ and the associated Kronecker-δ. Similarly, the Probability Density Function (PDF) indicates the probability that a random continuous variable takes on the value of z.

$$f(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}z^2}$$

The PDF concept will return when calculating the Schrödinger equation under a Hamiltonian Operator in Hilbert Space. Compendiously, the main fallacies of the model are based on the assumptions that volatility is constant and that returns are normally distributed. In order to solve this short-coming one must utilize an Adaptive Wave Model, which is a highly intricate alternative based on constrained Brownian Motion involving amendments for types of Schrödinger Equation. The continuous quantum model is an extension of Wave-Particle Dualism, which occurs when particles propagate themselves as if they were waves. Thus, the particle is taken to be the underlying inflation risk, as the underlying displays corpuscular properties such as momentum and divisibility. Under the original BS-Model, volatility (σ) was taken to be a constant term, however under the quantum wave-function model it is taken to be stochastic by nature. Stochastic volatility means state variables such as inflation propagation pathways, long-run reversion to the mean and the passage of time, all have an impact on the implied volatility. This is a necessity as it enables us to explicate the phenomena of a "volatility smile" (implied volatility is high if $K \to 0$ (in-the-money) $or\ K \to \infty$ (out-the-money), while being significantly lower for strike prices 'at-the-money' and "volatility skew" where implied volatility rises as $K_0 \to \infty\ (OTM)$. Something the BS-model cannot account for. The use of Schrödinger equations (SE) tends to be superior due to its nonrelativistic nature (particle propagation $<$ speed of light). Alternatively one can resort to the Maxwell equations, which are geared towards relativistic particles, i.e. they obey the laws of special and general relativity. Note here that a Hamiltonian operator can be used to approximate

[82] Orthonormality: The normality of a wave function means that the integral of the probability density function is equal to 1, i.e. the probability of finding the particle is equal to 1: $\int ||\Psi(x)||^2 dt$. Simultaneously, each of the wave functions must be orthogonal to one another, i.e. the observables are denoted as linear Hermitian operators and hence each eigenstate of the sub-wave function must necessarily have a separate eigenvalue: $\int \varphi_i\ \varphi_j dx = 0$ as long as $i \neq j$.

relativistic particles, but cannot be seen as equivalent. Thus, SE is the preferred choice for adaptive wave models in the financial sector. Indeed, according to Haven (2002), the BS model is naught more than a special case of the Schrödinger equation where financial markets are assumed to be efficient and implied volatility is constant. The time-dependent SE will give an accurate description of the quantum states' time evolution and hence the behaviour of the wave model. Utilization of a time-dependent linear Schrödinger Equation for price evolution ensures that the wave-function initially adheres to the Composition Principle or the Quantum Superposition Principle. In this case, the square of the absolute value of the wave-function will be derived from the sum of all possible states and associated state coefficients, i.e. a linear summation of the probabilistic value the stock would have taken in a quantum state in isolation (ceteris paribus). As long as the condition of linearity holds, then the quantum wave function will have a direct solution. The time-dependent state vectors under a SE can thus be transformed into the related Heisenberg Uncertainty Principle. Heisenberg's uncertainty principle (HUP) postulates that the precision with which pairs of physical quantities can be approximated simultaneously, is constrained by a fundamental limit. It is important to note that the uncertainty principle is present in all structures and systems that represent wave-like propagation under quantum states. Formally the HUP is represented as follows:

$$\sigma_\rho \sigma_x \geq \frac{\hbar}{2}$$

Here σ_ρ is the standard deviation of momentum of the underlying, and σ_x is the standard deviation of the position of the underlying. ħ is Planck's reduced constant which indicates the quantization of angular momentum, e.g. the rotational inertia inherent in a field of stocks when they are in motion (when inflation rates or inflation expectations are being altered/manipulated). The HUP indicates the existence of a trade-off, i.e. by adding an increasing number of plane waves we can gauge the position of the underlying with greater precision (σ_x reduction); nevertheless the accuracy of measuring 'momentum' also declines (σ_ρ rises). The standard deviations of momentum and position are calculated using the absolute square of the adaptive wave model $|\Psi(P,t)|^2$.

A Hamiltonian operator is a quantum mechanics operator that derives the system's total energy from the potential and kinetic energy. Potential energy is contained within the spatial configuration of a particle. In this case, the underlying stock. Whilst kinetic energy refers to motion-based energy. Hilbert space surpasses two-dimensional (Euclidean) and three-dimensional states by extending it to contain any number of finite or infinite dimensions. Thus it lends itself as a tool to modulate a wave operator that describes the quantum states inherent in a system. In laymen's terms it provides a framework or vantage point from which to start. The quantum states of the wave operator can be outlined in their most abstract form using the Bra-Ket notation, also referred to as the Dirac notation: $|\Psi> = \sum_n (C_n \, |\varphi_n>)$.

Where $|\Psi>$ is explicated as the state vector of the wave operator, denoted by the Ket-notation, whilst the right-hand side indicates the summation of each quantum state and its associated probability coefficient. Thus $|\varphi_n>$ indicates the possible state of the stock micro-system, while C_n is the coefficient of each state which in turn is equal to $<\varphi_n|\,\Psi>$, e.g. the probability amplitude that unanticipated inflation risk will be found at position/quantum state φ_n. Essentially it forms a scientific algorithm that can yield all possible values of Ψ, within the boundary conditions. $<\varphi_n|$ is also referred to as the Bra-connot ation and indicates the final state of inflation risk. Concisely, the probability density of finding the stock at position φ_n in the state vector of Ψ can be denoted by taking the absolute square of the probability amplitude function, e.g. $|<\varphi_n|\,\Psi>|^2$. Thus we know a specific state, for example state 1, will occur with probability $\rho_{\varphi_1} = (C_1)^2$.

For the sake of completeness, we assume that all quantum states are fully represented by the wave operator (Ψ) and thus the summation of all probabilities must equal 1: $\sum(\rho_{\varphi_n}) = 1$. Here the assumption of time-dependency comes into play as the probability density of inflation risk (π_u) at time t can be expressed thusly: $|\Psi(P,t)|^2$. Note that the exact probability of finding inflation risk in-between a and b can be found by solving the following integral:

$$\rho_t = \int_a^b |\Psi(P,t)|^2 dp$$

Furthermore, one could utilize an infinite square well with multiple particles, e.g. expected and unexpected inflation. To illustrate the principle I have outlined the beginnings and main properties of a simple one-dimensional quantum well with only one underlying. The following boundary conditions necessarily apply:

$$Potential\ V(x) = \begin{cases} 0, & 0 \le x \le a \\ \infty, & x < 0 \ \ or \ \ x > a \end{cases}$$

If we rely on the assumption that the potential energy V(x) is equal to zero within the boundaries, we negate the forces that act inflation risk solely based on the position in the well. The time-dependent SE for a single non-relativistic particle in the one-dimensional square well if $Potential\ V(x) = 0$, is equal to:

$$\iota\,\hbar \frac{\partial \Psi(x,t)}{\partial t} = \frac{-\hbar^2}{2m}\frac{\partial^2 \Psi(x,t)}{\partial x^2} = E\Psi(x,t)$$

Energy of the particle then is taken to be equal to:

$$E = \hbar\omega = \frac{\hbar^2 k^2}{2m}$$

Where: $k = \frac{\sqrt{2mE}}{\hbar}$

$\omega = \frac{\hbar k^2}{2m}$

$\hbar = \frac{h}{2\pi}$; h is merely Planck's Constant

Plug k into the ω-formula to arrive at $\omega = \frac{E}{\hbar}$.

ω is the angular frequency, e.g. the angular displacement per unit of time; m is the mass of the particle and k is the spatial frequency of a wave, e.g. how many cycles per unit of distance.
Similarly, assume that the wave function propagates itself through the time-space dimension inside the well as if it were a free particle. As the particle is isolated within the walls of the infinite square well, the potential energy is time-independent. In turn, the Hamiltonian operator must necessarily also be time-independent despite the presence of time-dependent features (SE). If these conditions are met, then the Hamiltonian can be separated into its time-dependent [*f(t)*] and spatial configuration [$\psi(x)$] part.

$$\Psi(x,t) = \psi(x)f(t)$$

The time-dependent part can be retrieved from the time-dependent SE.

$$\psi(x)\iota\,\hbar \frac{\partial f(t)}{\partial t} = f(t)\psi(x)\left[\frac{-\hbar^2}{2m}\frac{\partial^2 f(t)\psi(x)}{\partial x^2}\right]$$

$$\frac{\iota\,\hbar}{f(t)}\frac{\partial f(t)}{\partial t} = E \ \text{[standard solution}$$

As this constitutes a free particle (V=0), then the only finite solutions, i.e. within the fixed boundary conditions, can be found provided that E is positive. If E is positive, then it exhibits an oscillatory nature that requires Euler and can be described as follows:

$$\Psi(x,t) = \psi(x)f(t) = [A\sin(kx) + B\cos(kx)]e^{-ti\omega}$$

By using the spatial configuration $[\psi(x)]$ in conjunction with the boundary conditions of the potential well we can then gauge the spatial frequency of a wave (k). At the left boundary $(x = 0)$ and at the right boundary $(x = a)$. This translates as $\Psi(0) = \Psi(a) = 0$.

If $\Psi(0) = 0$, then:

$$A\sin 0 = 0$$
$$B\cos 0 = B$$

Thus B = 0.

If $\Psi(a) = 0$, then:

$$A\sin(ka) = 0$$
$$B\cos(ka) = 0$$

For $A\sin(ka)$ to be equal to zero, its inner product (ka) must be equal to zero. Thus, a sinusoid of the form $sin(ka)$ is always equal to zero as long as its inner product is equal to a multiplication of π, thus one can conclude that:

$$ka = c\pi$$
$$k = \frac{c\pi}{a}$$

Naturally, the floor of the quantum well could eventually be 'tilted' in order to reflect inherent skewness of the underlying inflation risk. Furthermore, one can start to incorporate 'moving' well walls and the impact on the 'velocity' or momentum of inflation risk propagation pathways, speed of divergence etc.

This simple example illustrates the versatility of Adaptive Wave Models. As not much research pertains to this area it would be a fruitful, if not challenging, academic pursuit.

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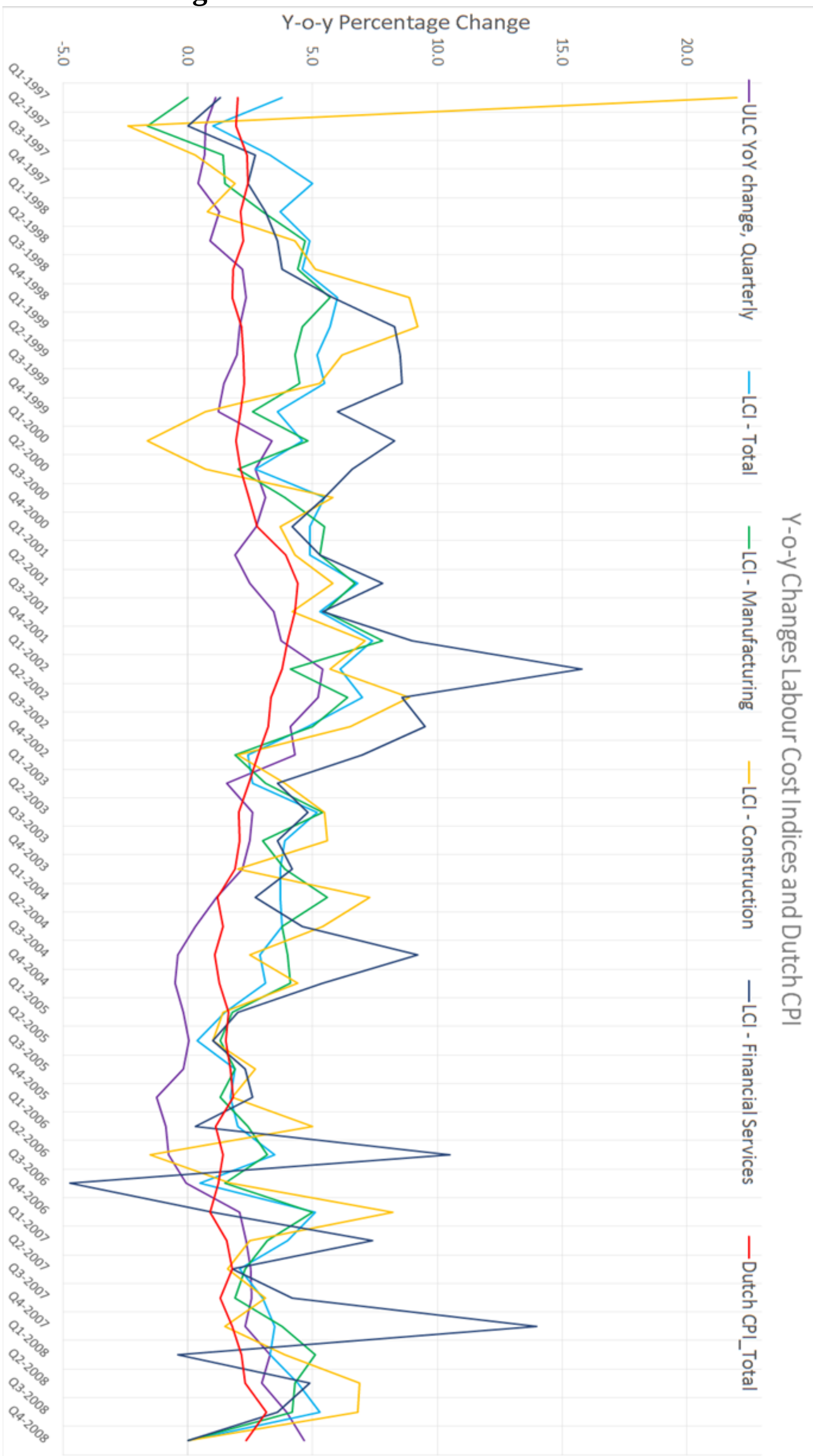
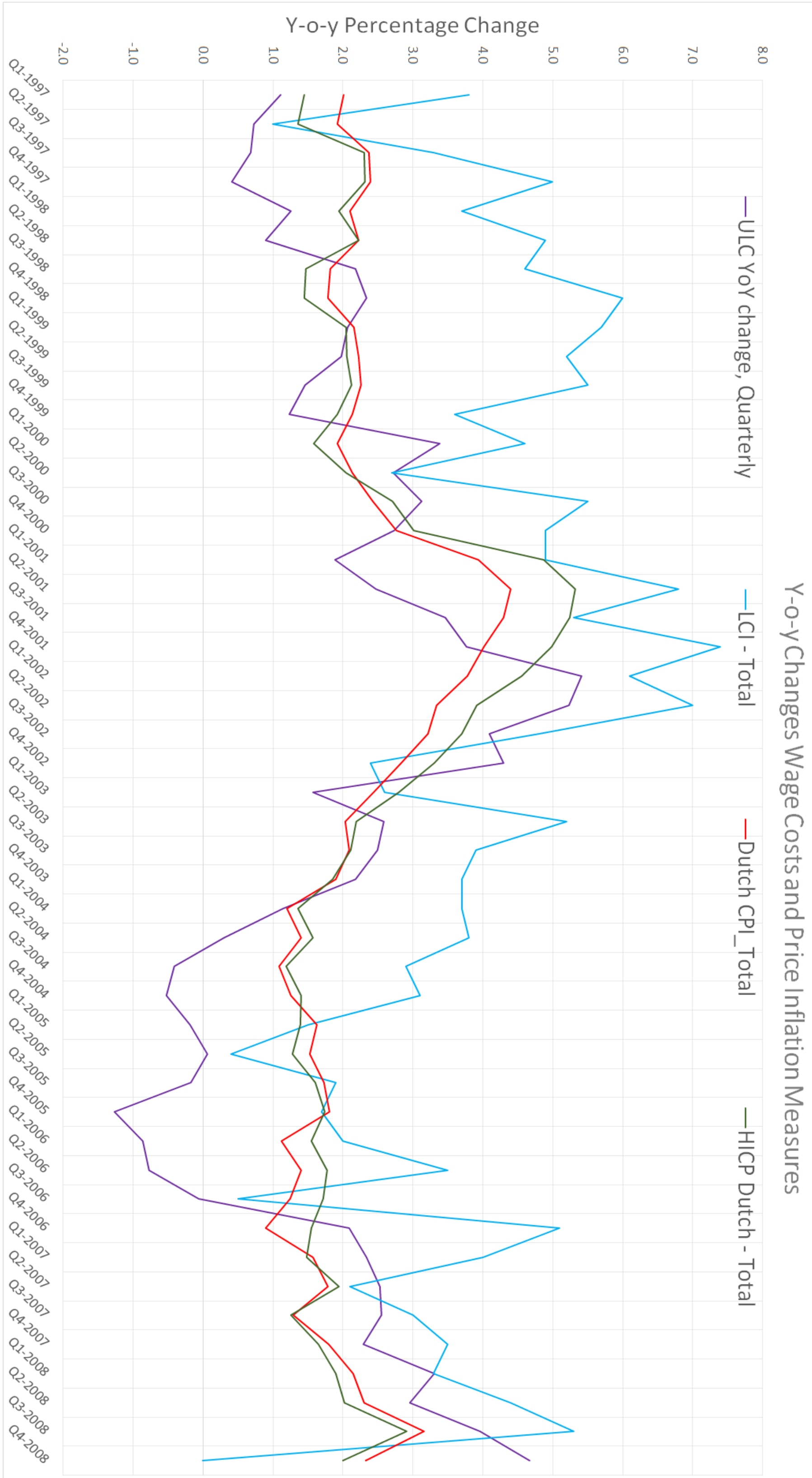
APPENDIX

Section I: *Extraneous Graphs and Tables of Section 5 – Inflation Measures*

Graph AA5.5: **Y-o-Y Change Labour Cost Indices and Dutch CPI**



Graph AA5.6: **Y-o-Y Change Wage Costs and Price Inflation Indices**



Section II: Data Sources

Table AA6.2 Data Sources Asset Classes

Asset Class [Broad]	Asset Class [Specific]	Index	Eviews Symbol	Frequency	Source/Database
Equity	Developed	S&P500		Monthly	Datastream
		STOXX EUROPE 600	SE6	Monthly	Datastream
	Emerging	MSCI Emerging Equity Index	MSEM	Monthly	Datastream
	Global	MSCI World Index	MSW	Monthly	World Bank Database
FIXED INCOME SECURITIES	Sovereign	US 1Y Tbill		Monthly	Federal Reserve Economic Database [FRED]
		NL 10Y Govt Bonds		Monthly	De Nederlandsche Bank
		EMU 10Y Govt Bond Index		Monthly	Bloomberg
		EMU 20-30Y Govt Bond Index	GCEU30	Monthly	Datastream
	Corporate	Moody's Aaa		Monthly	Federal Reserve Economic Database [FRED]
		Moody's Baa		Monthly	Federal Reserve Economic Database [FRED]
		Merrill Lynch EMU Corporate Bond Index	ML_CEU	Monthly	Datasream
		Bloomberg Barclays Euro Aggregate Corporate Index		Monthly	Bloomberg
		Bloomberg Barclays Pan-EU High Yield Bond Index		Monthly	Bloomberg
		Bank of America Merrill Lynch EU High Yield Bond Index		Monthly	Bloomberg
	Emerging	Bloomberg Barclays Emerging Markets Aggregate Fixed Income Index	EMBAG	Monthly	Bloomberg
		Bloomberg Barclays Emerging Markets Investment Grade Bond Index		Monthly	Bloomberg
	Inflation-Linked	Barclays Inflation-Linked Government Bond All Maturities Index		Monthly	Bloomberg
		Bank of America Merrill Lynch Index-Linked EU 10 year Government Bond Index	INF10	Monthly	Bloomberg
		US 10Y Treasury Inflation-Protected Securities (TIPS)		Monthly	Federal Reserve Economic Database [FRED]
ALTERNATIVES	Hedge Funds	Barclays Hedge Funds Index		Monthly	Datastream
		Credit Suisse Hedge Funds Index	CSHF	Monthly	Bloomberg
	Private Equity	STOXX EU Private Equity Index	SEPE	Monthly	Bloomberg
		Thomson Reuters Private Buyout Index		Monthly	Datastream
	Real Estate	FTSE NAREIT Real Estate Composite Index	FTNA	Monthly	Datastream
		MSCI Europe Real Estate Index		Monthly	Datastream
	Commodities	Gold Spot	G	Monthly	World Bank Database
		IMF All Commodities		Monthly	International Monetary Fund
		LB Crude Oil		Monthly	Datastream
		GSCI Commodity Index	COM	Monthly	Datastream
		Thomson Reuters/ CoreCommodity CRB Commodity Index		Monthly	Datastream

Table AA6.3 **Data Sources Risk Proxies and Rates**

Type	Category	Name	Eviews Symbol	Frequency	Source/Database	Construction/Notes
Risk Proxies	Spreads	Credit Spread	CSPREAD	Monthly	N/A	Moody's Seasoned Baa Corporate Bond Yield - 10y Govt Bond Yield
		Market Spread	MSPREAD	Monthly	N/A	Moody's Baa - Moody's Aaa
		Term Spread	TERM	Monthly	N/A	10Y Govt Bond Yield - 1M Euribor Rate
		Ted Spread	TED	Monthly	N/A	3M T-bill - 3M Euribor
	Other	Dividend Yield Stoxx Europe Index	DY	Monthly	Datastream	
		Volatility Index CBOE	VIX	Monthly	Federal Reserve Economic Database [FRED]	
Rates	Interest Rates	Long-Term Interest Rate EMU	LT_IR EMU	Monthly	Deutsche Bundesbank	
		1M Euribor		Monthly	Eurostat	Prior to 1994 the AIBOR
		3M Euribor		Monthly	Eurostat	Prior to 1994 the AIBOR
		US 3M T-bill Rate		Monthly	OECD	
		US 10Y T-bill Rate		Monthly	OECD	
	Inflation	Dutch CPI Inflation Rate	NL_CPI	Monthly	Central Bureau of Statistics (CBS)	
		Dutch HICP	HICP-Dutch	Monthly	Eurostat	
		HICP Excluding Tobacco	HICPxT	Monthly	Eurostat	
		Short Term Expected Inflation	STEI	Monthly	N/A	3 Month Moving Average
		Short Term Unexpected Inflation	STUI	Monthly	N/A	Dutch CPI - Short Term Expected Inflation
		Long Term Expected Inflation	LTEI	Monthly	N/A	Weighted Sixty Month Average and Implied 5-10 year Break-Even Euro Inflation Rate
		Long Term Unexpected Inflation	LTUI	Monthly	N/A	Dutch CPI - Long Term Expected Inflation

Section III: Descriptive Statistics

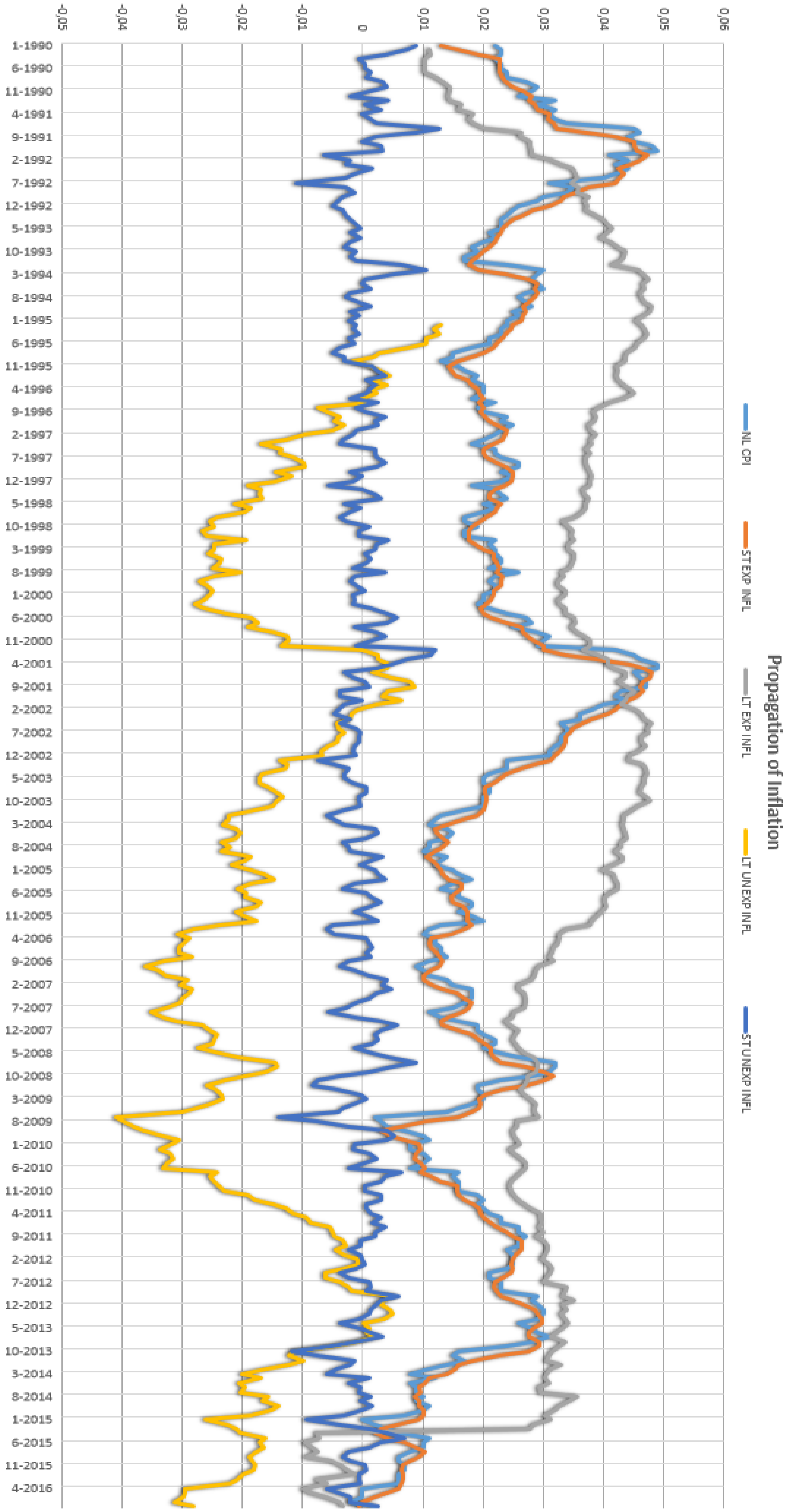
Preliminary Statistics – Part 1: *Rates*

❖ ***Table AA6.4:*** **Rates Descriptive Statistics**

Descriptive:	NL CPI	ST EXP INFL	LT EXP INFL	LT UNEXP INFL	ST UNEXP INFL	3M Tbill
Monthly Arithmetic Mean	0,180%	0,181%	0,270%	-0,128%	-0,001%	0,242%
Annual Arithmetic Mean	2,161%	2,168%	3,245%	-1,539%	-0,008%	2,909%
Monthly Geometric Mean	0,178%	0,179%	0,265%	-0,105%	-0,001%	0,237%
Annual Geometric Mean	2,135%	2,143%	3,180%	-1,265%	-0,008%	2,847%
Periods	320	320	320	319	320	313
Monthly Standard Deviation						
Arithmetic	1,010%	0,981%	1,244%	1,200%	0,349%	2,290%
Geometric	2,214%	2,127%	3,593%	1,798%	0,350%	3,484%
Annual Standard Deviation						
Arithmetic	3,500%	3,399%	4,309%	4,156%	1,209%	7,932%
Geometric	7,670%	7,367%	12,447%	6,230%	1,212%	12,071%
Median	2,100%	2,133%	3,395%	-1,756%	-0,033%	3,060%
Maximum	4,900%	4,800%	4,798%	1,302%	1,267%	7,900%
Minimum	-0,200%	-0,067%	-0,973%	-4,096%	-1,400%	0,010%
Skewness	0,504	0,570	-1,578	0,357	0,095	0,088
Kurtosis	0,452	0,424	2,880	-0,730	2,082	-1,292
Jarque-Bera	15,86	19,27	23,65	11,35	55,45	22,11
Probability	0.000361	0.000066	0.000000	0.003439	0.000000	0.000016

1MEuribor	3MEuribor	US 1Y Tbill	US 10Y Tbill	LT_IR EMU	EMU GOV 5Y	EMU GOV All Maturities	EMU 10Y GOV	NL 10Y GOV	US 10Y TIPS	EMU 20-30Y GOV	EMU 30Y AAA GOV
0,301%	0,309%	0,267%	0,398%	0,440%	0,391%	0,254%	0,440%	0,381%	0,098%	0,529%	0,263%
3,614%	3,703%	3,199%	4,771%	5,278%	4,695%	3,044%	5,278%	4,572%	1,178%	6,349%	3,162%
0,293%	0,300%	0,261%	0,388%	0,427%	0,380%	0,249%	0,427%	0,371%	0,097%	0,513%	0,259%
3,519%	3,605%	3,126%	4,654%	5,124%	4,562%	2,987%	5,124%	4,457%	1,168%	6,161%	3,109%
320	320	320	320	320	320	308	320	320	164	168	116
2,842%	2,803%	2,396%	1,881%	2,585%	2,793%	1,809%	2,585%	2,202%	0,935%	1,499%	1,242%
4,307%	4,344%	3,752%	4,725%	5,420%	5,061%	3,298%	5,420%	4,692%	1,427%	5,979%	3,148%
9,845%	9,711%	8,301%	6,516%	8,956%	9,674%	6,266%	8,956%	7,629%	3,240%	5,192%	4,302%
14,920%	15,049%	12,996%	16,369%	18,775%	17,532%	11,425%	18,775%	16,255%	4,943%	20,713%	10,904%
3,355%	3,399%	3,455%	4,720%	4,420%	4,133%	2,524%	4,420%	4,340%	1,415%	6,025%	3,219%
9,830%	9,820%	8,400%	8,890%	11,136%	11,115%	7,024%	11,136%	9,190%	2,890%	9,210%	4,947%
-0,370%	-0,298%	0,100%	1,500%	0,613%	-0,107%	-0,195%	0,613%	0,030%	-0,770%	3,870%	0,562%
0,515	0,524	0,090	0,136	0,678	0,697	0,557	0,678	0,175	-0,342	0,378	-0,364
-0,650	-0,620	-1,307	-0,827	-0,340	-0,128	-0,750	-0,340	-0,403	-0,968	-1,063	-0,920
19,80	19,81	23,14	25,98	25,98	25,98	23,12	25,98	39,21	96,43	11,90	66,96
0.000050	0.000050	0.000009	0.000002	0.000002	0.000002	0.000010	0.000002	0.140773	0.008057	0.002602	0.035159

