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GDP-linked bonds and their diversification benefits

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Abstract

This thesis examines the diversification benefits of simulated GDP-linked bonds issued by Greece and the Netherlands for the period 2002-2013 and under different portfolio investment strategies. The diversification effects are investigated based on correlations of GDP growth rate with the world, Eurozone, advanced economies and emerging markets and developing economies. It provides evidence that no significant diversification properties arise from portfolios consisted of simulated GDP-linked bonds and government bonds of each country or portfolios consisted of GDP-linked bonds from Greece and the Netherlands respectively. Nevertheless, diversification occurs when simulated Greek GDP-linked bonds are combined with GDP-linked bonds issued by advanced economies (before the start of the financial crisis) and with GDP-linked bonds issued by emerging markets and developing economies (after the start of the financial crisis). Diversification also exists when combining Dutch GDP-linked bonds with GDP-linked bonds issued by emerging markets and developing economies for both the investigated periods. However for the latter, the observed diversification decreases after the start of the financial crisis.

JEL Classification : G12, G11

Keywords : GDP-linked bond, Modern portfolio theory, Sharpe ratio

PREFACE AND ACKNOWLEDGEMENTS

Starting I would like to say that I am really grateful for the opportunity to study at the Erasmus School of Economics and live in one of the most vibrant cities of Europe, Rotterdam. In times of need the river view from my window relaxed me and gave me strength to continue. Studying is always a journey you need to do it alone, but everything must come to an end. This thesis reflects a new period starting based on firm foundations.

First of all, I would like to thank my supervision, Dr. Jan Lemmen for his guidance and constant support throughout my research. I am certain that our interests in debt restructuring and bonds aligned in the greatest extent and he enjoyed the topic as much as I did.

I would also like to thank my parents from the bottom of my heart. I am really proud of my father and his determination to return back to high school at the age of seventy. We were studying together through Skype all this time. He is the best role model I could ever have. As he is always saying, constant education is the most powerful weapon against time.

Last but not least, I would like to thank all the people I met during my staying in the Netherlands. They really changed my life by adding insightful experiences, expanding my personal and professional horizons and contributing in enjoying every single minute in Rotterdam and Amsterdam. Paraphrasing the famous poem of C. Cavafy, studying, like life itself, is a long journey full of adventure and full of knowledge, we just need to pray that the road is long. To be continued…

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Chapter 1 Introduction to the subject

1.1 European sovereign crisis

The European sovereign economic crisis of the last six years proves that Europe is still very vulnerable in external and internal discontinuities. Countries find themselves on the verge of bankruptcy by lack of funding, tremendous rising of corporate and government bond yields and cumulated stratospheric national debts. Aiming to prevent forthcoming financial "dead-ends", the national governments of southern Europe (Cyprus, Greece, Italy, Portugal and Spain) turn to their European counterparts for financial aid. In order to do so, EU and IMF through a bilateral audit in June 2011 introduce austerity measures in Greece with the aspiration to constrain government spending. Following this event, the rating agency Standard and Poor's downgraded the Greek sovereign debt to the last rating scale, CCC. A domino effect of the so-called negative spiral of "interest rate death" pushes EU to impose additional emergency measures. According to the official statement of the heads of the states or governments of the euro area and EU institutions on July 21, 2011 it has been agreed that "maturity of future EFSF loans to Greece will be extended to the maximum extent possible from the current 7.5 years to a minimum of 15 years and up to 30 years with a grace period of 10 years". In addition they also approved a new supporting package of €109 billion (Council of European Union, 2011). Nevertheless, the financial aid was not sufficient enough.

Three months later, the evening between 26 and 27 of October 2011, IMF and Eurozone leaders agreed that the privately held Greek debt should receive an approximate 50% write-off which is equivalent to a €100 billion. This could reduce the national debt level from €340 billion to €240 billion or alternatively set the debt on 120% of GDP by 2020. To be noted that no write-offs of the Greek government debt held by the official sector, such as ECB, occurred (Euro Summit, 2011).

According to the official press release of the Ministry of Finance of the Hellenic Republic (2012), on February 24th, 2012, the terms of invitations to private sectors holders have been finalized and approved by the ministerial council. The invitation provided the opportunity to private sector holders to exchange bonds selected to participate in the exchange program and issued or guaranteed by the Hellenic Republic. (Eurogroup, 2012). This process is known better as Private Sector Involvement or alternatively PSI.

The invitation allows holders from the private sector to exchange bonds selected to participate in the PSI program with (i) European Financial Stability Facility (EFSF) notes having a maturity date of two years or less, following the PSI Settlement date, (ii) new Greek bonds issued by the Hellenic Republic on the PSI settlement date and (iii) detachable GDP-linked

warrants issued by the Hellenic Republic. This in turn means that private sector holders exchange €1,000 with two EFSF short term payment notes and twenty New Greek bonds having a face value equal to 15% and 31.5% respectively of the face value of the exchanged bonds. In addition, the agreement offers GDP-linked instruments that have a notional amount equal to the face amount of the new bonds possessed by the holder. In figure 1, we can see the face value of the PSI short term payment notes and the New Greek bonds in relation to the face value of the old Greek bonds. The essential point is that 53.5% of the face value of the old Greek bonds was written off.

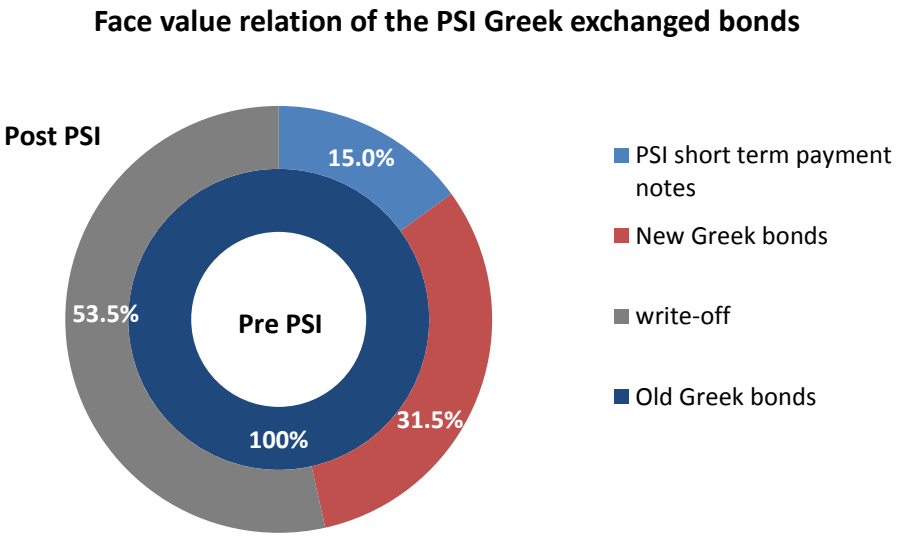


Figure 1: Face value relation of the PSI Greek exchange bonds

The GDP-linked securities offer annual payments starting in 2015 of up to 1% of their notional amount contingent upon the Hellenic Republic's nominal GDP exceeding a defined threshold and having positive GDP growth in real terms in excess of predetermined objectives (Hellenic Republic, Ministry of Finance, 2012). This in turn means that no payment will be made in case the Nominal GDP does not exceed the reference nominal GDP for that reference year[1] (2.5 The Greek rescue and the debt exchange). Furthermore in order for a payment to be released, three conditions needs to be met. Firstly the GDP index percentage[2] should not exceed 1% for any reference year[3] and if so, the excess percentage will not be considered in

[1] As a reference year is defined every calendar year from and including 2014 up to and including 2041

[2] GDP index percentage is defined as the real GDP growth rate minus the reference real GDP growth rates for the reference year.

[3] Table 3: reference GDP path for each reference year

calculations for the current or any following year. Secondly, in case the real GDP growth rate[4] is negative for the reference year then the GDP index percentage will be zero. Finally, in case of a lower real GDP growth rate than the reference real growth rate, the GDP index percentage is again zero for the reference year.

The current thesis examines the potential diversification benefits of the GDP-linked bonds in the Eurozone and brings into light some of the diversification properties in a portfolio context. Following the model of Borensztein and Mauro (2004), the simulated coupon rates of the Dutch and the Greek GDP-linked bonds for the period between 2002 and 2013 are used to determine the risk adjusted performance of the portfolio consisted of weighted combinations of GDP-linked bond and 10-year government bonds. A second analysis is being made based on portfolio consisted of weighted combinations of GDP-linked bonds from Greece and the Netherlands respectively. Two sets of time periods are taken into consideration, a six year-period before the starting point of the Euro Crisis from 2002 to 2007 which represents years of financial growth and stability and a six year-period from 2008 to 2013 which represents years of economic downturn and financial distress.

The current thesis aspires to investigate some of the diversification benefits arising from the Greek and the Dutch GDP-linked bond issuance. According to Schröder, Heinemann, Kruse & Meitner (2004) , in case of a low positive or negative correlation of a country's GDP growth rate with the GDP growth rate of the investor's areas of interest, diversification benefits might arise. This derives from the fact that GDP-linked bonds perform better than other high quality bonds in a risk-return concept (Kamal & Lashgari, 2012). Based on their findings, further research will be conducted with respect to correlations of the gross world product (GWP)[5], Eurozone's GDP, advanced economies and emerging markets and developing economies GDP growth rate. The main aim of this thesis is to provide ground for further research on diversified portfolios consisted of different European and International GDP-linked bonds and Government bonds and cultivate the idea to investors and issuing institutions of the GDP-linked securities.

[4] The real GDP growth rate is defined as the percentage change of GDP of the reference year in comparison to the GDP of the year preceding the reference year. Both are expressed in prices of the year preceding the reference year.

5 The gross world product is the total global gross domestic product (GDP) or the total global national product after completely eliminating imports with exports

1.2 Gross domestic product, debt and GDP-linked bonds

The recent worldwide credit crunch and the subsequent economic instability motivated countries to issue growth instruments which have the ability to minimise risks associated with the constant growing of capital outflows (Griffith-Jones & Hertova, 2013). The idea was first introduced around the 1980s and in the years that followed it became popular among many economists such as Borensztein and Mauro (2004), Williamson (2005) and Griffith-Jones and Sharma (2006).

Optimally, in times of prosperity and growth, countries should use growth-linked instruments as a protection shield against boom and bust. As a result, the premium incorporated to this instrument would be comparatively low. One of the obstacles arising is that governments, given their temporary nature, have minor incentives in issuing these instruments, especially when the possibility of a future economic crisis or a crunch is highly unlikely to happen. The application of GDP-linked instruments is also very limited to countries struggling with their debt service. Nevertheless, the latest years and due to the European economic recession, the subject of GDP-indexed debt has been strongly revived. The crucial question may therefore be what type of instrument is the GDP-linked bond?

The GDP-linked bond is a debt (or derivative) security instrument in which the issuer country or institution agrees to pay an amortized return depending on the behavior of the gross domestic product (GDP). This in turn means that this type of security incorporates countercyclical properties. In other words, this type of security pays more (less) when performance of the country is better (worse) than expected. The security has equity-like characteristics although it cannot be compared with a stock with regard to the absence of principal claims. The associated nature of the coupon with the GDP-growth rate classifies GDP-indexed bond as a form of floating-rate bond. This type of instrument can be issued with a reference to real GDP, nominal GDP and their growth levels. On this ground a further analysis in this thesis will examine the diversification properties of these financial instruments against 10-year government bonds and other simulated GDP-linked bonds.

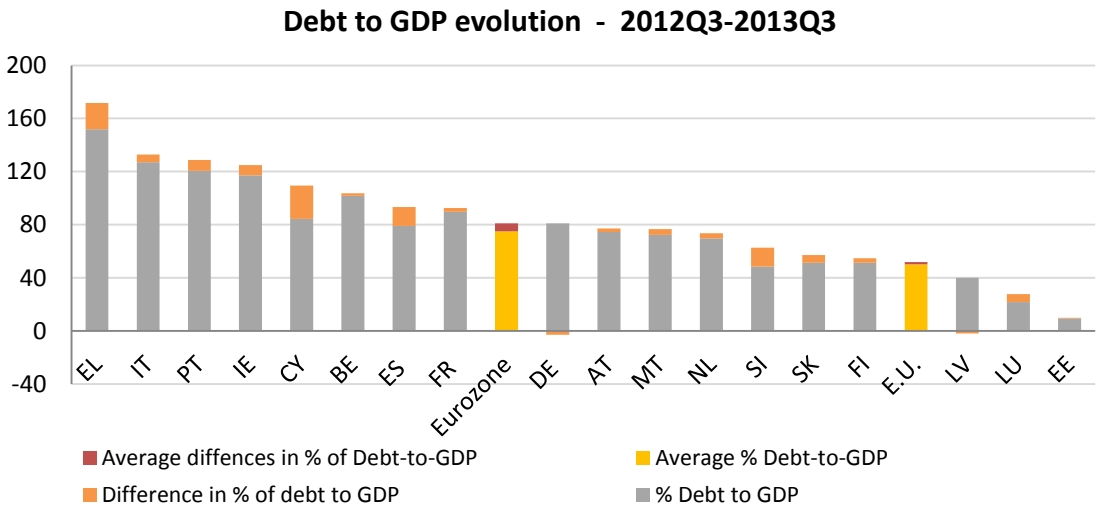
1.3 Debt to GDP ratio

The debt to GDP ratio is a way to measure the financial leverage of a country or economy. In addition, the debt to GDP ratio was also included in the Maastricht criteria. These criteria required that in order for a European member state to enter into the third[6] stage of the European Economic and Monetary Union (EMU) certain requirements should be met (European Monetary Institute, 1995). In line with this criterion, the ratio should not exceed

[6] Final stage before entering to EMU

60% at the end of the previous fiscal year or in case it does at least should have a sufficient decreasing trend in order to reach the required reference in the near future (European Monetary Institute, 1995). Not long after the formation of the Euro currency, the average debt to GDP ratio of the Euro area started to rise significantly for the majority of the countries. It was not until the third quarter of 2013 when economists observe the first in absolute terms decrease since 2007.

As figure 2 (Eurostat, 2014) shows, the majority of the Eurozone countries are classified above 60% something that sets a necessity for all the Eurozone countries to decrease the debt to GDP ratio. Borensztein and Mauro (2004) point out the advantages of GDP-indexed bonds to reduce both the probability of economic turbulences and the procyclical policies, by servicing as an "automatic-stabilizer". Therefore, the two important advantages of GDP-linked bonds tend to retain debt to GDP ratios within a narrower range than plain vanilla government bonds.



Source: Eurostat, news release euro indicators 10/2014 - 22 January 2014

Figure 2: Debt to GDP evolution (2012Q3-2013Q3)

1.4 GDP-linked instruments in advanced economies – developed countries

Evidence from former studies proves that GDP-linked bonds seem to be more beneficial for the developing rather than the advanced economies. Greece is becoming the first developed country to issue GDP warrants with similar characteristics to GDP-linked bonds. Schröder et al. (2004) suggest that developed countries with high debt obligations and low positive correlation to the GWP could issue GDP-linked warrants in order to reduce their cash payment obligations. In case of meeting the criteria, financially developed but economically unstable European countries located mainly in southern Europe could benefit from the

diversification properties of a newly formed GDP-linked bond market. Kamstra and Shiller (2009) also propose a similar to GDP-linked bond instrument for the American economy, known as the Trill, which stabilizes budget spending in times of recession and at the same time becomes largely accepted by institutional investors, public and private pension funds and other private investors.

Borensztein and Mauro (2004), on the other side, support that gradual implementation of a GDP-linked bond market would be challenging enough, since it is important for investors to have sufficiently liquid instruments actively traded on the market but also for issuers, where greater liquidity decreases the required risk premium. The high liquidity premium case discourages potential issuer countries from issuing GDP-linked bonds. According to the Dutch Ministry of Finance, Dutch Central Bank, Netherlands Bureau for Economic Policy Analysis (2005) the low liquidity and therefore the high premium would forbiden the Dutch government from issuing GDP-linked bonds.

