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Major in Finance

Course of Mathematical Finance

**Does Diversification Still Work? Portfolio Risk Before
and After Market Crises (Stocks–Bonds–Gold)**

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Chapter 1. Introduction

1.1 Background and motivation

Historically, asset allocation in research and professional investing has been built around the idea that equities and high-quality government bonds respond differently to changes in the macroeconomic environment. When equity markets fall, safe government debt has often been expected to partly offset equity losses. This expectation supported the popularity of balanced portfolios and made the negative or low stock-bond correlation a central assumption in many allocation frameworks. However, recent evidence suggests that this relationship cannot be assumed to hold in every market regime (Molenaar et al., 2024).

Modern portfolio theory forms the theoretical basis of this thesis. Its central insight is that diversification is not achieved merely by increasing the number of assets, but from combining assets with imperfectly correlated returns. Markowitz (1952) showed that portfolio risk depends on both the individual risk of each asset and the covariance between asset returns. This idea is important for this analysis because the focus is not only on whether equities, bonds, or gold are risky on their own, but on whether their interaction still reduces the risk of a combined portfolio under different market conditions.

Recent studies challenge the idea that the stock-bond relationship is stable. Using more than a century of data across several markets, Molenaar et al. show that the correlation between stocks and bonds varies across regimes and can shift from negative to positive. They identify inflation, real interest rates, and sovereign credit quality as key factors behind these changes (Molenaar et al., 2024). Their findings suggest that the negative co-movement observed in the years before the pandemic was linked to a specific macroeconomic environment, especially low and stable inflation, rather than reflecting a permanent market characteristic. When inflation rises and monetary policy tightens, equity and bond returns may become more positively related, reducing the traditional risk-reduction benefit of bonds.

A similar point is made by Ilmanen (2003), who argues that stock-bond correlations are sensitive to inflation, growth, volatility, and expectations about monetary policy. In other words, one full-sample correlation can hide important differences between periods. This is particularly relevant after 2021, when the euro area moved from a long period of low inflation into an environment of stronger inflation pressure and tighter monetary policy.

These issues became more visible after the COVID-19 pandemic and the subsequent inflation shock. The European Central Bank's Financial Stability Review of November 2022 reports broad-based corrections in euro-area asset prices, together with unusually strong co-

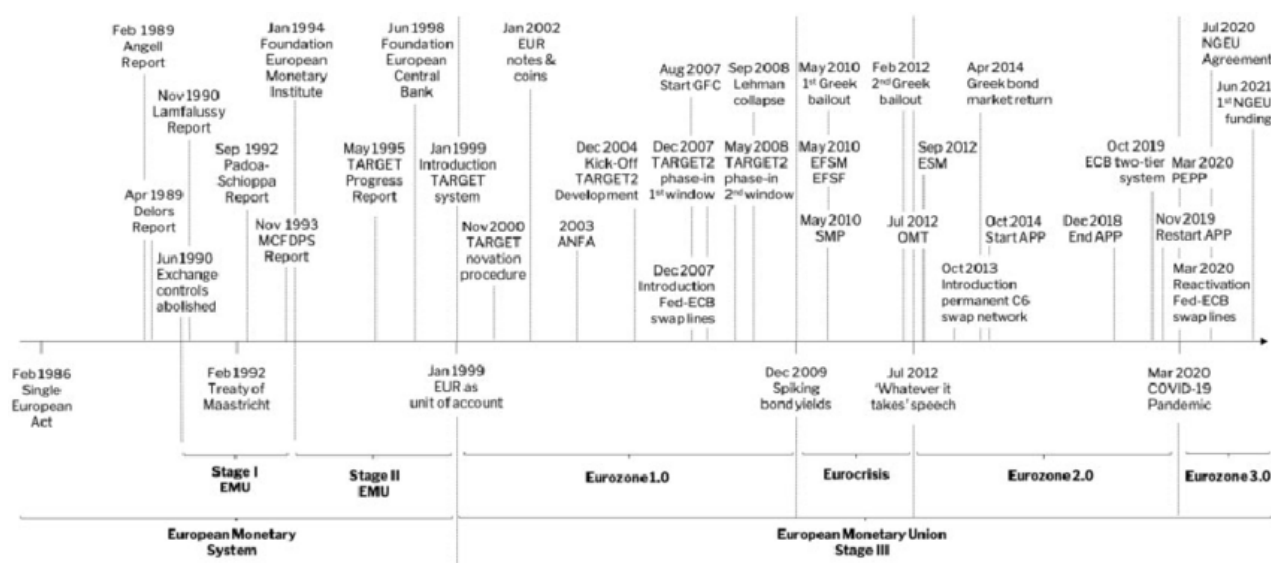
movement across equities, sovereign bonds, and other asset classes (ECB, 2022). The ECB notes that cross-asset correlations increased in the more inflationary environment and that balanced portfolios suffered losses on both stocks and bonds in 2022. This episode challenged the practical usefulness of diversification at the moment when investors needed it most (ECB, 2022).

For euro-area investors, the issue is especially important because the sovereign bond market is not a single homogeneous market. Government yields reflect common euro-wide factors, but also country-specific credit risk, spread dynamics, and concerns about financial fragmentation. The same ECB policy stance can therefore affect member states differently. Past episodes, including the euro-area sovereign debt crisis, also show that government bonds can become a source of risk rather than a stable safe asset. For this reason, the assumption that a broad euro-area government bond benchmark always hedges equity risk needs to be tested empirically.

Gold is included as a third asset because it is often discussed as a possible source of protection when traditional assets become unstable. In the literature, its role is usually described through the concepts of a hedge and a safe haven. Baur and Lucey define a hedge as an asset that is uncorrelated or negatively correlated with another asset on average, while a safe haven is an asset that keeps this protective behaviour during periods of market stress (Baur and Lucey, 2010). International evidence suggests that gold can protect investors in some European equity markets, but not equally across all countries or crisis periods (Baur and McDermott, 2010). More recent studies on epidemic and crisis episodes also find that gold's role depends on the type of shock and on the investment horizon (Choudhury, Kinatader, and Neupane, 2022). Therefore, this study treats gold not as a guaranteed safe asset, but as an additional diversifier whose role must be examined alongside equities and bonds.