❖ ***Graph AA6.5:* Inflation Rates Propagation**



Preliminary Statistics – Part 2: *Risk Proxies*

❖ *Table AA6.6 Risk Proxies Descriptive Statistics*

Descriptive:	Term Spread	Credit Spread	Market Spread	TED_Spread	DIVIDEND YIELD	VIX S&P500
Arithmetic Mean	1,663%	1,830%	0,962%	-0,857%	2,766%	1,583%
Geometric Mean	1,659%	1,821%	0,961%	-0,874%	2,764%	-0,199%
Periods	320	313	313	320	206	319
Monthly Standard Deviation:						
Arithmetic	0,972%	1,409%	0,407%	1,838%	0,595%	20,230%
Geometric	0,961%	1,400%	0,402%	1,889%	0,580%	20,417%
Median	1,603%	2,233%	0,880%	-0,663%	2,770%	-1,193%
Maximum	3,752%	5,014%	3,380%	2,025%	5,270%	134,571%
Minimum	-0,430%	-1,451%	0,550%	-6,690%	1,500%	-38,490%
Skewness	0,076	-0,646	3,099	-0,953	0,457	1,651
Kurtosis	2,239	3,239	4,239	5,239	6,239	7,239
Jarque-Bera	8,032	25,119	26,350	56,211	52,337	72,210
Probability	0,018	0,000	0,000	0,000	0,000	0,000
Observations	320	313	313	320	206	319

❖ *Table AA6.7 Within-Group Cross Correlation*

Cross Correlation: Within Same Group of Variables

	CREDIT_SPREAD	DIVIDEND_YIELD	MARKET_SPREAD	TED_SPREAD	TERM_SPREAD	VIX_S_P500
CREDIT_SPREAD	1	0,090	0,476	0,003	-0,373	0,009
DIVIDEND_YIELD	0,090	1	0,681	-0,464	0,228	-0,043
MARKET_SPREAD	0,476	0,681	1	-0,547	0,025	-0,038
TED_SPREAD	0,003	-0,464	-0,547	1	-0,012	-0,025
TERM_SPREAD	-0,373	0,228	0,025	-0,012	1	-0,099
VIX_S_P500	0,009	-0,043	-0,038	-0,025	-0,099	1

❖ *Table AA6.8 Confidence Intervals*

	Term Spread	Credit Spread	Market Spread	TED_Spread	DIVIDEND YIELD	VIX S&P500
Width either side	0,107%	0,157%	0,045%	0,202%	0,082%	2,228%
Actual Confidence Interval	[1,556% ; 1,770%]	[1,674% ; 1,987%]	[0,916%% ; 1,007%]	[-1,059% ; -0,655%]	[2,684% ; 2,848%]	[-0,645% ; 3,811%]

Preliminary Statistics – Part 3: *Asset Classes*

Table AA6.9 Asset Classes Descriptive Statistics

Averages	Descriptive:	S&P500	STOXX EUROPE 600	MSCI EM	MSCI WORLD
		Developed	Developed	Emerging	Global
0.582%	**Monthly Arithmetic Mean**	0.653%	0.468%	0.653%	0.379%
6.987%	**Annual Arithmetic Mean**	7.840%	5.620%	7.840%	4.551%
0.493%	**Monthly Geometric Mean**	0.564%	0.370%	0.471%	0.327%
5.916%	**Annual Geometric Mean**	6.769%	4.442%	5.650%	3.925%
	Periods	312	320	320	320
	Monthly Standard Deviation:				
3.641%	Arithmetic	4.205%	4.779%	6.616%	3.541%
4.424%	Geometric	4.334%	4.979%	6.942%	3.669%
	Annual Standard Deviation:				
12.614%	Arithmetic	14.565%	16.553%	22.917%	12.267%
15.324%	Geometric	15.013%	17.247%	24.046%	12.711%
1.758%	**Median**	1.049%	0.969%	1.275%	0.762%
15.234%	**Maximum**	11.159%	13.263%	26.637%	11.478%
-13.604%	**Minimum**	-16.943%	-21.682%	-26.524%	-20.328%
-0.314	**Skewness**	-0.585	-0.711	-0.376	-0.979
5.451	**Kurtosis**	4.159	4.482	4.455	7.190
196.762	**Jarque-Bera**	35.224	56.268	35.779	285.219
0.0184	**Probability**	0.000	0.000	0.000	0.000

Descriptive:	US 1Y Tbill	NL 10Y GOV	EMU 10Y GOV	EMU 20-30Y GOV
	Sovereign	Sovereign	Sovereign	Sovereign
Monthly Arithmetic Mean	0.268%	0.383%	0.442%	0.529%
Annual Arithmetic Mean	3.216%	4.601%	5.307%	6.349%
Monthly Geometric Mean	0.261%	0.371%	0.427%	0.513%
Annual Geometric Mean	3.126%	4.457%	5.124%	6.161%
Periods	320	320	320	168
Monthly Standard Deviation:				
Arithmetic	2.396%	2.202%	2.585%	1.499%
Geometric	3.751%	4.690%	5.418%	5.979%
Annual Standard Deviation:				
Arithmetic	8.301%	7.629%	8.956%	5.192%
Geometric	12.993%	16.247%	18.767%	20.713%
Median	3.455%	4.340%	4.420%	6.025%
Maximum	8.400%	9.190%	11.136%	9.210%
Minimum	0.100%	0.030%	0.613%	3.870%
Skewness	0.090	0.175	0.675	0.375
Kurtosis	1.695	2.585	2.647	1.933
Jarque-Bera	23.142	3.921	25.978	11.903
Probability	0.000	0.141	0.000	0.003

Preliminary Statistics - Asset Classes - Descriptive Statistics (continuation)

	Moody's Aaa	Moody's Baa	ML EMU Corporate	BloomB EURO AGG CORP	BB PAN-EU HY	BOFA ML EURO HY
Descriptive:	Corporate	Corporate	Corporate	Corporate	Corporate	Corporate
Monthly Arithmetic Mean	0.520%	0.601%	0.409%	0.410%	0.617%	-0.122%
Annual Arithmetic Mean	6.245%	7.207%	4.911%	4.920%	7.403%	-1.467%
Monthly Geometric Mean	0.505%	0.581%	0.410%	0.410%	0.384%	0.443%
Annual Geometric Mean	6.063%	6.970%	4.920%	4.919%	4.609%	5.321%
Periods	313	313	248	218	211	223
Monthly Standard Deviation:						
Arithmetic	1.547%	1.492%	0.969%	1.011%	0.937%	3.604%
Geometric	5.892%	6.728%	0.971%	1.015%	1.000%	3.757%
Annual Standard Deviation:						
Arithmetic	5.358%	5.168%	3.358%	3.502%	3.247%	12.486%
Geometric	20.411%	23.306%	3.365%	3.516%	3.464%	13.015%
Median	6.170%	7.310%	0.479%	0.551%	0.554%	0.685%
Maximum	9.560%	10.740%	3.114%	3.453%	3.244%	12.453%
Minimum	3.400%	4.450%	-4.356%	-4.364%	-4.122%	-18.646%
Skewness	0.100	0.125	-0.711	-0.588	-0.629	-0.715
Kurtosis	-0.862	-0.622	2.111	2.388	2.162	5.115
Jarque-Bera	10.337	6.008	64.521	60.700	200.377	435.483
Probability	0.006	0.0496	0.000	0.000	0.000	0.000

	Barc EM AGG	Barc EM IG	Barc ILB GOV All Maturities	BOFA ML ILB 10Y GOV EURO	US 10Y TIPS
Descriptive:	Emerging	Emerging	Inflation-Linked	Inflation-Linked	Inflation-Linked
Monthly Arithmetic Mean	0.885%	0.727%	0.388%	0.414%	1.192%
Annual Arithmetic Mean	10.621%	8.725%	4.657%	4.972%	14.306%
Monthly Geometric Mean	0.510%	0.707%	0.378%	0.405%	0.492%
Annual Geometric Mean	6.120%	8.486%	4.538%	4.857%	5.907%
Periods	283	224	200	215	164
Monthly Standard Deviation:					
Arithmetic	1.081%	3.446%	1.459%	1.384%	0.935%
Geometric	1.140%	3.531%	1.470%	1.394%	1.604%
Annual Standard Deviation:					
Arithmetic	3.745%	11.939%	5.055%	4.795%	3.240%
Geometric	3.947%	12.231%	5.091%	4.827%	5.558%
Median	0.671%	1.185%	0.572%	0.437%	1.415%
Maximum	4.048%	10.055%	5.582%	4.147%	2.890%
Minimum	-2.666%	-25.562%	-5.580%	-5.308%	-0.770%
Skewness	-0.225	-2.428	-0.434	-0.523	-0.342
Kurtosis	0.247	15.882	2.779	1.498	-0.968
Jarque-Bera	2452.216	2.129	66.036	28.123	9.643
Probability	0.000	0.345	0.000	0.000	0.008

Preliminary Statistics - Asset Classes - Descriptive Statistics (continuation)

	Barc HF	CS HF	STOXX EU PE	TR PE B	FTSE NAREIT REAL	MSCI EUROPE REAL
Descriptive:	Hedge Funds	Hedge Funds	Private Equity	Private Equity	Real Estate	Real Estate
Monthly Arithmetic Mean	0.702%	0.648%	0.863%	1.539%	0.980%	0.515%
Annual Arithmetic Mean	8.426%	7.772%	10.351%	18.473%	11.764%	6.179%
Monthly Geometric Mean	1.081%	0.634%	0.582%	0.879%	1.017%	0.684%
Annual Geometric Mean	12.967%	7.610%	6.985%	10.552%	12.207%	8.210%
Periods	236	272	239	235	320	259
Monthly Standard Deviation:						
Arithmetic	2.054%	2.017%	6.527%	7.782%	5.161%	6.364%
Geometric	1.589%	2.181%	3.679%	8.486%	5.274%	6.127%
Annual Standard Deviation:						
Arithmetic	7.115%	6.987%	22.610%	26.959%	17.878%	22.045%
Geometric	5.506%	7.554%	12.745%	29.398%	18.271%	21.225%
Median	0.760%	0.688%	1.134%	1.437%	1.346%	0.639%
Maximum	7.730%	8.528%	36.521%	44.327%	27.975%	27.216%
Minimum	-8.410%	-7.549%	-26.641%	-33.582%	-30.226%	-25.699%
Skewness	-0.606	-0.118	-0.125	0.509	-0.845	-0.223
Kurtosis	6.225	6.030	8.539	9.170	10.563	6.438
Jarque-Bera	116.755	104.655	306.190	382.982	800.823	129.673
Probability	0.000	0.000	0.000	0.000	0.000	0.000

	Gold Spot	IMF All Commodities	LB Crude	GSCI Commodity	TR/CC Commodities
Descriptive:	Commodities	Commodities	Commodities	Commodities	Commodities
Monthly Arithmetic Mean	0.468%	0.335%	0.812%	0.281%	0.507%
Annual Arithmetic Mean	5.611%	4.020%	9.746%	3.368%	6.084%
Monthly Geometric Mean	0.063%	0.582%	0.274%	0.408%	0.205%
Annual Geometric Mean	0.750%	6.986%	3.287%	4.899%	2.457%
Periods	319	295	320	304	271
Monthly Standard Deviation:					
Arithmetic	3.662%	4.397%	10.044%	6.211%	4.580%
Geometric	5.812%	3.629%	9.052%	8.183%	5.941%
Annual Standard Deviation:					
Arithmetic	12.686%	15.232%	34.793%	21.515%	15.864%
Geometric	20.135%	12.570%	31.358%	28.347%	20.582%
Median	0.352%	0.759%	1.755%	0.548%	1.163%
Maximum	15.284%	11.636%	49.113%	17.831%	11.868%
Minimum	-10.916%	-21.087%	-36.474%	-21.818%	-18.659%
Skewness	0.466	-0.920	-0.052	-0.355	-0.648
Kurtosis	4.491	5.586	4.776	3.713	3.934
Jarque-Bera	41.115	123.805	42.223	12.826	28.812
Probability	0.000	0.000	0.000	0.002	0.000

Table AA6.10 Cross-Correlations Compendium

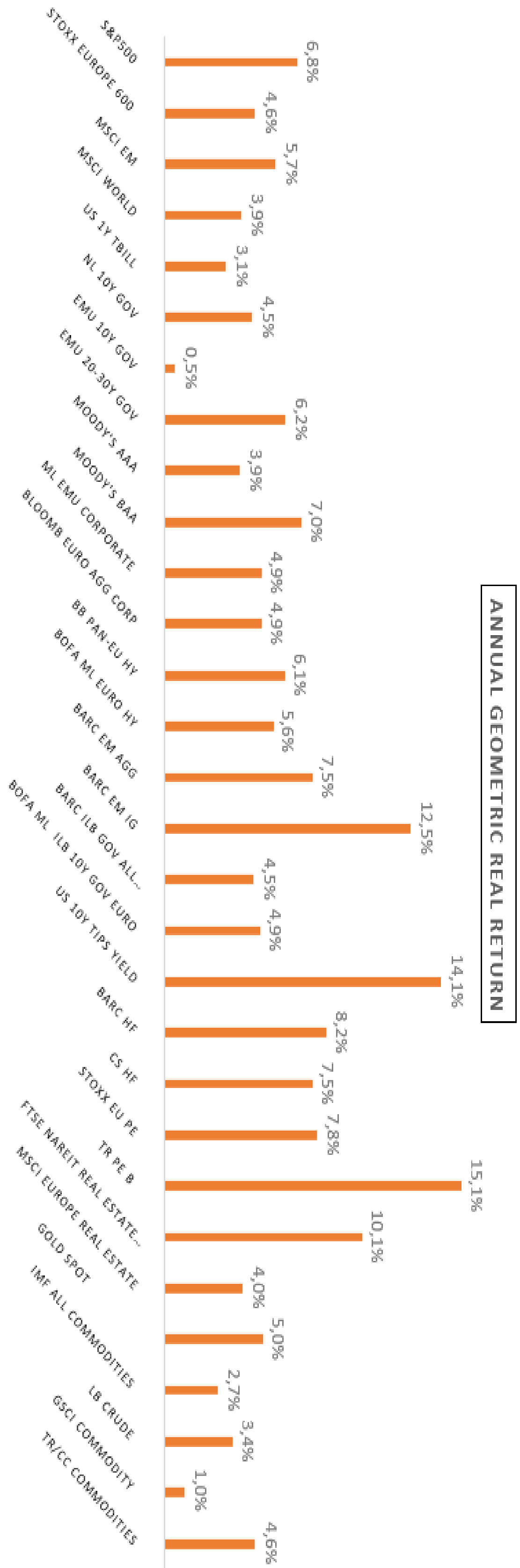
	COM	CSHF	CSPREAD	DY	EMBAG	FTNA	G	GCEU30	INF10	LTEI	LTUI
COM	1,0000	0,1757	-0,2094	-0,2795	0,1882	0,1472	-0,0539	-0,0185	-0,1335	0,0768	-0,0290
CSHF	0,1757	1,0000	-0,1149	-0,1486	0,2718	0,3841	-0,0445	0,0466	-0,0343	-0,1279	-0,1180
CSPREAD	-0,2094	-0,1149	1,0000	0,0910	-0,1205	-0,1098	-0,0300	0,0261	-0,0280	0,2385	-0,1950
DY	-0,2795	-0,1486	0,0910	1,0000	-0,0684	-0,1013	-0,0048	0,0272	-0,0268	-0,3405	-0,0782
EMBAG	0,1882	0,2718	-0,1205	-0,0684	1,0000	0,1908	0,0991	0,0015	0,0572	-0,1376	-0,0951
FTNA	0,1472	0,3841	-0,1098	-0,1013	0,1908	1,0000	-0,2402	-0,0928	0,0250	-0,1637	-0,0352
G	-0,0539	-0,0445	-0,0300	-0,0048	0,0991	-0,2402	1,0000	0,0265	-0,1024	0,0585	-0,1710
GCEU30	-0,0185	0,0466	0,0261	0,0272	0,0015	-0,0928	0,0265	1,0000	-0,0222	0,0055	-0,0139
INF10	-0,1335	-0,0343	-0,0280	-0,0268	0,0572	0,0250	-0,1024	-0,0222	1,0000	0,0033	0,1057
LTEI	0,0768	-0,1279	0,2385	-0,3405	-0,1376	-0,1637	0,0585	0,0055	0,0033	1,0000	-0,0305
LTUI	-0,0290	-0,1180	-0,1950	-0,0782	-0,0951	-0,0352	-0,1710	-0,0139	0,1057	-0,0305	1,0000
ML_CEU	0,1240	0,1950	-0,0988	0,0328	0,4684	0,1889	-0,0381	-0,0433	0,0177	-0,2616	0,0576
MSEM	0,2175	0,5784	-0,0803	-0,0141	0,3605	0,3253	0,0163	0,0772	-0,0069	-0,1223	-0,1598
MSPREAD	-0,2508	-0,1864	0,4744	0,6824	-0,0810	-0,1200	0,0504	0,0239	0,0497	-0,1143	-0,0870
MSW	0,3096	0,6200	-0,1549	-0,0226	0,3434	0,4667	-0,1785	-0,0073	-0,0451	-0,2289	-0,1206
SE6	0,2819	0,5153	-0,0893	-0,0199	0,2042	0,3079	-0,0566	-0,0362	-0,0042	-0,1659	-0,1348
SEPE	0,3036	0,4319	-0,0788	-0,1940	0,3636	0,3599	-0,0959	-0,0578	-0,0312	-0,1496	-0,1009
STEI	0,0176	-0,1080	0,0170	-0,2100	-0,0981	-0,0812	-0,0863	0,0027	0,1678	0,2326	0,7160
STUI	0,9892	0,1901	-0,2101	-0,2464	0,2011	0,1579	-0,0408	-0,0188	-0,1570	0,0421	-0,1337
TED	0,0885	0,2956	-0,0047	-0,4645	0,1487	0,1332	0,0140	0,0408	-0,1278	0,1122	-0,2546
TERM	-0,0237	0,1516	-0,3736	0,2279	0,1445	0,1682	0,0272	-0,0517	0,0014	-0,7533	0,0537
VIX	-0,0493	-0,4471	0,0041	-0,0428	-0,0049	-0,4311	0,1872	-0,0870	-0,0843	0,0740	-0,0139

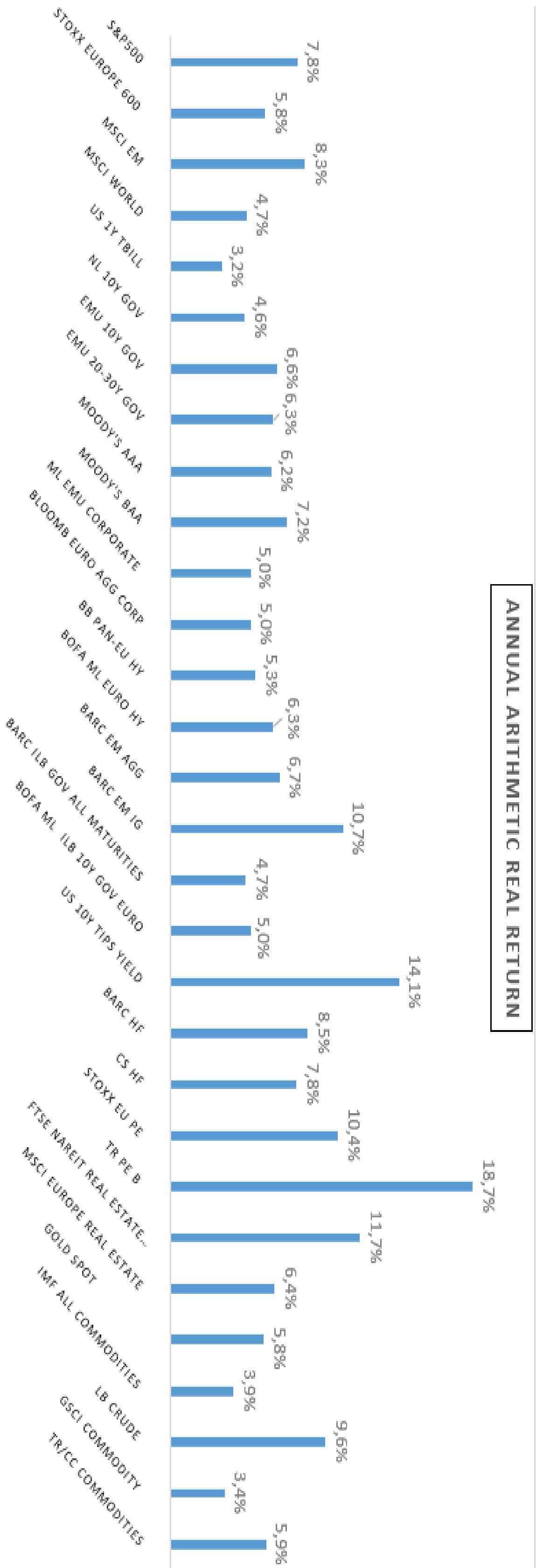
Preliminary Statistics - Asset Classes - Compendium Cross Correlations (continuation)

	ML_CEU	MSEM	MSPREAD	MSW	SE6	SEPE	STEI	STUI	TED	TERM	VIX
COM	0,1240	0,2175	-0,2508	0,3096	0,2819	0,3036	0,0176	0,9892	0,0885	-0,0237	-0,0493
CSHF	0,1950	0,5784	-0,1864	0,6200	0,5153	0,4319	-0,1080	0,1901	0,2956	0,1516	-0,4471
CSPREAD	-0,0988	-0,0803	0,4744	-0,1549	-0,0893	-0,0788	0,0170	-0,2101	-0,0047	-0,3736	0,0041
DY	0,0328	-0,0141	0,6824	-0,0226	-0,0199	-0,1940	-0,2100	-0,2464	-0,4645	0,2279	-0,0428
EMBAG	0,4684	0,3605	-0,0810	0,3434	0,2042	0,3636	-0,0981	0,2011	0,1487	0,1445	-0,0049
FTNA	0,1889	0,3253	-0,1200	0,4667	0,3079	0,3599	-0,0812	0,1579	0,1332	0,1682	-0,4311
G	-0,0381	0,0163	0,0504	-0,1785	-0,0566	-0,0959	-0,0863	-0,0408	0,0140	0,0272	0,1872
GCEU30	-0,0433	0,0772	0,0239	-0,0073	-0,0362	-0,0578	0,0027	-0,0188	0,0408	-0,0517	-0,0870
INF10	0,0177	-0,0069	0,0497	-0,0451	-0,0042	-0,0312	0,1678	-0,1570	-0,1278	0,0014	-0,0843
LTEI	-0,2616	-0,1223	-0,1143	-0,2289	-0,1659	-0,1496	0,2326	0,0421	0,1122	-0,7533	0,0740
LTUI	0,0576	-0,1598	-0,0870	-0,1206	-0,1348	-0,1009	0,7160	-0,1337	-0,2546	0,0537	-0,0139
ML_CEU	1,0000	0,1965	-0,0554	0,1887	0,1413	0,2158	-0,0011	0,1231	-0,0045	0,1413	-0,0352
MSEM	0,1965	1,0000	-0,0471	0,7399	0,7174	0,5122	-0,1466	0,2372	0,1723	0,1487	-0,3194
MSPREAD	-0,0554	-0,0471	1,0000	-0,1764	-0,1374	-0,2259	0,1451	-0,2700	-0,5507	0,0272	-0,0400
MSW	0,1887	0,7399	-0,1764	1,0000	0,8641	0,6332	-0,2185	0,3390	0,2713	0,2443	-0,3417
SE6	0,1413	0,7174	-0,1374	0,8641	1,0000	0,6257	-0,1922	0,3078	0,2552	0,1848	-0,2982
SEPE	0,2158	0,5122	-0,2259	0,6332	0,6257	1,0000	-0,1849	0,3282	0,3498	0,1730	-0,1819
STEI	-0,0011	-0,1466	0,1451	-0,2185	-0,1922	-0,1849	1,0000	-0,1290	-0,3374	-0,1627	-0,0011
STUI	0,1231	0,2372	-0,2700	0,3390	0,3078	0,3282	-0,1290	1,0000	0,1373	0,0004	-0,0487
TED	-0,0045	0,1723	-0,5507	0,2713	0,2552	0,3498	-0,3374	0,1373	1,0000	-0,0103	-0,0268
TERM	0,1413	0,1487	0,0272	0,2443	0,1848	0,1730	-0,1627	0,0004	-0,0103	1,0000	-0,0983
VIX	-0,0352	-0,3194	-0,0400	-0,3417	-0,2982	-0,1819	-0,0011	-0,0487	-0,0268	-0,0983	1,0000

Preliminary Statistics – Part 5: ***Arithmetic- and Geometric Mean Returns of Asset Classes***

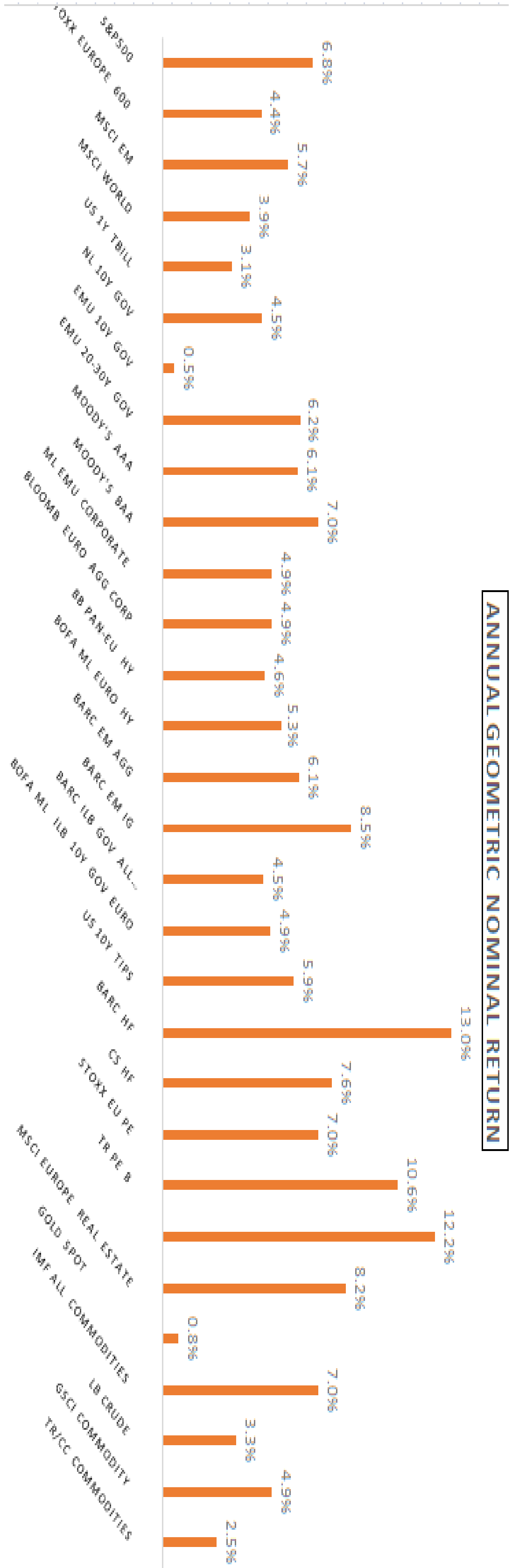
Table AA6.11 Arithmetic and Geometric Real Returns

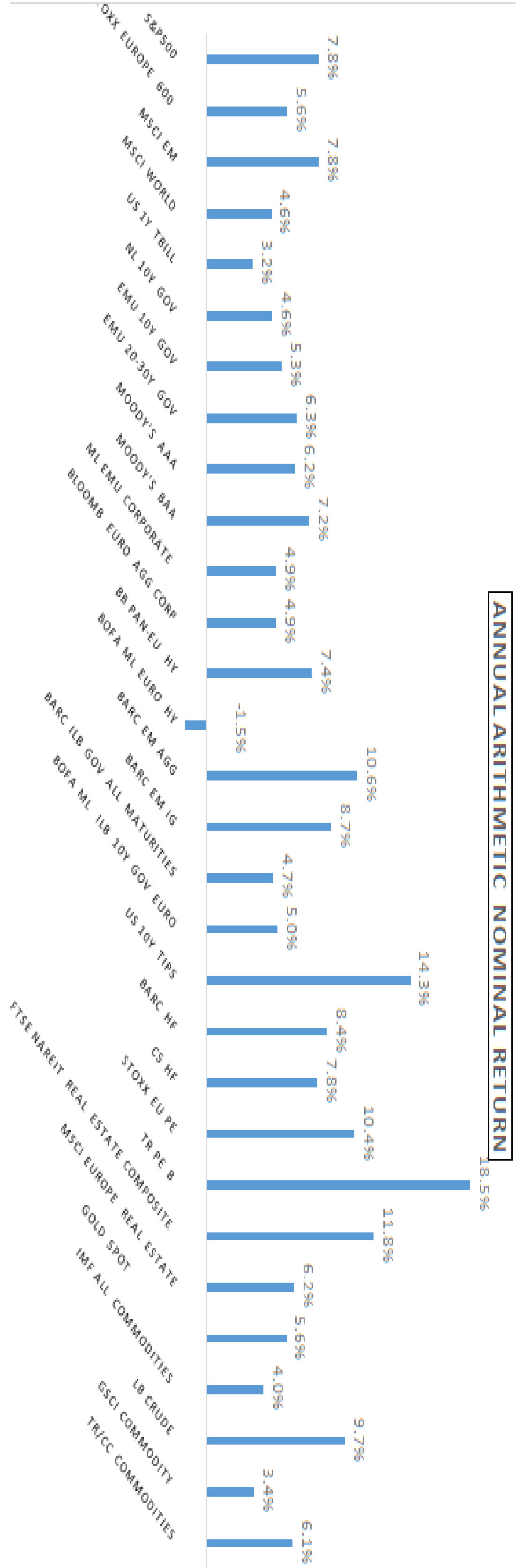




Preliminary Statistics Part 5 – *Nominal Mean Returns of Asset Classes (continuation)*

Table AA6.12 Arithmetic and Geometric Nominal Returns





Preliminary Statistics – Part 6: ***Geometric Mean and Standard Deviation Formulae***

Table AA6.13 **Geometric Mean and Standard Deviation**

Geometric Mean and Geometric Standard Deviation Formula

$$GM = \left[\left(\prod_{i=1}^{n \times P} (1 + r_i) \right)^{\frac{1}{n \times P}} - 1 \right] P$$

$$GSD = \left[\exp\left(\frac{1}{(n \times P - 1)} \sum_{i=1}^{n \times P} \left(\ln(1 + r_i) - \ln\left(1 + \frac{GM}{P^{\frac{1}{2}}} \right) \right)^2 \right)^{\frac{1}{2}} - 1 \right] P^{\frac{1}{2}}$$

n = number of years
P = number of periods per year
r = periodic return
ln() = natural log function
exp() = Exponential function

Preliminary Statistics – Part 7: ***Multiple Breakpoint Tests***

Long Term Expected Inflation [LTEI]

Table AA6.14 **Multiple Breakpoints A**

Multiple breakpoint tests			
Bai-Perron tests of L+1 vs. L sequentially determined breaks			
Breaks	F-statistic	Scaled F-statistic	Critical Value**
0 vs. 1 *	2.992.163	2.992.163	13.58
1 vs. 2	4.730.541	4.730.541	15.03
Break dates:		Sequential	Repartition
1		2009M01	2009M01

* Significant at the 0.01 level.
** Bai-Perron (2003) critical values.