1.5 Problem definition

The purpose of this study is to identify and distinguish the diversification benefits of GDP-linked bonds based on correlations between the Greek and the Dutch GDP growth rates and the GWP, Eurozone, advanced economies and emerging markets and developing economies GDP growth rates. These diversification benefits might serve as a hedging catalyst for investors and private/public institutions (i.e. pension funds) which are progressively oriented in fixed income securities. In the case of GDP-linked bonds, coupon payment and GDP growth level are positively correlated allowing investors to enjoy and share the profitability of a country in times of economic prosperity while governments have a reduced incentive to overspend when payment obligations are increasing. In times of economic distress on the other hand, GDP-linked bonds allow public issuing institutions to lower the debt exposure and investors to have a lower possibility of having their bonds default and therefore have claiming costs upon these bonds. In addition it should be noted that countries offer various diversifiable growth prospects which gradually enforce the idea of launching a GDP-linked bond market.

The second part of the analysis will focus on the quantitative hedging opportunities arising from a primary GDP-linked bond market. Until now limited countries used instruments similar to GDP-linked bonds. The analysis is made upon two countries namely Greece and the Netherlands. The simulated Greek and Dutch GDP-linked bonds, based on Borensztein and Mauro (2004) model, will be combined in a portfolio context with the Greek and Dutch 10-year plain vanilla government bond respectively. Further analysis will be made by constructing weighted portfolios consisting exclusively of Greek and Dutch simulated GDP-

linked bonds. For the purpose of the analysis the mean variance portfolio optimization model and the ex-ante Sharpe ratio will be employed in order to measure the risk adjusted performance of the two GDP-linked instruments in relation to other assets.

To sum up, the framework of this current thesis is to identify the diversification properties arising from investor's point of view. The first research question that this thesis will attempt to answer is:

1. **"Are the correlations between GWP, Eurozone, advanced economies and emerging markets and developing economies GDP growth rate on the one side and the Greek and the Dutch GDP growth rates on the other side low positive (below 20%) or negative concerning periods 2002-2007 and 2008-2013?"**

Also within the framework of the first part, the following sub-question will be answered:

1.1. What is the theoretical background behind GDP-linked bonds?
1.2. What are the benefits and obstacles of issuing GDP-linked bonds?
1.3. Which are past and current applications of similar GDP-linked instruments?

2. **"Are any diversification properties arising from a portfolio consisted of 10-year government bonds and simulated GDP-linked bonds issued by Greece and the Netherlands respectively?"**

3. **"Are there any diversification properties arising from a portfolio consisted of GDP-linked bonds issued by Greece and the Netherlands respectively?"**

1.6 Relevance to the problem and contribution

The topic of GDP-linked bonds is a pressing issue for all the European countries, European Union (E.U.) and the world in a broad sense. After the Eurozone formation, national constitutional weaknesses came into light. In an attempt to stabilise the economic turbulence in the recent years of the crisis, governments of Europe were forced to nationalise private debt derived from the mismanagement and exposure of the banking sector. As a result, national public debts were increased rapidly. Furceri and Zdzienicka (2012) support that the nationalization of banks in the area across the Organisation for Economic Co-operation and Development (OECD) increased the government gross debt to GDP ratio by 37%.

In addition, they proved that the debt to GDP ratio increased significantly in countries with poor quality of institutions, higher proportion of foreign debt and higher initial gross debt to GDP ratio. GDP-linked bonds could assist governments in refinancing their debt and decrease the debt to GDP ratio. Bondholders, public institutions, national governments, financial institutions and other interested parties such as pension funds will find the empirical results useful for investment and capital restructuring decisions.

Similar GDP-linked bond instruments have already been issued by Costa Rica, Bulgaria, Bosnia Herzegovina, Argentina, Greece and some other less known cases as a part of their debt restructuring. Nevertheless, Argentina and Greece included retrospectively the GDP-linked bonds into their debt restructuring plan. An ex-ante issuing of GDP-linked bonds could send positive signals to the financial markets concerning the short term but most importantly long term economic strength of the country. In order for such a plan to succeed further liquidity of the bonds needs to be available on the markets. Insufficient liquidity could cause rising of the required risk premium and subsequently demotivate governments from issuing GDP-linked bonds. During an economic boom from the government's point of view, the diversification benefits can stabilise further the service of the sovereign debt by increasing the national competitiveness and taxation in order to ease an economic overheating.

1.7 Methodology

For the purpose of the current thesis a correlation analysis is being made so as to examine the degree of influence of the real growth rates of the GWP, Eurozone, advanced economies and emerging markets and developing economies upon the Greek and the Dutch real GDP growth. A relatively low or negative correlation can indicate that GDP-linked bonds might provide hedging characteristics based on their relation with GDP growth rates.

Ruban, Poon & Vonatsos (2008) favour the indexation to growth of nominal GDP instead of the proposed by previous literature indexation to the real growth since the first offers a significant reduction in the possibility of default. Obstfeld and Peri (1988) also suggest that EU governments should index their liabilities to domestic nominal per-capital GDP growth in order to protect buyers of the security against inflation. Nevertheless, the current analysis uses real GDP growth rates instead of nominal in order to isolate the inflation factor and focus only on real year on year changes of GDP. Further to the analysis, the model of Borensztein and Mauro (2004) is employed in order to simulate the coupon payments of the Greek and the Dutch GDP-linked bond based on 10-year plain vanilla government bonds.

Furthermore, based on the Markowitz (1959) mean variance portfolio theory model, the author constructs two portfolios for Greece and the Netherlands respectively. Each portfolio

consists of GDP-linked bonds and 10-year government bonds under different weight allocation so as to conclude into the optimal combination in a risk return framework. Finally, in order to answer the third research question a portfolio consisting of Greek and Dutch simulated GDP-linked bonds is formed. The ex-ante Sharpe ratio is employed with the 10-year German government bond being the required benchmark in the Sharpe ratio calculations.

1.8 Limitations

This research is subject to various limitations. First of all, the validity and the time reporting of the GDP growth figures can be subject to changes even three years after publishing. Therefore the outcome may alter significantly during the last three years of the research. Second, no short positions are taken into consideration in the construction and optimization of the portfolio. Third, the Sharpe ratio analysis assumes the 10-year German government bond as the required benchmark where the selection could be subject of debate. Finally, the model of Borensztein et al. (2004) does not include any amortisation and taxation factors.

1.9 Structure of the thesis

The rest of the thesis has been organized as follows:

Chapter 2 will introduce the main literature and supporting theory of the GDP-linked instruments, various benefits and obstacles and an extensive retrospect of the various issuing cases by governments (usually facing economic distress) such as Argentina and Greece. Finally, an aspect of issuing GDP-linked bonds in developed countries is presented. The author elaborates on the hedging properties of a diverse portfolio of European GDP-linked bonds and presents the idea of creating a GDP bond market so as to increase liquidity and limit investment risk (liquidity risk, inflationary risk and market risk).

Chapter 3 will provide a thorough description of the research methodology that will be followed. Moreover the coupon simulation methodology based on the Borensztein and Mauro (2004) model, the periods under research, the mean-variance portfolio optimization model and the Sharpe ratio analysis will be commented on.

Chapter 4 will present the GDP growth rates and the 10-year benchmark government bond yields considered under the current research framework.

Chapter 5 will provide the empirical research, the empirical results and comments upon thee in regards with the hypotheses of this research.

Chapter 6 will conclude the findings of this thesis and elaborate on the limitations arose. Finally, the recommendations for future research will be provided.

Chapter 2 Literature review debt/derivative securities

Numerous studies have been done on constructing sophisticated mechanisms to restructure sovereign debts. One such mechanism − which is relatively known among economists, and particularly useful in times of economic distress − constitutes the GDP-linked bond. Existing literature proposes GDP-linked bonds as a way of reducing the impact of financial crises on sovereign debts, to stabilize the economic environment and to boost potential after-growth. As Vishnu & Sharma (2012) point out on their paper, GDP-linked bonds offer hedging characteristics against cases of unrepayable debts, abrupt changes in growth rates and external financial instability. The hedging properties of GDP-linked bonds, though, set a better performance compared to normal stocks and bonds. The simulation process constructed by Schröder et al. (2004) demonstrates that the performance of GDP-linked bonds is better in times of unpredicted rise of GDP and worse when a decline is anticipated. Lessard & Williamson, (1985), Shiller, (1993) and Griffith-Jones & Sharma (2006) examine the numerous benefits of GDP-linked bonds for the institutions responsible for issuance. Issuer countries would benefit from GDP-linked bonds by enjoying further stability on government spending, while in an economic downturn, this stability mechanism is able to reduce cash flow expenses responsible for public revenues decline.

On the assumption of increasing growth, investors will benefit from GDP-linked bonds and their outperformance. Griffith - Jones and Sharma (2006) retrospect on the last twenty years cases such as various Balkan countries[7] and argue that the main obstacles for issuing GDP bonds lies on the pricing complexity and the reporting methods of GDP. In a research made in 2009, Kamstra and Shiller propose the construction of a bond related to the United States GDP with a coupon of one – trillionth of the GDP. The authors further argue for the benefits of the GDP-linked bond deflator especially in the case of retirement funds where almost one third of the retirement fund assets are consisting of fixed income assets and inflation protected securities. Moreover, GDP-linked bonds could be very effective especially during a recession. Even though in a downturn, the return is lower than plain vanilla bonds, a risk averse pension fund manager that aims to reduce risk of his portfolio will move assets from more risky (corporate bonds, stocks and plain vanilla government bonds) to others less sensitive and more protected by inflation and economic instability bonds. This is the case with inflation and GDP-indexed bonds. Furthermore, as it has often been pointed by Schröder et al. (2004), Diaw, Bacha & Lahsasna (2011) and Vishnu & Sharma (2012) in their studies, GDP-linked bonds are considered as a proper financial instrument for funding the sovereign debts in

[7] Bulgaria, Bosnia, Costa Rica and Argentina

developing markets. Schröder et al. (2004) suggest that in order to issue GDP-linked bonds, a country's GDP should have low positive or even negative correlation with the gross world product (GWP).

2.2 Benefits and obstacles

In 2006, Griffith – Jones and Sharma observe in their groundbreaking article "GDP-Indexed bonds: Making it happen", that benefits arising from GDP-linked bonds can be classified into three main categories that include benefits for the borrowing countries, benefits for investors and benefits for the global economy.

More specifically in developing economies, GDP-linked bonds mitigate the pro-cyclicality of public spending in times of reduced growth (Griffith-Jones & Ocamp, 2007). As a result, the possibility of a future sovereign default is decreasing significantly since required interest payments of the debt service are shrinking and thus further stability is provided. Furthermore, during an economic boom, GDP-linked bonds increase debt service and provide to governments the incentive to keep more modest budgets or raise taxes and therefore prevent sudden economic outbreaks (Griffith-Jones & Hertova, 2013).

Additionally Griffith-Jones and Hertova (2013) state that by investing in GDP-linked bonds, one can participate in countries' long term growth prospects and at the same time create a diverse portfolio with hedging properties deriving from investing in countries with different growth levels (Schröder et al., 2004). Ruban et al. (2008) support that since cash flows from GDP-linked bonds are connected to the national growth rate, in times of economic distress the likelihood of default decreases. Griffith-Jones and Sharma (2006) by citing Eichengreen, (2004) and Griffith-Jones & Gottschalk, (2006), pointed the fact that since the debt service ratios are decreased when in an economic downturn, the possibility of default is also decreasing.

Griffith–Jones and Sharma (2006) argue that GDP-linked bonds share the same characteristics of a public good, due to their risk sharing properties and their mechanism of avoiding global disruptions arising upon formal default.

Notwithstanding the beneficial properties of GDP linked bonds, there are certain constraints that prevent the broad implementation. Firstly, it is likely possible that the issuing institution (or issuing country) could attempt to manipulate the GDP figures and therefore underestimate growth so as to meet lower payments. The above phenomenon is largely described in academic circles as the moral hazard issue.

In addition, national growth figures can be revised after some time, a change mainly attributable to further completion of the data set. Cavallo (2013) makes a research for online and official price indexes in Argentina and four more Latin America countries[8] where he presents the misreporting implications on the real GDP growth based on implications of online indices since 2007. Based on his article, the real GDP annual growth rate should have been 0.5% by March 2011 while the official growth rate was at the level of 10%. Also in order to enter to the Eurozone the Greek government started to manipulate public growth and fiscal indices aiming to hide part of the public deficit accumulated since 2000 (Stathakis, 2010). Table 1 and 2 summarize the advantages and disadvantages of the GDP-linked bonds for an investors and an issuer respectively during strong and poor economic performances of a country.

Strong Economic Performance

	Advantages	**Disadvantages**
Investor	• Income stream rising with average income but without the volatility of the stock market	• Not sufficient amount of participants (issuers or investors) or GDP-linked bond market • More countries need to issue so investors can diversify • Investors introduced into new risks (GDP level or growth, misreporting of GDP growth by issuer, complex methodology, no claim of principal, equity-like characteristics)
Issuer	• Automatic Stabilizer (reduce the incentive to overspend) • Useful for developing economies and emerging markets (with weak institutions) to discipline more volatile of policies[9]	• Cause of political turbulence, citizens can complain that governments favor lenders • Perverse incentives (moral hazard) to misreport GDP growth figures (or repress growth)

Table 1: strong economic performance - GDP-linked bond characteristics

[8] Brazil, Chile, Colombia and Venezuela

[9] See Acemoglu et al., (2003) for more information.

Poor Economic Performance

	Advantages	Disadvantages
Investor	• Reduces the possibility of default and therefore the possibility of having claiming costs upon the bonds	• Not sufficient amount of participants (issuers or investors) or GDP-linked bond market • More countries need to issue so investors can diversify • Investors introduced into new risks (GDP level or growth, misreported GDP growth by issuer, complex methodology, no claim of principal (equity-like characteristics)
Issuer	• Lower payments to investors (countercyclical features) • Reduces default probability • Less volatile tax policies (less need to increase taxes due to less debt payments) • Reduces the need to cut social benefits	• Low investment interest / demand for the bonds

Table 2: poor economic performance - GDP-linked bond characteristics

2.3 History of GDP-linked securities

This section provides a summary of all historical milestones prior to the creation of GDP-linked bonds. A number of countries have already implemented financial instruments with similar to GDP-linked bonds' equity-like characteristics. During 1970 Mexico issued bonds indexed to oil prices (Ricardo, 2002). Twenty years later, three countries from the American continent (Mexico, Uruguay and Venezuela) and one from the African (Nigeria) issued Brady bonds[10] which were later incorporated into a debt – reduction agreement. These bonds included the Value Recovery Rights (VRR), promises of paying higher returns in the event of a sufficient and predetermined increase in prices of certain commodities. Following the same framework, Bulgaria, Bosnia and Costa Rica issued the first pure GDP-linked bonds as a part of their debt restructuring agreements (Kopcke, 1999). Also as part of their recent sovereign

[10] Proposed by the U.S. Treasury Secretary Nicholas Brady

debt restructuring, Argentina and Greece in 2005 and 2012 respectively issued warrant - like instruments that share similar characteristics with the ones of GDP-linked bonds. The following section will provide further insights concerning the two countries.

2.4 The Argentinian case

Argentina was the first to launched growth-linked warrants in 2005, when in terms of its debt restructuring; the government issued GDP-linked instruments attached to an $81.8 billion bond exchange. At first, the GDP warrants were considered with a lot of skepticism from country's creditors, a point of view that could be explained upon their underlying aim to maximize their profit from negotiation and obtain a higher coupon. This could also be attributable to the lower liquidity of such bond. Nevertheless, in the short term GDP warrants were proved to increase their price and popularity in the market.

The core idea in the Argentinian bond is to relate the payments with the growth of the economy of the country. The Argentinian GDP warrants were implemented under the following principles. The payments would be made if three conditions were met; first if the real GDP exceeds base case GDP; second if the real growth of GDP versus the previous year is greater than base case GDP having the 4.26% as a real GDP growth threshold which is progressively decreasing to 3% for 2015 and onward and last but not least, if total payments do not exceed the payment cap, which is 0.48 per unit of currency of the warrant. The warrants expire immediately when the payment cap is reached and certainly before 2035 (The Republic of Argentina, 2005). Furthermore, the payments derived from these conditions are defined as 5 percent of the gap between actual and base case growth. Thirdly, the payments are made on December of the following year due to the lags in GDP publishing. Finally, warrants could be detached from the underlying bonds and be sold separately only 180 days after the issuing (The Republic of Argentina, 2005). So the payment is defined as:

> "Payment = ((0.05 * excess GDP) * unit of currency coefficient * notional value of GDP-linked securities)"

Equation 1: Argentinian GDP-linked warrant payment

The course of GDP-linked bonds was inherently affected by the high rates of growth of the country in combination with the efforts of the local bureau of statistics, INDEC to present lower GDP numbers.