In the empirical part, euro-area equities are proxied by the EURO STOXX 50 Net Return Index, using the Bloomberg ticker SX5T Index. Euro-area sovereign bonds are represented by Bloomberg's euro treasury total-return benchmark (LEATTREU), and gold is measured through a euro-denominated gold price series. The net return version of the equity index is used because the thesis evaluates investment returns and portfolio risk; therefore, the equity proxy should include reinvested net dividends and be more comparable with the total-return bond benchmark. These shorthand labels are introduced here for clarity, while the exact database mnemonics, return construction, and data treatment are reported in Chapter 3.

Figure 1.1. Timeline



Source: Adapted from Murau and Giordano (2024), “Forging monetary unification through novation: the TARGET system and the politics of central banking in Europe”, Figure 1. Data last updated: not applicable.

1.2 Problem statement

The problem addressed in this thesis comes from the gap between the traditional view of diversification and the more unstable market environment observed in recent years. Balanced portfolios have long relied on the idea that government bonds can offset part of the risk from equities. For euro-area investors, this assumption has influenced both institutional portfolios and long-term individual investment strategies. Yet recent evidence shows that the equity-bond relationship changes across macroeconomic regimes and can weaken sharply when inflation and interest rates rise together.

Molenaar et al. show that higher stock-bond correlations are associated with greater multi-asset portfolio risk and higher bond risk premia (Molenaar et al., 2024). This means that correlation changes are not only a statistical detail; they matter directly for investors. The ECB's Financial Stability Review provides a recent euro-area example. In 2022, many investors experienced losses on both equity and bond positions as higher discount rates and risk premia pushed asset prices down at the same time (ECB, 2022). When stocks and bonds fall together, a two-asset balanced portfolio offers much less protection than expected.

The role of gold is also uncertain. Baur and Lucey find that gold can act as a hedge and as a short-lived safe haven, but its behaviour depends on the nature and timing of the shock

(Baur and Lucey, 2010). Studies of epidemic episodes, including COVID-19, show that the interaction between gold, bonds, and equities is complex. In some cases, gold appears to provide weak safe-haven benefits; in others, its performance depends on the crisis definition, the market considered, and the investment horizon (Choudhury, Kinatader, and Neupane, 2022). As a result, it is not obvious whether adding gold to a euro-area stock-bond portfolio systematically restores diversification benefits.

The central issue is therefore whether a traditional euro-based diversified portfolio still works when market regimes change. If equity-bond co-movement rises during inflationary periods and gold's safe-haven role varies across crises, then a portfolio combining EURO STOXX 50 net-return equities, euro-area government bonds, and euro-denominated gold may not deliver the same risk reduction in every period. Static correlations may understate this instability, while strategies designed for the low-inflation years before the pandemic may be less effective in the post-2021 environment.

1.3 Research gap

Research on stock-bond diversification and on gold as a hedge or safe haven is extensive, but several limitations remain from the perspective of this thesis. First, studies of stock-bond correlation regimes, such as Molenaar et al., often focus on global or U.S. markets and treat the euro area as only one part of a broader sample (Molenaar et al., 2024). This can overlook the institutional features of the euro area, especially its fragmented sovereign bond market and the role of country-level spread risk. Second, many gold studies examine its relationship with equities or bonds separately, rather than analysing all three assets within one portfolio framework for a euro-based investor (Baur and Lucey, 2010; Choudhury, Kinatader, and Neupane, 2022). Third, some papers focus mainly on correlations and give less attention to whether changing co-movements actually translate into weaker risk reduction at the portfolio level.

There is also a growing methodological literature on changing dependence and financial connectedness. Dynamic conditional correlation models and other multivariate GARCH approaches make it possible to follow co-movements over time, while the connectedness framework of Diebold and Yilmaz helps explain how shocks are transmitted through financial systems (Diebold and Yilmaz, 2014; Gabauer, 2020). These methods show why static correlations can be misleading, especially in stress periods. At the same time, many connectedness studies are designed for broad systemic-risk analysis and involve more complexity than is necessary for a focused bachelor thesis on three core assets.

The gap addressed here is a concise euro-area analysis that brings three elements together:

- (i) a distinction between macro and crisis regimes that reflects evidence on stock-bond correlation shifts and the ECB's post-2021 inflation narrative;
- (ii) a three-asset portfolio setting based on EURO STOXX 50 net-return equities, a broad euro-area government bond benchmark, and euro-denominated gold; and
- (iii) a direct assessment of whether diversification still reduces risk once changing correlations and crisis-specific safe-haven behaviour are considered.

Table 1.1. Summary of the three asset classes and their role for a euro-area investor

Asset	Proxy	Portfolio role	Thesis relevance
Stocks	EURO STOXX 50 Net Return Index (SX5T Index)	Dividend-adjusted risky asset benchmark	Benchmark against which diversification is tested
Bonds	Bloomberg euro treasury total-return benchmark (LEATTREU)	Traditional defensive asset	Used to test whether bond-based diversification still works
Gold	EUR-denominated gold	Alternative hedge / safe haven	Used to compare gold with bonds in crisis periods

Source: Author's own compilation based on euro-area monetary and financial market events. Data last updated: not applicable.

1.4 Research question

Based on this background, the thesis addresses the following research question:

Does diversification across EURO STOXX 50 net-return equities, euro-area government bonds, and euro-denominated gold still reduce portfolio risk before, during, and after major market crises in the 21st century, once regime-dependent stock-bond correlations and the time-varying hedge and safe-haven properties of gold are taken into account?

This question keeps the analysis focused on the euro-area setting, the three-asset portfolio structure, and the practical effect of diversification on risk, rather than on correlation estimates alone.

1.5 Hypotheses

To make the research question empirically testable within a bachelor thesis, the analysis is organised around three hypotheses. Each hypothesis follows from the literature discussed

above and can be examined using time-series data on the EURO STOXX 50 Net Return Index, a broad euro-area government bond benchmark, and euro-denominated gold.

Hypothesis 1 (regime-dependent stock-bond diversification). In low-inflation, non-crisis regimes, euro-area government bonds have low or negative correlations with EURO STOXX 50 net-return equity returns and reduce portfolio volatility and maximum drawdowns when added to an equity-only position. In high-inflation and post-2021 regimes, equity-bond correlations are higher, and the additional risk reduction from bonds is materially weaker.

This expectation is based on Molenaar et al., who link stock-bond correlation shifts to inflation and real-rate conditions, as well as on the ECB's evidence of higher cross-asset correlations and simultaneous equity and bond losses during the recent inflationary episode (Molenaar et al., 2024; ECB, 2022).