Preliminary Statistics – Part 7: ***Multiple Breakpoint Tests (continuation)***

Long Term Expected Inflation [LTEI]

Table AA6.15 **Multiple Breakpoints B**

Multiple breakpoint tests			
Bai break tests of breaks recursively determined partitions			
Breaks	F-statistic	Scaled F-statistic	Critical Value**
0 vs. 1 *	2.992.163	2.992.163	13.58
1 vs. 2	4.620.578	4.620.578	13.56
1 vs. 2	4.730.541	4.730.541	15.03
Break dates:		Sequential	Repartition
1		2009M01	2009M01
* Significant at the 0.01 level.			
** Bai-Perron (2003) critical values.			

Short Term Expected Inflation [STEI]

Table AA6.16 **Multiple Breakpoints C**

Multiple breakpoint tests			
Bai-Perron tests of L+1 vs. L globally determined breaks			
Breaks	F-statistic	Scaled F-statistic	Critical Value**
0 vs. 1	7.195.927	7.195.927	13.58
1 vs. 2 *	2.409.438	2.409.438	15.03
2 vs. 3 *	2.308.501	2.308.501	15.62
Break dates:		Sequential	Repartition
		2001M02	2001M03
3		2003M02	2003M03
		2014M04	2014M05

* Significant at the 0.01 level.
** Bai-Perron (2003) critical values.

Section IV: Supplementary Methodological Information

Supplementary Information – Part 1: *Information Criterion and Lag Order Selection*

If one assumes that the actual underlying process is a k-dimensional AR(p), then the lag order selection in a VECM (or VAR) can either be based on the Schwartz-, Akaike- or the Hannan-Quinn selection criterion. The lag order estimate p minimizes the value of the chosen criterion. The HQ and Akaike Criterion were utilized to establish the Lag Order, though Akaike took precedence over the HQ in case of contradictory results.

The AIC is an estimator of the Kullback-Leibler Divergence (KLD) one can expect between the 'true' model and a fitted statistical model. KLD is non-symmetric, convex function that measures the 'distance' between two probability distributions, where distance (*d*) is equal to:

$$d = \sum_{k} p_k log^2 \left(\frac{p_k}{q_k}\right)$$

Two assumptions are instantly made; P is viewed as the 'true' distribution, whereas Q is the distribution implied by the 'fitted' model. KLD is often referred to as relative entropy, e.g., average uncertainty of all possible occurrences minus the true uncertainty apparent before observation (Shannon entropy). The Multivariate AIC itself is equal to:

$$AIC_{cm} = AIC + 2\,\frac{k(\check{\mathrm{k}} + 1 + p)}{n - \check{\mathrm{k}} - 1 - p}$$

Where $k = \check{\mathrm{k}}p + \frac{p(p+1)}{2}$ and $AIC = -2\ln(L) + 2k$. In turn, L is equal to the maximized value of the maximum likelihood ratio. The number of lags that minimizes the AIC_{cm} will be selected.

Supplementary Information – Part 2: ***Granger Causality/Block Exogeneity Wald Test***

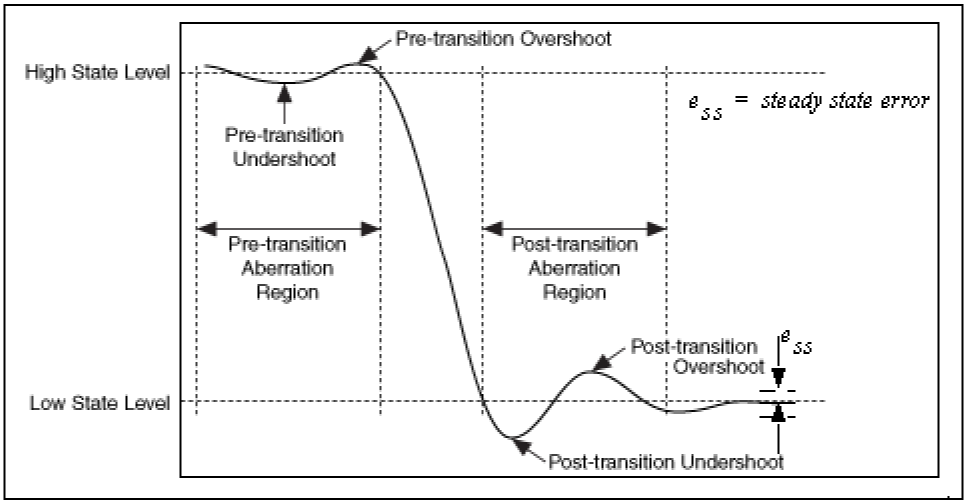
Table AA7.1 **Granger Causality**

		$H0: \Sigma(\beta yx,i) = 0$	
		Fail to reject	**Reject**
$H0: \Sigma(\beta xy,i) = 0$	**Fail to reject**	*No Granger Causality*	*x Granger causes y*
	Reject	*y Granger causes x*	*Bi-directional Granger Causality*

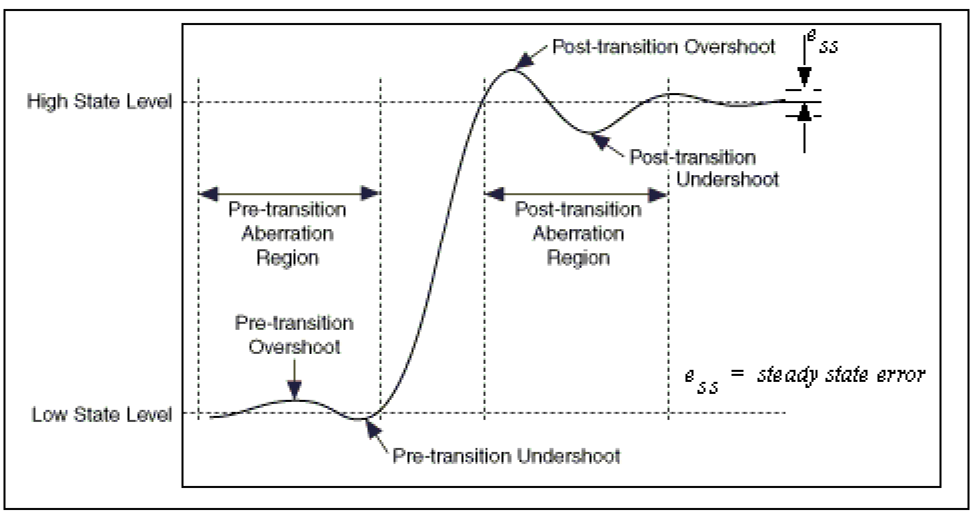
The Block Exogeneity Wald test is the multivariate form of the regular Granger Causality test. It allows one to test the joint significance of each lagged endogenous variable and test the joint significance of all endogenous variables under consideration simultaneously. The null hypothesis states that all lagged coefficients of an endogenous variable are equal to zero, i.e. $H_0: \sum \beta_i = 0$ (no Granger Causality). There are four possible outcomes for each set of tested variables considered, i.e. no granger causality, bidirectional (i.e., "feedback") or unidirectional granger causality for either X_t or Y_t. Thus, in an n-variable VEC(*p*) process, the Granger Causality Block Exogeneity Wald Test infers whether the lags of regressors Granger cause any other variable in the dynamic system.

Supplementary Information – Part 3: ***Undershooting/Overshooting Terminology***

Graph AA7.2 High to Low State Level Transition



Graph AA7.3 Low to High State Level Transition



Supplementary Information – Part 4: ***Addendum Johansen's Multivariate Cointegration***

A method that I ultimately rejected runs parallel to that of the Johansen method of cointegration, i.e. the Hankel matrix method. The Hankel 'catalecticant' matrix[83] $[\widehat{H}_p]$ enables one to indicate the size of the state space dimension and in turn the cointegrating rank based on the number of cointegrating relationships amongst lagged or non-contiguous variables. Like Johansen, the lag order is determined either via Akaike, Schwarz or Hannan-Quinn Information Criteria. Conversely, the quality of identification of the Hankel matrix tends to be left in tatters once relatively high dimensionality comes into play. As one can expect a high level of cointegrating relationships amongst variables considered, the Johansen method takes precedence.

Presence of ~I(2) variables is disconcerting as it implies the remaining presence of a unit root. In order to negate such an occurrence one can resort to the use of a control variable found amongst these ~I(2) variables, e.g. usually the consumer price index. After detrending via subtraction, the ~I(2) variables have undergone a nominal-to-real transformation. One must then take the first difference of the control variable, e.g. CPI, to ensure consistent stationarity for the long-run equilibrium[84]. Unfortunately, this method results in a strong price-homogeneity assumption that need not be empirically justified. A second method is to utilize the Haldrup method[85] of direct cointegration. By finding linear combinations of ~I(1) and ~I(2) variables for which the cointegration matrix β ensures stationarity $[\beta' y_t \sim \mathrm{I}(0)]$, i.e. coefficient matrices are asymptotically unbiased. If ~I(2) variables are detected, this last method will be employed to transform them into ~I(1) variables.

[83] A special case of the Hankel matrix is the Hilbert matrix. The latter is oft associated with Hilbert space(s), i.e. potentially infinite number of dimensions, which is essential for Fourier pathways, PDEs and single proton spin states.
[84] K. Juselius, (2007); T. Engsted and N. Haldrup, (1999).
[85] N. Haldrup, (1998).

Supplementary Information – Part 5: ***Principal Component Analysis vs. DOLS***

An alternative to the DOLS method described above is Principal Component Analysis which was devised to isolate *k* orthogonal variables (as dictated by the Kaiser criterion) that explicate maximum of total variance of original variables. The dominant set of principal components are then extracted and utilized in subsequent multiple regression analysis to illuminate the prime risk factors that drive the returns of various asset classes. Nevertheless, the model was deemed too restrictive and it does not account for short-run deviations from long-run equilibria. Furthermore, parsimony is relevant as it mitigates statistical noise[86] (and hence is an epistemological, metaphysical or heuristic preference), a model that is too parsimonious may fail to capture the correct future distribution pathways due to model misspecification.

[86] Occam's Razor as postulated by W. Ockham, (14th Century, 'Nunquam ponenda est pluralitas sine necessitate').

Results - Part 1: *Table AA8.3* **Group Augmented Dickey Fuller Unit Root Test**

- GROUP ADF UNIT ROOT TESTS -					
COM					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	0.12656	0.5504	2717	I(1)
	Breitung t-stat	2.70826	0.9966	2707	I(1)
First Difference	Levin, Lin & Chu t*	-42.2511	0.0000	2781	I(0)
	Breitung t-stat	-2.39116	0.0084	2771	I(0)
CSHF					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	-0.27564	0.3914	2797	I(1)
	Breitung t-stat	1.72146	0.9574	2787	I(1)
First Difference	Levin, Lin & Chu t*	-38.4112	0.0000	2749	I(0)
	Breitung t-stat	-2.28226	0.0112	2739	I(0)
EMBAG					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	-1.63061	0.0515	2809	I(1)
	Breitung t-stat	1.63261	0.9487	2799	I(1)
First Difference	Levin, Lin & Chu t*	-40.6936	0.0000	2759	I(0)
	Breitung t-stat	-2.32655	0.01	2749	I(0)
FTNA					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	0.01904	0.5076	2844	I(1)
	Breitung t-stat	1.73567	0.9587	2834	I(1)
First Difference	Levin, Lin & Chu t*	-39.7921	0.0000	2797	I(0)
	Breitung t-stat	-2.42934	0.0076	2787	I(0)
G					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	0.38926	0.6515	2771	I(1)
	Breitung t-stat	1.77529	0.9621	2761	I(1)
First Difference	Levin, Lin & Chu t*	-37.9948	0.0000	2796	I(0)
	Breitung t-stat	-2.38503	0.0085	2786	I(0)
GCEU30					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	-1.39651	0.0813	2795	I(1)
	Breitung t-stat	1.72779	0.958	2785	I(1)
First Difference	Levin, Lin & Chu t*	-38.3209	0.0000	2745	I(0)
	Breitung t-stat	-2.13189	0.0165	2735	I(0)

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution
All other tests assume asymptotic normality.

Results – Part 1 – ***Group Augmented Dickey Fuller Unit Root Test (continuation)***

- GROUP ADF UNIT ROOT TESTS -					
INF10					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	-0.22054	0.4127	2528	I(1)
	Breitung t-stat	1.8018	0.9642	2519	I(1)
First Difference	Levin, Lin & Chu t*	-25.026	0.0000	2479	I(0)
	Breitung t-stat	-1.4598	0.0722	2470	I(0)
ML CEU					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	0.02934	0.5117	2672	I(1)
	Breitung t-stat	1.65628	0.9512	2662	I(1)
First Difference	Levin, Lin & Chu t*	-37.5921	0.0000	2724	I(0)
	Breitung t-stat	-2.21129	0.0135	2714	I(0)
MSEM					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	0.09549	0.538	2843	I(1)
	Breitung t-stat	1.73653	0.9588	2833	I(1)
First Difference	Levin, Lin & Chu t*	-40.1403	0.0000	2797	I(0)
	Breitung t-stat	-2.43623	0.0074	2787	I(0)
MSW					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	0.13766	0.5547	2843	I(1)
	Breitung t-stat	1.73705	0.9588	2833	I(1)
First Difference	Levin, Lin & Chu t*	-38.0886	0.0000	2797	I(0)
	Breitung t-stat	-2.43975	0.0073	2787	I(0)
SE6					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	0.08653	0.5345	2843	I(1)
	Breitung t-stat	1.74439	0.9595	2833	I(1)
First Difference	Levin, Lin & Chu t*	-42.5148	0.0000	2797	I(0)
	Breitung t-stat	-2.43307	0.0075	2787	I(0)
SEPE					
Type	Method	Statsistic	Probability	Observations	Unit Root
Level	Levin, Lin & Chu t*	-0.22054	0.4127	2528	I(1)
	Breitung t-stat	1.8018	0.9642	2519	I(1)
First Difference	Levin, Lin & Chu t*	-25.026	0.0000	2479	I(0)
	Breitung t-stat	-1.4598	0.0722	2470	I(1)

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution
All other tests assume asymptotic normality.

Results - Part 2: ***Johansen Multivariate Cointegration Analysis – Compendium***

Table AA8.4 **Johansen's Multivariate Cointegration Analysis**

Johansen's Multiple Cointegration Test Results				
Asset Class	**Method**	**Order Cointegration Rank**	**Test Statistic**	**Probability**
COM	Trace Test	5	7.726	0.0025
	Maximum Eigenvalue Test	3	5.638	0.0017
CSHF	Trace Test	5	7.306	0.0069
	Maximum Eigenvalue Test	2	6.292	0.0017
EMBAG	Trace Test	5	7.463	0.0048
	Maximum Eigenvalue Test	2	6.029	0.0038
FTNA	Trace Test	5	7.440	0.0051
	Maximum Eigenvalue Test	2	6.862	0.0003
G	Trace Test	5	7.353	0.0062
	Maximum Eigenvalue Test	3	5.300	0.0047
GCEU30	Trace Test	5	7.369	0.0060
	Maximum Eigenvalue Test	2	7.300	0.0001
INF10	Trace Test	5	7.817	0.0020
	Maximum Eigenvalue Test	4	5.006	0.0015
ML_CEU	Trace Test	6	5.264	0.0041
	Maximum Eigenvalue Test	3	5.559	0.0022
MSEM	Trace Test	4	1.056	0.0018
	Maximum Eigenvalue Test	2	6.774	0.0004
MSW	Trace Test	5	7.209	0.0087
	Maximum Eigenvalue Test	3	6.014	0.0005
SE6	Trace Test	5	7.593	0.0035
	Maximum Eigenvalue Test	4	4.732	0.0036
SEPE	Trace Test	5	7.284	0.0073
	Maximum Eigenvalue Test	2	7.677	0.0000

** denotes rejection of the hypothesis at the 0.01 level*

***MacKinnon-Haug-Michelis (1999) p-values*

Results - Part 3: ***Multivariate Vector Error Correction Models – Long Run Equilibria***

Table AA8.5 **VECM Long-Run Equilibria**

LONG-RUN EQUILIBRIUM MULTIVARIATE VECTOR ERROR CORRECTION MODEL						
	COM	CSHF	EMBAG	FTNA	G	GCEU30
Asset Class Returns	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
DY(-1)	0.000000	0.000000			0.000000	0.000000
VIX(-1)	0.000000			0.000000		
TED(-1)		-0.030263 (0.07529) [-0.40197]				0.0772 (0.059) [1.31551]
TERM(-1)	0.547823 (0.18891) [2.89996]	-0.007722 (0.08835) [-0.08740]	0.000000	-0.828828 (0.29658) [-2.79466]	0.000000	
CSPREAD(-1)		0.252457 (0.13656) [1.84872]	-0.00222 (0.181) [-1.22961]	-0.572684 (0.56950) [-1.00560]	0.419035 (3.72709) [0.11243]	
MSPREAD(-1)	-2.0656 (0.50373) [-4.10056]	0.875388 (0.25378) [3.44945]				
STUI(-1)	-74.1146 (13.5375) [-5.47478]	0.063816 (0.02343) [2.72313]	-0.10110 (0.020) [-5.01383]	-0.270899 (0.06036) [-4.48786]	3.922580 (0.44042) [8.90639]	-0.02220 (0.015) [-1.45589]
LTUI(-1)	-0.7688 (0.06126) [-12.5490]	17.51373 (6.15543) [2.84525]	-0.26890 (0.086) [-3.12656]	-29.772890 (25.8704) [-1.15085]	378.3436 (187.762) [2.01502]	-0.11180 (0.068) [-1.64839]
@TREND(90M01)	0.008769 (0.00264) [3.32430]	0.003977 (0.00124) [3.20396]	0.19600 (0.0021) [0.94238]	0.002455 (0.00644) [0.38094]	0.052270 (0.03548) [1.47315]	0.00984 (0.001) [0.96028]
C	-3.46588	-2.606504	-0.89030	0.450152	0.355934	-0.86630

* Any t-statistic above |2.7|, |2| and |1.684| is significant at the 1%, 5% and 10% level respectively.

* [] refers to a t-statistic, whilst () refers to the standard error.

Results – Multivariate VEC Models – Long Run Equilibria (continuation)

LONG-RUN EQUILIBRIUM MULTIVARIATE VECTOR ERROR CORRECTION MODEL						
	INF10	ML_CEU	MSEM	MSW	SE6	SEPE
Asset Class Returns	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
DY(-1)	0.000000		0.000000	0.000000	0.000000	0.000000
VIX(-1)			2.060009 (0.21160) [9.73532]		0.000000	
TED(-1)	0.000000	0.000000	0.452831 (1.79821) [0.25182]	0.000000	0.000000	
TERM(-1)		0.000000		-0.222304 (0.24507) [-0.90708]	10.97002 (2.82339) [3.88541]	4.613559 (3.52340) [1.30941]
CSPREAD(-1)			0.412742 (3.14638) [0.13118]			-1.48858 (0.27526) [-5.40796]
MSPREAD(-1)	0.000000	-0.9919 (0.288) [-3.44778]				-1.168186 (1.10666) [-1.05560]
STUI(-1)	0.3106 (0.00065) [4.75811]	-0.0902 (0.017) [-5.18517]	2.993295 (0.50702) [5.90376]	-0.2405 (0.06193) [-3.88292]	1.501738 (1.76980) [0.84854]	-0.7075 (1.15569) [-0.61217]
LTUI(-1)	0.1880 (0.00163) [1.15530]	-0.2004 (0.0693) [-2.88315]	383.5083 (149.315) [2.56846]	3.666879 (15.6751) [0.23393]	13.69354 (3.55925) [3.84731]	-1.0980 (0.11634) [-9.43801]
@TREND(90M01)	0.0045 (3.7E-05) [1.21566]	0.0054 (0.00185) [0.08517]	-0.0140 (0.02992) [-0.46955]	-0.0061 (0.00331) [-1.83259]	0.076837 (0.04047) [1.89860]	0.006516 (0.01921) [0.33926]
C	-0.4726	0.1461	9.415931	1.127596	-33.7653	-9.0485

* Any t-statistic above |2.7|, |2| and |1.684| is significant at the 1%, 5% and 10% level respectively.

* [] refers to a t-statistic, whilst () refers to the standard error.

Results - Part 4: *Table AA8.6* Multivariate VECM Error Correction Terms

VECTOR ERROR CORRECTION TERMS					
Asset Type/Class	Variable Considered	Error Correction Term	α˚= - (1 - α)	Standard Error	t-statistic
COM	D(COM)	-3.6252	-4.62524	(1.73039)	[-2.09505]
	D(DY)	-0.0796	-1.07965	(0.03744)	[-2.12745]
	D(VIX)	-3.7922	-4.79215	(5.56487)	[-0.68144]
	D(TERM)	-0.0440	-1.04395	(0.05397)	[-0.81442]
	D(MSPREAD)	0.1524	-0.84760	(0.02497)	[6.10523]
	D(LTUI)	-0.0026	-1.00258	(0.00070)	[-3.69616]
	D(STUI)	-3.6280	-4.62805	(1.72974)	[-2.09745]
CSHF	D(CSHF)	-1.4560	-2.456020	(0.19720)	[-7.38364]
	D(DY)	-0.0395	-1.039544	(0.02248)	[-1.75888]
	D(TED)	-0.0289	-1.028886	(0.02338)	[-1.23532]
	D(TERM)	0.0591	-0.940911	(0.03274)	[1.80452]
	D(CSPREAD)	-0.0183	-1.018290	(0.02964)	[-0.61699]
	D(MSPREAD)	-0.0260	-1.026017	(0.01482)	[-1.75509]
	D(STUI)	0.2010	-0.799000	(1.06990)	[0.18749]
	D(LTUI)	0.0001	-0.999940	(0.00041)	[0.14614]
EMBAG	D(EMBAG)	-1.0270	-2.027036	(0.12096)	[-8.49101]
	D(TERM)	-6.0193	-7.019324	(2.22175)	[-2.70927]
	D(CSPREAD)	3.4369	2.436900	(2.27242)	[1.51364]
	D(STUI)	-65.9508	-66.950820	(69.3214)	[-0.95138]
	D(LTUI)	2.1585	1.158500	(2.89427)	[0.74578]
FTNA	D(FTNA)	0.0053	-0.994700	(0.19246)	[0.02735]
	D(VIX)	-3.0424	-4.042402	(0.77917)	[-3.90469]
	D(TERM)	-0.0070	-1.006971	(0.00879)	[-0.79278]
	D(CSPREAD)	-0.0065	-1.006533	(0.00791)	[-0.82615]
	D(STUI)	0.4750	-0.525000	(0.26563)	[1.78788]
	D(LTUI)	0.0003	-0.999720	(0.00010)	[2.70719]
G	D(G)	-0.8691	-1.869142	(0.24459)	[-3.55351]
	D(DY)	0.0064	-0.993649	(0.00436)	[1.45734]
	D(TERM)	-0.0128	-1.012782	(0.01649)	[-0.77501]
	D(CSPREAD)	0.0116	-0.988400	(0.00551)	[2.10647]
	D(STUI)	-0.0555	-1.055543	(0.51341)	[-0.10818]
	D(LTUI)	0.0000177	-0.999982	(0.00021)	[0.08342]
GCEU30	D(GCEU30)	-1.0500	-2.049962	(0.08886)	[-11.8153]
	D(MSPREAD)	-0.0892	-1.089204	(0.85688)	[-0.10410]
	D(TED)	-1.8664	-2.866396	(1.64203)	[-1.13664]
	D(STUI)	-33.2458	-34.245760	(52.1043)	[-0.63806]
	D(LTUI)	2.0291	1.029060	(2.36386)	[0.85837]

* Any t-statistic above |2.7|, |2| and |1.684| is significant at the 1pp, 5pp and 10pp level respectively.

Results – Part 4 – Multivariate VEC Models – Error Correction Terms (continuation)

VECTOR ERROR CORRECTION TERMS					
Asset Type/Class	Variable Considered	Error Correction Term	α˚= - (1 - α)	Standard Error	t-statistic
INF10	D(INF10)	-1.3626	-2.3626	(0.21380)	[-6.37324]
	D(DY)	3.2707	2.2707	(2.40085)	[1.36235]
	D(TED)	3.3845	2.3845	(2.23965)	[1.51118]
	D(MSPREAD)	-4.3492	-5.3492	(1.46161)	[-2.97566]
	D(STUI)	111.8169	110.8169	(98.2723)	[1.13783]
	D(LTUI)	5.3136	4.3136	(3.97450)	[1.33693]
ML_CEU	D(ML_CEU)	-0.9408	-1.9408	(0.11871)	[-7.92483]
	D(TED)	-3.7780	-4.7780	(2.25197)	[-1.67766]
	D(TERM)	-6.3765	-7.3765	(2.71644)	[-2.34737]
	D(MSPREAD)	-4.0660	-5.0660	(1.21860)	[-3.33665]
	D(STUI)	26.0347	25.0347	(80.5431)	[0.32326]
	D(LTUI)	3.2087	2.2087	(3.41330)	[0.93984]
MSEM	D(MSEM)	0.0142	-0.9858	(0.03046)	[0.46681]
	D(DY)	0.0015	-0.9985	(0.00072)	[2.14197]
	D(VIX)	-0.7982	-1.7982	(0.10426)	[-7.65549]
	D(TED)	-0.0011	-1.0011	(0.00078)	[-1.41671]
	D(CSPREAD)	0.0008	-0.9992	(0.00093)	[0.85984]
	D(STUI)	-0.1265	-1.1265	(0.03456)	[-3.66031]
	D(LTUI)	0.0000	-1.0000	(1.4E-05)	[0.89113]
MSW	D(MSW)	-1.6967	-2.6967	(0.43425)	[-3.90725]
	D(DY)	-0.0535	-1.0535	(0.02096)	[-2.55405]
	D(TED)	0.0051	-0.9949	(0.02196)	[0.23430]
	D(TERM)	-0.0387	-1.0387	(0.03048)	[-1.26831]
	D(STUI)	-1.0051	-2.0051	(0.50934)	[-1.97332]
	D(LTUI)	-0.0004	-1.0004	(0.00039)	[-1.00157]
SE6	D(SE6)	-1.4817	-2.4817	(0.25421)	[-5.82875]
	D(DY)	-0.0093	-1.0093	(0.00875)	[-1.05765]
	D(VIX)	-0.3762	-1.3762	(1.27339)	[-0.29545]
	D(TED)	0.0033	-0.9967	(0.00956)	[0.33847]
	D(TERM)	0.0099	-0.9901	(0.01319)	[0.75339]
	D(STUI)	-0.0040	-1.0040	(0.00552)	[-0.72004]
	D(LTUI)	0.0155	-0.9845	(0.01610)	[0.94050]
SEPE	D(SEPE)	-1.2667	-2.2667	(0.15411)	[-8.21955]
	D(DY)	-0.0040	-1.0040	(0.00531)	[-0.76116]
	D(TERM)	-0.0034	-1.0034	(0.00406)	[-0.84828]
	D(CSPREAD)	-0.0025	-1.0025	(0.00277)	[-0.90538]
	D(MSPREAD)	0.0000	-1.0000	(7.1E-05)	[-0.25010]
	D(STUI)	-0.2707	-1.2707	(0.18855)	[-1.43584]
	D(LTUI)	0.0031	-0.9969	(0.00431)	[0.71584]
	D(TED)	-0.0055	-1.0055	(0.00592)	[-0.93070]
	D(VIX)	1.3790	0.3790	(0.53969)	[2.55430]

* Any t-statistic above |2.7|, |2| and |1.684| is significant at the 1pp, 5pp and 10pp level respectively.