Particularly, the fact that this exceptional growth was established very early increased the value of the warrant as long as it could be safely assumed that GDP would stay high in the

following years and thus the first payment condition would continue to be met. Despite this relative success of the instrument, the market for this type of warrants is not that liquid.

Concerns over GDP-linked bonds are based on figures accuracy. However, it is proved that it is quite difficult to manipulate GDP data because standards, policies and frequent controls that have been established by IMF and other international institutions asserting further a high level of consistency. On the other hand, in the case of Argentina there were two major drawbacks. At first, the relative complexity initially pushed back many investors who could not detect the benefits of the bonds. Secondly, the bonds design could lead to fairly large debt-servicing payments if Argentina's economy did not grow so fast.

2.5 The Greek rescue and the debt exchange

Some years later and as part of the largest debt restructuring in history, Greece issues GDP-linked warrants that incorporate equity-like features almost similar to a GDP-linked bond. According to the prospectus of the Hellenic Ministry of Finance, investors can be compensated only up to 1% of their notional in a year given that all necessary conditions are met (Hellenic Ministry of Finance, 2012). The payment obligations on the GDP-linked warrants demand that Greece will achieve a certain level of growth on its GDP. As in the case of Argentina, the GDP warrants are not technically bonds since the Greek government has no obligation to pay principal to investors. The GDP-linked warrants became available to the investors as per Private Sector Involvement (PSI) Agreement. The terms of the Greek debt exchange are mentioned below.

The Greek debt restructuring is a unique case of its own since it incorporates a retroactive collective action clause (CAC) which allows the majority of bondholders to agree to a debt restructuring that legally bind all private bondholders including the remaining part who opposed. By focusing more on the terms of the exchange, one can see that regardless of the maturity of the bonds held, each title with a face value of EUR 1000 received two PSI payment notes, twenty New Greek bonds and one GDP-linked bond.

The PSI payment notes issued from the European Financial Stability Facility (EFSF) have an annual interest payment following EFSF's normal borrowing rate at approximately 0.30%-0.50%. The face value of each note is set at EUR 75.0 and the maturity date at Mar 12, 2013 and Mar 12, 2014.

The second set of the twenty bonds are issued by the Hellenic Republic with a maturity date on February 24 of each year from 2023 to 2042 which are consisting of five bonds maturing within the period 2023 to 2027 have a face value of EUR 15, and fifteen bonds maturing from

2028 to 2042 have a face value of EUR 16, adding up to a total face value of EUR 315. The coupon payment has been set on February 24 each year and it depends on the payment year. More specifically payments concerning the years from 2013 to 2015, 2016 to 2020, 2021 and 2022 to 2042 have an interest rate of 2%, 3%, 3.65% and 4.3%, respectively.

Last but not least, a GDP-linked warrant issued by the Hellenic Republic, which in case that the Greek GDP growth meet certain criteria, is meant to enforce the coupon payment of the outstanding New Greek bonds. According to table 3, payments are released in any reference year, in case the Hellenic Republic's actual real GDP for that year exceeds a specified amount and annual growth rate (Hellenic Republic, Ministry of Finance, 2012).

Year	Reference Nominal GDP (€bn.)	Reference Real GDP Growth Rate)
2014	210.1014	2.345000%
2015	217.9036	2.896049%
2016	226.3532	2.845389%
2017	235.7155	2.796674%
2018	245.4696	2.596544%
2019	255.8822	2.496864%
2020	266.4703	2.247354%
2021-2041	266.4703	2.000000%

Table 3: reference GDP path for each reference year

Source: (Exchange Offer Memorandum, 2012)

Payments are determined based on the performance of the Greek GDP. The GDP-linked instrument pays no principal and the payment dates for interests are on October 15 of each year between 2015 and 2042 given that the nominal gross domestic product in any reference year (year preceding any payment) equals or exceeds the reference nominal GDP. The payment amount can be determined based on the following formula:

$$\text{Payment amount} = \text{GDP Index Percentage} \times \text{notional}$$

Equation 2: Greek GDP-linked warrant payment

Where: the gross domestic product Index Percentage equals to:

$$\text{GDP Index Percentage} = 1.5 \times [\text{real GDP growth rate} - \text{reference real GDP growth rate}]$$

Equation 3: Greek GDP index percentage

In any case and according to the prospectus of the Hellenic Republic the GDP Index Percentage cannot exceed 1%. Additionally, the GDP Index Percentage is zero, when either

the real GDP growth rate is below zero, or below the reference GDP growth rate. The real GDP growth rate for all the relevant years is published by EUROSTAT and the reference GDP growth rates and notional amounts for all the relevant payments dates are determined based on the tables below:

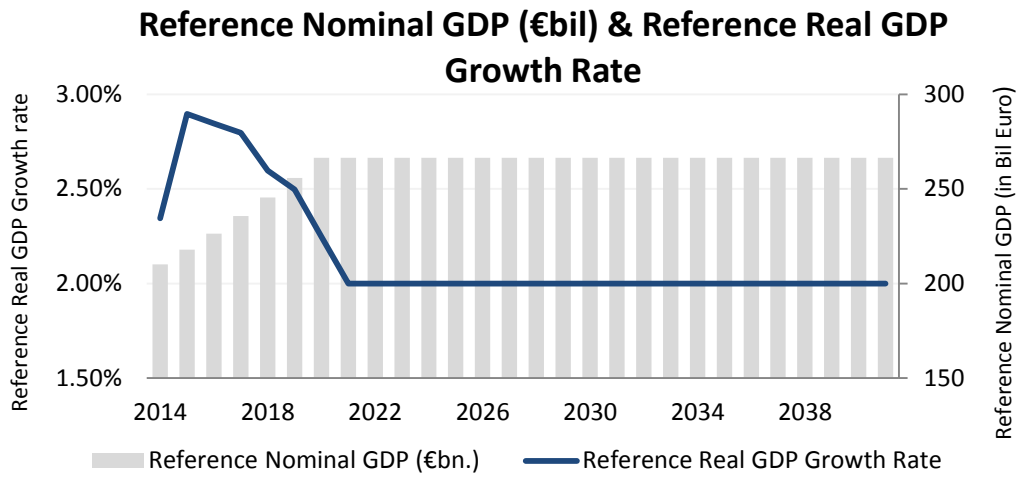


Figure 3: reference nominal GDP (in Euro bil.) & reference real GDP growth rate

Date	Fraction of Original Notional	Original Notional	Notional (%)
Up to 15-Oct-23	315	315	100%
15-Oct-24	300	315	95.24%
15-Oct-25	285	315	90.48%
15-Oct-26	270	315	85.71%
15-Oct-27	255	315	80.95%
15-Oct-28	240	315	76.19%
15-Oct-29	224	315	71.11%
15-Oct-30	208	315	66.03%
15-Oct-31	192	315	60.95%
15-Oct-32	176	315	55.87%
15-Oct-33	160	315	50.79%
15-Oct-34	144	315	45.71%
15-Oct-35	128	315	40.63%
15-Oct-36	112	315	35.56%
15-Oct-37	96	315	30.48%
15-Oct-38	80	315	25.40%
15-Oct-39	64	315	20.32%
15-Oct-40	48	315	15.24%
15-Oct-41	32	315	10.16%

Table 4: reference notional for each reference year

Source: (Morgan Stanley Research, 2012)

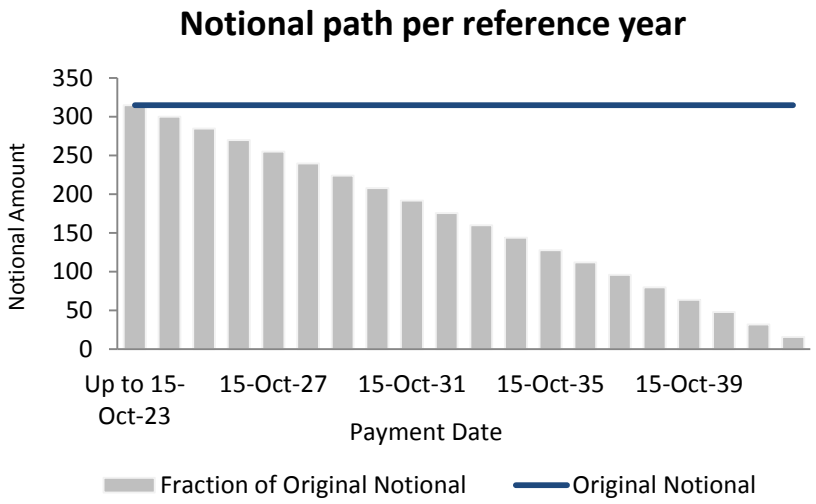


Figure 3: notional path per reference year source: (Morgan Stanley Research, 2012)

To be noted that from 2021 onwards, in case the real GDP growth rate for any year preceding the reference year is below zero, the real gross domestic product growth rate for reference year shall be assumed to be the sum of the real GDP growth rates for both such years.

2.6 GDP vs GWP, Eurozone GDP, advanced economies and emerging markets and developing economies GDP

In their paper, Schröder et al. (2004) support that potential issuer countries of GDP-linked bonds need to have low positive or negative correlation with investor's regions of interest. The low correlation decreases the risk premium that bondholders require for holding an instrument incorporating GDP risk[11]. Governments aspire to keep as low as possible the risk premium since this will entail lower debt servicing costs. Consequently, a low correlation with the GWP is highly relevant to an investor that holds a well-diversified international portfolio. According to Borensztein and Mauro (2002) these correlations were negative for countries such as Bangladesh, Egypt, India, Pakistan, Syria and Vietnam. The negative risk premium for the aforementioned countries makes them eligible for issuing GDP-linked bonds.

The shocking spiral of uncertainty followed by the global and especially European economic meltdown seems like a window of opportunity for issuing GDP-linked bonds. Various European economies with tremendous prospects of growth observed a decrease over their national growth level for the past few years. In this thesis the correlation of the Greek and the Dutch GDP growth rates with the GWP, Eurozone, advanced economies and emerging and developing economies GDP growth rates will be evaluated in order to reveal potential diversification benefits among different investment regions.

[11] GDP risk refers to the risk of GDP fluctuations.

2.7 Advanced economies vs emerging markets and developing economies

Past studies have presented numerous diversification benefits on emerging markets. Nevertheless, the diversification benefits of GDP-linked bonds in advanced economies and in a Monetary Union context are yet to be determined. This thesis aims to investigate some of the diversification benefits of the GDP-linked bonds issued by countries of the European Union. As Griffith – Jones and Sharma (2006) observed in their article "GDP – Indexed Bonds: Making it Happen" countries from EMU would be interested in issuing GDP bonds. The International Monetary Fund and the European Central Bank (and National Banking Systems across Europe) could assist and coordinate the countries concerning the time of issuing and pricing methods needed.

In addition, in the case of GDP-linked bonds, payment obligations are connected with domestic growth and therefore will be lower in times of economic distress. This important element can make GDP-linked bond particularly attractive to pension funds which might be more risk averse/fixed income oriented. Furthermore during an economic growth period, payment obligations are increasing but nevertheless the positive relation between growth and pension fund assets is allowing a more stable debt servicing (Davis & Hu, 2004). Northern European economies have already debated the use of Indexed-linked bonds even prior to the European economic crisis. In 2005, a working group making a study on budget in real terms has been discussed possible features of index-linked bonds from a viewpoint of the Dutch State (Ministry of Finance, Dutch Central Bank, Netherlands Bureau for Economic Policy Analysis, 2005). Moreover, the creation of a GDP linked bond market could set the foundations for overcoming the obstacle of non-accurate GDP growth forecasts and therefore design a more accurate pricing method.

An additional key element for the developed countries and the issuing of GDP-linked bonds is that in most of the developed countries, governments do not run big budget surpluses in good times, even though they should. Issuing GDP-linked bonds could be a determined step to show investors that they can share the profits altogether creating a shield of trust against lean ages.

2.8 Summary

The purpose of this chapter was to present a comprehensive overview of prior studies that imply evidence related to the issues examined in the study. Previous literature has extensively researched on the corresponding features of GDP-linked bonds as well as the risk premium required by investors. In order to understand thoroughly the diversification properties of the asset in a portfolio context the obstacles and benefits from issuing the bond were presented. Moreover to the literature review, various cases of previously or currently issued GDP-linked

bonds came into light focusing further to the most recent cases of Argentina and Greece in 2005 and 2012, respectively.

Furthermore a theoretical approach of the correlations between domestic GDP growth rate and GWP, Eurozone, advanced economies and emerging markets and developing economies GDP growth rate debates on the diversification benefits that might arise from GDP-linked bonds. Last but not least, the fact that a few research studies have been done in relation to GDP-linked bonds in advanced economies vis-à-vis emerging markets and developing economies is pointed out.

All this sets the ground for a further research upon the diversification properties of the GDP-linked bonds. In the next chapter the employed research methodology will be presented.

Chapter 3 Research methodology

3.1 Introduction

In this chapter the preferred methodology and the selected periods employed on this empirical research are presented. The present study aims to explore the diversification opportunities of GDP-linked bonds issued by the Netherlands and Greece and to focus on the investor's perspective for investing in such growth-indexed bonds. Since GDP-linked bonds are connected with the growth rate of an economy, a positive/negative growth could increase/decrease the coupon rate to the investor. Also in line with Schröder et al. (2004) findings, a country should have a low positive or negative GDP growth rate correlation with investor's area of interest in order for its GDP-linked bonds to provide diversification properties in a portfolio context. On this ground a correlation analysis will be made among the Greek and Dutch GDP year-on-year growth rates with growth rates from various areas of investor's interest namely GWP, Eurozone, advanced economies and emerging markets and developing economies GDP growth rates.

Furthermore, the simple model of Borensztein and Mauro (2004) is applied in order to simulate the coupon rate of the Greek and the Dutch growth-indexed bonds. In order to do so, 10-year benchmark government bond yields and twenty-year quarterly real GDP growth rates (year on year basis) from 2002 to 2013, have been collected from Bloomberg terminal. The annually growth rates of GDP figures have been averaged for the sake of adjustment into the monthly 10-year benchmark government bond yields.

Following the simulation process, two portfolios are formed, each including GDP-linked bonds and 10-year government bonds for Greece and the Netherlands respectively. The two portfolios have been simulated on a yearly basis from 2002 to 2013. Different weights are assigned to the GDP-Indexed and the government bonds so that the Markowitz mean-variance portfolio optimization model can export the optimal combination that delivers the maximum portfolio rate of return. Last but not least, by employing the ex-ante Sharpe ratio using as a risk free rate the 10-year German government bond, the reward to variability of each asset is presented throughout the twelve years.

3.2 Selection of countries

Existing literature supports that GDP-linked bonds can be highly applicable in developing countries as they decrease cyclical vulnerabilities (Griffith-Jones & Sharma, 2006). Furthermore, Schröder et al. (2004) support that GDP-linked bonds could benefit countries without current access to capital markets. Many researchers are in favour of GDP-linked

bonds and they highly support their application into the advanced economies and especially the countries of the Eurozone (Griffith-Jones & Sharma, 2006). Moreover, they conclude that a simultaneous introduction of GDP-linked bonds by emerging markets and developing economies and advanced economies could significantly increase the possibility of a GDP-linked bond market. On this ground, Greece and the Netherlands have been selected. On the one hand Greece faced various economic turbulences during the post-crisis years, which are reflected on its Gross Domestic Product and on the other hand, the Netherlands maintained its strong economic status even during European sovereigns' meltdown.

3.3 Periods

The selected periods for the correlation analysis include a twelve-year period starting from 2002 and up to 2013. Following the Borensztein and Mauro (2004) model, a twenty-year average prior to every year is employed in order to extract the base case GDP. The selected periods for the portfolio formation process are consisting of two data sets which include years preceding (2002-2007) and following (2008-2013) the beginning of the financial crisis in Europe.

3.4 Correlation analysis

As discussed in the literature review, the GDP-linked bond can be an attractive instrument for investors depending on the GDP correlation of the issuing country with respect to investor's other areas of interest. In cases when the correlation is low positive or negative, GDP-linked bonds can act as a risk stabilizing mechanism of the total portfolio rate of return. Nevertheless it should be pointed out that during financial crises the regional and global movements of GDP have an increased correlation (Abiad, Furceri, Kalemli-Ozcan, & Pescatori, 2013) . The equation for the correlation coefficient is:

$$R = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \sum(y - \bar{y})^2}}$$

Equation 4: Correlation coefficient

Where $\bar{x}$ and $\bar{y}$ are the twenty year average with respect to the reference year

The correlation analysis is based on correlations among Greece and the Netherlands with the GWP, Eurozone, advance economies and emerging markets and developing economies GDP growth rates. The two data sets employed for the correlation analysis with respect to every year are of a twenty-year moving period.