Hypothesis 2 (gold as a regime-dependent hedge and safe haven). Gold priced in euro behaves as at least a weak hedge and, in some crisis episodes, a safe haven relative to EURO STOXX 50 net-return equities and euro-area government bonds. However, this protective role differs across crises and does not hold uniformly in all stress periods.

The reasoning follows Baur and Lucey's distinction between hedge and safe-haven behaviour and their finding that gold's protection can be temporary and shock-specific (Baur and Lucey, 2010). It is also consistent with epidemic-focused studies, which show that gold's performance relative to bonds and equities depends on the crisis period and the investment horizon (Choudhury, Kinatader, and Neupane, 2022).

Hypothesis 3 (portfolio-level weakening of diversification). When changing dependence between EURO STOXX 50 net-return equities, euro-area government bonds, and euro-denominated gold is modelled using a DCC-GARCH framework, three-asset portfolios deliver less risk reduction after major crises and during the post-2021 inflation regime than would be suggested by pre-crisis static correlations.

This hypothesis builds on the finding by Molenaar et al. that higher stock-bond correlations are linked to increased multi-asset portfolio risk, and on the ECB's observation that stronger cross-asset co-movement has made diversification more difficult in the recent inflationary environment (Molenaar et al., 2024; ECB, 2022). It also reflects the broader literature on dynamic dependence, which shows that correlations can rise sharply in crises and that static measures may underestimate the strength and duration of such episodes (Gabauer, 2020).

Taken together, the hypotheses connect the euro-area macro context, the selected three-asset portfolio, and the use of a dynamic correlation framework with a clear focus on portfolio risk.

1.6 Structure of the thesis

The rest of the thesis is organised as follows. Chapter 2 reviews the relevant literature and develops the theoretical foundation for the empirical analysis. It discusses changes in stock-bond correlations and their macroeconomic drivers, especially inflation, real rates, and sovereign risk as highlighted by Molenaar et al. It also summarises the ECB's evidence on cross-asset correlations in the post-2021 inflation environment and reviews the literature on gold as a hedge and safe haven (Molenaar et al., 2024; ECB, 2022; Baur and Lucey, 2010; Choudhury, Kinatader, and Neupane, 2022). Finally, the chapter introduces the basic logic of time-varying dependence models and connectedness, while explaining why the empirical part focuses on dynamic correlations and portfolio risk rather than on full network analysis (Diebold and Yilmaz, 2014; Gabauer, 2020).

Chapter 3 details the data and variables. It specifies the financial proxies used for EURO STOXX 50 net-return equities (Bloomberg ticker: SX5T Index), euro-area government bonds (Bloomberg ticker: LEATTREU), and euro-denominated gold (Bloomberg ticker: XAUEUR BGN Curncy). The chapter explains the construction of daily return series, the sample period, and subperiods representing pre-crisis, crisis, and post-crisis or inflationary regimes. It also presents descriptive statistics and an initial comparison of return distributions and pairwise correlations across regimes.

Chapter 4 presents the methodological framework. It begins with descriptive statistics and static correlations by regime, followed by rolling correlations and the DCC-GARCH model to measure evolving dependence among the three assets. The chapter also describes how portfolio volatility, maximum drawdown, and simple risk-adjusted performance measures are calculated for different stock-bond-gold combinations. In addition, it explains how bonds and gold are classified as hedges or safe havens relative to equities according to definitions in the literature.

Chapter 5 presents the empirical results. It reports the behaviour of equities, bonds, and gold across regimes using descriptive statistics, static and dynamic correlations, and portfolio-level risk measures. It also evaluates the hedge and safe-haven properties of euro-denominated gold and euro-area government bonds during major crisis episodes.

Chapter 6 discusses the implications of the findings for euro-area investors and for the broader debate on whether diversification still works in a world of higher inflation and more frequent macro-financial shocks. It compares the results with the three hypotheses and relates them to the ECB's policy concerns and to regime-based evidence in the academic literature.

Chapter 7 concludes by summarising the main contributions and limitations of the study, answering the research question, and suggesting directions for further research on diversification and portfolio risk in European and global settings.

Chapter 2. Literature Review

2.1 Stock-bond diversification as a conventional portfolio logic

Stock-bond diversification became a central idea in portfolio construction because equities and government bonds are expected to react differently to macroeconomic shocks. Equities are mainly exposed to growth expectations, earnings revisions and risk appetite, while government bonds are more closely linked to interest rates, inflation expectations and confidence in public debt. When these forces move in different directions, a mixed portfolio can reduce volatility without giving up all return potential. This logic explains why balanced portfolios have remained popular in both academic finance and asset management practice.

The key issue is not only the average return of each asset class, but how the two assets move together. A low or negative stock-bond correlation allows bond gains to cushion equity losses during market stress, making government bonds a traditional defensive component in asset allocation. The ECB (2022) links this idea directly to the recent diversification debate by stressing that portfolio resilience depends on whether asset classes still provide offsetting returns when conditions worsen. If that offset disappears, the argument for bonds as a stabilising asset becomes weaker.

For this reason, the conventional stock-bond relationship should be tested rather than assumed. The view that government bonds reliably hedge equity risk was more convincing during the low-inflation decades before the pandemic, but the literature reviewed in this chapter shows that the relationship is not stable across all market environments. Diversification is therefore treated here as an empirical question, not as a permanent feature of financial markets.

The chapter begins with that problem. If the defensive role of bonds depends on their interaction with equities, the stability of this interaction becomes central to the thesis. The following sections review evidence on regime-dependent stock-bond co-movement, the specific features of the euro-area setting, the role of gold as an additional defensive asset, and the need for dynamic methods when studying portfolio risk.

Table 2.1. Key strands of the literature and their implications for the thesis design

Authors and year	Main idea
Molenaar et al. (2024)	Stock-bond co-movement is regime-dependent and changes with inflation, real rates and sovereign creditworthiness.
ECB (2022)	In the post-2021 inflation environment, euro-area cross-asset correlations increased and diversification became less reliable.

Baur and Lucey (2010)	Gold can act as a hedge on average and as a safe haven in stress periods, but these roles are not identical.
Choudhury, Kinatader and Neupane (2022)	The protective role of gold and bonds is crisis-specific and time-varying rather than stable across episodes.
Gabauer (2020)	Financial dependence changes over time, so dynamic methods are needed when studying crisis-period co-movement.
Diebold and Yilmaz (2014)	Financial markets become more tightly linked through spillovers in periods of stress.
Vieira et al. (2023)	Gold's hedging and safe-haven properties differ across European stock and bond markets and should be tested empirically.