Results - Part 5: *Granger Causality Block Exogeneity Wald Tests*

Table AA8.7 **Granger Causality Block Exogeneity Wald Test A**

Dependent variable: D(COM)			
Excluded	Chi-sq	df	Prob.
D(DY)	26.26881	11	0.0059
D(VIX)	17.79540	11	0.0865
D(TED)	14.61967	11	0.2006
D(TERM)	18.37482	11	0.0733
D(CSPREAD)	15.88048	11	0.1456
D(MSPREAD)	22.34317	11	0.0218
D(STUI)	11.79844	11	0.3790
D(LTUI)	11.66961	11	0.3890
All	118.0771	88	0.0179

Dependent variable: D(FTNA)			
Excluded	Chi-sq	df	Prob.
D(DY)	7.846669	11	0.7270
D(VIX)	10.54620	11	0.4820
D(TED)	9.078502	11	0.6146
D(TERM)	14.66722	11	0.1982
D(CSPREAD)	12.81720	11	0.3054
D(MSPREAD)	4.214638	11	0.9632
D(STUI)	7.989728	11	0.7142
D(LTUI)	11.91295	11	0.3702
All	109.4363	88	0.0606

Dependent variable: D(CSHF)			
Excluded	Chi-sq	df	Prob.
D(DY)	25.35645	11	0.0081
D(VIX)	15.06135	11	0.1797
D(TED)	38.24593	11	0.0001
D(TERM)	21.04701	11	0.0329
D(CSPREAD)	18.94067	11	0.0622
D(MSPREAD)	20.91135	11	0.0343
D(STUI)	9.251867	11	0.5987
D(LTUI)	9.173319	11	0.6059
All	172.8227	88	0.0000

Dependent variable: D(EMBAG)			
Excluded	Chi-sq	df	Prob.
D(DY)	6.155951	11	0.8628
D(VIX)	8.628205	11	0.6562
D(TED)	10.52791	11	0.4836
D(TERM)	32.73039	11	0.0006
D(CSPREAD)	27.35272	11	0.0041
D(MSPREAD)	9.523833	11	0.5737
D(STUI)	4.858708	11	0.9378
D(LTUI)	6.168672	11	0.8619
All	135.8105	88	0.0008

Results Part 5 – *Granger Causality Block Exogeneity Wald Tests (continuation)*

Table AA8.8 **Granger Causality Block Exogeneity Wald Test B**

Dependent variable: D(G)

Excluded	Chi-sq	df	Prob.
D(DY)	26.89501	11	0.0048
D(VIX)	13.21194	11	0.2797
D(TED)	8.137628	11	0.7009
D(TERM)	30.91314	11	0.0011
D(CSPREAD)	20.68130	11	0.0368
D(MSPREAD)	14.58460	11	0.2023
D(STUI)	29.88991	11	0.0016
D(LTUI)	8.589190	11	0.6598
All	154.0224	88	0.0000

Dependent variable: D(GCEU30)

Excluded	Chi-sq	df	Prob.
D(DY)	28.60414	11	0.0026
D(VIX)	7.277671	11	0.7762
D(TED)	18.07695	11	0.0798
D(TERM)	13.98210	11	0.2340
D(CSPREAD)	10.27290	11	0.5060
D(MSPREAD)	14.10724	11	0.2271
D(STUI)	9.988426	11	0.5314
D(LTUI)	13.85383	11	0.2412
All	108.7421	88	0.0662

Dependent variable: D(INF10)

Excluded	Chi-sq	df	Prob.
D(DY)	17.46473	11	0.0949
D(VIX)	4.061872	11	0.9681
D(TED)	17.54429	11	0.0928
D(TERM)	4.609255	11	0.9486
D(CSPREAD)	9.320311	11	0.5924
D(MSPREAD)	10.74417	11	0.4649
D(STUI)	18.12233	11	0.0788
D(LTUI)	9.212249	11	0.6023
All	98.94812	88	0.1996

Dependent variable: D(ML_CEU)

Excluded	Chi-sq	df	Prob.
D(DY)	10.41665	11	0.4933
D(VIX)	15.97344	11	0.1421
D(TED)	17.17186	11	0.1029
D(TERM)	32.82902	11	0.0006
D(CSPREAD)	11.40921	11	0.4096
D(MSPREAD)	19.31021	11	0.0557
D(STUI)	12.45696	11	0.3303
D(LTUI)	11.56265	11	0.3974
All	137.7417	88	0.0006

Results Part 5 – ***Granger Causality Block Exogeneity Wald Tests (continuation)***

Table AA8.9 **Granger Causality Block Exogeneity Wald Test C**

Dependent variable: D(MSEM)

Excluded	Chi-sq	df	Prob.
D(DY)	21.19302	11	0.0314
D(VIX)	26.48561	11	0.0055
D(TED)	26.53839	11	0.0054
D(TERM)	15.03488	11	0.1809
D(CSPREAD)	15.61898	11	0.1559
D(MSPREAD)	4.689157	11	0.9453
D(STUI)	12.73363	11	0.3111
D(LTUI)	23.20068	11	0.0166
All	136.0833	88	0.0008

Dependent variable: D(MSW)

Excluded	Chi-sq	df	Prob.
D(DY)	12.08964	11	0.3569
D(VIX)	8.867702	11	0.6341
D(TED)	17.18099	11	0.1026
D(TERM)	13.75148	11	0.2471
D(CSPREAD)	6.803923	11	0.8147
D(MSPREAD)	6.547242	11	0.8345
D(STUI)	11.10211	11	0.4347
D(LTUI)	19.42931	11	0.0538
All	120.3906	88	0.0125

Dependent variable: D(SE6)

Excluded	Chi-sq	df	Prob.
D(DY)	8.030963	11	0.7105
D(VIX)	9.120180	11	0.6108
D(TED)	14.81739	11	0.1910
D(TERM)	6.126085	11	0.8648
D(CSPREAD)	4.321798	11	0.9595
D(MSPREAD)	4.822346	11	0.9395
D(STUI)	6.334484	11	0.8501
D(LTUI)	9.033029	11	0.6188
All	103.0850	88	0.1298

Dependent variable: D(SEPE)

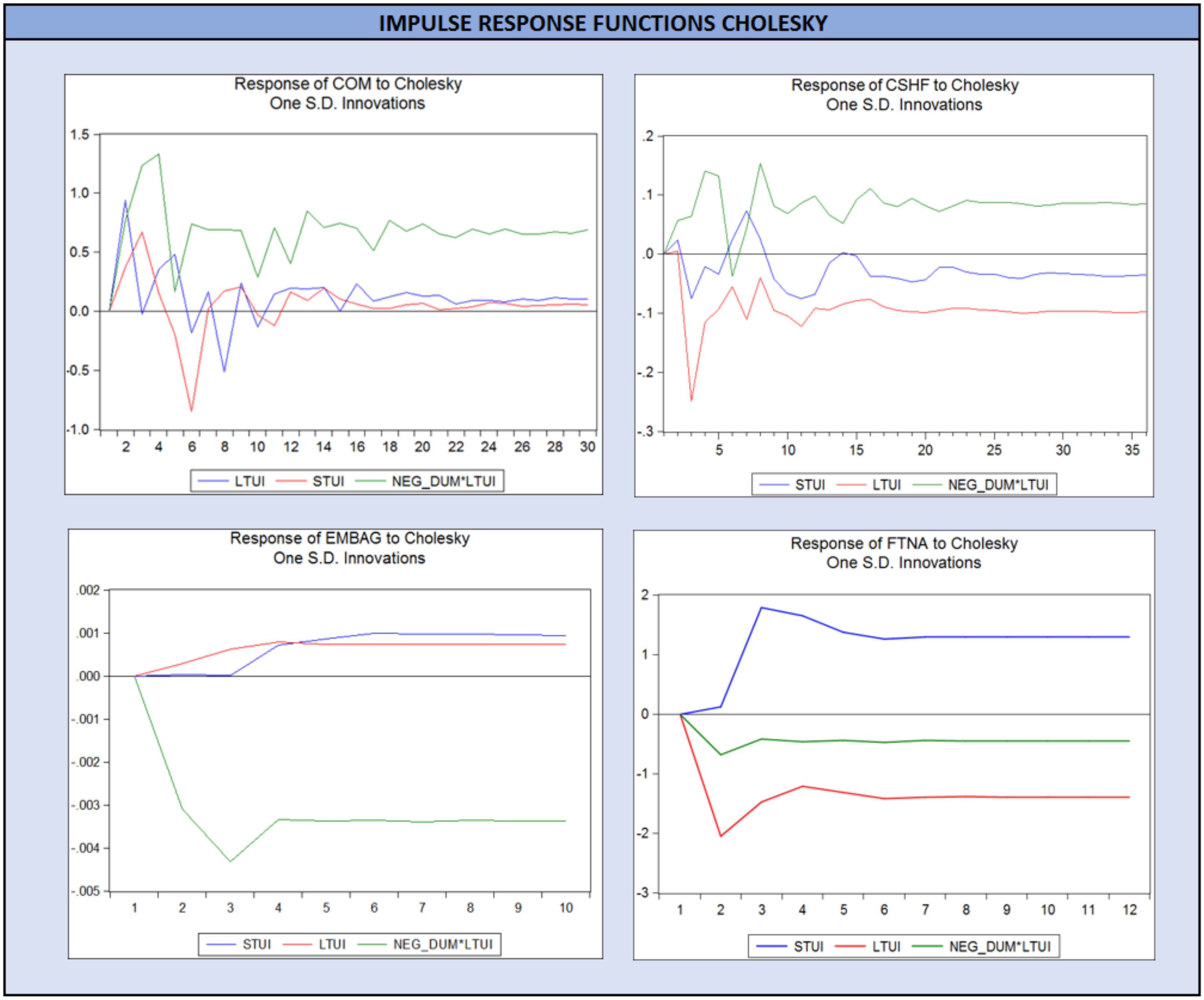
Excluded	Chi-sq	df	Prob.
D(DY)	20.52173	11	0.0387
D(VIX)	15.09273	11	0.1783
D(TED)	13.82074	11	0.2431
D(TERM)	33.17040	11	0.0005
D(CSPREAD)	26.57109	11	0.0053
D(MSPREAD)	20.53385	11	0.0385
D(STUI)	21.12010	11	0.0321
D(LTUI)	11.99161	11	0.3643
All	203.1655	88	0.0000

Results Part 5 – *Granger Causality Block Exogeneity Wald Tests (continuation)*

On the whole, the models in question explicated changes in the dependent variables with the exception of the models for the ML_CEU and SE6 asset classes. In the presence of risk proxies and dividend yield, the unanticipated inflation variables do not Granger-cause changes in most asset class returns. LTUI is significantly Granger-causal for the MSEM and MSW category. STUI is significantly Granger-causal for changes in G, INF10 and SEPE. Nevertheless, note that VAR Granger Causality is merely an indication as it cannot account for interdependencies, i.e. cointegration. Furthermore, inflation variables shall be added to the VECM regardless of the GCBEW results.

Results - Part 6: ***Impulse Response Functions***

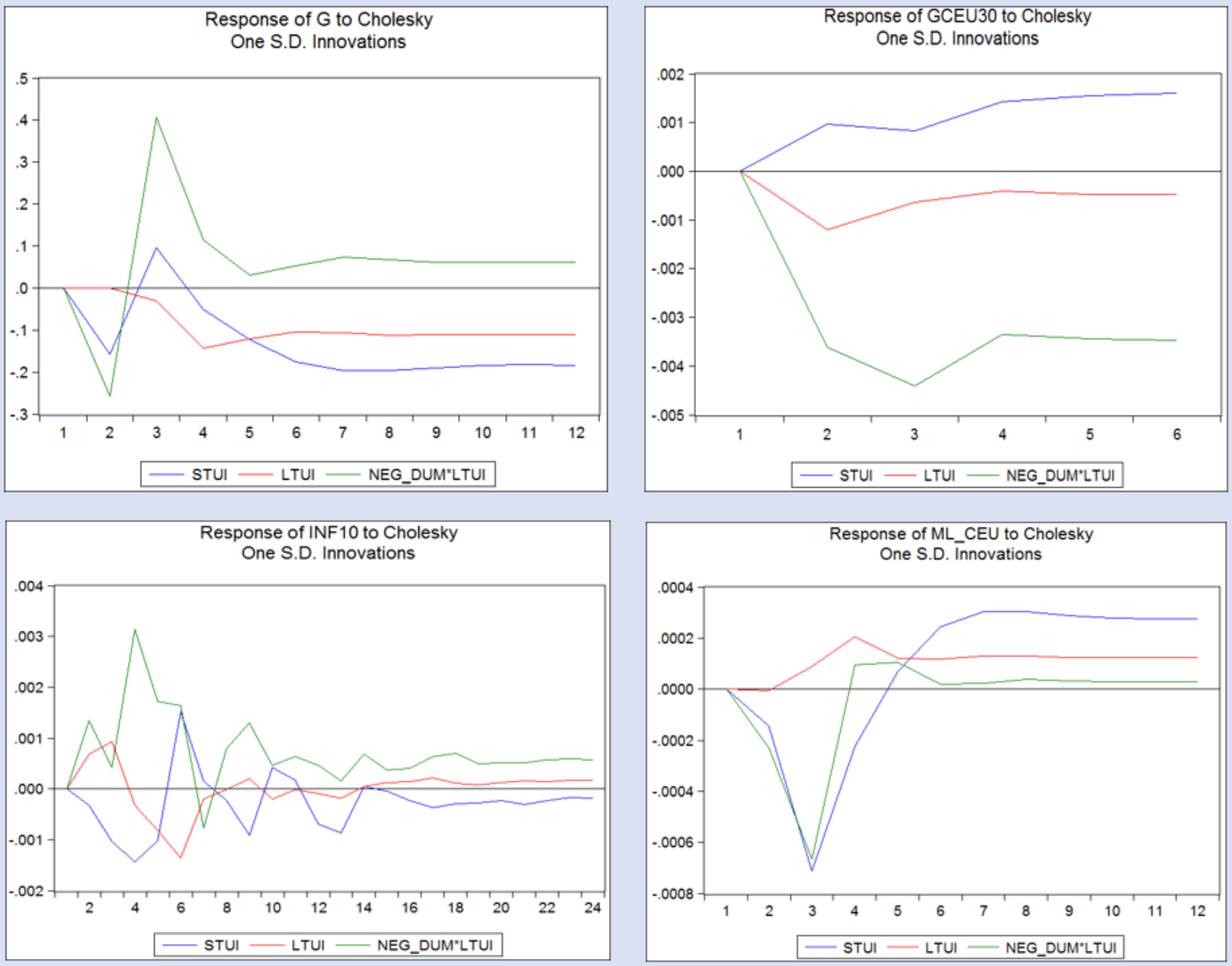
Table AA8.10 **Impulse Response Functions A**



Results Part 6 – I*mpulse Response Functions (continuation)*

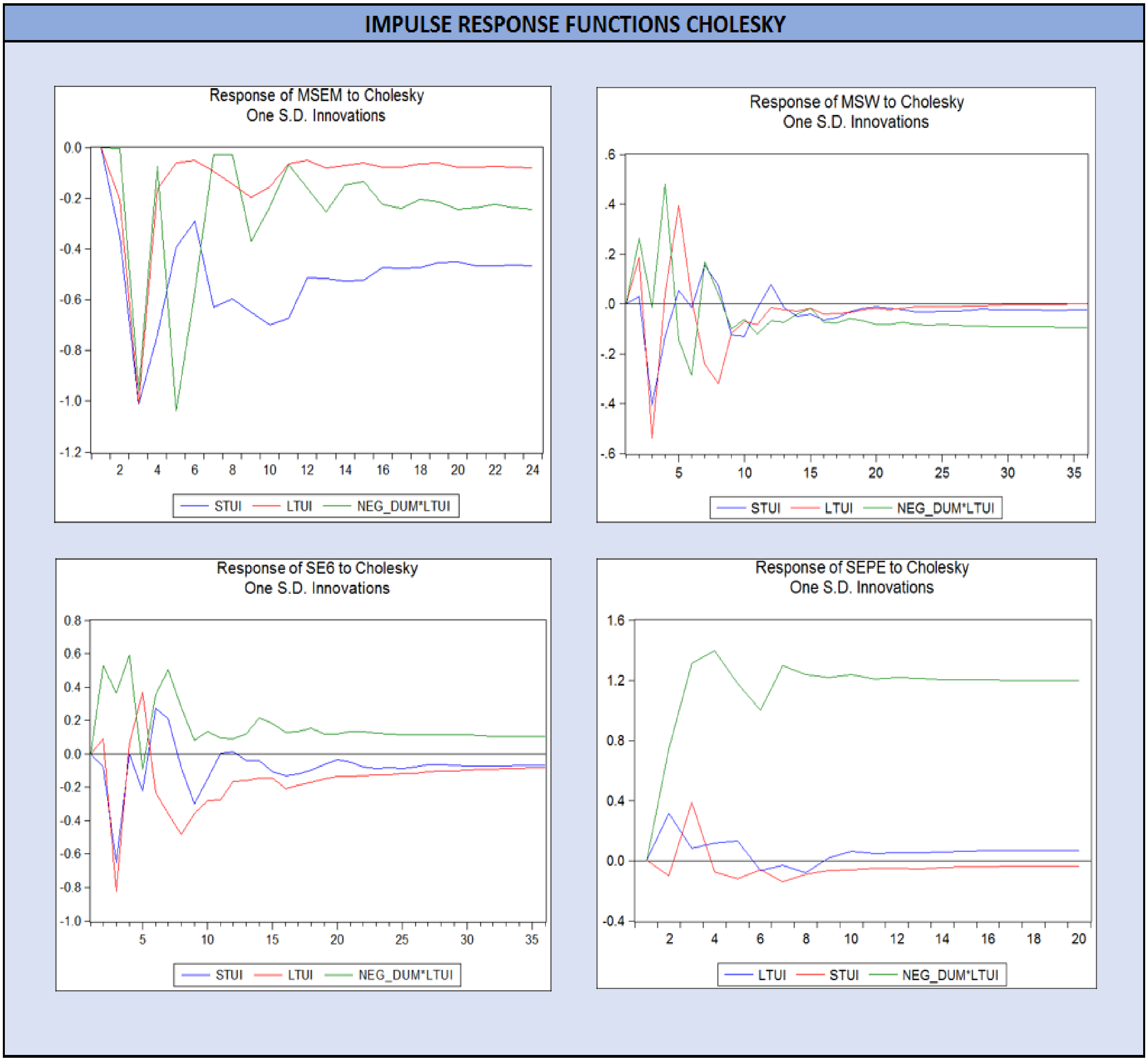
Table AA8.11 **Impulse Response Functions B**

IMPULSE RESPONSE FUNCTIONS CHOLESKY



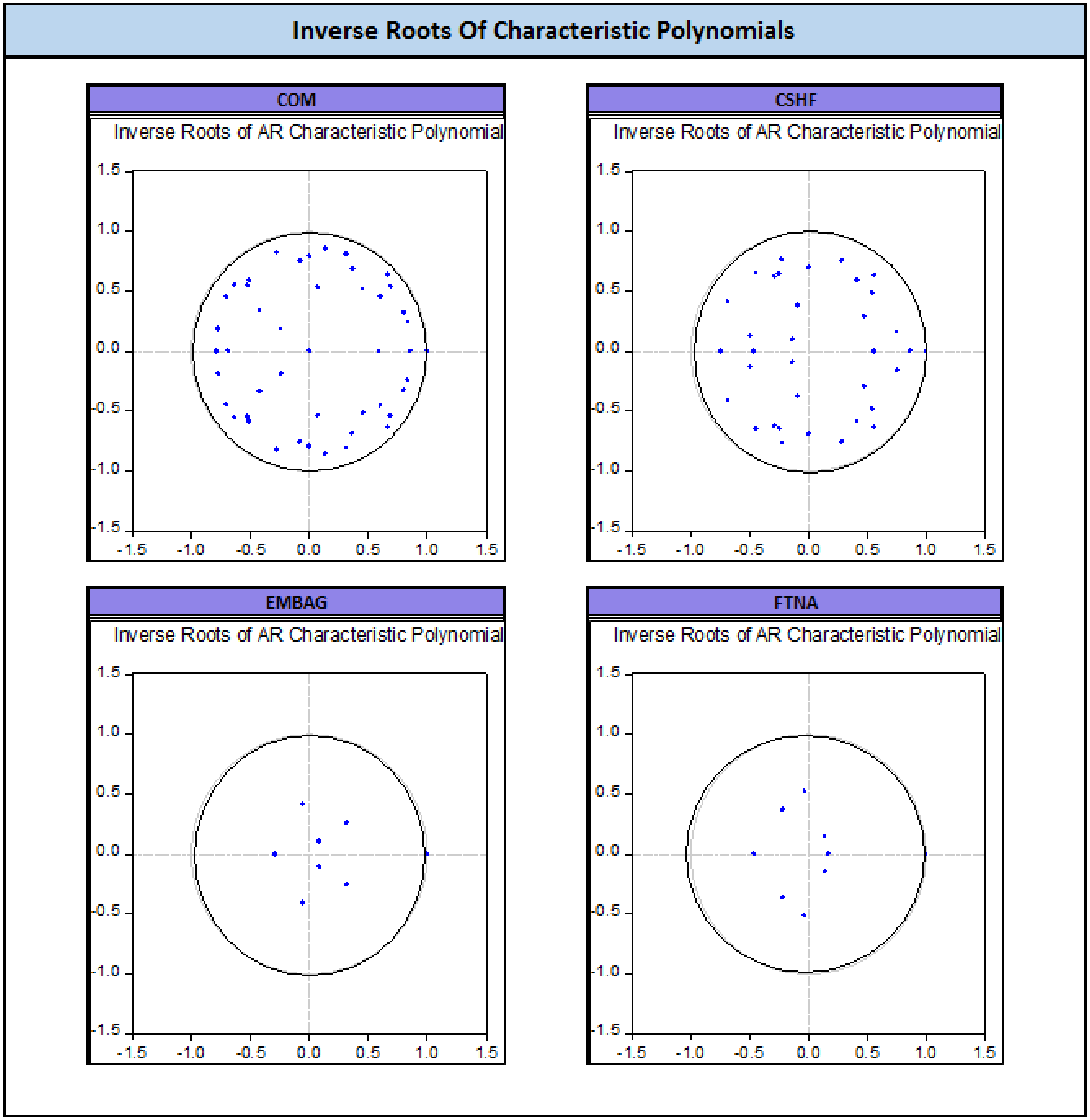
Results Part 6 – I*mpulse Response Functions (continuation)*

Table AA8.12 **Impulse Response Functions C**



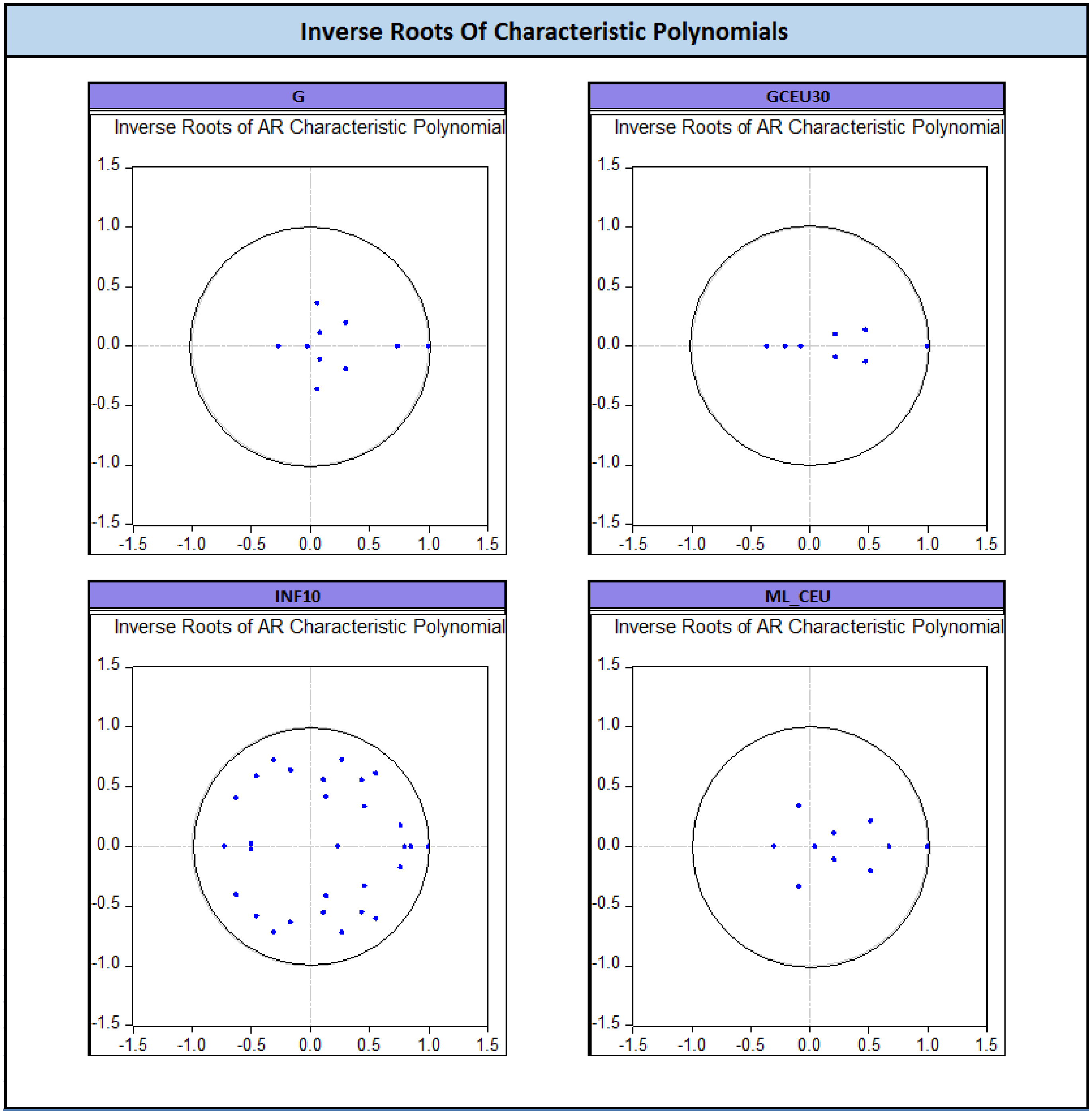
Results - Part 7: ***Inverse Roots of Characteristic Polynomials***

Table AA8.13 **Inverse Root Function A**



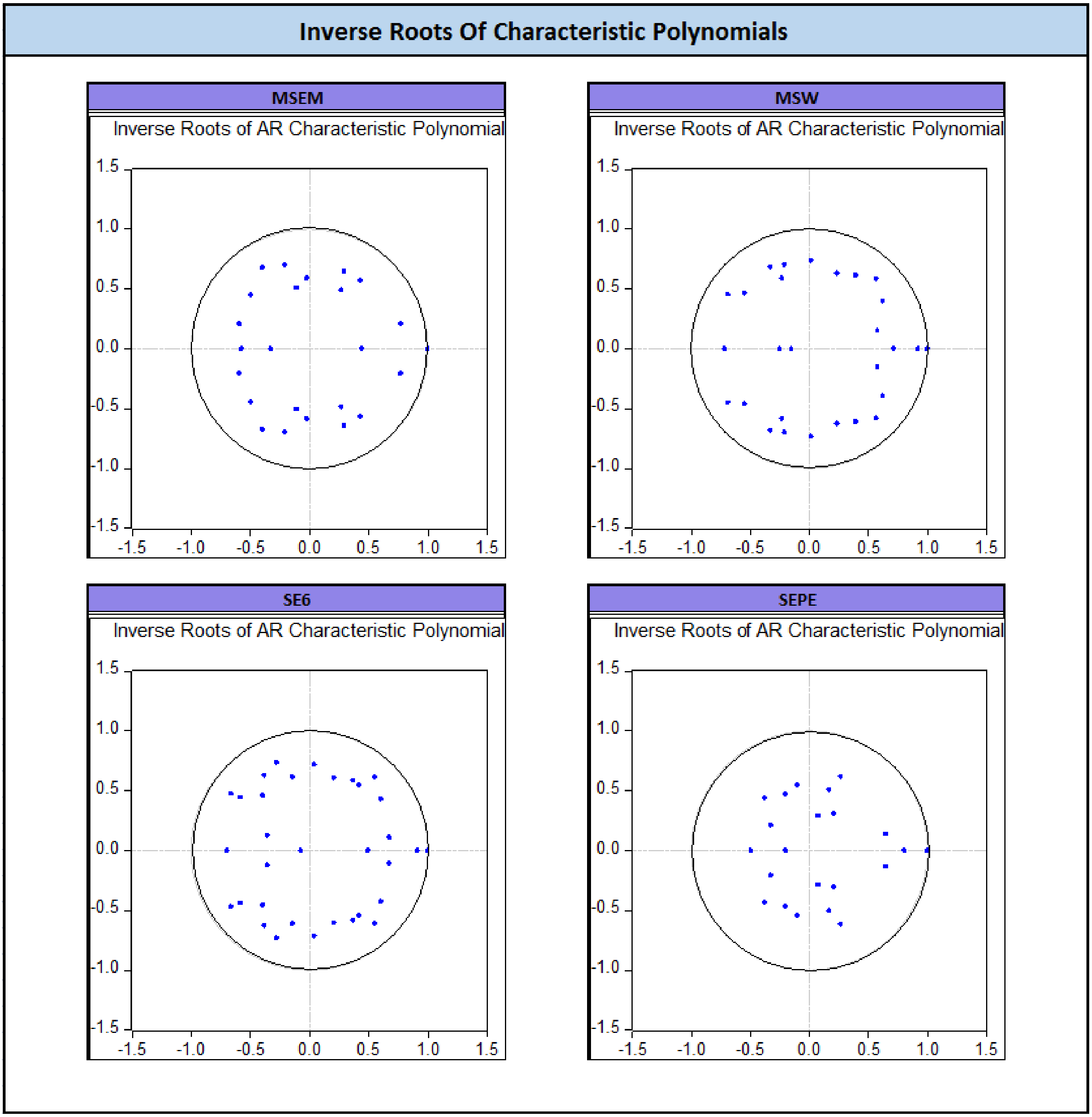
Results Part 7 – ***Inverse Roots of Characteristic Polynomial (continuation)***