Correlation pairs	Gross World Product (GWP)	Advanced Economies	Eurozone	Emerging & Developing Economies
Greece	x	x	x	x
Netherlands	x	x	x	x

Table 5: correlation pairs

3.5 Simulation

In order to simulate the coupon rate of the Greek and the Dutch GDP-linked bonds, the simple model of Borensztein and Mauro (2004) is employed. According to this approach, the simulated coupon rate of the GDP-linked bond can be described as follows:

$$coupon_t = \max\ [\mu + (g_t - \bar{g}), 0]$$

Equation 5: Simulated GDP-linked bond coupon payment

Where $\bar{g}$ is the baseline growth rate of the GDP which, for simplicity reasons, is calculated based on the past twenty years average GDP growth rate with respect to each reference year. The g_t variable is the real growth rate of the given year t and the μi is the 10-year benchmark government bond yield. To take an illustration, it is assumed that μ=3%. In times of economic robust GDP-linked bond will offer a coupon rate higher that 3% while in times when actual growth rate equals the average growth rate, GDP-linked bond offers the same coupon as the 10-year government bond. Only in times of economic downturn the coupon rate is less than 3% but always above zero.

3.6 Mean variance model

As previously mentioned, the ambition of this thesis is not only to investigate the low positive or negative correlations that potentially exist among GDP growth rates from different areas of investor's interest but also the relation between GDP-linked bond and 10-year government bonds in a portfolio context. According to the modern portfolio theory first introduced by Harry Markowitz in his article (1952) and book (1959), assets should not be selected separately but rather considered as interactive assets of the same portfolio. The theory aims to maximize portfolio expected return in a given risk-return framework or to minimize risk for a given level of expected return. Even in cases where correlation between GDP-linked bonds and government bonds are not negative, modern portfolio theory can provide diversification by lowering the total risk of the portfolio. More specifically, the modern portfolio theory defines the total return of the portfolio as the weighted combination of the individual returns, the risk as the standard deviation of the return and the individual asset's return as normally

distributed variable. The model aims to decrease the total variance of the portfolio based on combined, not necessarily positively, correlated returns. Under the assumption that investor is risk averse meaning that given various portfolios providing the same expected return, the less risky will be preferred by the investor as the optimal portfolio. Therefore, higher risk portfolios are compensated with higher total returns and an investor aiming to higher return will favor a higher risk portfolio. The expected return can be described as follows:

$$E\ (\mu_P) = \sum_i wi\ E(\mu_i\ )$$

Equation 6: expected return

Where μ_p is the portfolio's return, μ_i is the return of the individual asset and w_i is the weighting coefficient of the asset i (fraction of the asset i in the total portfolio)[12]. The average yearly return and the standard deviation will be extracted from the monthly simulated GDP-linked bond coupon rates.

The variance of the portfolio's return can be described as follows:

$$\sigma_p^2 = \sum_i w_i^2\ \sigma_i^2 + \sum_i \sum_{j \neq i} w_i w_j\ \sigma_i \sigma_j \rho_{ij}$$

Equation 7: variance of the portfolio

Where ρ_{ij} represents the correlation coefficient among various individual assets of the portfolio. The standard deviation (volatility) of the portfolio can be written as:

$$\sigma_\rho\ = \sqrt{\sigma_\rho^2}$$

Equation 8: standard deviation (volatility) of the portfolio

The current thesis focuses on simulating a two-asset portfolio with simulated GDP-linked bonds in line with the Borensztein and Mauro (2004) model and 10-year government bonds. Furthermore the Modern Portfolio Theory model makes certain assumptions about investors and markets. First, the model assumes that all returns are normally distributed variables and also that correlations among assets are fixed and constant. The latest assumption makes the model relatively vulnerable to economic shocks and especially in times of crises where all assets tend to be more positively correlated due to a general market downturn. The Market Portfolio theory is based also on the efficient market hypothesis, where investors are only aiming to the maximization of their profit and that all investors are by definition risk-averse. Some others assumptions also include the fact that all investors have simultaneously access to

[12] If the weight for an asset is negative, then investor has to short (sell) an asset.

all information, investors are price takers and that risk of the asset is well-known a priori. The mean variance portfolio optimization analysis is completed by constructing a second series of twelve portfolios consisting of GDP-linked bonds from Greece and the Netherlands in order to reveal the optimal weight allocation and determine the trend if any.

3.7 Sharpe ratios

Finally, the last section of the current empirical research includes an analysis based on ex-ante Sharpe ratio. This ratio measures the risk premium (excess return) per deviation unit in a traded asset or investment strategy (Sharpe 1966). When comparing assets with a common benchmark, the asset with the higher Sharpe ratio provides a better return in a same risk framework or lower risk in a same return framework compared to the other assets.

The ex-ante Sharpe ratio as defined by Sharpe (1966) is:

$$SR_p = \frac{\mu_p - \mu_{rf}}{\sigma_p}$$

Equation 9: ex-ante Sharpe ratio

Where:

μ_p: is the portfolio return (expected return)

μ_{rf}: is the return of the benchmark asset (risk free rate) and

σ_ρ: is the standard deviation of the portfolio

For the purposes of the current empirical research the 10-year German government bond has been considered as the benchmark asset. Furthermore the standard deviation of the monthly returns is being multiplied by square root of twelve in order to be annualized.

Sharpe (1994) uses the same formula as above but substitutes the expected returns with the realized returns of the assets and benchmark (ex-post ratio). Since realized returns are not available on simulated GDP-linked bonds the ex-ante Sharpe ratio is employed. Moreover, the Sharpe ratio has as its principal advantage that it is observing both systemic and idiosyncratic risks.

3.8 Summary

The chapter provides a comprehensive overview of the employed research methodology. It begins with a description of the research framework and presents the GDP-linked bond return simulation process in line with Borensztein and Mauro (2004) model. According to this

model, the return of the GDP-linked bond varies with the growth rate of real GDP. Although there are quite some models incorporating various coupon payment conditions such as the Argentinian and the Greek cases, the basic idea lies on the difference between actual and base case GDP growth rate. The difference then is added to the 10-year government bond rate forming the GDP-linked bond coupon rate which under no circumstances can drop below zero.

Consistent with the Markowitz mean variance portfolio optimization approach, two different portfolio scenarios have been formed in order to examine the diversification benefits of simulated GDP-linked bonds from Greece and the Netherlands in a domestic and cross country portfolio context. Finally, the Sharpe ratio was employed in the analysis as a way of measuring the performance of the assets adjusted for their risk. The ex-ante Sharpe ratio was favoured over the ex-post as the current analysis produces expected rather than realised returns.

The next chapters will provide data description over government bonds and real GDP growth rates and empirical results and attempts to answer the three main questions of this research.

Chapter 4 Data description

In this section, data used during the research is presented. This section is split in a separate section for Gross Domestic Product growth rates of Greece, the Netherlands, GWP, advanced economies and emerging markets and developing economies GDP growth rates and a section for 10-year benchmark government bond yields of Greece, the Netherlands[13] and Germany[14].

4.1 GDP growth rate categories

The correlation analysis compares GDP growth rates of Greece and the Netherlands with respect to GWP, Eurozone and the GDP of advanced economies and emerging market and developing economies growth rates. In order to do so, quarterly real GDP growth rate figures (year-on-year change) of all the areas of interest have been extracted from Bloomberg terminal. Growth rates were selected to be real in order to isolate the effect of inflation. Thereafter, real GDP growth rates from Greece and the Netherlands have been incorporated into the Borensztein et al. (2004) model so as to simulate the GDP-linked bonds.

4.2 Benchmark government bond yields

The Bloomberg terminal is also used to collect the monthly 10-year benchmark government bond yields for the two European countries that are included on the current empirical research namely Greece (GGGB10YR: IND) and the Netherlands (GNTH10YR: IND). The government bond yield figures are collected for the period 2002-2013 which later is divided into two sub data sets each of six years. The two data sets are covering a period of economic robustness in European economy (2002-2007) and a period of economic downturn (2008-2013). In addition the monthly 10-year benchmark government bond yields have also been selected as the benchmark yields used in the Sharpe ratio analysis.

The next chapter will present the empirical results of the correlation analysis, the simulated GDP-linked bonds from Greece and the Netherlands and the diversification benefits that these bonds have against 10-year government bonds and other GDP-linked bonds.

[13] Countries of the analysis
[14] Benchmark country

Chapter 5 Empirical results

5.1 Introduction

In this chapter, results of the different stages of the analysis are presented. After some general findings the results section is constructed as follows; as a starting point the correlation analysis among the Greek and Dutch GDP growth rates on the one side and the GWP, Eurozone, advanced economies and emerging markets and developing economies GDP growth rates on the other side is discussed. In line with Borensztein et al. (2004) methodology, coupon rates of GDP-linked bonds of Greece and the Netherlands respectively are simulated. Finally the chapter ends with the Markowitz mean variance portfolio optimization approach and the ex-ante Sharpe ratio analysis made upon yearly portfolios of two periods, namely 2002-2007 and 2008 to 2013. Every year includes five weight allocations between 10-year Government bonds and GDP-linked bonds, namely 100%/0%, 75%/25%, 50%/50%, 75%/25%, 0%/100% and one weight allocation aiming on maximising the Sharpe Ratio. In all the cases, a constant weight allocation throughout the year produces the same or lower Sharpe ratio than the portfolio maximum Sharpe ratio and the same or higher Sharpe ratio from the individual assets separately. All the portfolios can be found in Appendix C.

5.2 Correlation results

As discussed in chapter 4 all required GDP growth rate data used in the current empirical research concerning the diversification properties of GDP-linked bonds are obtained from Bloomberg terminal. The years included in the analysis are ranging from a thirty three year period of actual data between 1983 and 2013. The correlation coefficients are calculated by considering data sets of the last twenty years with respect to each year. Therefore, the first results of the correlation analysis are available from 2002 up to 2013.

The GDP correlations table of Greece and the Netherlands with the GWP, Eurozone, advanced economies and emerging markets or developing economies GDP growth rate can be found in Appendix A. The correlation coefficient for each year is calculated with respect to period of the past twenty years.

5.2.1 Greece

Figure 5 displays correlations of the Greek GDP growth rates with five areas of interest namely the Netherlands, GWP, Eurozone, advanced economies and emerging markets and developing economies. Results show higher correlation between Greece and Eurozone GDP growth rates and lower correlation partially with the Netherlands and emerging economies. According to Schröder et al. (2004), an issuing country needs to have low positive or negative correlation with investor's area in order for the investor to have desirability for GDP -linked bonds. In line with Abiad et al. (2013) findings, although pre-crisis correlations of regional and global GDP remained in a modest level, they increased drastically for the first time in decades around the financial crisis peak of 2007-2009. Moreover, in the case of Greece and the Eurozone we observe a high correlation and therefore we are expecting low investment interest. Further to the analysis, one can observe that diversification benefits might arise under a portfolio consisting of Greek and advanced economies GDP-linked bonds for the period between 2002 and 2007. On the other hand after 2008 and up to 2013 portfolio diversification can be achieved if Greek and emerging markets and developing economies GDP-linked bonds combined. Last but not least, concerning GWP and Greek GDP growth rates, one can observe low positive correlation between 2001 and 2005 and again from 2010 onwards with a continuously decreasing trend which paves the way for further diversified portfolios. Results also point that diversification benefits between Greek and Dutch GDP-linked bonds might arose from 2006 to 2008 due to low correlation. The pink area represents years after crisis.

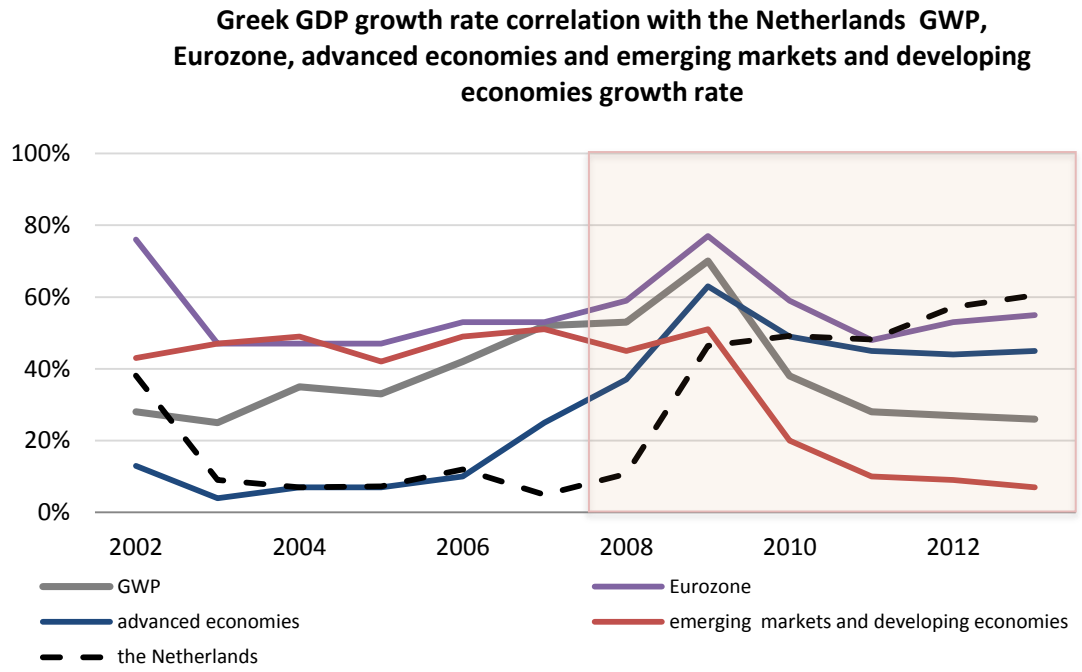


Figure 4: Greek GDP growth rate correlations with the Netherlands, GWP, Eurozone, advanced economies and emerging markets and developing economies growth rate

5.2.2 The Netherlands

The second leg of the correlation analysis took place among GDP growth rates of the Netherlands and Greece, GWP, Eurozone, advanced economies and emerging markets and developing economies GDP growth rates. The relationship between the Netherlands GDP growth rate and Eurozone GDP growth rate proved to be the highest among other investment areas of interest. We can observe that correlations of the Netherlands with advanced economies and GWP are almost following the same pattern with the latest to have lower correlation. On the other hand, correlations of the Netherlands GDP growth rates with emerging market and developing economies are either negative (2003-2008) or low positive (2008-2013). Finally, for the period between 2008 and 2013, the correlation between GWP and the Netherlands remains above 50%, preventing that way possible diversification of GDP-linked bonds in a portfolio context. Based on Schröder et al. (2004) findings, Dutch GDP-linked bonds are not offering diversification benefits to an investor holding an internationally well diversified portfolio and might not be chosen to be a part of his portfolio.