Source: Author's own compilation based on the reviewed literature.

2.2 Regime-dependent stock-bond correlation

The strongest challenge to the conventional portfolio logic comes from evidence that stock-bond correlations change across macroeconomic regimes. Molenaar et al. (2024) show that the correlation between stock and bond returns is not constant, but varies across historical periods and reacts to inflation, real rates and government creditworthiness. Their findings shift the discussion from the simple question of whether stocks and bonds are correlated to the more relevant question of when and under which macroeconomic conditions this correlation changes.

This regime view is especially important when interpreting the diversification benefits observed after 2000. During much of the low-inflation period before the pandemic, stock-bond correlations were often negative, so government bonds worked well as a portfolio stabiliser. Molenaar et al. (2024) argue, however, that this should be seen as a feature of a particular macroeconomic environment rather than a permanent market rule. Once inflation rises and real rates adjust sharply, the same bond allocation may offer weaker protection.

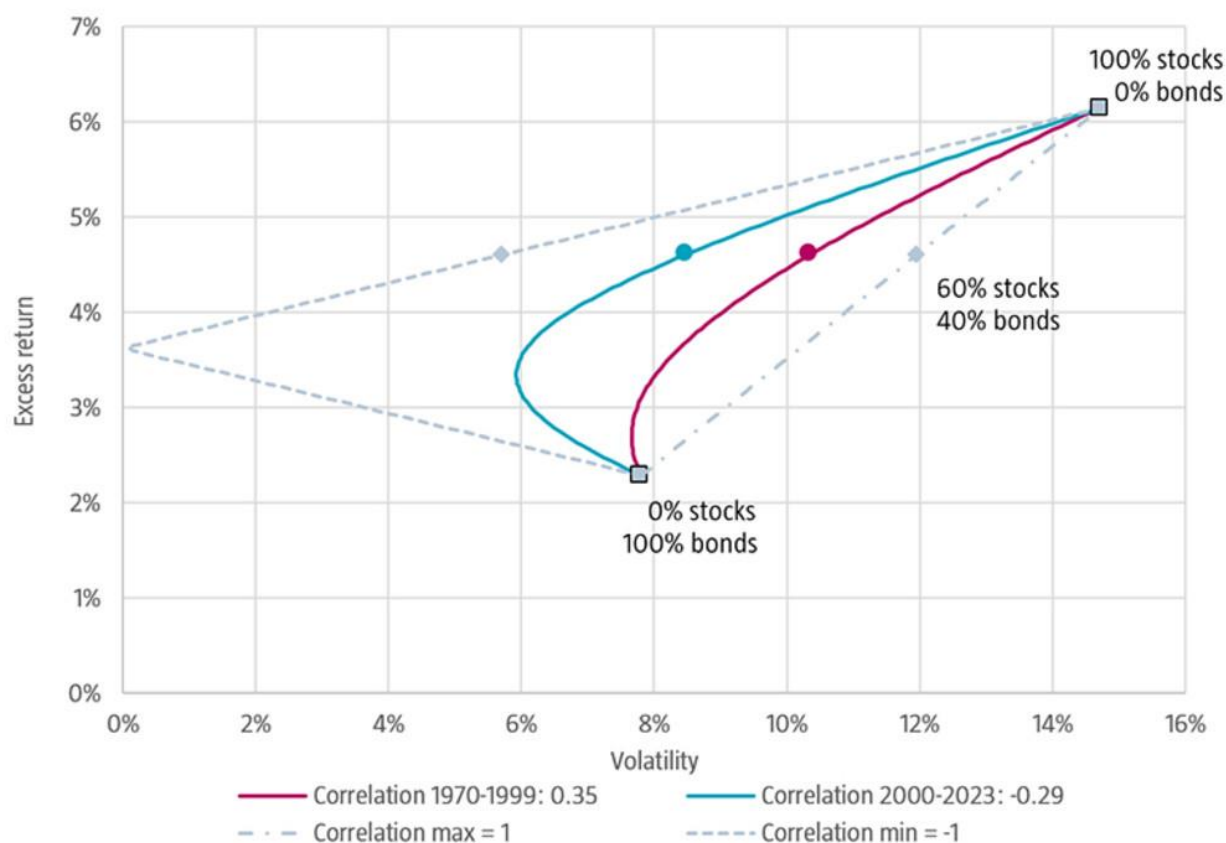
Other studies explain why this relationship moves over time. Andersson, Krylova and Vähämaa (2008) find that inflation expectations, growth expectations and stock-market uncertainty all affect the time-varying correlation between stocks and bonds. Their results are consistent with the idea that negative stock-bond correlation is more likely in low-inflation environments, while higher inflation can cause the two asset classes to move more closely together. This is directly relevant after 2021, when the euro area moved away from the pre-pandemic low-inflation setting.

Connolly, Stivers and Sun (2005) add a further perspective by focusing on stock-market uncertainty. They show that the stock-bond relationship is affected by changes in uncertainty, as investors may move away from equities and into safer assets during periods of market stress. This supports the view that the defensive role of bonds can strengthen or weaken depending on the type of shock affecting the market.

Baele, Bekaert and Inghelbrecht (2010) also treat stock-bond co-movement as a changing relationship shaped by macroeconomic and financial-market conditions. Their evidence strengthens the case for studying diversification across regimes and crisis periods instead of relying only on a single full-sample average. For this thesis, that supports the decision to compare stock-bond and stock-gold relationships across distinct periods before moving to dynamic modelling.

The ECB (2022) points in a similar direction. Its discussion of cross-asset correlations in a more inflationary environment shows that diversification benefits can weaken when inflation shocks and policy tightening affect several asset classes at once. The euro-area case adds another layer to this problem because monetary policy is common across member states, while sovereign bond markets still reflect country-specific credit risk and spread dynamics. As a result, the stock-bond relationship depends not only on broad macroeconomic variables, but also on the structure of the euro-area bond market.

Figure 2.1. Stock-bond correlation



Source: Adapted from Molenaar et al. (2024), Figures 1 and 2. Figure 1 uses monthly return data from January 1970 to June 2023; Figure 2 uses U.S. monthly equity and 10-year government bond returns from January 1875 to June 2023. Data last updated: June 2023.