Table AA8.14 **Inverse Root Function B**



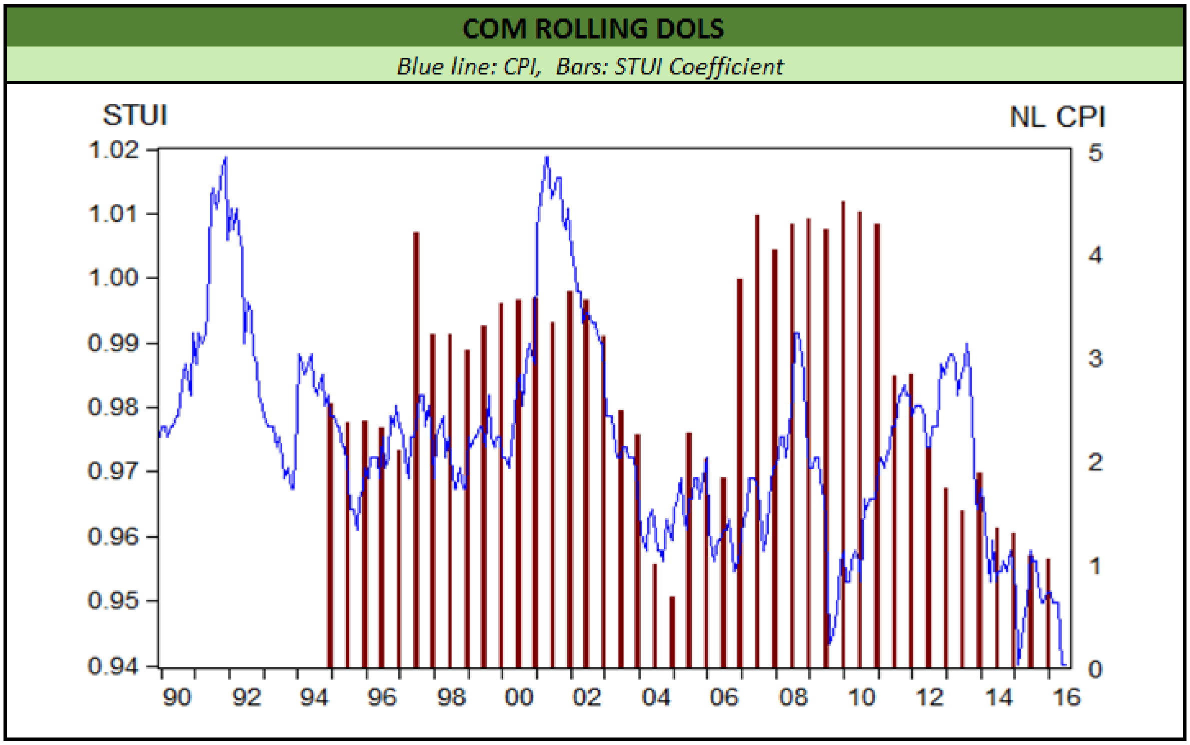
Results Part 7 – ***Inverse Roots of Characteristic Polynomial (continuation)***

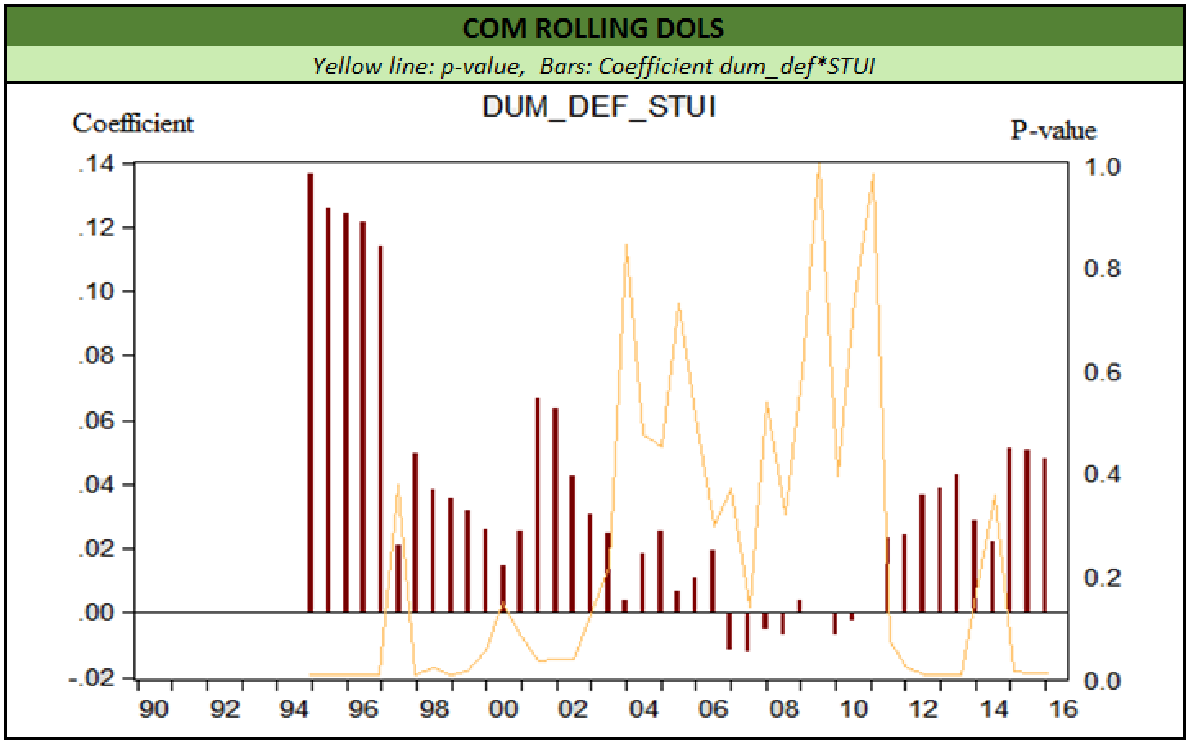
Table AA8.15 **Inverse Root Function C**



Results Part 8: ***Rolling Dynamic Ordinary Least Squares***

Table AA8.16 **Rolling DOLS A**



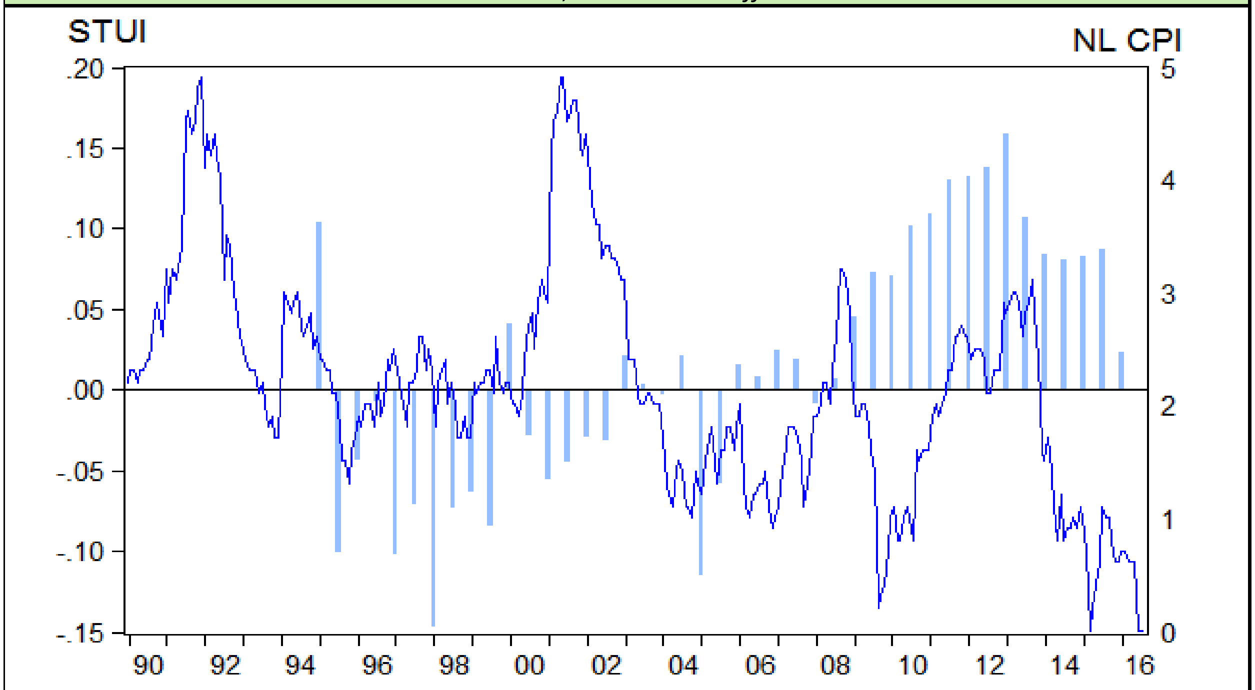


Results Part 8 – *Rolling Dynamic Ordinary Least Squares*

Table AA8.17 **Rolling DOLS B**

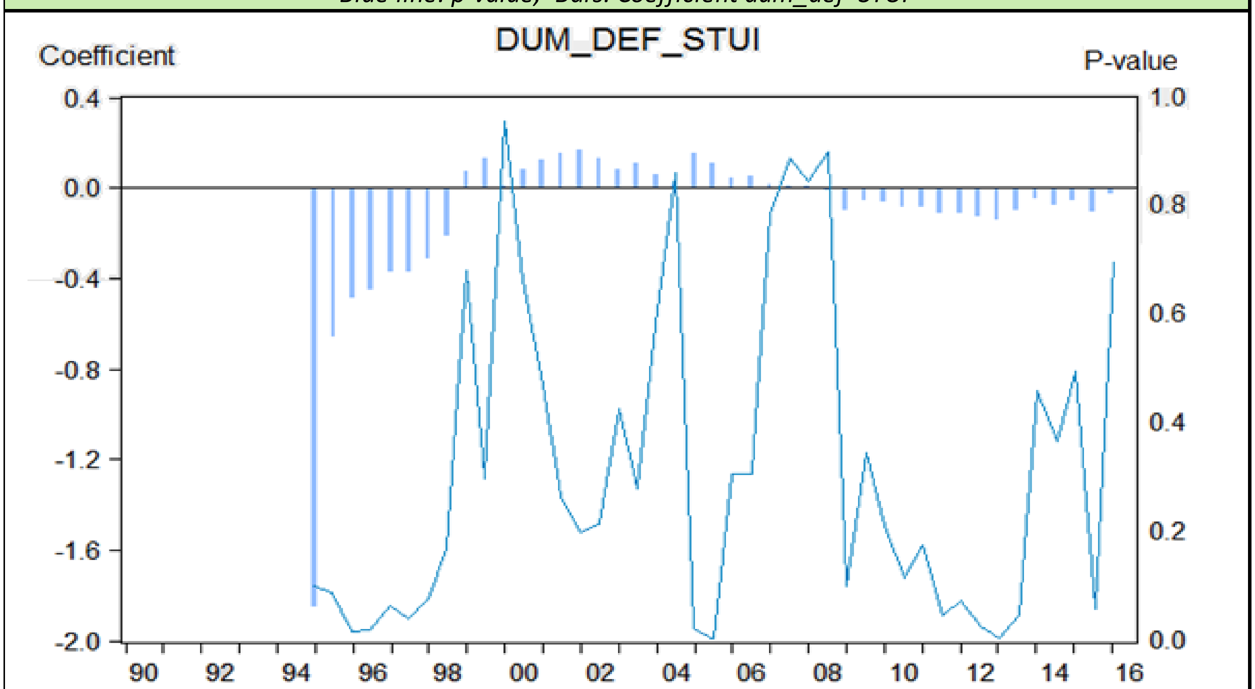
CSHF ROLLING DOLS

Blue line: CPI, Bars: STUI Coefficient



CSHF ROLLING DOLS

*Blue line: p-value, Bars: Coefficient dum_def*STUI*

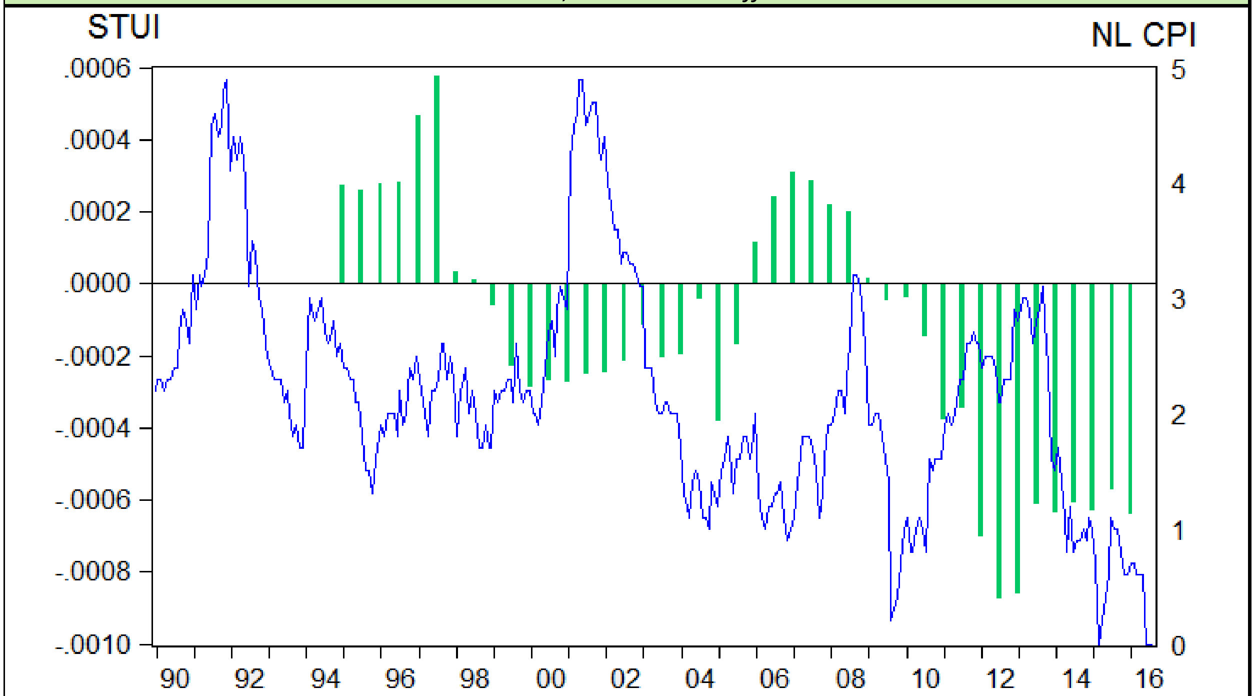


Results Part 8 – *Rolling Dynamic Ordinary Least Squares*

Table AA8.18 **Rolling DOLS C**

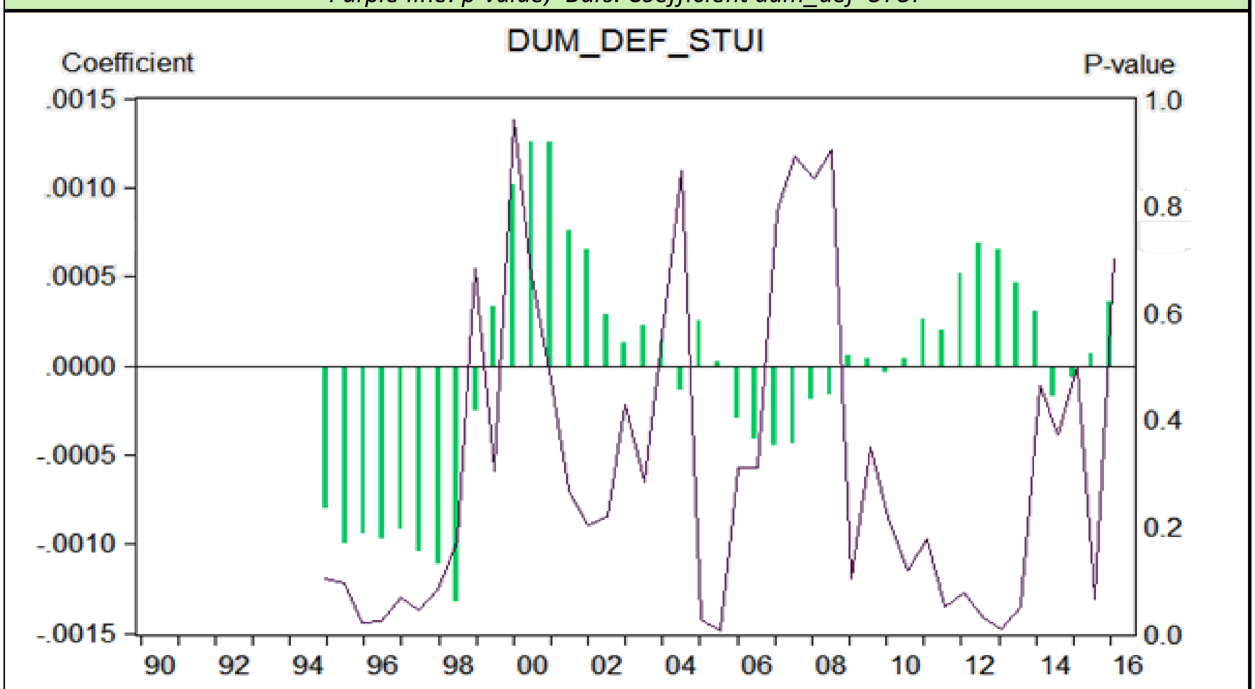
EMBAG ROLLING DOLS

Blue line: CPI, Bars: STUI Coefficient



EMBAG ROLLING DOLS

*Purple line: p-value, Bars: Coefficient dum_def*STUI*

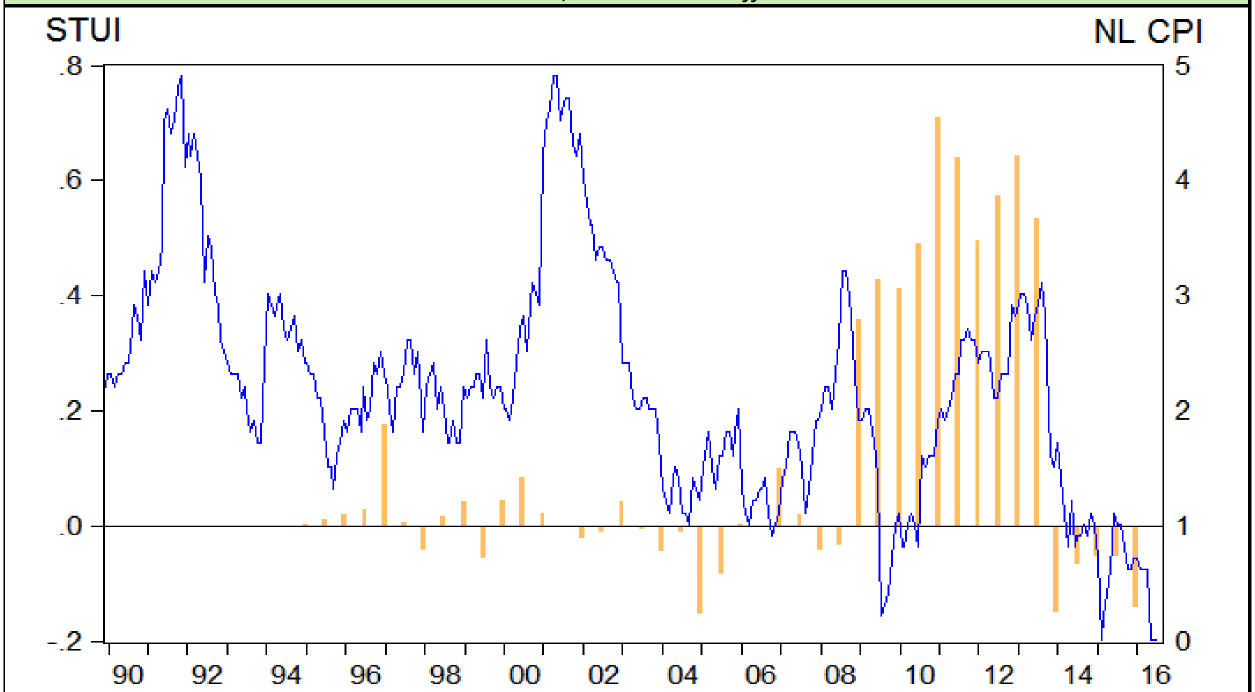


Results Part 8 – ***Rolling Dynamic Ordinary Least Squares***

Table AA8.19 **Rolling DOLS D**

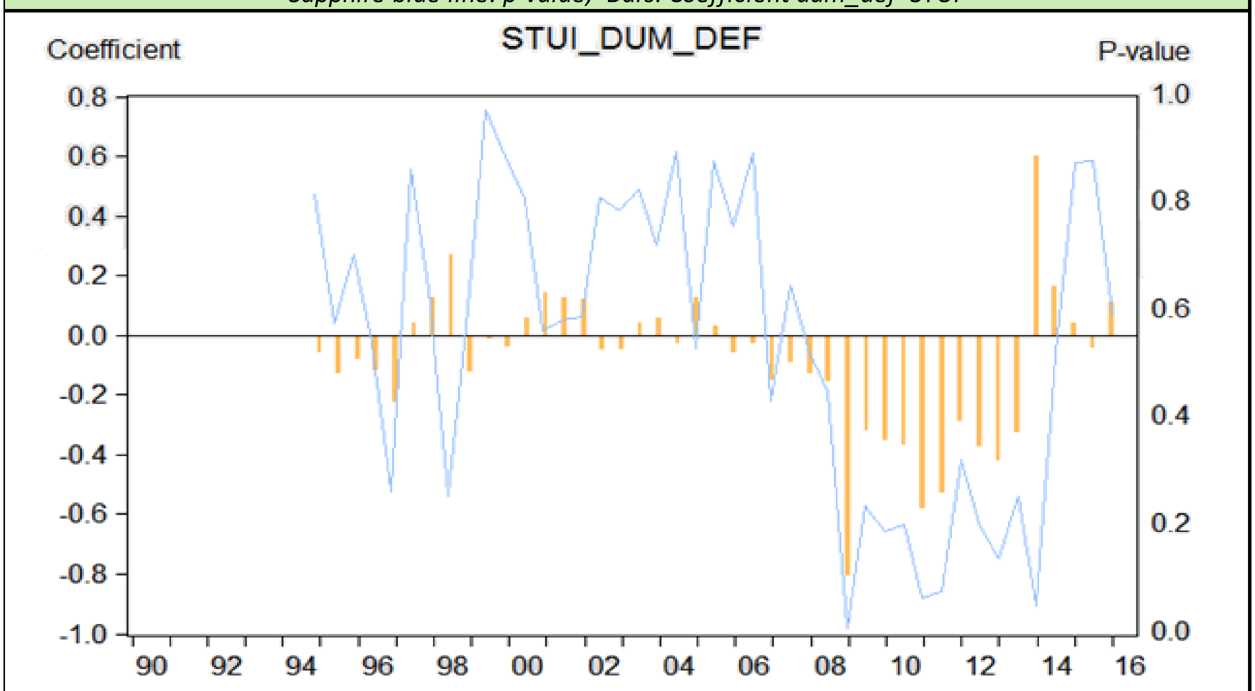
FTNA ROLLING DOLS

Blue line: CPI, Bars: STUI Coefficient



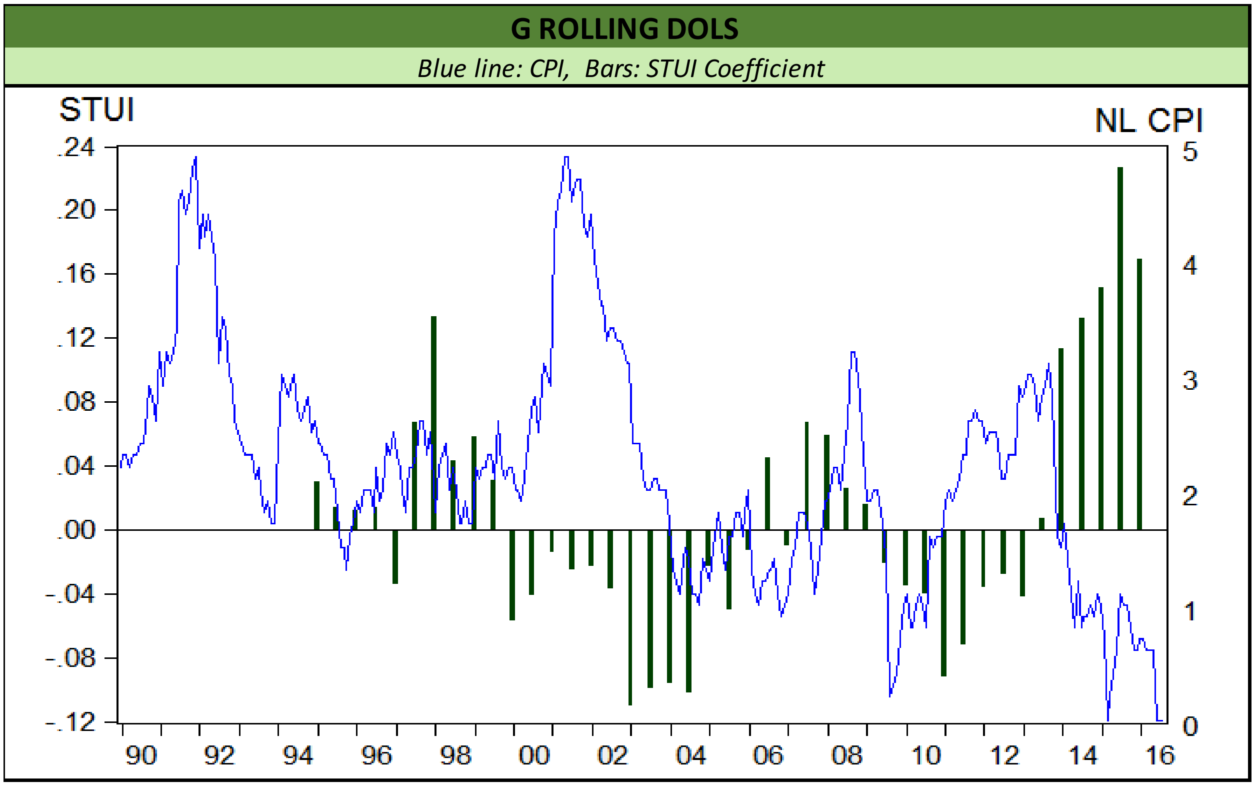
FTNA ROLLING DOLS

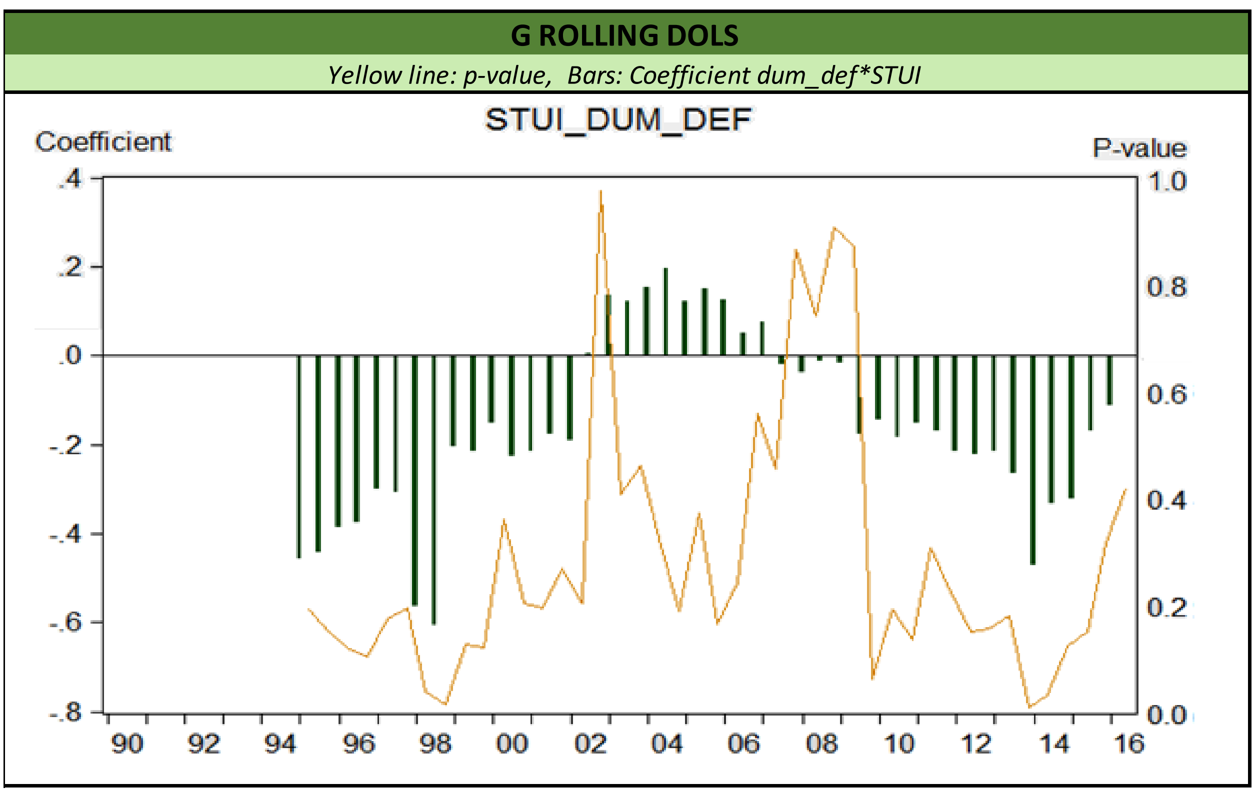
*Sapphire blue line: p-value, Bars: Coefficient dum_def*STUI*