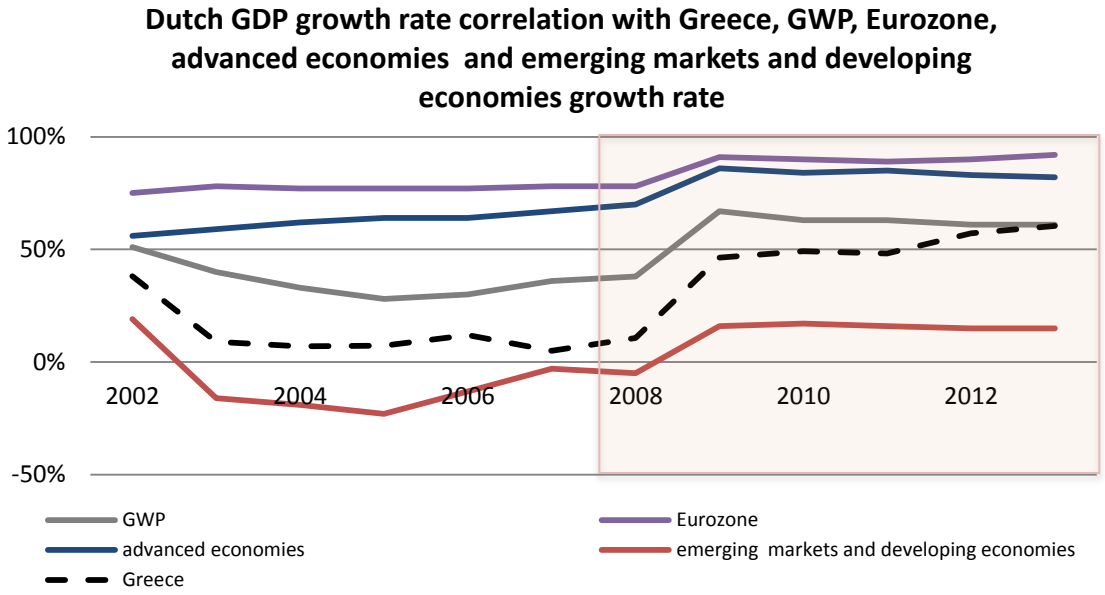


Figure 5: Dutch GDP growth rate correlations with Greece, GWP, Eurozone, advanced economies and emerging markets and developing economies growth rate

To summarize the result of the correlation analysis, GDP-linked bonds could be employed as hedging assets in times of low or negative correlation between the GDP of the two areas of interest on the investors perspective. In the case of Greece, diversification might be achieved by combining GDP-linked bonds issued from Greece with GDP-linked bonds issued by advanced economies for the period between 2002 and 2007 and with GDP-linked bonds issued by emerging economies for the period between 2008 and 2013. Furthermore, future

diversification benefits might arise in a portfolio consisted of Greek GDP and GWP-linked bonds but further research needs to be made to validate the results. In the case of the Netherlands, it is clearer that diversification lies in combining Dutch GDP-linked bonds with bonds issued by emerging markets and developing economies, especially for the period between 2002 and 2007. Moreover the analysis concludes that diversification benefits might arise for an investor holding a portfolio of Greek and Dutch GDP-linked bonds for the period of 2006 to 2008.

Finally, the diversification benefits arising before and after the start of the financial crisis are deriving from different investment areas. To be more specific, one can observe that prior to 2008 there is low positive correlation of Greek GDP growth rates with the Dutch, the advanced economies and the GWP growth rates. Nevertheless, the correlation between Greek and GWP growth rates is increasing around the financial crisis peak and then shortly after is decreasing again. Following 2008, we see a change in figures with emerging markets and developing economies and GWP to form low positive correlation and the correlation with the advanced economies to increase significantly.

On the other hand, concerning the Netherlands, we see that figures follow a relatively stable trend without any major changes. More specifically, prior to 2008 one can observe low positive correlation between the Netherlands and the GWP, even lower but still positive with Greece and negative with the emerging markets and developing economies. For the years after 2008, we see that correlation of the GDP growth rates of the Netherlands with GWP and Greece are rising to above 50% and with emerging markets and developing economies to above zero. Higher correlation of GDP growth rates means lower diversification properties in a portfolio context. The correlation analysis reveals that limited or no diversification properties arising from the Dutch GDP-linked bonds especially after 2008.

5.3 Coupon simulation results

Following the model of Borensztein and Mauro (2004), monthly data of the 10-year Greek Government Bond Index (GGGB10YR: IND) and the 10-year Netherlands Government Bond Index (GNTH10YR: IND) have been selected from Bloomberg terminal. Figure 7, shows that GDP-linked bonds increase payment obligations in the first period (2002-2007) where there is higher growth rate than the twenty-year average while during the second period (2008-2013) the opposite occurs. Bondholders have a great incentive in investing in GDP-linked bonds in periods of higher than the 20-year moving average growth which is not the case for sovereigns that would alternatively prefer plain vanilla bonds. Furthermore, possible issuing

of GDP-linked bonds in 2008 would reflect a drastic decrease in sovereign payment obligations for the following years.

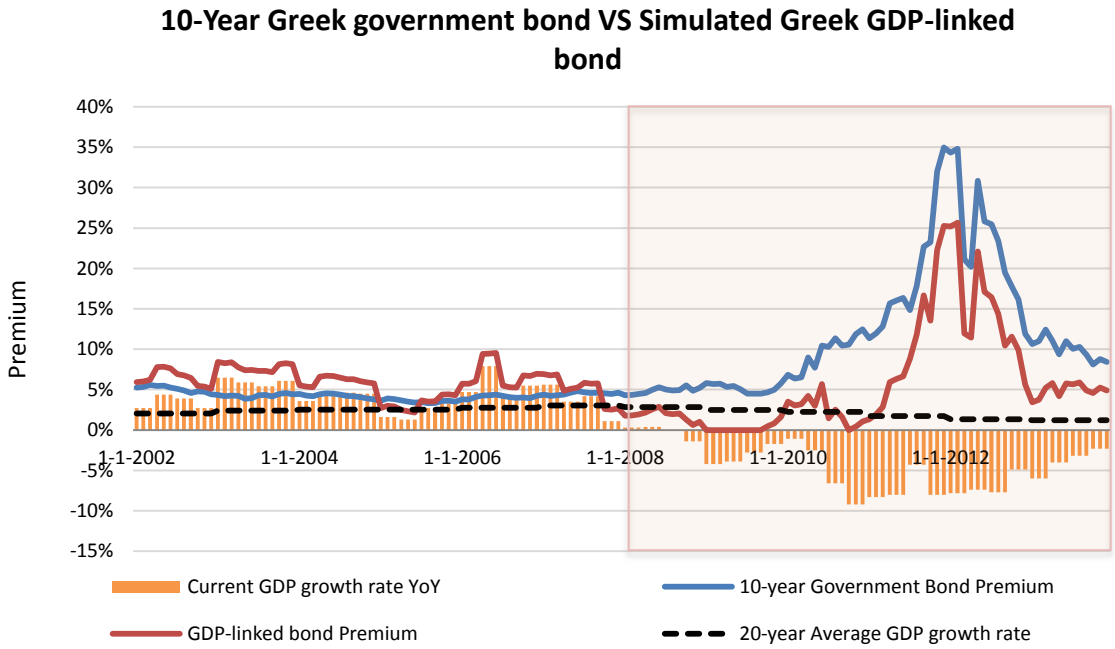


Figure 6: 10-year Greek government bond versus simulated Greek GDP-linked bond

* Pink area represents years after the start of the financial crisis

Date	10-year government bond premium	current GDP growth rate year on year	20-year average GDP growth rate	current minus 20-year average GDP growth rate	GDP-linked bond premium
31/12/2013	8.42%	-2.30%	1.22%	-3.52%	4.90%
29/11/2013	8.78%	-2.30%	1.22%	-3.52%	5.26%
31/10/2013	8.09%	-2.30%	1.22%	-3.52%	4.57%
30/9/2013	9.32%	-3.20%	1.22%	-4.42%	4.90%
30/8/2013	10.30%	-3.20%	1.22%	-4.42%	5.88%
31/7/2013	10.06%	-3.20%	1.22%	-4.42%	5.64%
28/6/2013	10.98%	-4.00%	1.22%	-5.22%	5.76%
31/5/2013	9.39%	-4.00%	1.22%	-5.22%	4.17%
30/4/2013	11.02%	-4.00%	1.22%	-5.22%	5.80%
29/3/2013	12.44%	-6.00%	1.22%	-7.22%	5.22%
28/2/2013	10.98%	-6.00%	1.22%	-7.22%	3.76%
31/1/2013	10.65%	-6.00%	1.22%	-7.22%	3.43%
31/12/2012	11.90%	-4.90%	1.33%	-6.23%	5.67%
30/11/2012	16.13%	-4.90%	1.33%	-6.23%	9.90%

31/10/2012	17.77%	-4.90%	1.33%	-6.23%	11.53%
28/9/2012	19.49%	-7.70%	1.33%	-9.03%	10.46%
31/8/2012	23.41%	-7.70%	1.33%	-9.03%	14.37%
31/7/2012	25.46%	-7.70%	1.33%	-9.03%	16.42%
29/6/2012	25.83%	-7.40%	1.33%	-8.73%	17.10%
31/5/2012	30.83%	-7.40%	1.33%	-8.73%	22.09%
30/4/2012	20.18%	-7.40%	1.33%	-8.73%	11.44%
30/3/2012	21.08%	-7.80%	1.33%	-9.13%	11.95%
29/2/2012	34.79%	-7.80%	1.33%	-9.13%	25.66%
31/1/2012	34.31%	-7.80%	1.33%	-9.13%	25.18%
30/12/2011	34.96%	-8.00%	1.72%	-9.72%	25.25%
30/11/2011	32.00%	-8.00%	1.72%	-9.72%	22.29%
31/10/2011	23.24%	-8.00%	1.72%	-9.72%	13.52%
30/9/2011	22.69%	-4.30%	1.72%	-6.02%	16.67%
31/8/2011	17.81%	-4.30%	1.72%	-6.02%	11.79%
29/7/2011	14.83%	-4.30%	1.72%	-6.02%	8.81%
30/6/2011	16.34%	-8.00%	1.72%	-9.72%	6.62%
31/5/2011	16.04%	-8.00%	1.72%	-9.72%	6.32%
29/4/2011	15.66%	-8.00%	1.72%	-9.72%	5.95%
31/3/2011	12.84%	-8.30%	1.72%	-10.02%	2.82%
28/2/2011	11.94%	-8.30%	1.72%	-10.02%	1.92%
31/1/2011	11.34%	-8.30%	1.72%	-10.02%	1.32%
31/12/2010	12.47%	-9.20%	2.23%	-11.43%	1.05%
30/11/2010	11.86%	-9.20%	2.23%	-11.43%	0.43%
29/10/2010	10.56%	-9.20%	2.23%	-11.43%	0.00%
30/9/2010	10.45%	-6.60%	2.23%	-8.83%	1.63%
31/8/2010	11.35%	-6.60%	2.23%	-8.83%	2.52%
30/7/2010	10.30%	-6.60%	2.23%	-8.83%	1.47%
30/6/2010	10.43%	-2.50%	2.23%	-4.73%	5.70%
31/5/2010	7.71%	-2.50%	2.23%	-4.73%	2.98%
30/4/2010	8.96%	-2.50%	2.23%	-4.73%	4.24%
31/3/2010	6.53%	-1.10%	2.23%	-3.33%	3.20%
26/2/2010	6.36%	-1.10%	2.23%	-3.33%	3.04%
29/1/2010	6.85%	-1.10%	2.23%	-3.33%	3.53%
31/12/2009	5.77%	-1.70%	2.47%	-4.17%	1.60%
30/11/2009	5.00%	-1.70%	2.47%	-4.17%	0.82%
30/10/2009	4.65%	-1.70%	2.47%	-4.17%	0.48%
30/9/2009	4.52%	-2.80%	2.47%	-5.27%	0.00%
31/8/2009	4.49%	-2.80%	2.47%	-5.27%	0.00%
31/7/2009	4.52%	-2.80%	2.47%	-5.27%	0.00%

30/6/2009	5.04%	-3.90%	2.47%	-6.37%	0.00%
29/5/2009	5.45%	-3.90%	2.47%	-6.37%	0.00%
30/4/2009	5.32%	-3.90%	2.47%	-6.37%	0.00%
31/3/2009	5.74%	-4.20%	2.47%	-6.67%	0.00%
27/2/2009	5.68%	-4.20%	2.47%	-6.67%	0.00%
30/1/2009	5.82%	-4.20%	2.47%	-6.67%	0.00%
31/12/2008	5.23%	-1.40%	2.82%	-4.22%	1.00%
28/11/2008	4.84%	-1.40%	2.82%	-4.22%	0.62%
31/10/2008	5.51%	-1.40%	2.82%	-4.22%	1.29%
30/9/2008	4.95%	-0.10%	2.82%	-2.92%	2.03%
29/8/2008	4.88%	-0.10%	2.82%	-2.92%	1.96%
31/7/2008	5.00%	-0.10%	2.82%	-2.92%	2.08%
30/6/2008	5.28%	0.40%	2.82%	-2.42%	2.86%
30/5/2008	4.97%	0.40%	2.82%	-2.42%	2.55%
30/4/2008	4.59%	0.40%	2.82%	-2.42%	2.17%
31/3/2008	4.46%	0.30%	2.82%	-2.52%	1.94%
29/2/2008	4.34%	0.30%	2.82%	-2.52%	1.81%
31/1/2008	4.30%	0.30%	2.82%	-2.52%	1.78%
31/12/2007	4.63%	1.10%	3.05%	-1.95%	2.68%
30/11/2007	4.46%	1.10%	3.05%	-1.95%	2.52%
31/10/2007	4.54%	1.10%	3.05%	-1.95%	2.60%
28/9/2007	4.63%	4.20%	3.05%	1.15%	5.78%
31/8/2007	4.57%	4.20%	3.05%	1.15%	5.72%
31/7/2007	4.67%	4.20%	3.05%	1.15%	5.83%
29/6/2007	4.81%	3.50%	3.05%	0.45%	5.27%
31/5/2007	4.63%	3.50%	3.05%	0.45%	5.09%
30/4/2007	4.40%	3.50%	3.05%	0.45%	4.85%
30/3/2007	4.31%	5.60%	3.05%	2.55%	6.86%
28/2/2007	4.21%	5.60%	3.05%	2.55%	6.76%
31/1/2007	4.36%	5.60%	3.05%	2.55%	6.92%
29/12/2006	4.21%	5.50%	2.76%	2.74%	6.95%
30/11/2006	3.95%	5.50%	2.76%	2.74%	6.69%
31/10/2006	4.01%	5.50%	2.76%	2.74%	6.76%
29/9/2006	4.00%	4.00%	2.76%	1.24%	5.24%
31/8/2006	4.07%	4.00%	2.76%	1.24%	5.31%
31/7/2006	4.23%	4.00%	2.76%	1.24%	5.48%
30/6/2006	4.38%	7.90%	2.76%	5.14%	9.52%
31/5/2006	4.30%	7.90%	2.76%	5.14%	9.45%
28/4/2006	4.28%	7.90%	2.76%	5.14%	9.42%
31/3/2006	4.09%	4.70%	2.76%	1.94%	6.03%

28/2/2006	3.79%	4.70%	2.76%	1.94%	5.73%
31/1/2006	3.77%	4.70%	2.76%	1.94%	5.71%
30/12/2005	3.50%	3.30%	2.51%	0.79%	4.30%
30/11/2005	3.64%	3.30%	2.51%	0.79%	4.43%
31/10/2005	3.60%	3.30%	2.51%	0.79%	4.39%
30/9/2005	3.36%	2.70%	2.51%	0.19%	3.55%
31/8/2005	3.32%	2.70%	2.51%	0.19%	3.51%
29/7/2005	3.46%	2.70%	2.51%	0.19%	3.65%
30/6/2005	3.37%	1.30%	2.51%	-1.21%	2.17%
31/5/2005	3.52%	1.30%	2.51%	-1.21%	2.31%
29/4/2005	3.67%	1.30%	2.51%	-1.21%	2.46%
31/3/2005	3.84%	1.60%	2.51%	-0.91%	2.93%
28/2/2005	3.90%	1.60%	2.51%	-0.91%	2.99%
31/1/2005	3.64%	1.60%	2.51%	-0.91%	2.73%
31/12/2004	3.80%	4.50%	2.52%	1.98%	5.78%
30/11/2004	3.91%	4.50%	2.52%	1.98%	5.89%
29/10/2004	4.06%	4.50%	2.52%	1.98%	6.04%
30/9/2004	4.19%	4.60%	2.52%	2.08%	6.27%
31/8/2004	4.21%	4.60%	2.52%	2.08%	6.29%
30/7/2004	4.40%	4.60%	2.52%	2.08%	6.48%
30/6/2004	4.51%	4.70%	2.52%	2.18%	6.69%
31/5/2004	4.55%	4.70%	2.52%	2.18%	6.73%
30/4/2004	4.41%	4.70%	2.52%	2.18%	6.59%
31/3/2004	4.19%	3.60%	2.52%	1.08%	5.27%
27/2/2004	4.27%	3.60%	2.52%	1.08%	5.35%
30/1/2004	4.46%	3.60%	2.52%	1.08%	5.54%
31/12/2003	4.43%	6.10%	2.40%	3.70%	8.13%
28/11/2003	4.57%	6.10%	2.40%	3.70%	8.27%
31/10/2003	4.45%	6.10%	2.40%	3.70%	8.15%
30/9/2003	4.15%	5.40%	2.40%	3.00%	7.15%
29/8/2003	4.33%	5.40%	2.40%	3.00%	7.33%
31/7/2003	4.32%	5.40%	2.40%	3.00%	7.32%
30/6/2003	3.94%	5.90%	2.40%	3.50%	7.44%
30/5/2003	3.88%	5.90%	2.40%	3.50%	7.38%
30/4/2003	4.24%	5.90%	2.40%	3.50%	7.74%
31/3/2003	4.26%	6.50%	2.40%	4.10%	8.36%
28/2/2003	4.17%	6.50%	2.40%	4.10%	8.27%
31/1/2003	4.34%	6.50%	2.40%	4.10%	8.44%
31/12/2002	4.43%	2.70%	2.05%	0.65%	5.08%
29/11/2002	4.72%	2.70%	2.05%	0.65%	5.37%

31/10/2002	4.79%	2.70%	2.05%	0.65%	5.44%
30/9/2002	4.60%	3.90%	2.05%	1.85%	6.45%
30/8/2002	4.90%	3.90%	2.05%	1.85%	6.75%
31/7/2002	5.09%	3.90%	2.05%	1.85%	6.94%
28/6/2002	5.27%	4.40%	2.05%	2.35%	7.62%
31/5/2002	5.48%	4.40%	2.05%	2.35%	7.83%
30/4/2002	5.45%	4.40%	2.05%	2.35%	7.80%
29/3/2002	5.57%	2.70%	2.05%	0.65%	6.22%
28/2/2002	5.34%	2.70%	2.05%	0.65%	5.99%
31/1/2002	5.27%	2.70%	2.05%	0.65%	5.92%

Table 6: simulation of the Greek GDP-linked bond premium

On the other hand, as it can be observed in the cause of the Netherlands, GDP-linked bonds are offering lower payment obligation throughout time. More specifically, from the early 2002 to early 2006, GDP-linked bond payments are lower than the payments on the 10-year government bond. The period that followed and up until mid-2008, GDP-linked bond produced higher return than the plain vanilla bond attributable to significant rise of the Dutch GDP in relation to the twenty-year moving average. After 2008, the impact of the financial crisis to the Dutch GDP leads to a GDP-linked bond premium significantly lower than the 10-year government bond. From the government's perspective, financing public debt with GDP-linked bonds is a more attractive solution compared to plain-vanilla bonds, especially in times of economic contraction.