The methodological implication is clear. If correlation changes are linked to inflation, real-rate movements and sovereign credibility, they should be analysed across separate subperiods rather than averaged over the full sample. A single full-sample coefficient would hide the periods in which diversification matters most, especially crises and regime shifts. The literature therefore supports an empirical design based on pre-crisis, crisis and post-crisis periods, rather than a purely unconditional comparison.

2.3 The euro-area context and the post-2021 diversification problem

The euro-area setting is not simply a regional version of the U.S. case. It has a different bond-market structure, a common monetary policy regime and a history of sovereign stress. The ECB (2022) argues that the deterioration in financial conditions after the pandemic, combined with the inflation surge, increased the risk of simultaneous adjustments across asset classes. This is not only a point about volatility. It also concerns the limits of diversification in

a monetary union where one central bank sets policy for countries with different fiscal positions and different sovereign risk premia.

This matters because euro-area government bonds are not a single homogeneous safe asset in the way U.S. Treasuries are often treated in U.S.-centred studies. Episodes of sovereign stress, especially the euro-area debt crisis, showed that spreads between core and peripheral sovereign bonds can widen sharply. Country-specific risk can therefore coexist with common euro-wide monetary shocks.

The post-2021 inflation regime made this issue more visible. Higher inflation and tighter ECB policy increased discount rates and put pressure on valuations in both equity and bond markets. The ECB review notes that risk premia and liquidity conditions deteriorated at the same time, making portfolio de-risking harder exactly when inflation was weakening the traditional bond cushion. This is why the euro-area case deserves separate attention: the shock was not limited to one asset class, and it interacted with the institutional features of the monetary union.

The literature therefore suggests that the euro area should be analysed on its own terms. A study based on the EURO STOXX 50 Net Return Index as the equity proxy, a broad euro sovereign bond benchmark and euro-denominated gold is not merely a U.S. framework translated into another currency. It examines how a common currency area behaves when inflation, policy tightening and sovereign risk interact with portfolio diversification.

2.4 Gold's hedge and safe haven properties

Gold is part of the diversification debate for another reason. In contrast to bonds, its value does not directly depend on interest payments, government repayment risk or projected company profits. This makes it a plausible candidate for protective allocation, particularly when stocks and bonds both face losses. Baur and Lucey (2010) set out the usual distinction: a hedge refers to an asset that is weakly or negatively related with another asset in normal conditions, while a safe haven offers protection mainly in periods of financial stress. This distinction matters because an asset can behave differently in calm and stressed periods.

Baur and Lucey (2010) show that gold may hedge equities in normal conditions and may also serve as a safe haven in some severe stock-market declines. At the same time, they show that this protection is not constant and varies with market conditions. Their contribution remains important because it avoids treating gold as naturally protective. For this thesis, gold

is therefore considered a potential protective asset whose role needs to be examined across regimes.

Later research gives a more mixed picture. Choudhury, Kinatder and Neupane (2022) examine gold and sovereign bonds during epidemic-related shocks and find that gold frequently provides only weak safe-haven benefits. Sovereign bonds may provide greater protection during certain stress episodes, although the relative performance depends on the specific episode and market. Their use of a DCC-GARCH framework is also important because it indicates that safe-haven behaviour is time-varying and should be evaluated using conditional correlations instead of relying only on unconditional averages.

Huang and Chang (2021) add to this literature by comparing gold and government bonds as safe-haven assets during equity-market stress. Their study is useful because it compares gold directly with bonds as an alternative protective asset, instead of treating it separately. This is consistent with the empirical strategy of this thesis, where gold and euro-area government bonds are compared directly.

Ciner, Gurdgiev and Lucey (2013) extend the analysis by examining changing relationships between stocks, bonds, gold, oil and exchange rates. They show that hedge and safe-haven properties differ by asset class and market environment. This supports the three-asset structure used here because gold should be assessed together with bonds and equities, not assumed to provide automatic protection.

Hood and Malik (2013) add another layer by showing that gold can act as a hedge and a weak safe haven during shifts in stock-market volatility, but that it is not necessarily the most effective protective asset. This supports a cautious view of gold in the thesis: it is included as a potential diversifier, while its real protective role remains to be tested empirically.

Vieira et al. (2023) provide a newer European view by showing that gold's hedging and safe-haven properties vary between equity and bond markets. For a euro-area thesis, this is particularly relevant because the role of gold should be understood in relation to euro-area inflation, ECB tightening and sovereign bond-market structure. Gold is therefore treated as a conditional hedge and safe haven, not as an automatic solution to diversification failure.

2.5 Time-varying dependence and the portfolio-risk perspective

The literature reviewed above points to a common problem: static correlations are too limited to capture how stocks, bonds and gold behave across crises. A single coefficient can be

useful as a first description, but it hides the timing of dependence shifts, the length of stress episodes and the possibility that an asset protects the portfolio in one regime but not in another. This is why time-varying dependence models are widely used in crisis-related finance research.

The methodological literature provides direct support for dynamic correlation models. Tse and Tsui (2002) propose a multivariate GARCH model with time-varying correlations, showing that financial dependence can be modelled as a changing process rather than as a constant parameter. For this thesis, the point is not only technical. If correlations change mainly during stress periods, then portfolio risk cannot be assessed reliably through unconditional correlations alone.

Longin and Solnik (2001) show that correlations can increase in extreme market conditions, which supports the broader argument that average correlations may understate dependence during stress. Although their study focuses on international equity markets, the implication applies here as well: diversification should be evaluated with attention to crisis periods and tail behaviour, not only through full-sample averages.

Gabauer (2020) provides further methodological support. His work on dynamic dependence and connectedness shows how financial relationships evolve over time and why conditional correlation structures are more appropriate in crisis environments than static measures. DCC-GARCH is particularly relevant because it allows both conditional volatilities and correlations to change with the data. This matches the central question of the thesis, which concerns the instability of diversification benefits across regimes.

This is especially important for portfolio analysis. Two assets may look weakly correlated on average but fail to diversify each other during the periods when protection is most needed. The ECB (2022) captures this problem in its discussion of simultaneous losses across asset classes in a more inflationary environment. The same logic appears in the stock-bond regime literature: if correlations rise during inflationary or crisis periods, the average correlation understates the risk faced by a portfolio investor. DCC-GARCH is therefore used to connect changing dependence with portfolio risk, not simply to add methodological complexity.