Results Part 8 – ***Rolling Dynamic Ordinary Least Squares***

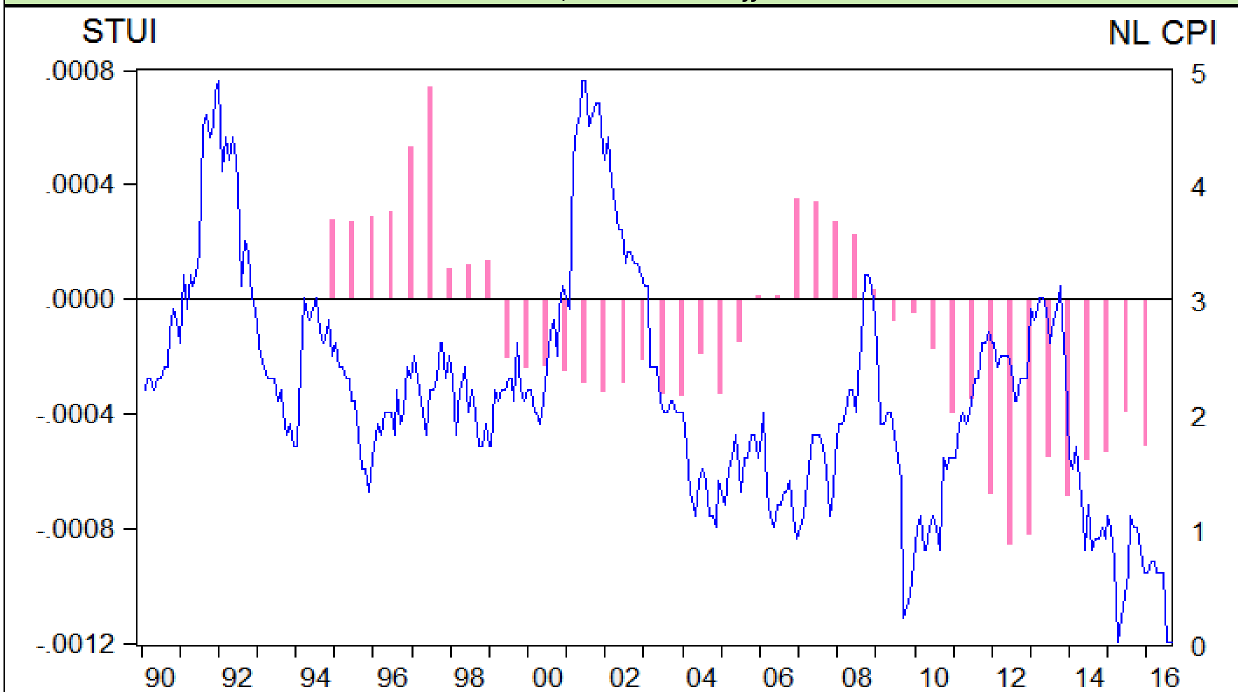
Table AA8.20 **Rolling DOLS E**

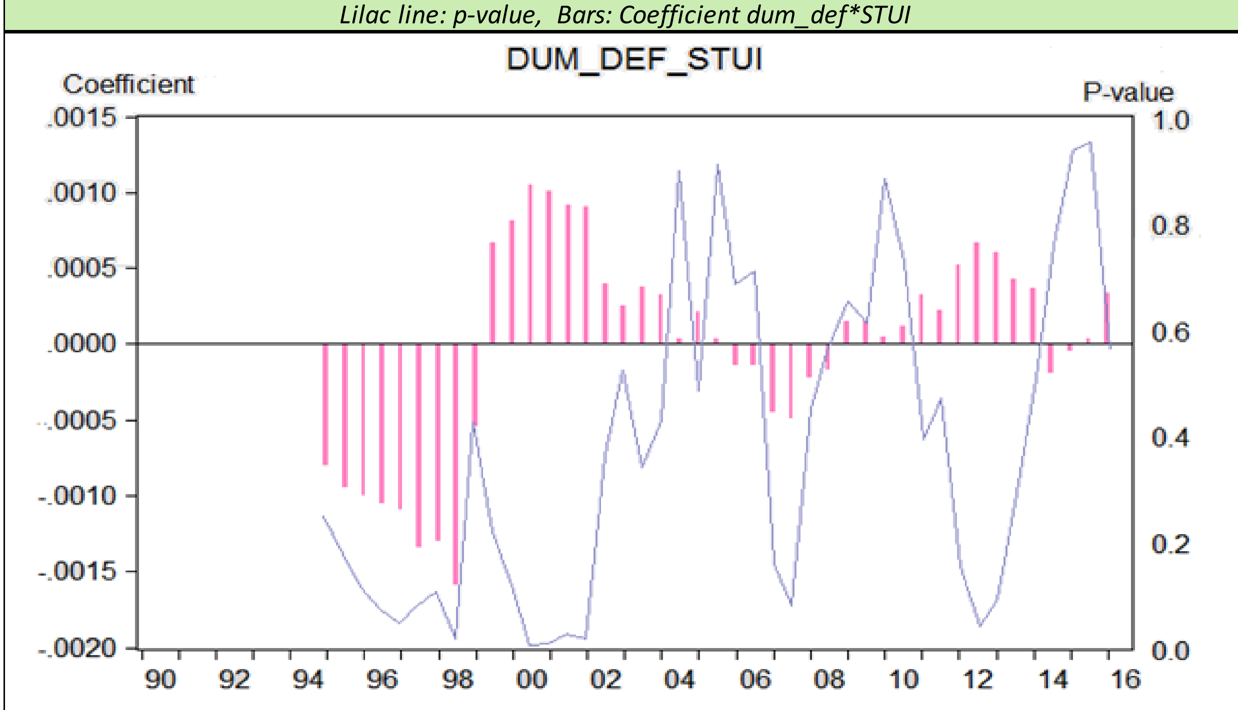




Results Part 8 – *Rolling Dynamic Ordinary Least Squares*

Table AA8.21 **Rolling DOLS F**

GCEU30 ROLLING DOLS
Blue line: CPI, Bars: STUI Coefficient


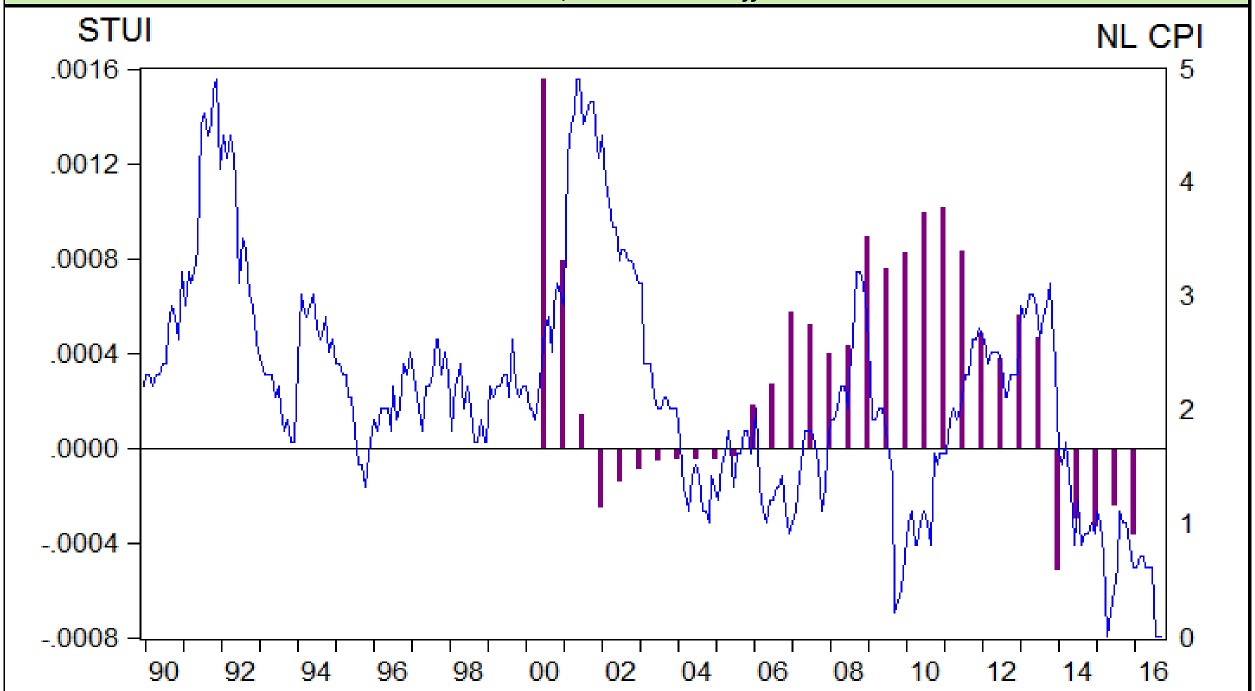
GCEU30 ROLLING DOLS
*Lilac line: p-value, Bars: Coefficient dum_def*STUI*