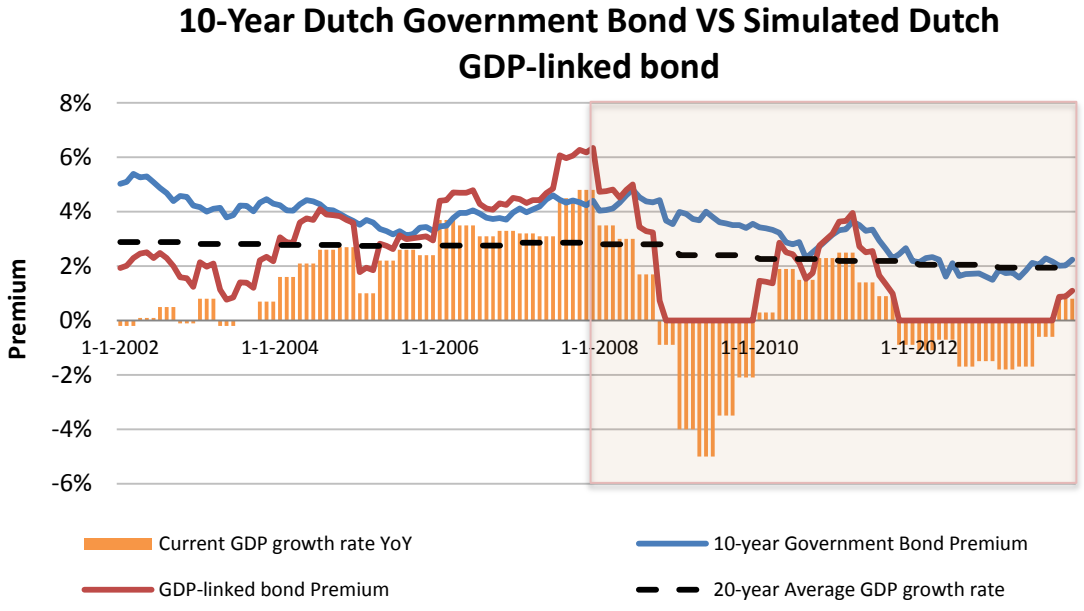


Figure 7: 10-year Dutch government bond versus simulated Dutch GDP-linked bond

* Pink area represents years after the start of the financial crisis

Date	10-year government bond premium	current GDP growth rate year on year	20-year average GDP growth rate	current minus 20-year average GDP growth rate	GDP-linked bond premium
31/12/2013	2.23%	0.80%	1.94%	-1.14%	1.09%
29/11/2013	2.03%	0.80%	1.94%	-1.14%	0.89%
31/10/2013	2.01%	0.80%	1.94%	-1.14%	0.87%
30/9/2013	2.16%	-0.60%	1.94%	-2.54%	0.00%
30/8/2013	2.29%	-0.60%	1.94%	-2.54%	0.00%
31/7/2013	2.05%	-0.60%	1.94%	-2.54%	0.00%
28/6/2013	2.12%	-1.70%	1.94%	-3.64%	0.00%
31/5/2013	1.84%	-1.70%	1.94%	-3.64%	0.00%
30/4/2013	1.58%	-1.70%	1.94%	-3.64%	0.00%
29/3/2013	1.77%	-1.80%	1.94%	-3.74%	0.00%
28/2/2013	1.74%	-1.80%	1.94%	-3.74%	0.00%
31/1/2013	1.87%	-1.80%	1.94%	-3.74%	0.00%
31/12/2012	1.50%	-1.50%	2.04%	-3.54%	0.00%
30/11/2012	1.61%	-1.50%	2.04%	-3.54%	0.00%
31/10/2012	1.73%	-1.50%	2.04%	-3.54%	0.00%
28/9/2012	1.72%	-1.70%	2.04%	-3.74%	0.00%
31/8/2012	1.71%	-1.70%	2.04%	-3.74%	0.00%
31/7/2012	1.63%	-1.70%	2.04%	-3.74%	0.00%
29/6/2012	2.10%	-0.70%	2.04%	-2.74%	0.00%
31/5/2012	1.61%	-0.70%	2.04%	-2.74%	0.00%
30/4/2012	2.24%	-0.70%	2.04%	-2.74%	0.00%
30/3/2012	2.33%	-1.10%	2.04%	-3.14%	0.00%
29/2/2012	2.30%	-1.10%	2.04%	-3.14%	0.00%
31/1/2012	2.15%	-1.10%	2.04%	-3.14%	0.00%
30/12/2011	2.19%	-0.90%	2.19%	-3.09%	0.00%
30/11/2011	2.66%	-0.90%	2.19%	-3.09%	0.00%
31/10/2011	2.44%	-0.90%	2.19%	-3.09%	0.00%
30/9/2011	2.29%	0.90%	2.19%	-1.29%	0.99%
31/8/2011	2.62%	0.90%	2.19%	-1.29%	1.33%
29/7/2011	2.95%	0.90%	2.19%	-1.29%	1.66%
30/6/2011	3.34%	1.40%	2.19%	-0.79%	2.55%
31/5/2011	3.30%	1.40%	2.19%	-0.79%	2.51%
29/4/2011	3.51%	1.40%	2.19%	-0.79%	2.71%
31/3/2011	3.64%	2.50%	2.19%	0.31%	3.95%
28/2/2011	3.36%	2.50%	2.19%	0.31%	3.67%

31/1/2011	3.32%	2.50%	2.19%	0.31%	3.63%
31/12/2010	3.15%	2.30%	2.27%	0.03%	3.19%
30/11/2010	2.94%	2.30%	2.27%	0.03%	2.97%
29/10/2010	2.72%	2.30%	2.27%	0.03%	2.76%
30/9/2010	2.51%	1.50%	2.27%	-0.77%	1.74%
31/8/2010	2.30%	1.50%	2.27%	-0.77%	1.53%
30/7/2010	2.89%	1.50%	2.27%	-0.77%	2.12%
30/6/2010	2.81%	1.90%	2.27%	-0.37%	2.44%
31/5/2010	2.88%	1.90%	2.27%	-0.37%	2.51%
30/4/2010	3.23%	1.90%	2.27%	-0.37%	2.86%
31/3/2010	3.33%	0.30%	2.27%	-1.97%	1.36%
26/2/2010	3.39%	0.30%	2.27%	-1.97%	1.42%
29/1/2010	3.42%	0.30%	2.27%	-1.97%	1.46%
31/12/2009	3.56%	-2.10%	2.40%	-4.50%	0.00%
30/11/2009	3.41%	-2.10%	2.40%	-4.50%	0.00%
30/10/2009	3.51%	-2.10%	2.40%	-4.50%	0.00%
30/9/2009	3.51%	-3.50%	2.40%	-5.90%	0.00%
31/8/2009	3.57%	-3.50%	2.40%	-5.90%	0.00%
31/7/2009	3.62%	-3.50%	2.40%	-5.90%	0.00%
30/6/2009	3.80%	-5.00%	2.40%	-7.40%	0.00%
29/5/2009	4.01%	-5.00%	2.40%	-7.40%	0.00%
30/4/2009	3.68%	-5.00%	2.40%	-7.40%	0.00%
31/3/2009	3.74%	-4.00%	2.40%	-6.40%	0.00%
27/2/2009	3.92%	-4.00%	2.40%	-6.40%	0.00%
30/1/2009	3.99%	-4.00%	2.40%	-6.40%	0.00%
31/12/2008	3.55%	-0.90%	2.80%	-3.70%	0.00%
28/11/2008	3.67%	-0.90%	2.80%	-3.70%	0.00%
31/10/2008	4.43%	-0.90%	2.80%	-3.70%	0.73%
30/9/2008	4.35%	1.70%	2.80%	-1.10%	3.24%
29/8/2008	4.39%	1.70%	2.80%	-1.10%	3.28%
31/7/2008	4.54%	1.70%	2.80%	-1.10%	3.43%
30/6/2008	4.81%	3.00%	2.80%	0.20%	5.01%
30/5/2008	4.61%	3.00%	2.80%	0.20%	4.80%
30/4/2008	4.33%	3.00%	2.80%	0.20%	4.53%
31/3/2008	4.12%	3.50%	2.80%	0.70%	4.82%
29/2/2008	4.06%	3.50%	2.80%	0.70%	4.76%
31/1/2008	4.04%	3.50%	2.80%	0.70%	4.73%
31/12/2007	4.41%	4.80%	2.86%	1.94%	6.35%
30/11/2007	4.24%	4.80%	2.86%	1.94%	6.18%
31/10/2007	4.34%	4.80%	2.86%	1.94%	6.28%

28/9/2007	4.42%	4.50%	2.86%	1.64%	6.06%
31/8/2007	4.34%	4.50%	2.86%	1.64%	5.97%
31/7/2007	4.44%	4.50%	2.86%	1.64%	6.08%
29/6/2007	4.61%	3.10%	2.86%	0.24%	4.85%
31/5/2007	4.45%	3.10%	2.86%	0.24%	4.69%
30/4/2007	4.19%	3.10%	2.86%	0.24%	4.43%
30/3/2007	4.09%	3.20%	2.86%	0.34%	4.43%
28/2/2007	3.98%	3.20%	2.86%	0.34%	4.32%
31/1/2007	4.12%	3.20%	2.86%	0.34%	4.46%
29/12/2006	3.97%	3.30%	2.76%	0.54%	4.51%
30/11/2006	3.71%	3.30%	2.76%	0.54%	4.25%
31/10/2006	3.77%	3.30%	2.76%	0.54%	4.31%
29/9/2006	3.73%	3.10%	2.76%	0.34%	4.07%
31/8/2006	3.78%	3.10%	2.76%	0.34%	4.12%
31/7/2006	3.94%	3.10%	2.76%	0.34%	4.28%
30/6/2006	4.05%	3.50%	2.76%	0.74%	4.79%
31/5/2006	3.96%	3.50%	2.76%	0.74%	4.70%
28/4/2006	3.95%	3.50%	2.76%	0.74%	4.69%
31/3/2006	3.77%	3.70%	2.76%	0.94%	4.71%
28/2/2006	3.48%	3.70%	2.76%	0.94%	4.42%
31/1/2006	3.46%	3.70%	2.76%	0.94%	4.40%
30/12/2005	3.29%	2.40%	2.74%	-0.34%	2.95%
30/11/2005	3.44%	2.40%	2.74%	-0.34%	3.10%
31/10/2005	3.41%	2.40%	2.74%	-0.34%	3.07%
30/9/2005	3.17%	2.60%	2.74%	-0.14%	3.03%
31/8/2005	3.13%	2.60%	2.74%	-0.14%	2.99%
29/7/2005	3.28%	2.60%	2.74%	-0.14%	3.14%
30/6/2005	3.17%	2.20%	2.74%	-0.54%	2.62%
31/5/2005	3.28%	2.20%	2.74%	-0.54%	2.74%
29/4/2005	3.37%	2.20%	2.74%	-0.54%	2.83%
31/3/2005	3.60%	1.00%	2.74%	-1.74%	1.85%
28/2/2005	3.69%	1.00%	2.74%	-1.74%	1.95%
31/1/2005	3.52%	1.00%	2.74%	-1.74%	1.78%
31/12/2004	3.66%	2.70%	2.78%	-0.08%	3.59%
30/11/2004	3.77%	2.70%	2.78%	-0.08%	3.70%
29/10/2004	3.92%	2.70%	2.78%	-0.08%	3.84%
30/9/2004	4.05%	2.60%	2.78%	-0.18%	3.87%
31/8/2004	4.08%	2.60%	2.78%	-0.18%	3.90%
30/7/2004	4.27%	2.60%	2.78%	-0.18%	4.09%
30/6/2004	4.38%	2.10%	2.78%	-0.68%	3.70%

31/5/2004	4.43%	2.10%	2.78%	-0.68%	3.76%
30/4/2004	4.27%	2.10%	2.78%	-0.68%	3.60%
31/3/2004	4.04%	1.60%	2.78%	-1.18%	2.86%
27/2/2004	4.05%	1.60%	2.78%	-1.18%	2.87%
30/1/2004	4.24%	1.60%	2.78%	-1.18%	3.06%
31/12/2003	4.29%	0.70%	2.82%	-2.12%	2.17%
28/11/2003	4.46%	0.70%	2.82%	-2.12%	2.34%
31/10/2003	4.34%	0.70%	2.82%	-2.12%	2.22%
30/9/2003	4.02%	0.00%	2.82%	-2.82%	1.20%
29/8/2003	4.21%	0.00%	2.82%	-2.82%	1.39%
31/7/2003	4.22%	0.00%	2.82%	-2.82%	1.40%
30/6/2003	3.87%	-0.20%	2.82%	-3.02%	0.85%
30/5/2003	3.79%	-0.20%	2.82%	-3.02%	0.77%
30/4/2003	4.15%	-0.20%	2.82%	-3.02%	1.13%
31/3/2003	4.11%	0.80%	2.82%	-2.02%	2.09%
28/2/2003	4.00%	0.80%	2.82%	-2.02%	1.98%
31/1/2003	4.17%	0.80%	2.82%	-2.02%	2.15%
31/12/2002	4.23%	-0.10%	2.89%	-2.99%	1.24%
29/11/2002	4.54%	-0.10%	2.89%	-2.99%	1.55%
31/10/2002	4.58%	-0.10%	2.89%	-2.99%	1.58%
30/9/2002	4.39%	0.50%	2.89%	-2.39%	2.00%
30/8/2002	4.69%	0.50%	2.89%	-2.39%	2.30%
31/7/2002	4.87%	0.50%	2.89%	-2.39%	2.48%
28/6/2002	5.08%	0.10%	2.89%	-2.79%	2.29%
31/5/2002	5.30%	0.10%	2.89%	-2.79%	2.51%
30/4/2002	5.26%	0.10%	2.89%	-2.79%	2.47%
29/3/2002	5.39%	-0.20%	2.89%	-3.09%	2.30%
28/2/2002	5.10%	-0.20%	2.89%	-3.09%	2.01%
31/1/2002	5.02%	-0.20%	2.89%	-3.09%	1.93%

Table 7: simulation of the Dutch GDP-linked bond premium

5.4 Results from the mean-variance portfolio optimization - Sharpe ratio analysis

5.4.1. Greece

The Markowitz mean-variance portfolio optimization approach has been selected in order to investigate diversification benefits of the GDP-linked bonds in relation to 10-year government bonds in a portfolio context. In order to measure the reward-to-variability of each asset separately in single asset portfolios or in two asset-portfolios, the ex-ante Sharpe ratio has been employed. Consequently, years have been separated into two periods namely 2002-2007

and 2008-2013 so as to measure the influence of a negative growth into the diversification properties of GDP-linked bonds.