The connectedness literature remains relevant as background, although it is not the central framework of this thesis. Diebold and Yilmaz (2014) show that dependence can also be studied through spillovers and transmission channels across markets, and Gabauer's later work builds on that insight. For a bachelor thesis focused on three assets, however, the aim is not to map a full network of spillovers. The main task is to assess whether dependence changes over

time in a way that alters portfolio risk. For that purpose, DCC-GARCH and portfolio-level evaluation are more transparent and sufficient.

2.6 Implications for the thesis design

The reviewed literature shapes the empirical design of this thesis in several ways. First, it justifies the euro-area focus. The ECB's policy regime, the structure of euro sovereign bond markets and the post-2021 inflation shock create conditions that differ from those in many U.S.-centred studies. The euro area is therefore not a secondary case, but an appropriate setting for testing whether diversification still works under common monetary policy and sovereign fragmentation risk.

Second, the three-asset structure follows from the research problem. The thesis does not only ask whether bonds still hedge equities, but also whether gold adds protection when the traditional stock-bond relationship weakens. Baur and Lucey (2010) define the conceptual role of gold, while Choudhury, Kinatder and Neupane (2022) and Vieira et al. (2023) show that its behaviour should be studied in relation to both equities and bonds. A two-asset design would miss this comparison.

Third, regime analysis is necessary. Molenaar et al. show that stock-bond correlations move with inflation, real rates and sovereign creditworthiness, while the ECB review highlights the importance of the post-2021 inflation shift. The empirical analysis must therefore distinguish pre-crisis, crisis and post-crisis subperiods instead of relying only on one full-sample estimate. This allows the thesis to ask when diversification works and when it becomes weaker.

Fourth, static correlation is not enough. The literature on dynamic dependence, especially Gabauer (2020), shows that correlations change through time and often intensify during periods of stress. Reporting only one long-run correlation matrix would miss the central feature of the problem: diversification may fail exactly when market conditions deteriorate. Rolling correlations and DCC-GARCH are therefore used as necessary tools rather than optional additions.

Finally, the literature supports a portfolio-risk perspective. Pairwise correlations alone cannot answer whether diversification is useful for an investor. Portfolio volatility, drawdowns and risk-adjusted performance show how the assets behave when combined in an actual allocation. This is why the empirical chapters move from dependence measures to portfolio construction and risk measurement.

The following chapters build on this sequence. Chapter 3 defines the EURO STOXX 50 Net Return Index as the equity proxy, together with the euro sovereign bond benchmark and euro-denominated gold. It also explains the sample period, regime definitions and return construction. Chapter 4 then turns these literature-based arguments into the methods used for the empirical tests. In this sense, the literature review is directly connected to the design of the analysis rather than standing apart from it.

Chapter 3. Data and Variables

3.1 Data sources and asset proxies

The empirical analysis uses three euro-denominated asset classes: euro-area equities, euro-area government bonds, and gold. These assets match the portfolio setting developed in Chapters 1 and 2, where the main issue is whether a simple multi-asset allocation still reduces risk across crisis and macro-financial regimes. The data were downloaded from the Bloomberg Terminal, which provides consistent daily series for the selected benchmarks.

The equity leg is represented by the EURO STOXX 50 Net Return Index, identified on Bloomberg by the ticker SX5T Index. The index covers large blue-chip companies from the euro area and is a standard benchmark for euro-denominated equity exposure. The net return version is used because the thesis studies investment returns and portfolio risk, not only price movements. Unlike the price index, it includes reinvested net dividends, which makes the equity proxy more comparable with the total-return bond benchmark used in the same portfolio framework.

The bond leg is represented by a broad euro-area government bond benchmark. In the dataset, this is the Bloomberg code LEATTREU Index, which tracks euro-denominated sovereign bonds issued by euro-area member states across a range of maturities. The series is an index-level benchmark rather than the price of a single bond, so it better reflects the diversified government-bond exposure that euro-area investors may hold for capital preservation and risk reduction. This choice is also consistent with the ECB discussion of broad sovereign benchmarks and the changing defensive role of bonds after 2021 (ECB, 2022).

Gold exposure is measured by the Bloomberg series XAUEUR BGN Curncy, which reports the price of gold in euro. This keeps all three assets in the same currency and reflects the return that a euro-based investor would actually observe. Gold is included because the literature treats it as a possible hedge and safe haven against both equities and bonds, although

this role is known to vary across stress episodes (Baur and Lucey, 2010; Huang and Chang, 2021; Choudhury et al., 2022; Vieira et al., 2023).

For all three assets, Bloomberg PX_LAST is used as the observed daily level. These levels are the starting point for return construction, the normalised level plots, and the descriptive analysis. The selected series therefore keep the empirical work close to the portfolio interpretation of the thesis: a euro-area investor combining equity risk, sovereign bond exposure, and gold.

3.2 Sample period and empirical scope

The formal sample window runs from 1 January 2005 to 31 December 2025. This period is long enough to include a relatively calm pre-crisis benchmark, the global financial crisis, the euro-area sovereign debt crisis, the low-inflation and quantitative-easing period, the COVID-19 shock, and the post-2021 inflation and monetary-tightening regime. These episodes are central to the thesis because the literature links stock-bond correlation changes to inflation, real rates, and macro-financial stress (Molenaar et al., 2024; ECB, 2022).

The sample design is therefore not only a matter of data availability. It is chosen to capture the main environments in which diversification may work differently. The pre-GFC and low-inflation periods provide a benchmark for the traditional stock-bond diversification logic, while the GFC, COVID-19, and the post-2021 inflation shock test whether this logic weakens under market stress or policy tightening.

The actual estimation uses the common overlapping sample across the three assets. Because the three Bloomberg series have slightly different trading calendars and because returns require one lagged level, a small number of early or non-overlapping observations is dropped. The aligned sample runs from 5 January 2005 to 31 December 2025 and contains 5,224 daily observations with valid return information for stocks, bonds, and gold.

This distinction between the formal window and the working sample is important. The formal 2005-2025 period defines the economic scope of the study, while the common sample ensures that each observation used in the empirical analysis is synchronised across the three assets.

3.3 Data treatment and return construction

The raw Bloomberg series for SX5T, LEATTREU, and XAUEUR were imported, sorted by date, and restricted to the formal 2005-2025 window. Duplicate dates and non-trading observations were removed so that each date corresponds to at most one observation per asset.