Results Part 8 – *Rolling Dynamic Ordinary Least Squares*

Table AA8.22 **Rolling DOLS G**

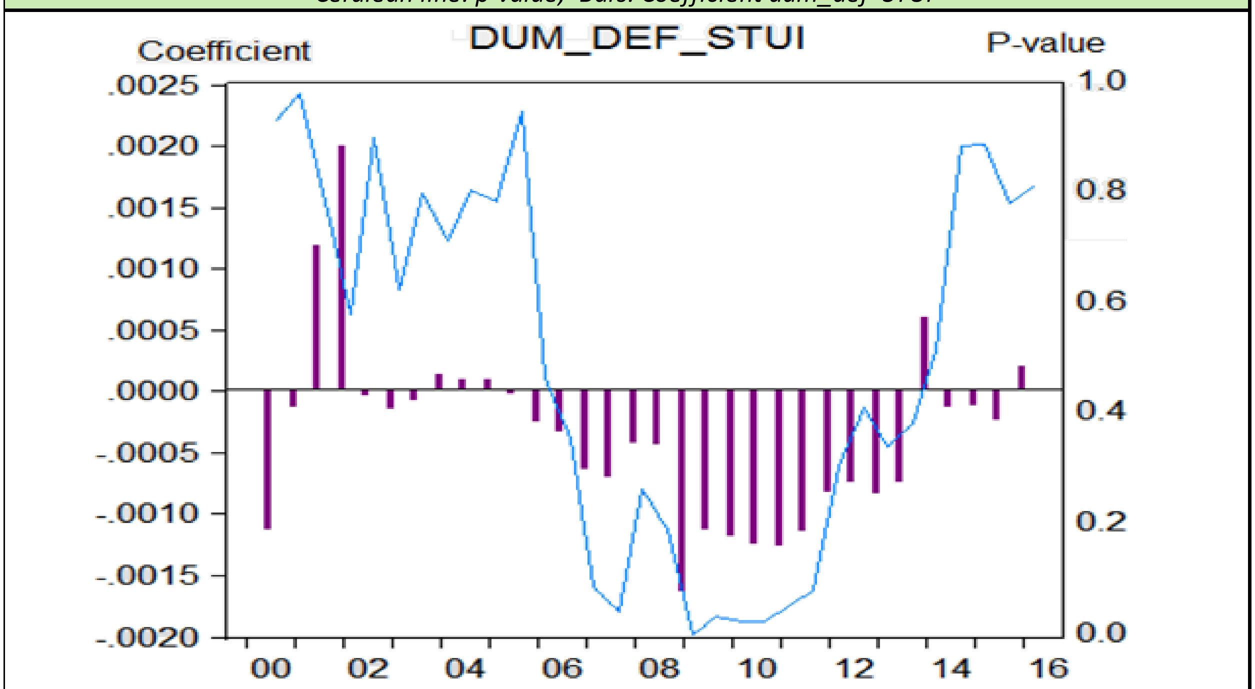
INF10 ROLLING DOLS

Blue line: CPI, Bars: STUI Coefficient



INF10 ROLLING DOLS

*Cerulean line: p-value, Bars: Coefficient dum_def*STUI*

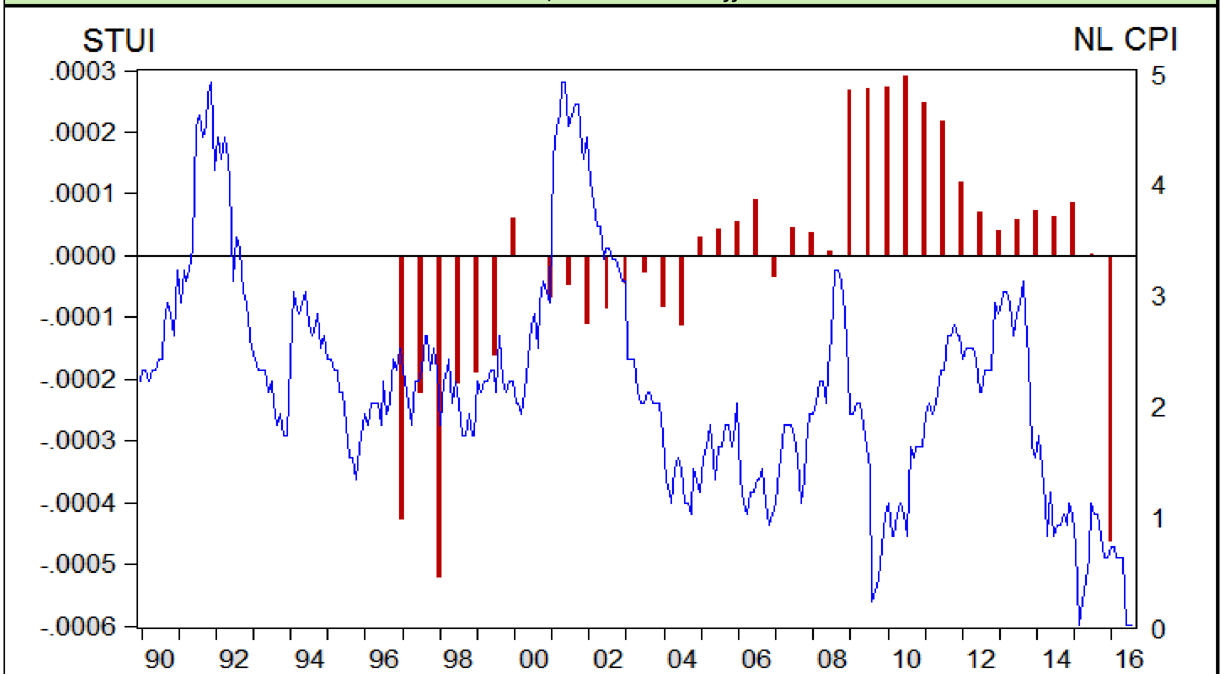


Results Part 8 – *Rolling Dynamic Ordinary Least Squares*

Table AA8.23 **Rolling DOLS H**

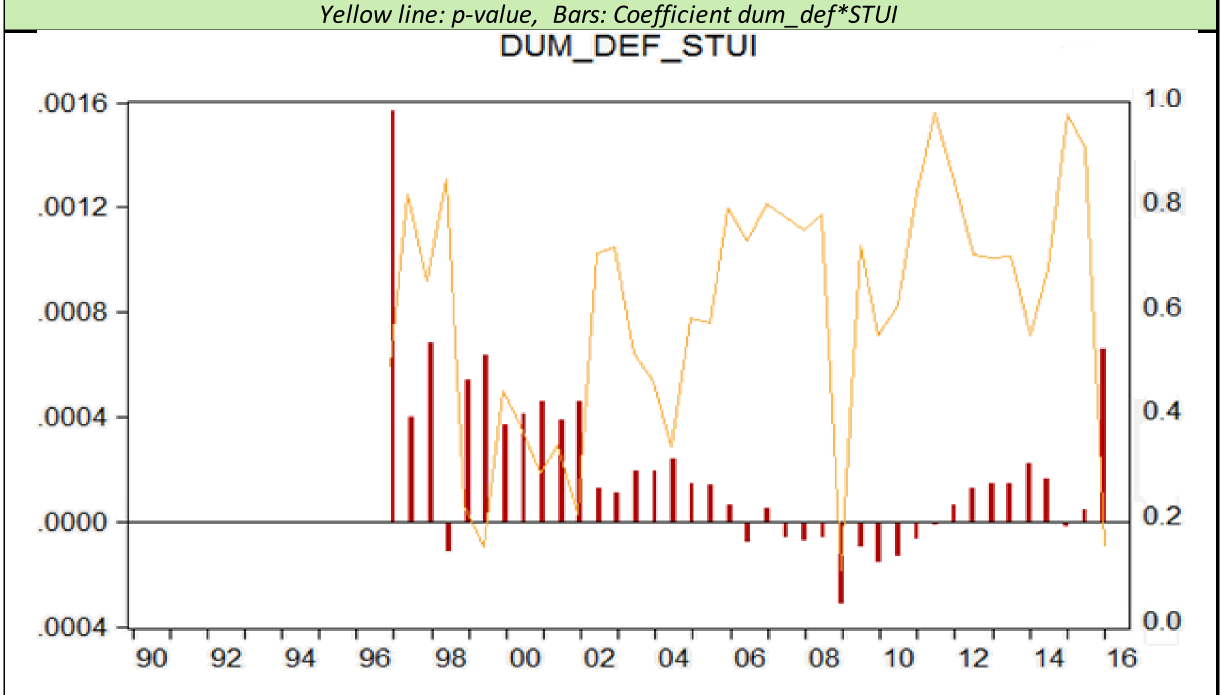
ML_CEU ROLLING DOLS

Blue line: CPI, Bars: STUI Coefficient



ML_CEU ROLLING DOLS

*Yellow line: p-value, Bars: Coefficient dum_def*STUI*

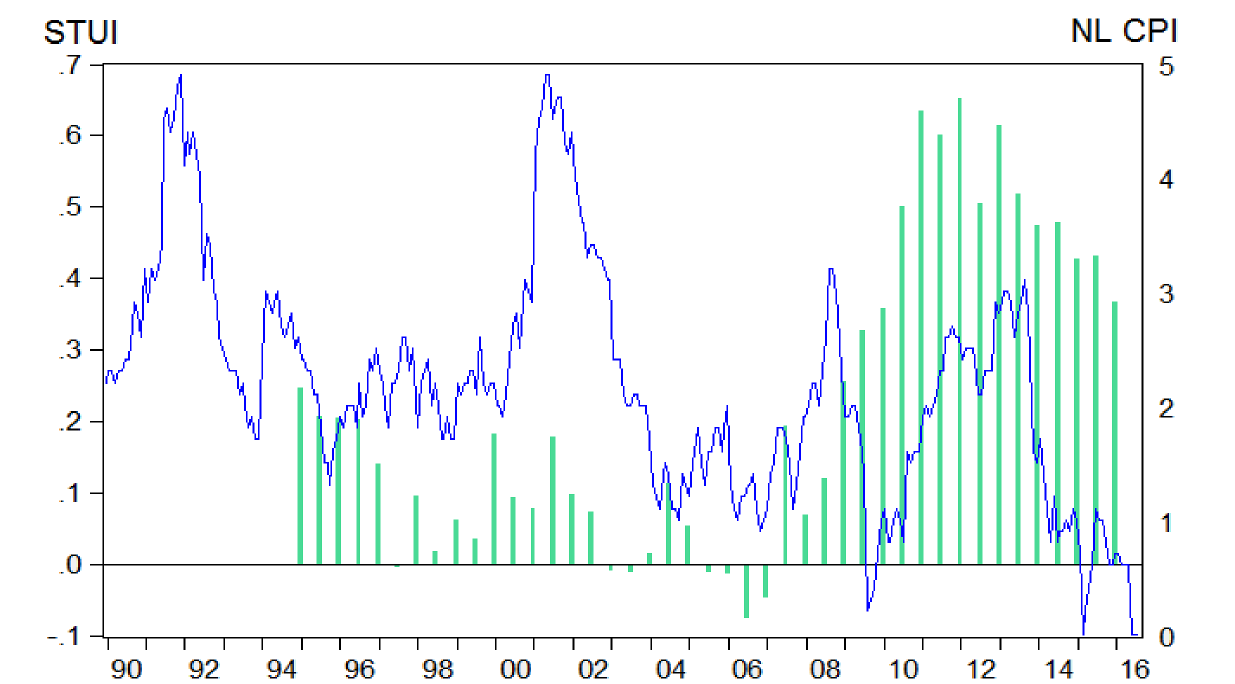


Results Part 8 – *Rolling Dynamic Ordinary Least Squares*

Table AA8.24 **Rolling DOLS I**

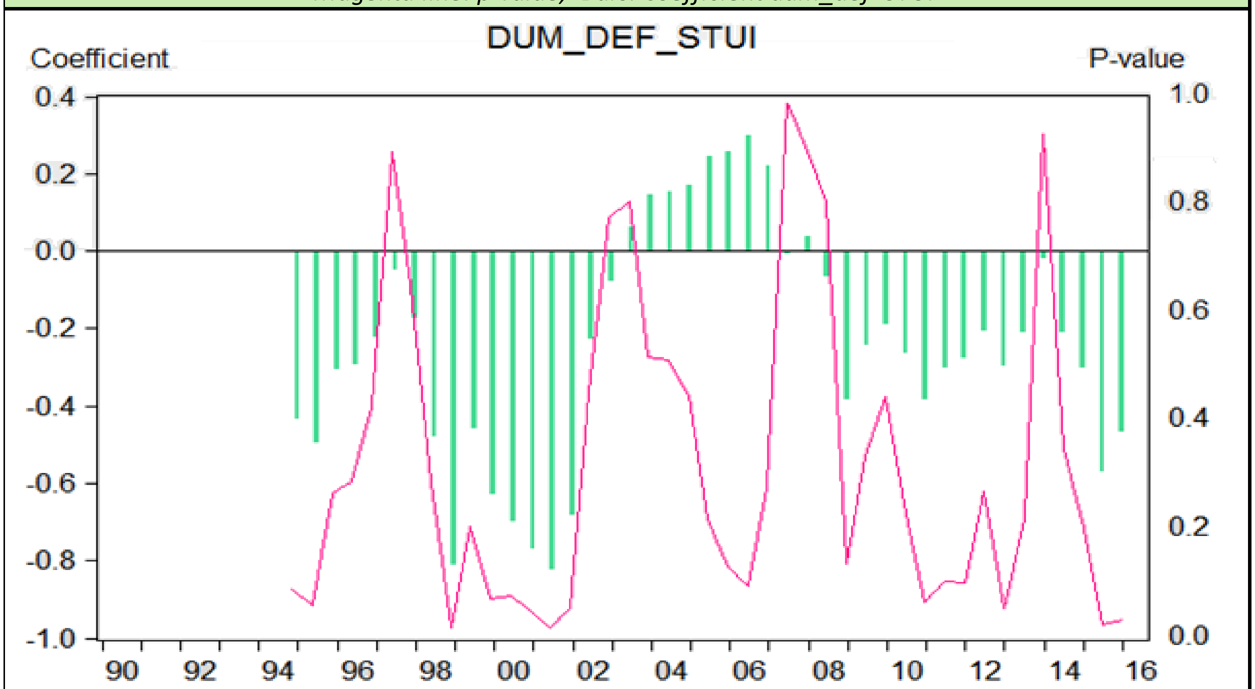
MSEM ROLLING DOLS

Blue line: CPI, Bars: STUI Coefficient



MSEM ROLLING DOLS

*Magenta line: p-value, Bars: Coefficient dum_def*STUI*

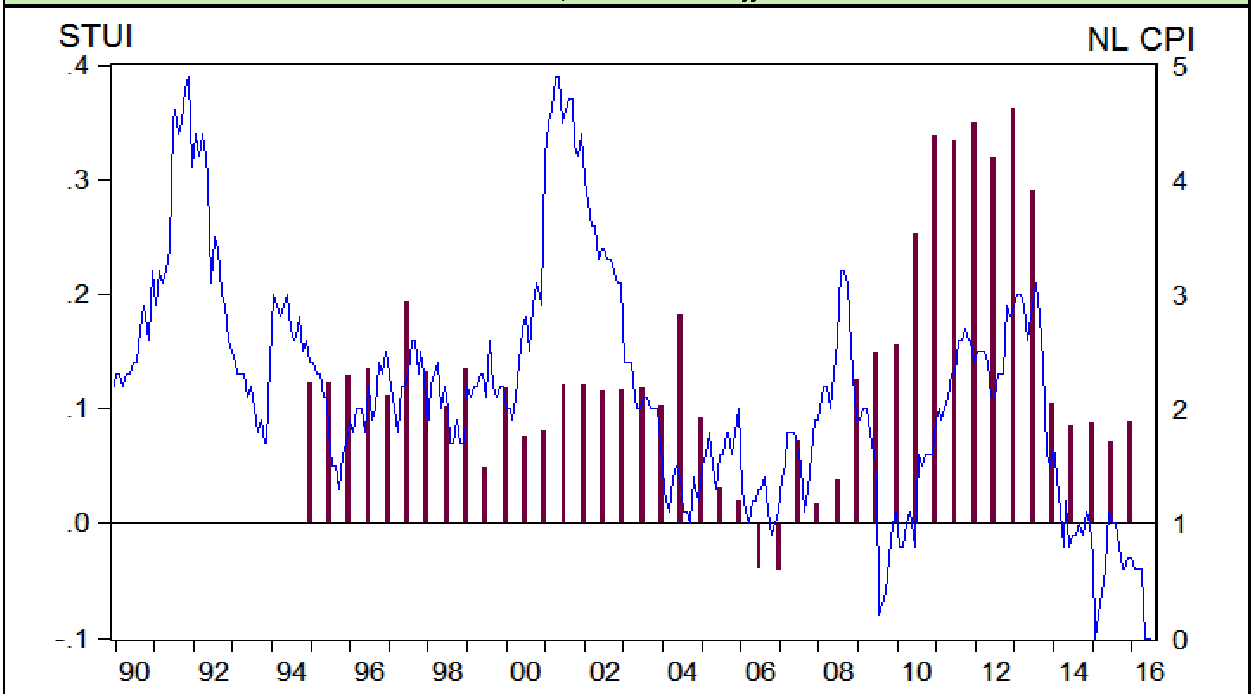


Results Part 8 – ***Rolling Dynamic Ordinary Least Squares***

Table AA8.25 **Rolling DOLS J**

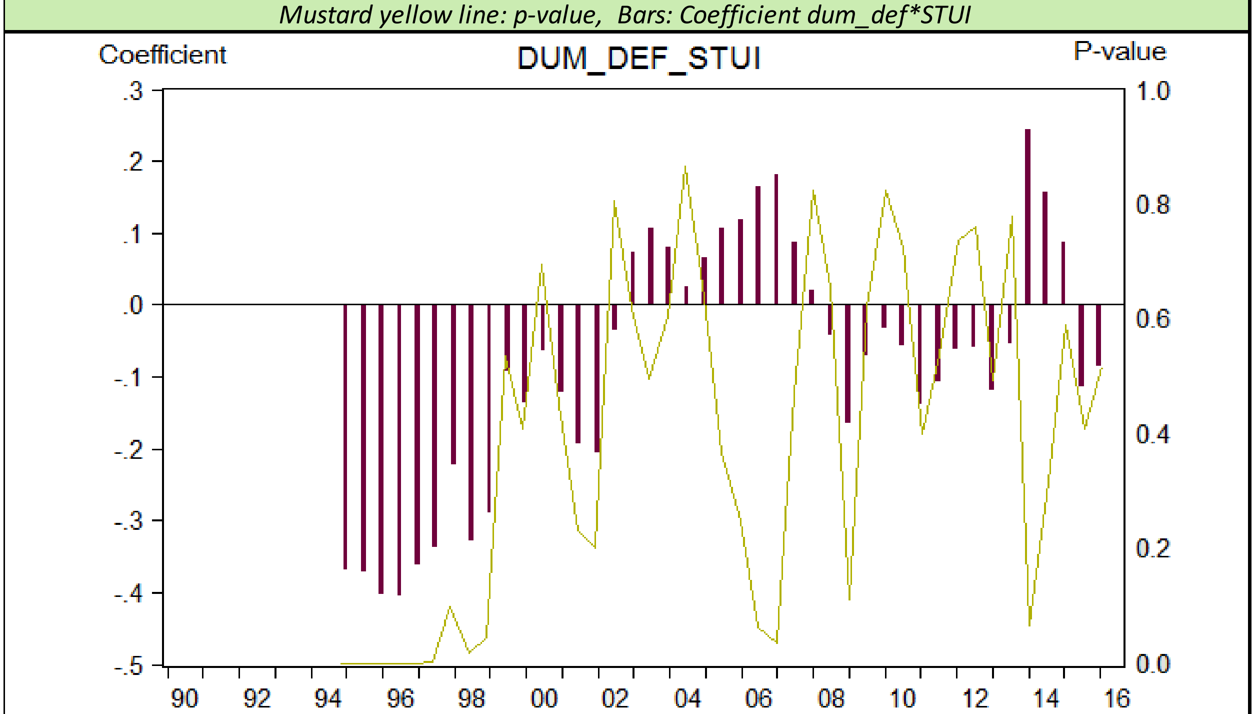
MSW ROLLING DOLS

Blue line: CPI, Bars: STUI Coefficient



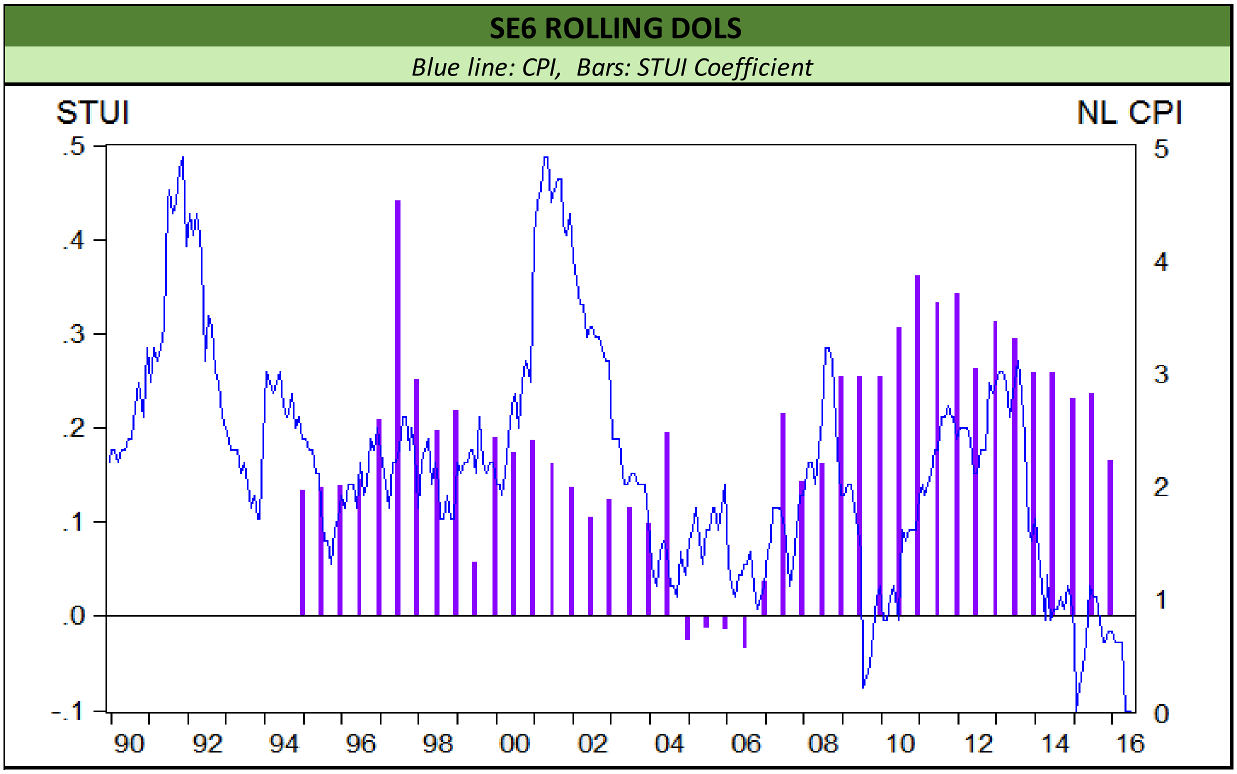
MSW ROLLING DOLS

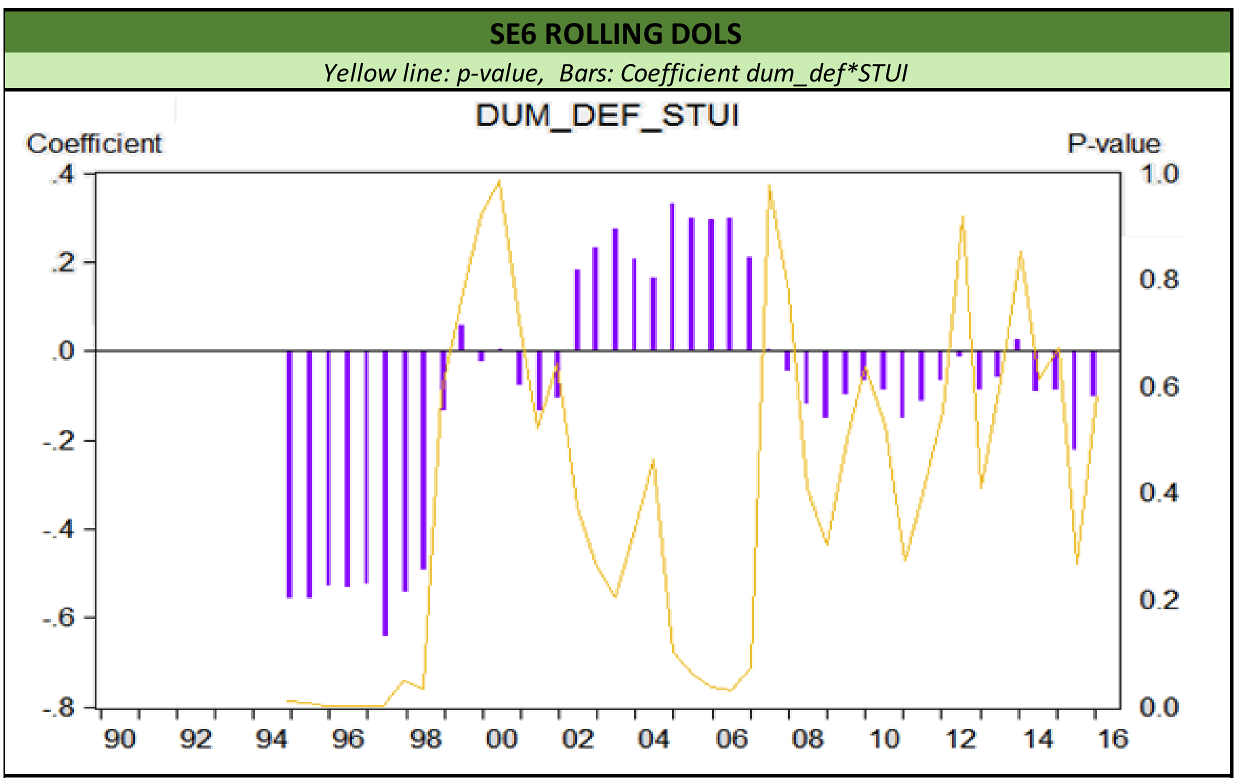
*Mustard yellow line: p-value, Bars: Coefficient dum_def*STUI*



Results Part 8 – ***Rolling Dynamic Ordinary Least Squares***

Table AA8.26 **Rolling DOLS K**



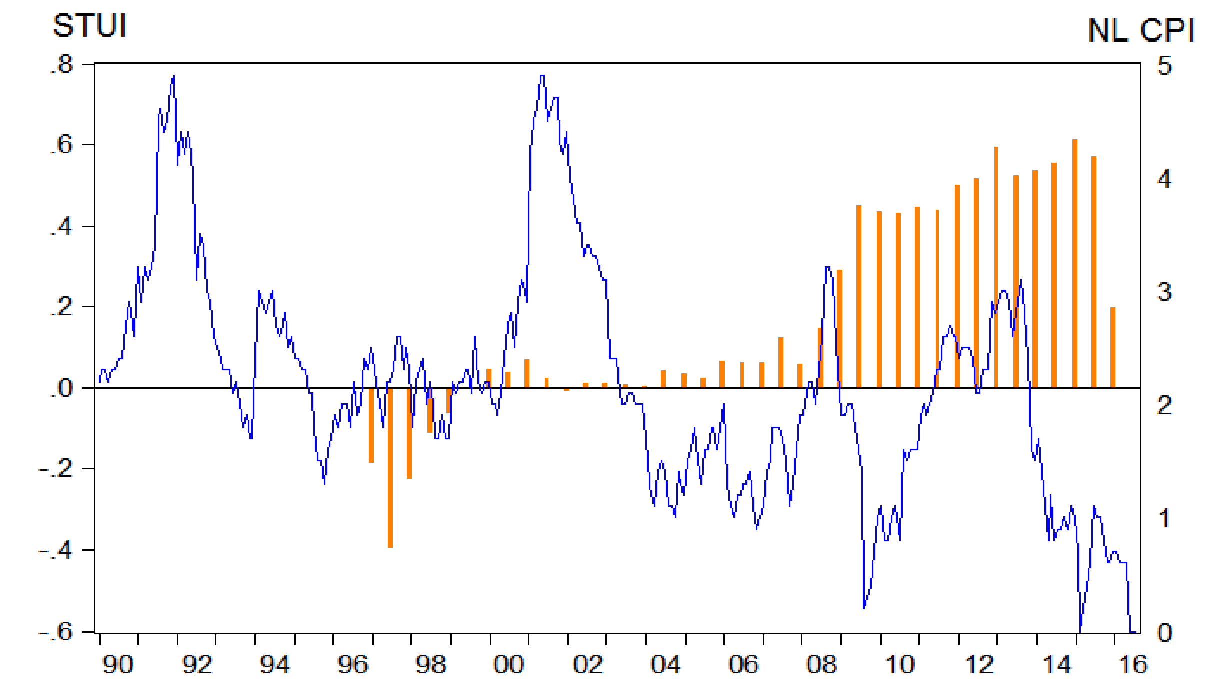


Results Part 8 – ***Rolling Dynamic Ordinary Least Squares***

Table AA8.27 **Rolling DOLS L**

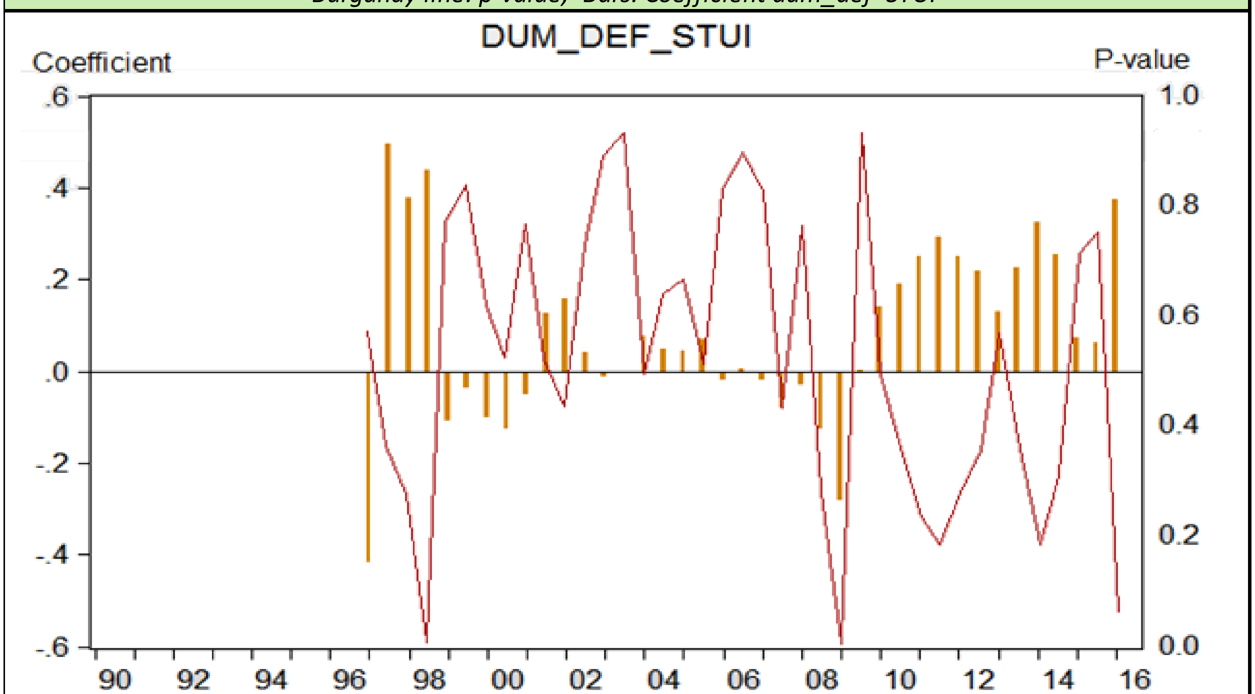
SEPE ROLLING DOLS

Blue line: CPI, Bars: STUI Coefficient



SEPE ROLLING DOLS

*Burgundy line: p-value, Bars: Coefficient dum_def*STUI*

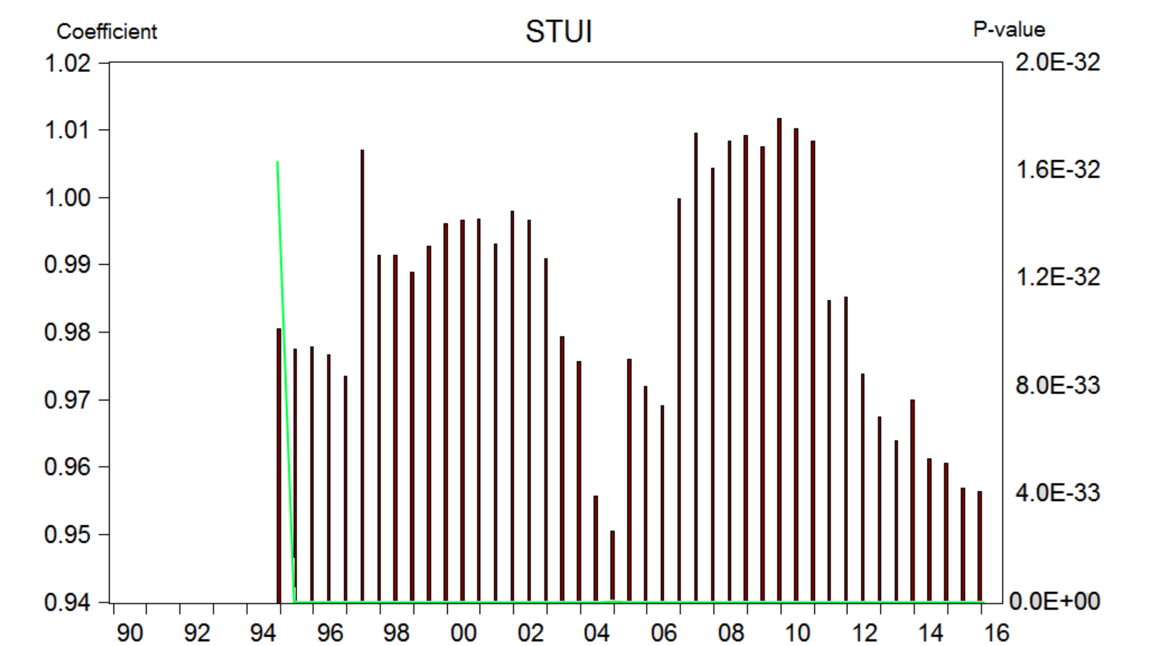


Results Part 8 – ***Rolling Dynamic Ordinary Least Squares – P-values STUI Coefficient***

Table AA8.28 **Rolling DOLS M**

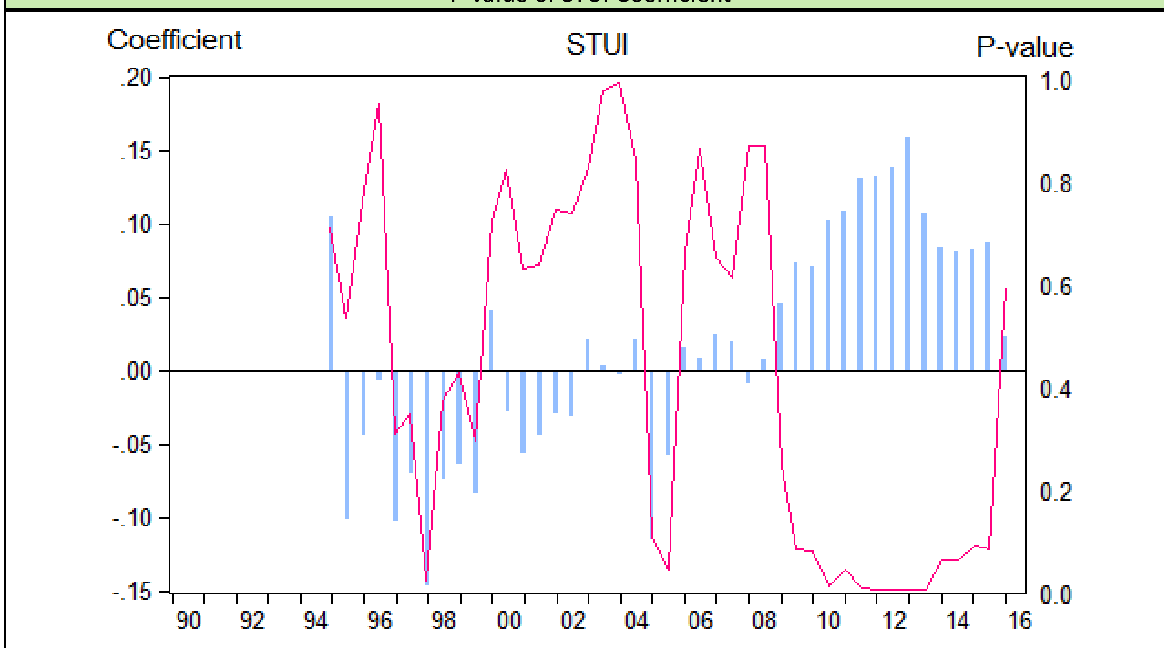
COM ROLLING DOLS

P-value of STUI Coefficient



CSHF ROLLING DOLS

P-value of STUI Coefficient

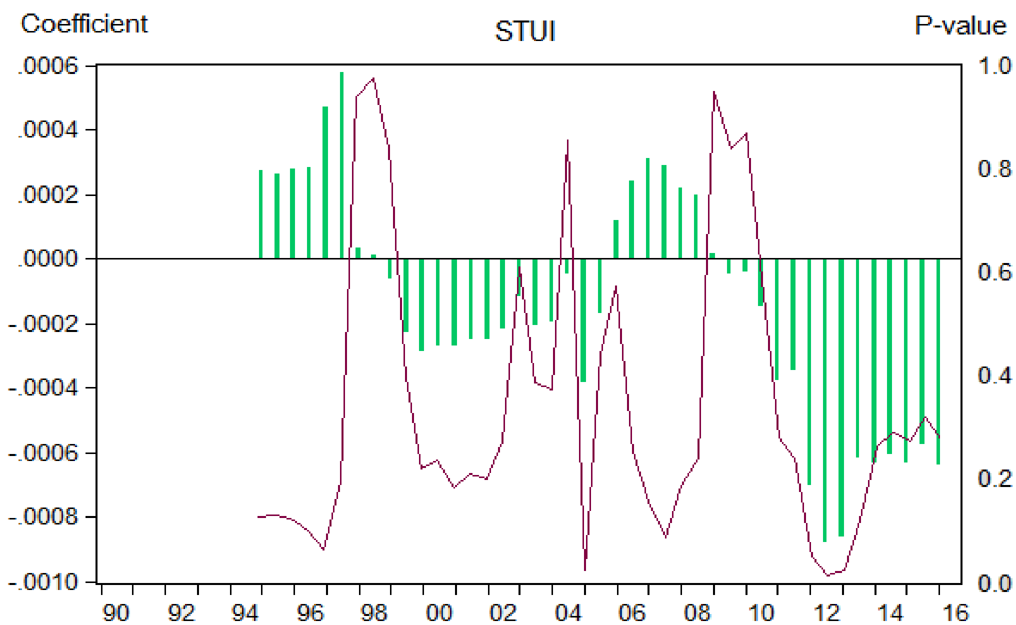


Results Part 8 – *Rolling Dynamic Ordinary Least Squares – P-values STUI Coefficient*

Table AA8.29 **Rolling DOLS N**

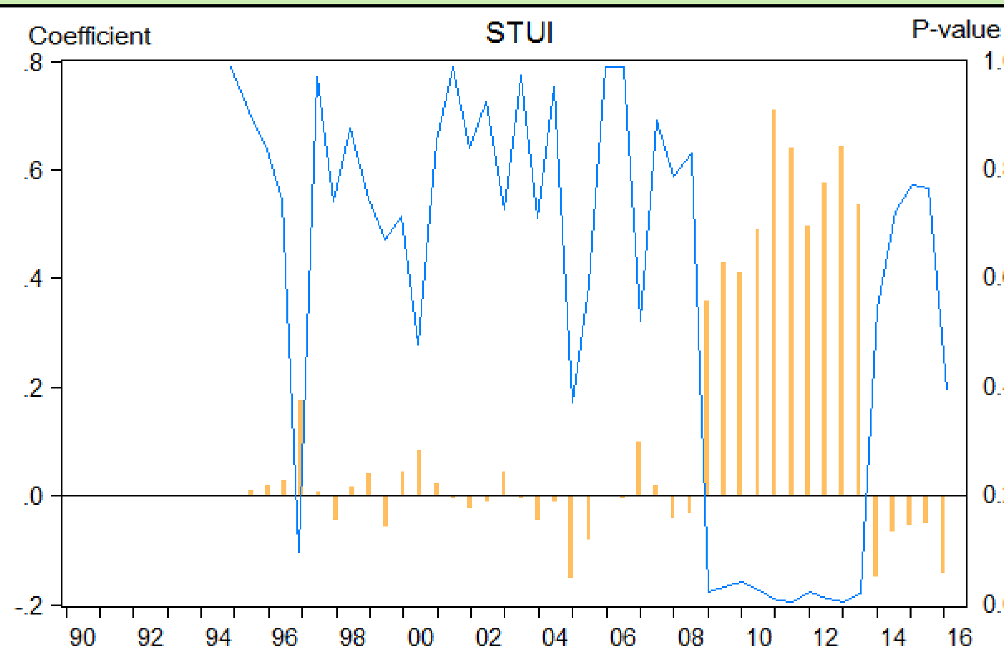
EMBAG ROLLING DOLS

P-value of STUI Coefficient



FTNA ROLLING DOLS

P-value of STUI Coefficient

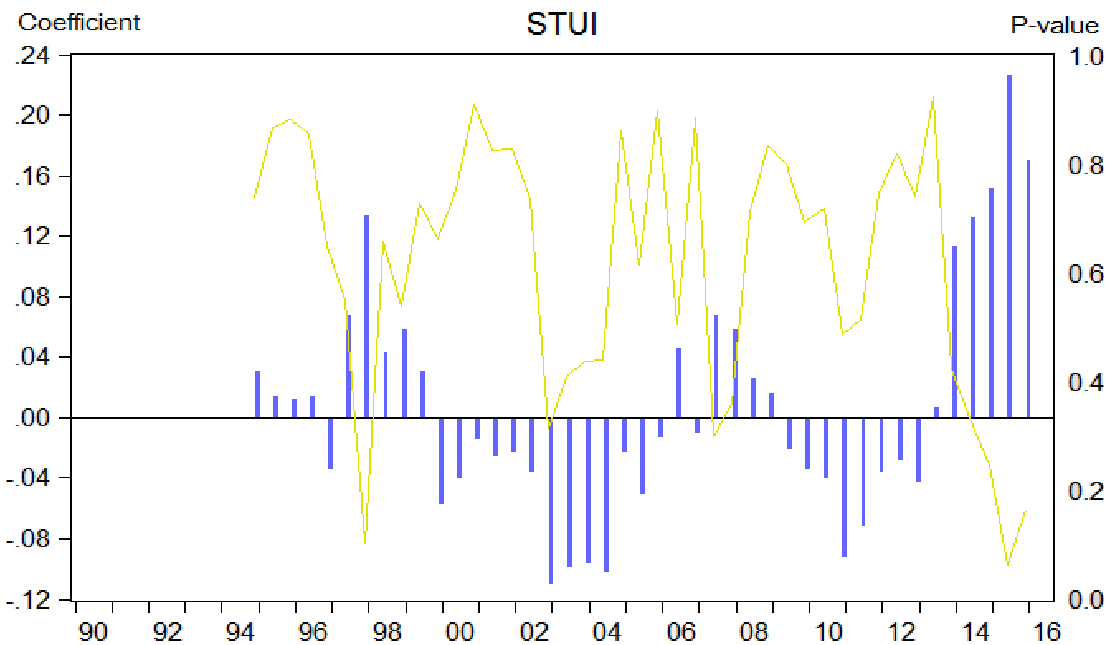


Results Part 8 – ***Rolling Dynamic Ordinary Least Squares – P-values STUI Coefficient***

Table AA8.29 **Rolling DOLS O**

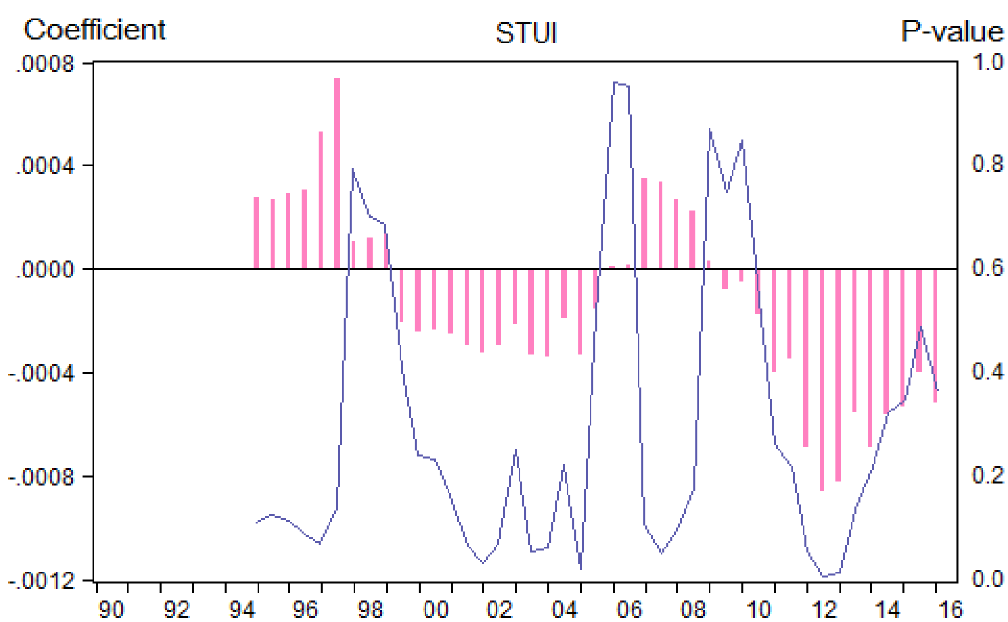
G ROLLING DOLS

P-value of STUI Coefficient



GCEU30 ROLLING DOLS

P-value of STUI Coefficient

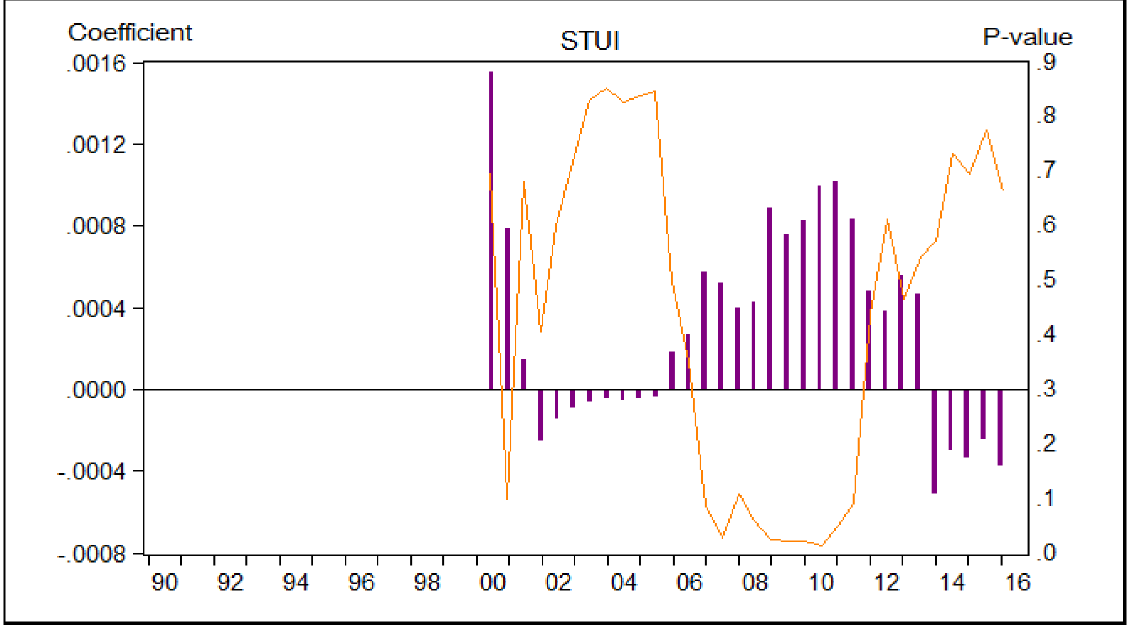


Results Part 8 – ***Rolling Dynamic Ordinary Least Squares – P-values STUI Coefficient***