In both Greece and the Netherlands respectively, it can be observed that the diversification benefits arising from GDP-linked bonds are offering limited diversification properties. Nevertheless the optimal asset allocation should be subject to changes throughout the years in order to achieve the maximum return.

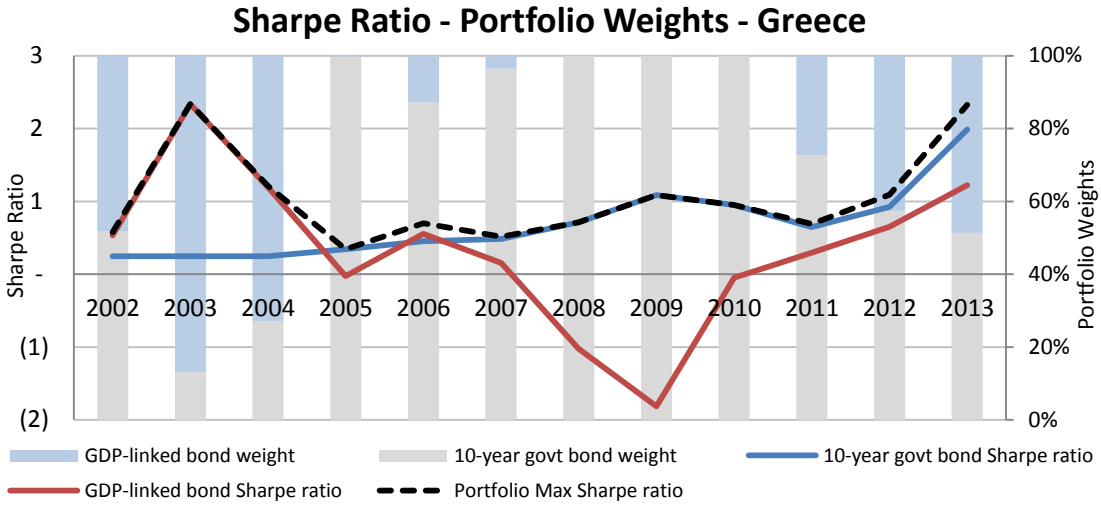


Figure 8: Sharpe ratio, maximum portfolio Sharpe ratio - Greece

We can see that prior to 2005, the contribution of GDP-linked bonds in a portfolio of 10-year government bonds would be more than 50% with the return being driven mainly by GDP-linked bonds. We can observe some diversification benefits in 2006 with a contribution of 13% of GDP-linked bonds versus 87% of government bonds. For the years 2011, 2012 and 2013 we can see a significant constantly rising diversification pattern with a portfolio participation of GDP-linked bonds of 27%, 43% and 49% respectively.

5.4.2. The Netherlands

In the case of the Netherlands it can be observed that there are no diversification benefits arising for an investor holding a portfolio consisting of 10-year Dutch government bonds and GDP-linked bonds for the period 2002 -2013. Only the year 2007 is characterised by low diversification between GDP-linked bonds and 10-year Government bonds. In case a portfolio was formed it would require 60% of Dutch GDP-linked bonds and 40% of 10-year government bonds to produce a Sharpe ratio of 0.39 while a single asset portfolio of 10-year government bonds would produce a Sharpe ratio of 0.38.

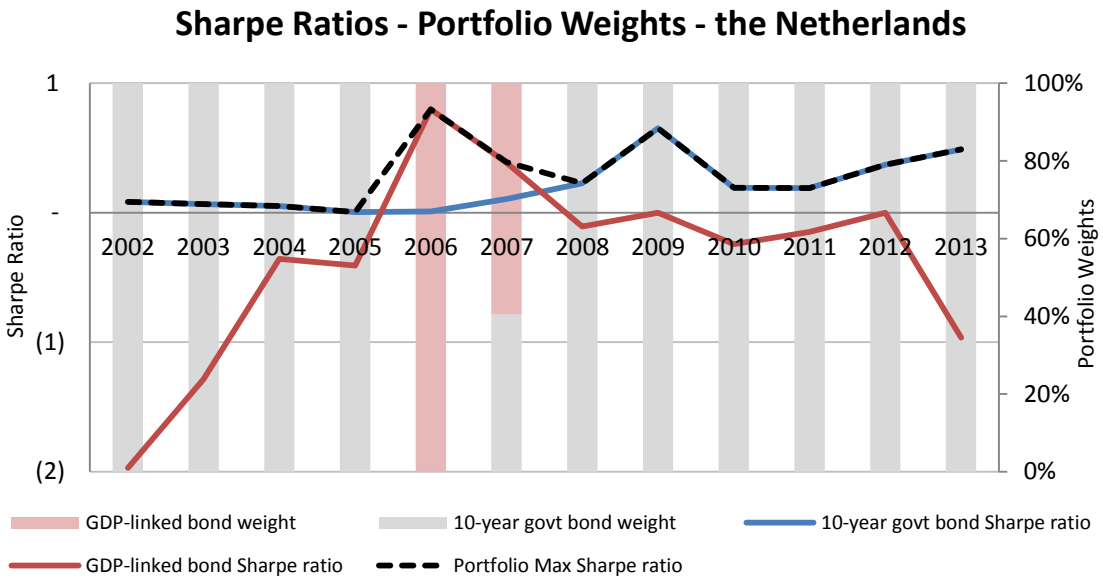


Figure 9: Sharpe ratios, maximum portfolio Sharpe ratio- the Netherlands

5.4.3. Greek and Dutch GDP-linked bond portfolio

Finally the mean-variance portfolio optimization approach is completed with the presentation of the cross country GDP-linked bond portfolio. Figure 11 presents portfolio weight allocations, Sharpe ratios of the Greek and the Dutch GDP-linked bond and the portfolio maximum Sharpe ratio. In line with the correlation analysis of this thesis, we can observe that low diversification properties arise for the years 2006 and 2007.

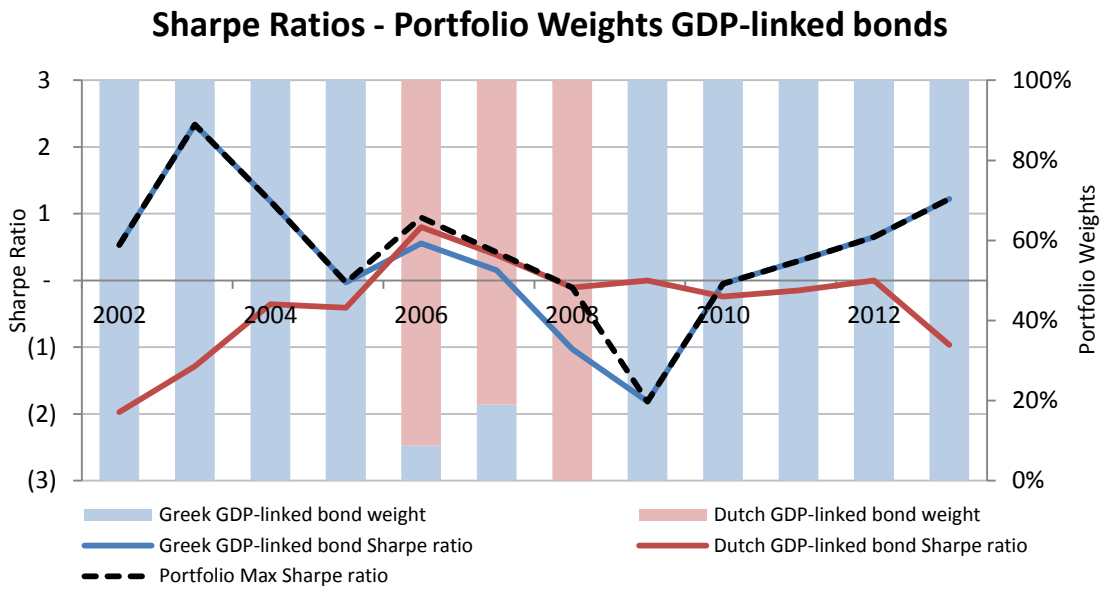


Figure 10: Sharpe ratio, maximum portfolio Sharpe ratio, GDP-linked bonds

5.5 Summary

In this chapter the correlation analysis, the simulated coupon rates of the Greek and the Dutch GDP-linked bond and the optimal portfolio weight allocation based on the Markowitz mean-variance portfolio optimization approach and the Sharpe ratio analysis were presented.

"Are the correlations between GWP, Eurozone Area GDP and Advanced and Developing GDP growth on the one side and the Greek and the Dutch GDP growth respectively on the other side low or negative concerning periods 2002-2007 and 2008-2013?"

In order to answer the first question of this empirical study, it can be concluded that the findings of the correlation analysis indicate that an investor can diversify more his portfolio by combining Greek or Dutch GDP-linked bonds with GDP-linked bonds issued by emerging markets and developing economies. On this ground, diversification benefits arise from a portfolio consisting of Greek or Dutch GDP-linked bonds with GDP-linked bonds connected to the Gross World Product, the GDP of Eurozone or the GDP of advanced economies would be lower. This is consistent with the proposal of Schröder et al. (2004) that potential issuer countries of GDP-linked bonds need to have low positive or negative correlation with the region of interest of the investor.

"Are any diversification properties arising from a portfolio consisting of 10-year Government bonds and simulated GDP-linked bonds for Greece and the Netherlands respectively?"

Moreover, concerning the second question, the mean-variance portfolio optimization approach and the ex-ante Sharpe ratio analysis show that there are no significant diversification benefits for an investor holding a portfolio consisting of Greek (Dutch) GDP-linked bonds and 10-year Greek (Dutch) government bonds.

"Are there any diversification properties arising from a portfolio consisting of GDP-linked bonds from the Netherlands and Greece?"

Finally, concerning the third question of this empirical research, a portfolio consisted of Greek and Dutch GDP-linked bonds for the period 2002-2013 offer no or relatively low diversification benefits to the investor. According to the Sharpe ratio analysis, the portfolio maximum Sharpe ratio coincides in most of the cases with the Sharpe ratio of one of two assets.

Chapter 6 Conclusion

The purpose of this thesis is to investigate whether any diversification benefits arising from the use of GDP-linked bonds in a portfolio context with 10-year government bonds of the Greece and the Netherlands respectively and also diversification benefits of a cross country GDP-linked bond portfolio. In addition to that, a correlation analysis of the Greek and the Dutch GDP growth rates with the GWP, the Eurozone GDP and the advanced economies and emerging markets and developing economies GDP growth rates is presented. The purpose of the study was to determine and evaluate the merits of using GDP-linked bonds to achieve higher return to a given level of risk or same return in a lower level of risk.

Implementation and application of GDP-linked bonds is very limited in real market and therefore the model of Borensztein et al. (2004) has been employed in order to simulate the coupon rates of the GDP-linked bonds for the two countries. Monthly 10-year government bond indexed yields of Greece and the Netherlands and quarterly year on year real GDP growth rates have been extracted from Bloomberg terminal. The simulation model required monthly inputs and therefore GDP growth rates have been adjusted towards a monthly frequency.

The Markowitz mean-variance portfolio optimization approach was employed in combination with a Sharpe ratio analysis in order to provide the higher reward to variability weight allocation. The 10-year German government index bond was preferred among others as the base rate of the analysis. The empirical findings suggest that GDP-linked bonds of Greece or the Netherlands could offer diversification benefits to an investor if combined with GDP-linked bonds issued by emerging markets and developing economies.

Furthermore, in the case of the Netherlands, the negative correlation with emerging markets and developing economies prior to the start of the financial crisis and the low positive correlation (below 20%) indicate high possibility of potential diversification. Nevertheless, results of the Sharpe ratio analysis reveal that even though the correlation of the Greek and the Dutch GDP growth rates is low positive (below 10%), the available diversification benefits are very limited. Furthermore, in the case of the Netherlands there are no diversification benefits arising between 10-year Government bonds and GDP-linked bonds. In any case it seems clear that Dutch GDP-linked bonds offer no diversification benefits to an investor if combined either with 10-year Dutch government bonds or Greek GDP-linked bonds.

Moreover, the correlation analysis revealed potential diversification benefits for Greek GDP-linked bonds if combined in a portfolio with GDP-linked bonds issued by the advanced economies during the period of 2002-2007 or with GDP-linked bonds issued by the emerging markets and developing economies during the period of 2008-2013. In addition, the mean variance optimization approach indicated that, in a portfolio consisted of 10-year government bonds and Greek GDP-linked bonds, no significant diversification properties arose until 2011. Nevertheless, in 2011, the Sharpe ratio of the portfolio started to increase in relation to the individual Sharpe ratios of the two assets.

6.1 Limitations

As every empirical thesis also this one has been a subject to various limitations which will be commented below. At first, the validity of the reported GDP growth figures could be subject to changes even three years after publishing due to incomplete or misreported data. Due to this reason, the outcome may alter significantly during the last three years of the empirical research. An updated version of this research might provide a valuable insight and identify the variations.

The second limitation is related to the risk free rate employed for the Sharpe ratio analysis. The 10-year German government bond has been considered as the risk free rate where the selection could be subject of debate. Nevertheless, the 10-year German government bond was considered the most appropriate risk free rate due to extended application in various studies.

Furthermore, the third limitation is related to the methodology followed during the analysis. The results have been generalized in the mean-variance portfolio optimization approach to utility maximization under no-short selling constraints. A revised version of the current methodology including short selling can reveal the effect of the position in the portfolio Sharpe ratio.

Finally, the fact that this research has been conducted in the settings of Greece and the Netherlands and under specific circumstances makes it hard to generalize the results to other European countries as well. Nevertheless, the findings of this research might contribute to further understanding of GDP-linked bonds and their application and desirability in a portfolio context.

6.2 Recommendation for future research

This thesis attempted to identify the diversification benefits of simulated GDP-linked bonds issued by Greece and the Netherlands respectively in a portfolio context. However, the time framework and the exact settings that this empirical analysis was conducted, as well as the methodology employed leave opportunities for future research to shed further light on this relationship and add value to the findings of this research.

More specifically, the correlation analysis revealed negative correlation between GDP growth rates of the Netherlands and emerging markets and developing economies and therefore a mean-variance portfolio optimization analysis will provide more accurate results concerning application of Dutch GDP-linked bonds in such context.

Another suggestion for future research is related to the portfolio consisting of 10-year Greek Government bonds and simulated Greek GDP-linked bonds and whether the diversification properties observed in the last three years of the analysis will continue to grow in the future. An instrument similar to GDP-linked bond, the GDP-linked warrant has already been issued in Greece under the Private Sector Involvement (PSI) program and possible results of the future research could provide information for a more attractive investor framework of issuing of GDP-linked bonds.

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Appendix A

Correlation table among Greece and the Netherlands GDP growth rates and the GWP, Eurozone, advanced economies and emerging markets and developing economies GDP growth rates.