Within this restricted window, the level series contain 5,391 observations for stocks, 5,340 for bonds, and 5,471 for gold. The differences mainly reflect market holidays and asset-specific trading calendars.

Returns were then recomputed after the sample restriction and the three assets were merged by date. This avoids using pre-sample lagged values and keeps the return calculation consistent with the final sample. All descriptive statistics, correlations, figures, and later econometric models are based on the aligned daily return dataset.

The main return measure is the daily log return, defined for each asset as:

$$r_{i,t} = \ln(P_{i,t}) - \ln(P_{i,t-1})$$

where $P_{i,t}$ is the observed Bloomberg PX_LAST level of asset i on day t . Log returns are used because they are additive over time, common in volatility modelling, and appropriate for dynamic correlation methods. This is consistent with financial time-series practice, where transformed return series rather than price levels are usually analysed when the focus is volatility, dependence, and conditional variance (Tsay, 2010; Gabauer, 2020).

The resulting panel contains contemporaneous daily log returns for the EURO STOXX 50 Net Return Index, the euro-area government bond benchmark, and euro-denominated gold. This alignment is required for the multivariate analysis in Chapter 4, where correlations and portfolio risk measures must be estimated from the same set of dates.

3.4 Regime classification

Chapter 2 showed that stock-bond and stock-gold relationships are unlikely to remain constant across time. Inflation, monetary policy, sovereign risk, and crisis conditions can all change how the three assets move together. For that reason, the daily observations are assigned to six regimes that reflect the main macro-financial episodes of the 2005-2025 period:

1. Pre-GFC: 1 January 2005 - 31 July 2007
2. Global financial crisis (GFC): 1 August 2007 - 30 June 2009
3. Euro sovereign debt crisis: 1 July 2009 - 31 December 2012
4. Low-inflation / QE: 1 January 2013 - 31 December 2019
5. COVID-19: 1 January 2020 - 31 December 2021
6. Post-2021 inflation / tightening: 1 January 2022 - 31 December 2025

The Pre-GFC period is used as a benchmark for stock-bond and stock-gold behaviour before the major crisis sequence begins. The GFC regime captures global systemic stress, funding pressure, and sharp risk repricing. For a euro-based investor, this period tests whether bonds and gold offered protection when equity markets were under severe pressure.

The euro sovereign debt crisis is treated separately because the stress was concentrated in the euro area. Concerns about sovereign solvency and redenomination risk led to large spread differences between core and peripheral government bonds. This matters for the thesis because a broad euro sovereign bond index may not behave like a single risk-free asset during such a period.

The Low-inflation / QE regime covers the period from 2013 to 2019, when inflation remained subdued, policy rates were very low or negative, and the ECB relied on large-scale asset purchases. Molenaar et al. (2024) show that such environments are often associated with lower or negative stock-bond correlations, making this period a useful benchmark for traditional diversification.

The COVID-19 regime covers the pandemic shock and the immediate policy response. It is included separately because liquidity conditions, emergency support measures, and sudden changes in risk appetite affected equities, bonds, and gold at the same time (Choudhury et al., 2022; ECB, 2022).

The final regime captures the post-2021 inflation and monetary-tightening period. Inflation surged, the ECB raised rates from negative territory, and the role of bonds as a cushion became less reliable. The ECB (2022) links this environment to higher cross-asset correlations and simultaneous pressure on equities and bonds. This regime is therefore central to the question of whether diversification still works for a euro-area investor.

Using these regimes keeps the data structure aligned with the literature. Instead of relying only on one full-sample estimate, the analysis can compare behaviour across calm periods, crisis episodes, and the recent inflation shock.

3.5 Preliminary descriptive statistics

Before moving to dynamic correlation and portfolio-risk analysis, the return series are first described using standard summary statistics. These figures provide a starting point for understanding average returns, volatility, distributional shape, and stationarity over the full common sample.

Table 3.1. Full-sample descriptive statistics of stock, bond, and gold return series

Variable	Mean (%)	Median (%)	SD (%)	Skewness	Kurtosis	J-B statistic	Pearson with Stock	ADF statistic	PP statistic
Stock	0.0187	0.0510	1.3191	-0.3189	8.4555	15616.6580	—	-33.8218	-74.7398
Bond	0.0105	0.0151	0.2841	0.1461	4.6259	4665.1903	-0.0605	-69.5614	-69.5235
Gold	0.0391	0.0435	1.0236	-0.2113	6.4772	9150.1919	-0.0588	-16.3534	-75.4300

Source: Calculated by the author using daily Bloomberg Terminal PX_LAST observations for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data last accessed: 31 December 2025.

The full-sample statistics show small average daily returns, which is expected for daily data. The mean return is 0.0187% for the EURO STOXX 50 Net Return Index, 0.0105% for the euro sovereign bond benchmark, and 0.0391% for euro-denominated gold. These numbers are modest on a daily basis, but they become economically relevant over a long sample, especially when compounded across different market regimes.

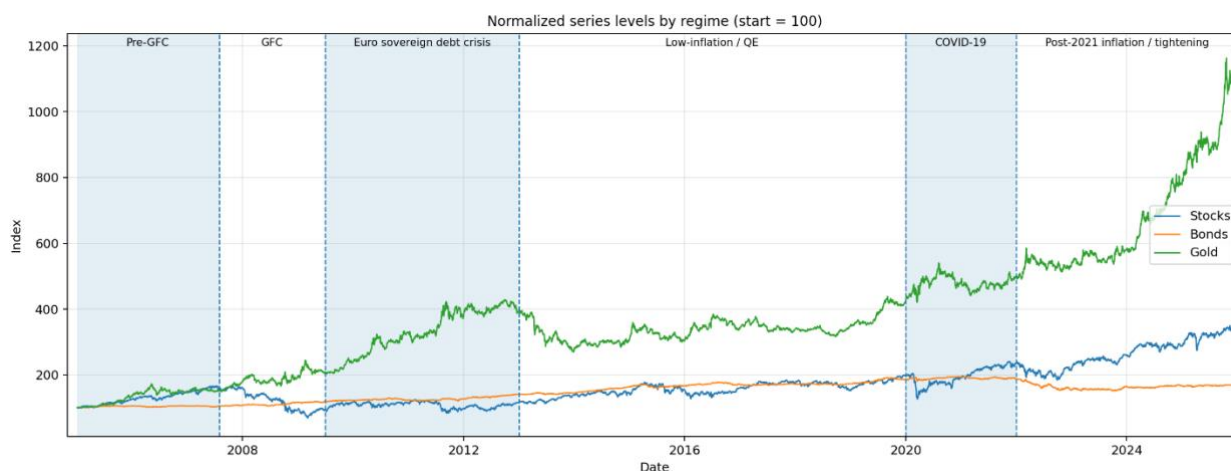
The volatility ranking is clearer than the mean-return ranking. Stock returns have a daily standard deviation of about 1.32%, while the bond benchmark is much less volatile at 0.28%. Gold stands between the two, with a standard deviation of roughly 1.02%. This pattern fits the portfolio interpretation of the three assets: equities are the main risk asset, bonds are the defensive anchor, and gold is a separate exposure that may behave defensively in some periods but not in all of them (Baur and Lucey, 2010; Choudhury et al., 2022).