Table AA8.30 **Rolling DOLS P**

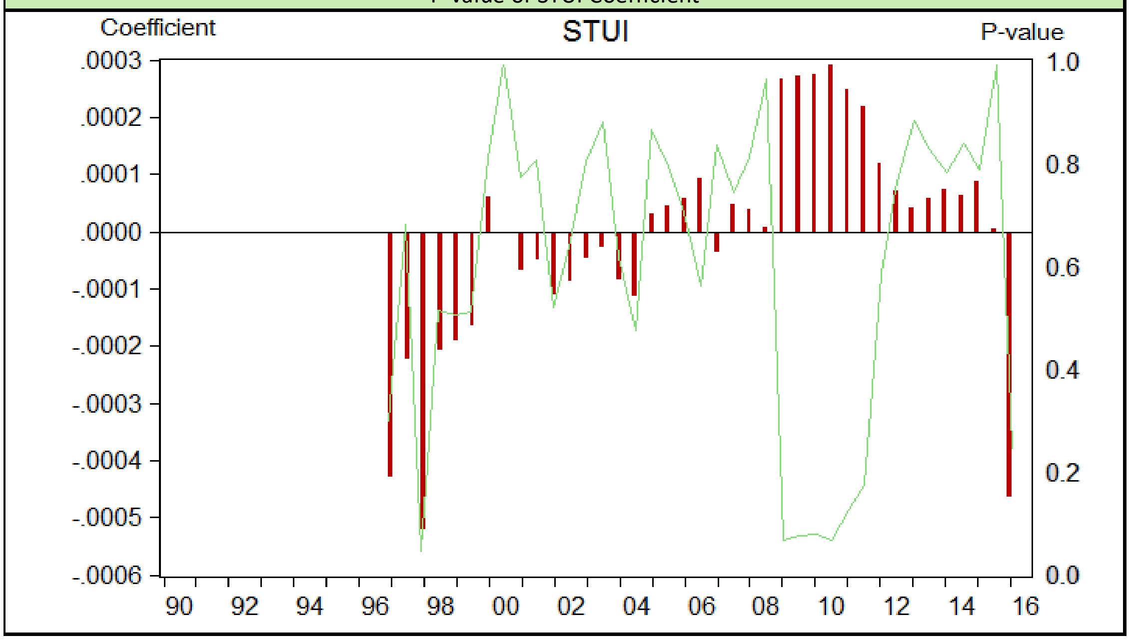
INF10 ROLLING DOLS

P-value of STUI Coefficient



ML_CEU ROLLING DOLS

P-value of STUI Coefficient

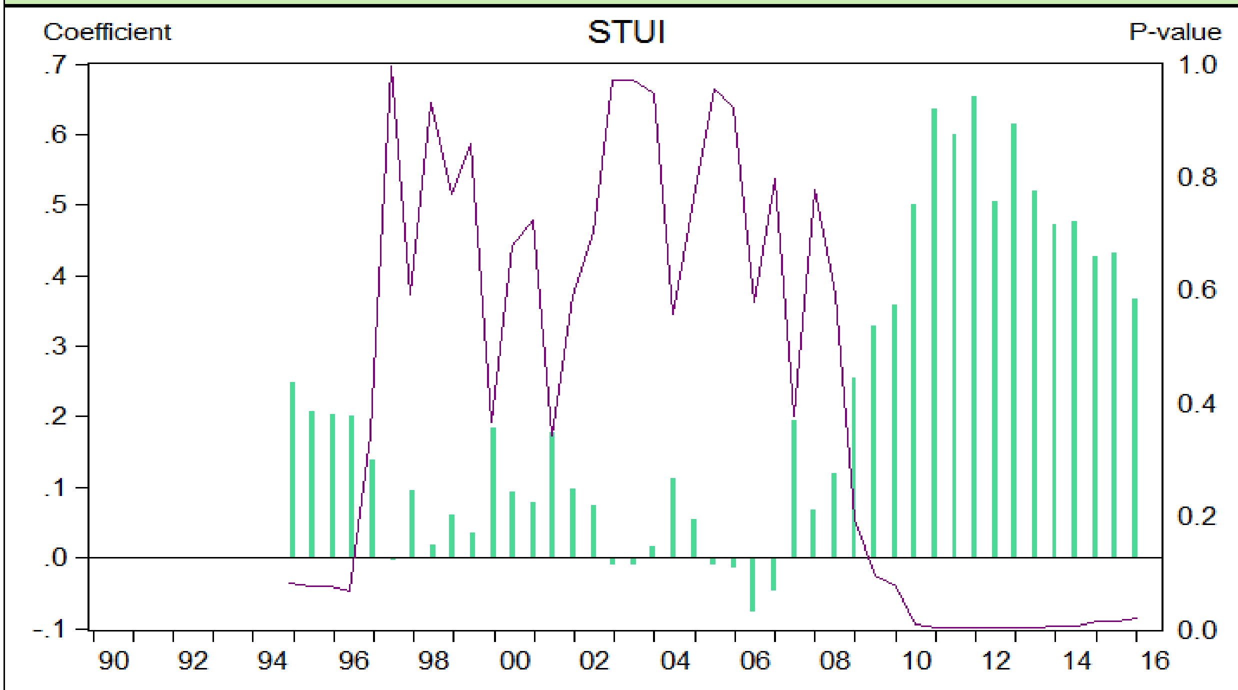


Results Part 8 – ***Rolling Dynamic Ordinary Least Squares – P-values STUI Coefficient***

Table AA8.31 **Rolling DOLS Q**

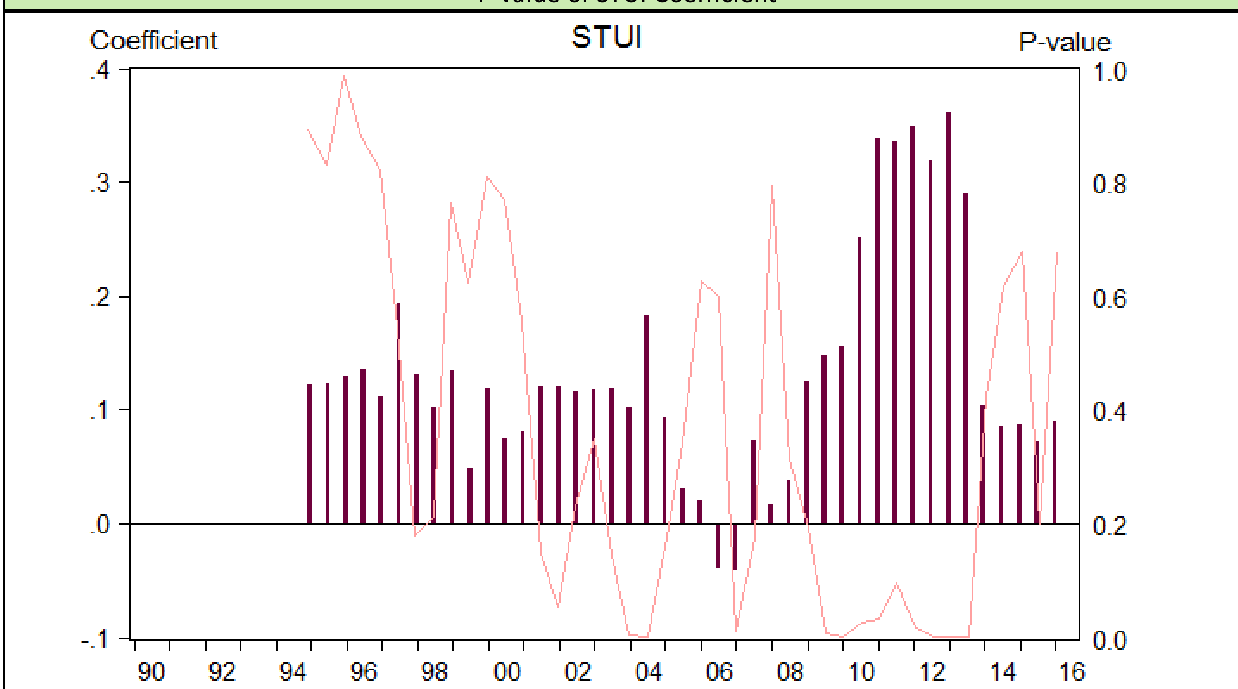
MSEM ROLLING DOLS

P-value of STUI Coefficient



MSW ROLLING DOLS

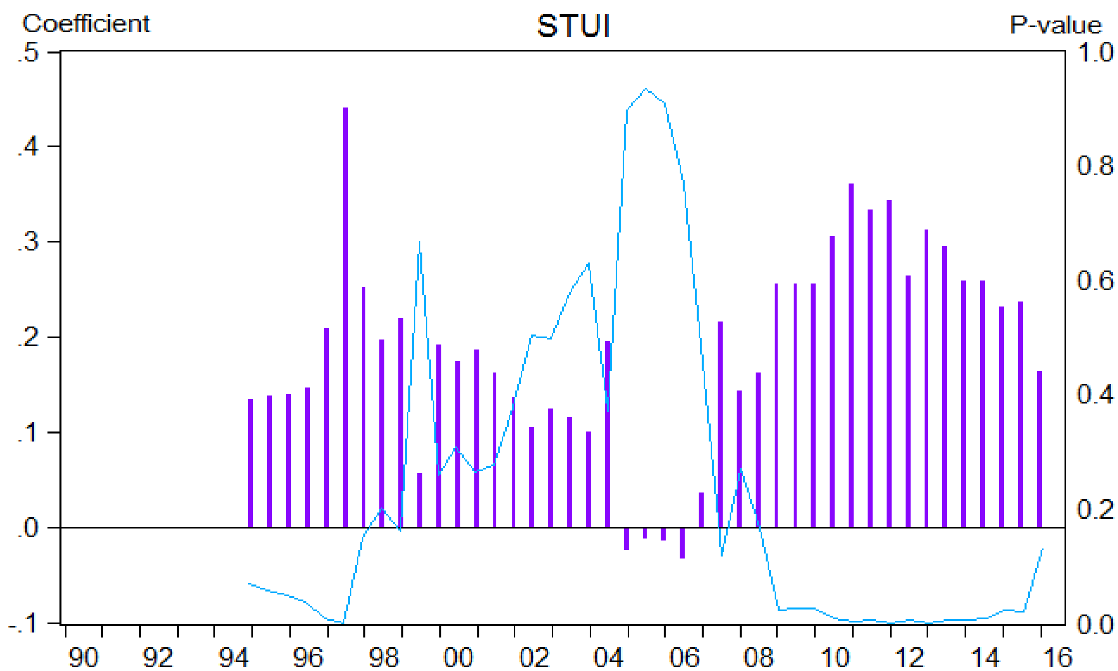
P-value of STUI Coefficient



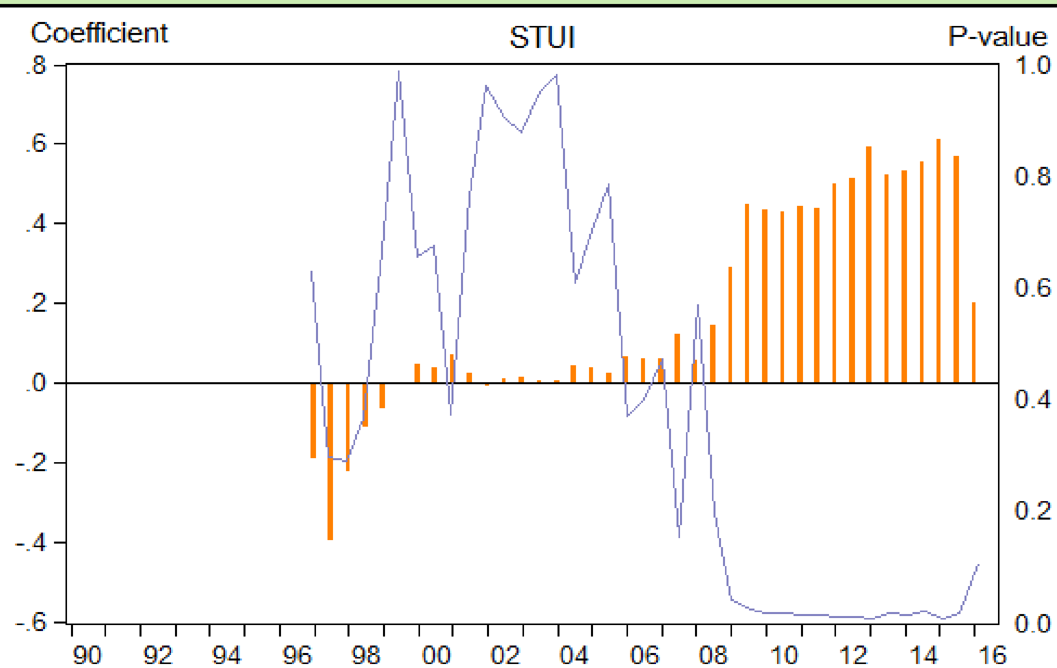
Results Part 8 – ***Rolling Dynamic Ordinary Least Squares – P-values STUI Coefficient***

Table AA8.32 **Rolling DOLS R**

SE6 ROLLING DOLS
P-value of STUI Coefficient



SEPE ROLLING DOLS
P-value of STUI Coefficient



Results Part 9: ***Jensen's Alpha Calculation and T-test (Nominal Returns)***

Table AA8.34 Jensen's Alpha Nominal

Jensen's Alpha

	For Nominal Returns	STOXX EUROPE 600	MSCI EM	MSCI WORLD	ML EMU Corporate	BloomB EURO AGG CORP	ER00 EU	BOFA ML EURO HY	Barc EM AGG	Barc EM IG	Barc ILB GOV All Maturities	BOFA ML ILB 10Y GOV EURO
	Mean (mu)	0.00246	0.00392	0.00127	0.00196	0.00221	0.00213	0.00325	0.00289	0.00632	0.00223	0.00227
Methods:												
1. Cov/Var	Covariance (Rm, Ri)	0.0009	0.0009	0.0009	0.0001	0.0001	0.0001	0.0010	0.0000	0.0008	0.0001	0.0000
	Variance (Rm)	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
	β'volatility	0.5013	0.5229	0.5108	0.0307	0.0557	0.0482	0.5652	-0.0052	0.4544	0.0441	-0.0223
2. Slope	β'market	0.5013	0.5229	0.5108	0.0277	0.0489	0.0436	0.5010	-0.0052	0.4519	0.0407	-0.0197
Jensen's Alpha: =Rp-[Rf+b(Rm-Rf)]	Monthly α	-0.0007	0.0007	-0.0019	-0.0006	-0.0004	-0.0004	0.0001	0.0004	0.0032	-0.0003	-0.0002
	α per annum	-0.0088	0.0083	-0.0232	-0.0070	-0.0043	-0.0053	0.0007	0.0047	0.0384	-0.0040	-0.0025
H0: α = 0	p-value	0.3881	0.2760	0.4173	0.2666	0.1775	0.1803	0.2476	0.0254	0.0124	0.2599	0.2235
One-Sample T-test:	Count	312	312	312	239	210	240	216	312	275	192	215
	Mean	0.0008	0.0022	-0.0004	0.0004	0.0007	0.0006	0.0017	0.0012	0.0047	0.0007	0.0007
	Std. Dev	0.0477	0.0661	0.0355	0.0101	0.0105	0.0097	0.0368	0.0109	0.0349	0.0149	0.0140
	Std. Error	0.0027	0.0037	0.0020	0.0007	0.0007	0.0006	0.0025	0.0006	0.0021	0.0011	0.0010
	Hypothesis mu	0										
	alpha	0.05										
	tails	1										
	df	311	311	311	238	209	239	215	311	274	191	214
	t stat	0.2845	0.5954	0.2090	0.6239	0.9270	0.9161	0.6832	1.9607	2.2566	0.6450	0.7617
	t critical	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628
	Significant	no	no	no	no	no	no	no	yes	yes	no	no

Results Part 9 – ***Jensen's Alpha Calculation and T-test Nominal Returns (continuation)***

Jensen's Alpha												
	For Nominal Returns	Barc HF	CS HF	STOXX EU PE	TR PE B	FTSE NAREIT REAL ESTATE Composite	MSCI EUROPE REAL ESTATE	Gold Spot	IMF All Commodities	LB Crude	GSCI Commodity	TR/CC Commodities
	Mean (mu)	0.00515	0.00432	0.00649	0.01381	0.00689	0.00305	0.00163	0.00044	0.00466	0.00022	0.00242
Methods:												
1. Cov/Var	Covariance (Rm, Ri)	0.0007	0.0005	0.0008	0.0012	0.0012	0.0012	-0.0004	0.0002	-0.0001	0.0002	0.0002
	Variance (Rm)	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
	β'volatility	0.4013	0.2800	0.4362	0.6900	0.6946	0.6568	-0.2068	0.1220	-0.0537	0.1368	0.1211
2. Slope	β'market	0.3538	0.2692	0.3937	0.6095	0.6946	0.6149	-0.2085	0.1255	-0.0537	0.1399	0.1161
Jensen's Alpha: =Rp-[Rf+b(Rm-Rf)]	Monthly α	0.0022	0.0014	0.0034	0.0105	0.0034	-0.0003	-0.0006	-0.0022	0.0022	-0.0025	-0.0002
	α per annum	0.0259	0.0173	0.0413	0.1257	0.0413	-0.0035	-0.0071	-0.0268	0.0268	-0.0298	-0.0030
H0: α = 0	p-value	0.0042	0.0141	0.1212	0.0092	0.0384	0.3551	0.4895	0.3233	0.2997	0.2632	0.3820
One-Sample T-test:	Count	228	264	239	227	312	251	311	287	312	300	263
	Mean	0.0036	0.0027	0.0049	0.0123	0.0052	0.0015	-0.0001	-0.0012	0.0030	-0.0023	0.0008
	Std. Dev	0.0204	0.0202	0.0650	0.0778	0.0518	0.0639	0.0368	0.0435	0.1000	0.0621	0.0455
	Std. Error	0.0014	0.0012	0.0042	0.0052	0.0029	0.0040	0.0021	0.0026	0.0057	0.0036	0.0028
	Hypothesis mu											
	alpha											
	tails											
	df	227	263	238	226	311	250	310	286	311	299	262
	t stat	2.6578	2.2070	1.1720	2.3757	1.7757	0.3721	0.0262	0.4590	0.5257	0.6343	0.3006
	t critical	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628
	Significant	yes	yes	no	yes	yes	no	no	no	no	no	no

Results Part 9: ***Jensen's Alpha Calculation and T-test (Real Returns)***

Table AA8.35 Jensen's Alpha Real

Jensen's Alpha	For Real Returns	STOXX EUROPE 600	MSCI EM	MSCI WORLD	ML EMU Corporate	BloomB EURO AGG CORP	ER00 EU	BOFA ML EURO HY	Barc EM AGG	Barc EM IG	Barc ILB GOV All Maturities	BOFA ML ILB 10Y GOV EURO
	Mean (mu)	0.00077	0.00223	-0.00042	0.00041	0.00067	0.00057	0.00171	0.00121	0.00474	0.00069	0.00073
Methods: 1. Cov/Var	Covariance (Rm, Ri)	0.0009	0.0009	0.0009	0.0001	0.0001	0.0001	0.0010	0.0000	0.0008	0.0001	0.0000
	Variance (Rm)	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
	β'volatility	0.5052	0.5259	0.5140	0.0341	0.0597	0.0515	0.5697	-0.0027	0.4566	0.0483	-0.0190
2. Slope	β'market	0.5052	0.5259	0.5140	0.0308	0.0523	0.0466	0.5043	-0.0027	0.4537	0.0444	-0.0167
Jensen's Alpha: =Rp-[Rf+b(Rm-Rf)]	Monthly α	-0.0016	-0.0001	-0.0028	-0.0021	-0.0018	-0.0019	-0.0006	-0.0013	0.0024	-0.0018	-0.0018
	Annual α	-0.0189	-0.0013	-0.0331	-0.0251	-0.0218	-0.0230	-0.0076	-0.0156	0.0286	-0.0216	-0.0215
H0: α = 0	p-value	0.3885	0.2763	0.4177	0.2683	0.1793	0.1820	0.2487	0.0257	0.0126	0.2603	0.2228
One-Sample T-test:	Count	312	312	312	239	210	240	216	312	275	192	215
	Mean	0.0008	0.0022	-0.0004	0.0004	0.0007	0.0006	0.0017	0.0012	0.0047	0.0007	0.0007
	Std. Dev	0.0478	0.0662	0.0356	0.0101	0.0106	0.0098	0.0370	0.0109	0.0349	0.0149	0.0139
	Std. Error	0.0027	0.0037	0.0020	0.0007	0.0007	0.0006	0.0025	0.0006	0.0021	0.0011	0.0009
	Hypothesis mu	0										
	alpha	0.05										
	tails	1										
	df	311	311	311	238	209	239	215	311	274	191	214
	t stat	0.2836	0.5946	0.2081	0.6190	0.9203	0.9095	0.6799	1.9558	2.2516	0.6435	0.7643
	t critical	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628
	Significant	no	no	no	no	no	no	no	yes	yes	no	no

Results Part 9 – ***Jensen's Alpha Calculation and T-test Real Returns (continuation)***

Jensen's Alpha

	For Real Returns	Barc HF	CS HF	STOXX EU PE	TR PE B	FTSE NAREIT REAL ESTATE Composite	MSCI EUROPE REAL ESTATE	Gold Spot	IMF All Commodities	LB Crude	GSCI Commodity	TR/CC Commodities
	Mean (mu)	**0.00360**	**0.00274**	**0.00493**	**0.01226**	**0.00521**	**0.00150**	**-0.00005**	**-0.00118**	**0.00298**	**-0.00227**	**0.00084**
Methods:												
1. Cov/Var	Covariance (Rm, Ri)	0.0007	0.0005	0.0008	0.0012	0.0012	0.0012	-0.0004	0.0002	-0.0001	0.0002	0.0002
	Variance (Rm)	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
	β'volatility	0.4036	0.2828	0.4417	0.6927	0.6956	0.6600	-0.2010	0.1245	-0.0513	0.1282	0.1238
2. Slope	**β'market**	0.3555	0.2716	0.3983	0.6112	0.6956	0.6175	-0.2027	0.1279	-0.0513	0.1311	0.1186
Jensen's Alpha:												
=Rp-[Rf+b(Rm-Rf)]	**Monthly α**	0.0012	0.0003	0.0026	0.0100	0.0029	-0.0008	-0.0026	-0.0036	0.0005	-0.0047	-0.0016
	Annual α	0.0144	0.0039	0.0306	0.1194	0.0351	-0.0097	-0.0315	-0.0437	0.0054	-0.0569	-0.0195
H0: α = 0	**p-value**	0.0043	0.0145	0.1216	0.0092	0.0386	0.3553	0.4896	0.3233	0.2997	0.2483	0.3820
One-Sample T-test:	Count	228	264	239	227	312	251	311	287	312	300	263
	Mean	0.0036	0.0027	0.0049	0.0123	0.0052	0.0015	-0.0001	-0.0012	0.0030	-0.0023	0.0008
	Std. Dev	0.0205	0.0203	0.0652	0.0778	0.0519	0.0640	0.0369	0.0435	0.1000	0.0578	0.0455
	Std. Error	0.0014	0.0012	0.0042	0.0052	0.0029	0.0040	0.0021	0.0026	0.0057	0.0033	0.0028
	Hypothesis mu											
	alpha											
	tails											
	df	227	263	238	226	311	250	310	286	311	299	262
	t stat	2.6466	2.1965	1.1698	2.3738	1.7735	0.3715	0.0261	0.4589	0.5257	0.6808	0.3005
	t critical	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628	0.0628
	Significant	yes	yes	no	yes	yes	no	no	no	no	no	no

Results Part 10: *Nominal Ex-Post Sharpe Ratio*

Table AA8.36 Ex-Post Sharpe Ratio Nominal

Number of Periods		319
Risk free		
Arithmetic	Monthly	0.26%
	Yearly	3.20%
Geometric	Monthly	0.26%
	Yearly	3.18%

Sharpe ratio		S&P500	STOXX EUROPE 600	MSCI EM	MSCI WORLD
Arithmetic	Monthly	0.093	0.043	0.059	0.033
	Yearly	0.319	0.146	0.203	0.110
Geometric	Monthly	0.070	0.022	0.030	0.018
	Yearly	0.239	0.073	0.103	0.059

		ML EMU Corporate	BloomB EURO AGG CORP	BB PAN-EU HY	BOFA ML EURO HY	Barc EM AGG	Barc EM IG	Barc ILB GOV All Maturities	BOFA ML ILB 10Y GOV EURO
Arithmetic	Monthly	0.150	0.145	0.377	-0.107	0.575	0.135	0.085	0.109
	Yearly	0.510	0.491	1.295	-0.374	1.982	0.463	0.288	0.370
Geometric	Monthly	0.153	0.147	0.123	0.049	0.218	0.126	0.080	0.103
	Yearly	0.517	0.495	0.413	0.165	0.745	0.434	0.267	0.348

		Barc HF	CS HF	STOXX EU PE	TR PE B	FTSE NAREIT REAL ESTATE Composite	MSCI EUROPE REAL ESTATE	Gold Spot	IMF All Commodities	LB Crude	GSCI Commodity	TR/CC Commodities
Arithmetic	Monthly	0.214	0.190	0.092	0.164	0.139	0.040	0.056	0.016	0.055	0.003	0.053
	Yearly	0.735	0.654	0.316	0.567	0.479	0.135	0.190	0.054	0.188	0.008	0.182
Geometric	Monthly	0.516	0.171	0.087	0.073	0.143	0.069	-0.034	0.088	0.001	0.018	-0.009
	Yearly	1.778	0.586	0.299	0.251	0.494	0.237	-0.121	0.303	0.003	0.061	-0.035

Results Part 10 – *Real Ex-Post Sharpe Ratio*

Table AA8.37 Ex-Post Sharpe Ratio Real

		Number of Periods	319
Risk free			
Arithmetic	Monthly		0.263%
	Yearly		3.199%
Geometric	Monthly		0.261%
	Yearly		3.180%

Ex-Post Sharpe ratio		S&P500	STOXX EUROPE 600	MSCI EM	MSCI WORLD
Arithmetic	Monthly	0.082	0.034	0.121	0.053
	Yearly	0.280	0.115	0.417	0.180
Geometric	Monthly	0.070	0.025	0.030	0.018
	Yearly	0.239	0.085	0.103	0.059

		ML EMU Corporate	BloomB EURO AGG CORP	BB PAN-EU HY	BOFA ML EURO HY	Barc EM AGG	Barc EM IG	Barc ILB GOV All Maturities	BOFA ML ILB 10Y GOV EURO
Arithmetic	Monthly	0.151	0.162	0.048	0.245	0.087	0.428	0.091	0.161
	Yearly	0.513	0.549	0.165	0.840	0.297	1.476	0.306	0.547
Geometric	Monthly	0.153	0.147	0.244	0.055	0.319	0.190	0.080	0.103
	Yearly	0.517	0.495	0.832	0.186	1.092	0.655	0.267	0.348

		Barc HF	CS HF	STOXX EU PE	TR PE B	FTSE NAREIT REAL ESTATE Composite	MSCI EUROPE REAL ESTATE	Gold Spot	IMF All Commodities	LB Crude	GSCI Commodity	TR/CC Commodities
Arithmetic	Monthly	0.220	0.059	0.077	0.250	0.112	0.075	0.050	0.006	0.086	0.004	0.120
	Yearly	0.757	0.203	0.265	0.865	0.386	0.256	0.169	0.020	0.296	0.011	0.410
Geometric	Monthly	0.205	0.181	0.057	0.125	0.106	0.011	0.042	-0.008	0.002	-0.027	0.026
	Yearly	0.703	0.621	0.194	0.430	0.366	0.035	0.141	-0.030	0.007	-0.096	0.087

Results Part 11: ***Ex-Post Sortino Ratios***

Table AA8.38a **Nominal Ex-Post Sortino Ratios**

Nominal Ex-Post Sortino Ratio								
		S&P500	STOXX EUROPE 600	MSCI EM	MSCI WORLD	EMU 20-30Y GOV	ML EMU Corporate	BloomB EURO AGG CORP
Downside Standard Deviation	**Annual Arithmetic**	10.55%	12.49%	15.93%	10.08%	2.08%	2.38%	2.45%
Ex-Post Sortino Ratio		0.44	0.19	0.29	0.13	1.38	0.72	0.70
T-statistics	**Annual arithmetic**	7.77	3.47	5.21	2.40	0.00	11.33	10.37
		BB PAN-EU HY	BOFA ML EURO HY	Barc EM AGG	Barc EM IG	Barc ILB GOV	BOFA ML ILB 10Y EURO	
Downside Standard Deviation	**Annual Arithmetic**	2.23%	11.31%	2.04%	12.75%	3.76%	3.38%	
Ex-Post Sortino Ratio		1.89	-0.41	3.64	0.43	0.39	0.52	
T-statistics	**Annual arithmetic**	27.40	-6.16	61.25	6.49	5.48	7.68	
		Barc HF	CS HF	STOXX EU PE	TR PE B	FTSE NAREIT REAL ESTATE Composite	MSCI EUROPE REAL ESTATE	
Downside Standard Deviation	**Annual Arithmetic**	5.53%	5.27%	18.14%	19.70%	15.10%	16.20%	
Ex-Post Sortino Ratio		2.01	0.99	0.25	0.36	1.01	0.53	
T-statistics	**Annual arithmetic**	30.83	16.34	3.90	5.57	18.10	8.51	
		Gold Spot	IMF All Commodities	LB Crude	GSCI Commodity	TR/CC Commodities		
Downside Standard Deviation	**Annual Arithmetic**	7.01%	12.14%	22.77%	15.05%	11.46%		
Ex-Post Sortino Ratio		0.43	0.20	0.04	0.43	0.01		
T-statistics	**Annual arithmetic**	7.59	3.41	0.65	7.58	0.24		

Results Part 11 – *Ex-Post Sortino Ratios (continued)*

Table AA8.38b Real Ex-Post Sortino Ratios

Real Ex-Post Sortino Ratio							
		S&P500	STOXX EUROPE 600	MSCI EM	MSCI WORLD	ML EMU Corporate	BloomB EURO AGG CORP
Downside Standard Deviation	**Annual Arithmetic**	10.55%	12.49%	15.93%	10.08%	2.38%	2.45%
Ex-Post Sortino Ratio		0.44	0.21	0.32	0.15	0.75	0.73
T-statistics	**Annual arithmetic**	7.77	3.78	5.75	2.65	11.89	10.73
		BB PAN-EU HY	BOFA ML EURO HY	Barc EM AGG	Barc EM IG	Barc ILB GOV	BOFA ML ILB 10Y EURO
Downside Standard Deviation	**Annual Arithmetic**	2.23%	11.31%	2.04%	12.75%	2.38%	2.45%
Ex-Post Sortino Ratio		0.92	0.28	1.74	0.59	0.62	0.72
T-statistics	**Annual arithmetic**	13.42	4.16	29.29	8.76	8.71	10.61
		Barc HF	CS HF	STOXX EU PE	TR PE B	FTSE NAREIT REAL ESTATE Composite	MSCI EUROPE REAL ESTATE
Downside Standard Deviation	**Annual Arithmetic**	2.23%	11.31%	2.04%	12.75%	3.76%	3.38%
Ex-Post Sortino Ratio		2.37	0.41	3.51	1.21	2.26	0.96
T-statistics	**Annual arithmetic**	36.46	6.69	54.24	18.58	40.45	15.45
		Gold Spot	IMF All Commodities	LB Crude	GSCI Commodity	TR/CC Commodities	
Downside Standard Deviation	**Annual Arithmetic**	0.81%	5.53%	5.27%	18.14%	19.70%	
Ex-Post Sortino Ratio		3.16	0.13	1.21	0.01	0.14	
T-statistics	**Annual arithmetic**	56.51	2.15	21.63	0.16	2.25	

Results Part 12: ***STUI Graph***

Table AA8.39 STUI Graphic Representation