Greece

Year	GWP	Euro area	advanced economies	emerging markets	Netherlands
2002	28%	76%	13%	43%	38%
2003	25%	47%	4%	47%	9%
2004	35%	47%	7%	49%	7%
2005	33%	47%	7%	42%	7%
2006	42%	53%	10%	49%	12%
2007	52%	53%	25%	51%	5%
2008	53%	59%	37%	45%	11%
2009	70%	77%	63%	51%	46%
2010	38%	59%	49%	20%	49%
2011	28%	48%	45%	10%	48%
2012	27%	53%	44%	9%	57%
2013	26%	55%	45%	7%	60%

The Netherlands

Year	GWP	Euro area	advanced economies	emerging markets	Greece
2002	51%	75%	56%	19%	38%
2003	40%	78%	59%	-16%	9%
2004	33%	77%	62%	-19%	7%
2005	28%	77%	64%	-23%	7%
2006	30%	77%	64%	-13%	12%
2007	36%	78%	67%	-3%	5%
2008	38%	78%	70%	-5%	11%
2009	67%	91%	86%	16%	46%
2010	63%	90%	84%	17%	49%
2011	63%	89%	85%	16%	48%
2012	61%	90%	83%	15%	57%
2013	61%	92%	82%	15%	60%

Appendix B

Borensztein & Mauro (2004) summary table of returns, standard deviations and Sharpe ratios per asset

Greece	10-year government bond premium			GDP-linked bond premium			German bond
	μ_i	σ_i	$(\mu_i-\mu_{rf})/\sigma_i$	μ_i	σ_i	$(\mu_i-\mu_{rf})/\sigma_i$	μ_{rf}
2013	10.04%	4.23%	1.99	4.94%	2.71%	1.22	1.62%
2012	23.43%	23.71%	0.92	15.15%	21.02%	0.65	1.51%
2011	19.14%	25.45%	0.65	10.27%	26.03%	0.29	2.65%
2010	9.49%	7.11%	0.95	2.48%	5.46%	- 0.05	2.74%
2009	5.17%	1.75%	1.09	0.24%	1.66%	- 1.82	3.26%
2008	4.86%	1.26%	0.71	1.84%	2.07%	- 1.03	3.96%
2007	4.52%	0.58%	0.48	5.07%	5.42%	0.15	4.24%
2006	4.09%	0.65%	0.45	6.86%	5.53%	0.55	3.79%
2005	3.57%	0.60%	0.34	3.29%	2.69%	- 0.03	3.36%
2004	4.25%	0.78%	0.24	6.08%	1.70%	1.19	4.06%
2003	4.26%	0.66%	0.25	7.83%	1.60%	2.33	4.09%
2002	5.07%	1.26%	0.25	6.45%	3.17%	0.53	4.76%

The Netherlands	10-year government bond premium			GDP-linked bond premium			German bond
	μ_i	σ_i	$(\mu_i-\mu_{rf})/\sigma_i$	μ_i	σ_i	$(\mu_i-\mu_{rf})/\sigma_i$	μ_{rf}
2013	1.97%	0.72%	0.49	0.24%	1.44%	-0.96	1.62%
2012	1.89%	1.03%	0.37	0.00%	0.00%	0.00	1.51%
2011	2.97%	1.69%	0.19	1.92%	4.88%	-0.15	2.65%
2010	2.96%	1.17%	0.19	2.20%	2.24%	-0.24	2.74%
2009	3.69%	0.66%	0.65	0.00%	0.00%	0.00	3.26%
2008	4.24%	1.23%	0.23	3.28%	6.45%	-0.11	3.96%
2007	4.30%	0.60%	0.11	5.34%	2.87%	0.38	4.24%
2006	3.80%	0.62%	0.01	4.44%	0.81%	0.80	3.79%
2005	3.36%	0.58%	0.00	2.67%	1.70%	-0.41	3.36%
2004	4.10%	0.78%	0.05	3.57%	1.36%	-0.36	4.06%
2003	4.14%	0.64%	0.07	1.64%	1.91%	-1.29	4.09%
2002	4.87%	1.26%	0.08	2.05%	1.37%	-1.97	4.76%

Appendix C

1. Portfolios consisting of 10-year Greek government bonds and Greek simulated GDP-linked bonds

Σwi	: Sum of weights employed by the two assets in the portfolio (always equals 100%)
μp	: return of the portfolio
σp	: standard deviation of the portfolio
μp-μrf/σp	: Sharpe ratio of the portfolio
μrf	: return of the risk free rate (German government bond)
N/A	Not Applicable
Max SR	Portfolio maximum Sharpe ratio

2013 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	51%
GDP-linked bond	0%	25%	50%	75%	100%	49%
Σwi	100%	100%	100%	100%	100%	100%
μp	10.04%	8.76%	7.49%	6.21%	4.94%	7.56%
σp	4.23%	3.25%	2.52%	2.30%	2.71%	2.55%
μp-μrf/σp	1.99	2.20	2.32	1.99	1.22	2.32

2012 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	57%
GDP-linked bond	0%	25%	50%	75%	100%	43%
Σwi	100%	100%	100%	100%	100%	100%
μp	23.43%	21.36%	19.29%	17.22%	15.15%	19.91%
σp	23.71%	18.95%	16.48%	17.29%	21.02%	16.90%
μp-μrf/σp	0.92	1.05	1.08	0.91	0.65	1.09

2011 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	73%
GDP-linked bond	0%	25%	50%	75%	100%	27%
Σwi	100%	100%	100%	100%	100%	100%
μp	19.14%	16.92%	14.71%	12.49%	10.27%	16.72%
σp	25.45%	20.66%	18.93%	21.02%	26.03%	20.34%
μp-μrf/σp	0.65	0.69	0.64	0.47	0.29	0.69

2010 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μp	9.49%	7.73%	5.98%	4.23%	2.48%	9.49%
σp	7.11%	5.45%	4.39%	4.40%	5.46%	7.11%
μp-μrf/σp	0.95	0.92	0.74	0.34	-0.05	0.95

2009 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μp	5.17%	3.93%	2.70%	1.47%	0.24%	5.17%
σp	1.75%	1.39%	1.22%	1.33%	1.66%	1.75%
μp-μrf/σp	1.09	0.49	-0.46	-1.34	-1.82	1.09

2008 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μp	4.86%	4.11%	3.35%	2.60%	1.84%	4.86%
σp	1.26%	1.08%	1.21%	1.58%	2.07%	1.26%
μp-μrf/σp	0.71	0.14	-0.50	-0.86	-1.03	0.71

2007 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	96%
GDP-linked bond	0%	25%	50%	75%	100%	4%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	4.52%	4.66%	4.80%	4.93%	5.07%	4.54%
σ_p	0.58%	1.41%	2.72%	4.07%	5.42%	0.59%
$\mu_p-\mu_{rf}/\sigma_p$	0.48	0.30	0.21	0.17	0.15	0.51

2006 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	87%
GDP-linked bond	0%	25%	50%	75%	100%	13%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	4.09%	4.78%	5.47%	6.17%	6.86%	4.45%
σ_p	0.65%	1.49%	2.80%	4.16%	5.53%	0.94%
$\mu_p-\mu_{rf}/\sigma_p$	0.45	0.66	0.60	0.57	0.55	0.70

2005 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	3.57%	3.50%	3.43%	3.36%	3.29%	3.57%
σ_p	0.60%	0.81%	1.37%	2.02%	2.69%	0.60%
$\mu_p-\mu_{rf}/\sigma_p$	0.34	0.17	0.05	-0.00	-0.03	0.34

2004 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	27%
GDP-linked bond	0%	25%	50%	75%	100%	73%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	4.25%	4.70%	5.16%	5.62%	6.08%	5.58%
σ_p	0.78%	0.73%	0.95%	1.30%	1.70%	1.26%
$\mu_p-\mu_{rf}/\sigma_p$	0.24	0.88	1.17	1.21	1.19	1.21

2003 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	13%
GDP-linked bond	0%	25%	50%	75%	100%	87%
Σwi	100%	100%	100%	100%	100%	100%
μp	4.26%	5.15%	6.04%	6.94%	7.83%	7.36%
σp	0.66%	0.65%	0.88%	1.22%	1.60%	1.40%
μp-μrf/σp	0.25	1.62	2.22	2.33	2.33	2.34

2002 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	52%
GDP-linked bond	0%	25%	50%	75%	100%	48%
Σwi	100%	100%	100%	100%	100%	100%
μp	5.07%	5.42%	5.76%	6.11%	6.45%	5.74%
σp	1.26%	1.26%	1.73%	2.41%	3.17%	1.69%
μp-μrf/σp	0.25	0.52	0.58	0.56	0.53	0.58

2. Portfolios consisting of 10-year Dutch Government Bonds and Dutch Simulated GDP-linked bonds

Σwi	: Sum of weights employed by the two assets in the portfolio (always equals 100%)
μ	: return of the portfolio
σp	: standard deviation of the portfolio
μ-μrf/σ	: Sharpe ratio of the portfolio
μrf	: return of the risk free rate (German government bond)
N/A	Not Applicable
Max SR	Portfolio maximum Sharpe ratio

2013 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μp	1.97%	1.54%	1.11%	0.67%	0.24%	1.97%
σp	0.72%	0.68%	0.84%	1.11%	1.44%	0.72%
μp-μrf/σp	0.49	-0.12	-0.62	-0.86	-0.96	0.49

2012 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μp	1.89%	1.41%	0.94%	0.47%	0.00%	1.89%
σp	1.03%	0.77%	0.51%	0.26%	0.00%	1.03%
μp-μrf/σp	0.37	-0.12	-1.10	-4.03	#DIV/0!	0.37

2011 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μp	2.97%	2.70%	2.44%	2.18%	1.92%	2.97%
σp	1.69%	1.97%	2.78%	3.79%	4.88%	1.69%
μp-μrf/σp	0.19	0.03	-0.07	-0.12	-0.15	0.19

2010 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μp	2.96%	2.77%	2.58%	2.39%	2.20%	2.96%
σp	1.17%	1.03%	1.25%	1.70%	2.24%	1.17%
μp-μrf/σp	0.19	0.03	-0.13	-0.21	-0.24	0.19

2009 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μp	3.69%	2.77%	1.85%	0.92%	0.00%	3.69%
σp	0.66%	0.50%	0.33%	0.17%	0.00%	0.66%
μp-μrf/σp	0.65	-0.99	-4.26	-14.10	#DIV/0!	0.65

2008 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	4.24%	4.00%	3.76%	3.52%	3.28%	4.24%
σ_p	1.23%	1.99%	3.38%	4.90%	6.45%	1.23%
$\mu_p-\mu_{rf}/\sigma_p$	0.23	0.02	-0.06	-0.09	-0.11	0.23

2007 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	40%
GDP-linked bond	0%	25%	50%	75%	100%	60%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	4.30%	4.56%	4.82%	5.08%	5.34%	4.92%
σ_p	0.60%	0.90%	1.50%	2.18%	2.87%	1.76%
$\mu_p-\mu_{rf}/\sigma_p$	0.11	0.36	0.39	0.39	0.38	0.39

2006 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	0%
GDP-linked bond	0%	25%	50%	75%	100%	100%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	3.80%	3.96%	4.12%	4.28%	4.44%	4.44%
σ_p	0.62%	0.53%	0.54%	0.65%	0.81%	0.81%
$\mu_p-\mu_{rf}/\sigma_p$	0.01	0.31	0.60	0.75	0.80	0.80

2005 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	3.36%	3.19%	3.02%	2.84%	2.67%	3.36%
σ_p	0.58%	0.54%	0.84%	1.25%	1.70%	0.58%
$\mu_p-\mu_{rf}/\sigma_p$	0.00	-0.32	-0.41	-0.41	-0.41	0.00

2004 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μp	4.10%	3.96%	3.83%	3.70%	3.57%	4.10%
σp	0.78%	0.68%	0.79%	1.05%	1.36%	0.78%
μp-μrf/σp	0.05	-0.13	-0.28	-0.34	-0.36	0.05

2003 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μp	4.14%	3.51%	2.89%	2.26%	1.64%	4.14%
σp	0.64%	0.74%	1.07%	1.47%	1.91%	0.64%
μp-μrf/σp	0.07	-0.78	-1.13	-1.24	-1.29	0.07

2002 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
10-year government bond	100%	75%	50%	25%	0%	100%
GDP-linked bond	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μp	4.87%	4.17%	3.46%	2.76%	2.05%	4.87%
σp	1.26%	1.08%	1.03%	1.14%	1.37%	1.26%
μp-μrf/σp	0.08	-0.56	-1.26	-1.76	-1.97	0.08

3. Portfolios of Greek and Dutch Simulated GDP-linked bonds

Σwi	: Sum of weights employed by the two assets in the portfolio (always equals 100%)
μ	: return of the portfolio
σp	: standard deviation of the portfolio
μ-μrf/σp	: Sharpe ratio of the portfolio
μrf	: return of the risk free rate (German government bond)
N/A	Not Applicable
Max SR	Portfolio maximum Sharpe ratio

2013 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	100%
Netherlands	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	4.94%	3.76%	2.59%	1.41%	0.24%	4.94%
σ_p	2.71%	2.07%	1.53%	1.27%	1.44%	2.71%
$\mu_p-\mu_{rf}/\sigma_p$	1.22	1.04	0.63	-0.16	-0.96	1.22

2012 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	100%
Netherlands	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	15.15%	11.36%	7.57%	3.79%	0.00%	15.15%
σ_p	21.02%	15.76%	10.51%	5.25%	0.00%	21.02%
$\mu_p-\mu_{rf}/\sigma_p$	0.65	0.63	0.58	0.43	#DIV/0!	0.65

2011 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	100%
Netherlands	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	10.27%	8.18%	6.10%	4.01%	1.92%	10.27%
σ_p	26.03%	19.47%	13.05%	7.22%	4.88%	26.03%
$\mu_p-\mu_{rf}/\sigma_p$	0.29	0.28	0.26	0.19	-0.15	0.29

2010 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	100%
Netherlands	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	2.48%	2.41%	2.34%	2.27%	2.20%	2.48%
σ_p	5.46%	4.12%	2.92%	2.14%	2.24%	5.46%
$\mu_p-\mu_{rf}/\sigma_p$	-0.05	-0.08	-0.14	-0.22	-0.24	-0.05

2009 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	100%
Netherlands	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	0.24%	0.18%	0.12%	0.06%	0.00%	0.24%
σ_p	1.66%	1.25%	0.83%	0.42%	0.00%	1.66%
$\mu_p-\mu_{rf}/\sigma_p$	-1.82	-2.47	-3.78	-7.70	#DIV/0!	-1.82

2008 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	0%
Netherlands	0%	25%	50%	75%	100%	100%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	1.84%	2.20%	2.56%	2.92%	3.28%	3.28%
σ_p	2.07%	2.32%	3.46%	4.90%	6.45%	6.45%
$\mu_p-\mu_{rf}/\sigma_p$	-1.03	-0.76	-0.41	-0.21	-0.11	-0.11

2007 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	19%
Netherlands	0%	25%	50%	75%	100%	81%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	5.07%	5.14%	5.21%	5.27%	5.34%	5.29%
σ_p	5.42%	4.09%	3.00%	2.48%	2.87%	2.49%
$\mu_p-\mu_{rf}/\sigma_p$	0.15	0.22	0.32	0.42	0.38	0.42

2006 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	9%
Netherlands	0%	25%	50%	75%	100%	91%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	6.86%	6.25%	5.65%	5.04%	4.44%	4.65%
σ_p	5.53%	4.16%	2.82%	1.55%	0.81%	0.91%
$\mu_p-\mu_{rf}/\sigma_p$	0.55	0.59	0.66	0.81	0.80	0.94

2005 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	100%
Netherlands	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	3.29%	3.13%	2.98%	2.82%	2.67%	3.29%
σ_p	2.69%	2.08%	1.62%	1.47%	1.70%	2.69%
$\mu_p-\mu_{rf}/\sigma_p$	-0.03	-0.11	-0.24	-0.37	-0.41	-0.03

2004 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	100%
Netherlands	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	6.08%	5.45%	4.82%	4.20%	3.57%	6.08%
σ_p	1.70%	1.34%	1.12%	1.13%	1.36%	1.70%
$\mu_p-\mu_{rf}/\sigma_p$	1.19	1.04	0.68	0.13	-0.36	1.19

2003 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	100%
Netherlands	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	7.83%	6.28%	4.74%	3.19%	1.64%	7.83%
σ_p	1.60%	1.32%	1.29%	1.51%	1.91%	1.60%
$\mu_p-\mu_{rf}/\sigma_p$	2.33	1.65	0.50	-0.60	-1.29	2.33

2002 Scenarios	1	2	3	4	5	Max SR
Constraining Variables	None	None	None	None	None	None
Value constraint	N/A	N/A	N/A	N/A	N/A	N/A
Greece	100%	75%	50%	25%	0%	100%
Netherlands	0%	25%	50%	75%	100%	0%
Σwi	100%	100%	100%	100%	100%	100%
μ_p	6.45%	5.35%	4.25%	3.15%	2.05%	6.45%
σ_p	3.17%	2.43%	1.77%	1.35%	1.37%	3.17%
$\mu_p-\mu_{rf}/\sigma_p$	0.53	0.24	-0.29	-1.20	-1.97	0.53