The return distributions are clearly non-normal. Skewness is mildly negative for stocks and gold and slightly positive for bonds. Kurtosis is above the normal-distribution benchmark of three for all three assets, with the stock series above eight and the gold series above six. The Jarque-Bera statistics are large for each asset, indicating strong rejection of normality at conventional significance levels. This pattern is typical for financial returns, where crisis episodes create fat tails and volatility clustering (Brooks, 2019).

The Augmented Dickey-Fuller and Phillips-Perron tests point to stationarity in all three log-return series. The reported statistics are strongly negative, which supports the use of these returns in the dynamic conditional correlation and GARCH-based models introduced in Chapter 4 (Gabauer, 2020).

The level series are also useful for visual comparison once they are normalised to start at 100.

Figure 3.1. Normalized series levels (start = 100)

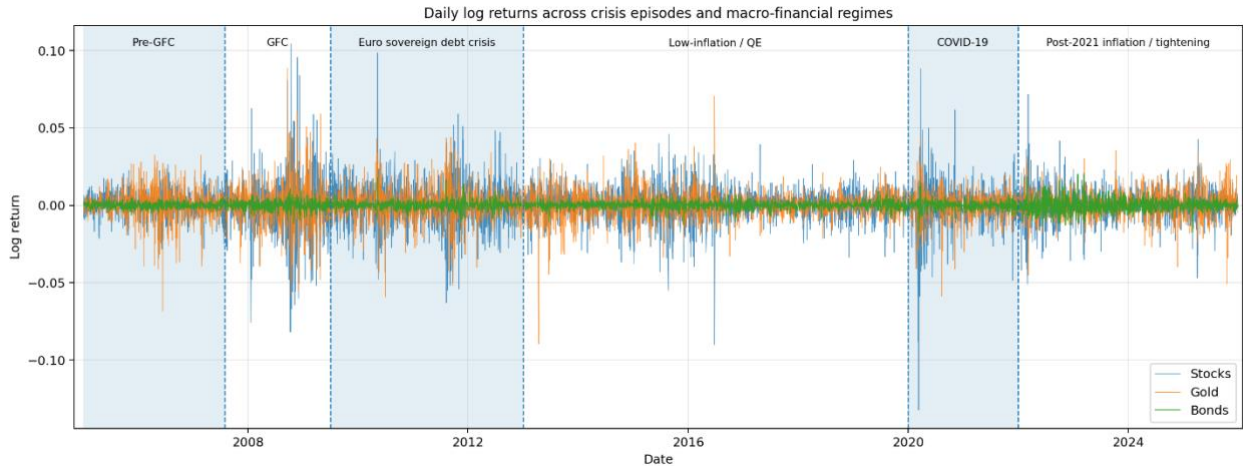


Source: Author's computation from daily Bloomberg Terminal PX_LAST observations for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data last accessed: 31 December 2025.

The normalised level plot shows that euro-denominated gold recorded the strongest cumulative increase over the sample, especially after the GFC and again in the post-2021 inflation period. The bond index follows a smoother path for most of the period, before weakening during the tightening cycle. The equity series, now measured by the EURO STOXX 50 Net Return Index, shows large drawdowns during the major crises but also a stronger cumulative recovery than a price-only equity index would show because reinvested net dividends are included.

Daily log returns provide a clearer view of short-run stress and volatility clustering.

Figure 3.2. Daily log returns of stocks, bonds, and gold



Source: Author's own processing of daily Bloomberg PX_LAST observations for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data accessed on 31 December 2025.

The return plot confirms that the largest equity shocks occur around the GFC and the initial phase of COVID-19. Gold and bonds show smaller spikes on average, but their volatility also rises around stress periods. These patterns support the regime classification above and motivate the use of methods that allow both volatility and dependence to change over time.

3.6 Preliminary correlation evidence

The last descriptive step is to examine unconditional correlations between the three daily return series. These correlations are useful as a baseline, but they average across all regimes and therefore cannot show whether diversification behaves differently during crises or inflationary periods.

Table 3.2. Full-sample correlation matrix

	Stocks	Bonds	Gold
Stocks	1	-0.0605	-0.0588
Bonds	-0.0605	1	0.1298
Gold	-0.0588	0.1298	1

Source: Author's correlation calculations using daily Bloomberg-based log returns for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data accessed on 31 December 2025.

The full-sample correlation matrix shows weak average co-movement. The correlation between the EURO STOXX 50 Net Return Index and the euro sovereign bond benchmark is -0.0605, while the stock-gold correlation is -0.0588. The bond-gold correlation is slightly

positive at 0.1298. At first glance, these values suggest that both bonds and gold offer some diversification against equity risk, and that bonds and gold themselves are not strongly related over the full sample.

However, these correlations should be interpreted carefully. They combine low-inflation years, crisis episodes, the COVID-19 shock, and the post-2021 tightening period into one average. The literature reviewed in Chapter 2 shows that stock-bond correlations can change sign across regimes (Molenaar et al., 2024; ECB, 2022). A small negative full-sample coefficient can therefore hide much stronger co-movement in specific stress periods.

The same caution applies to gold. A low average stock-gold correlation does not prove that gold works as a safe haven during equity market stress. The distinction between a hedge in normal times and a safe haven in crisis periods is central to Baur and Lucey (2010) and to later studies on gold, bonds, and crises. For this reason, full-sample correlations are treated as preliminary evidence only.

Overall, the descriptive correlations confirm that the three assets are not strongly correlated on average. They do not answer the main thesis question on their own. The next chapter therefore moves from unconditional statistics to regime-specific analysis, rolling correlations, DCC-GARCH estimates, and portfolio-level risk measures.

3.7 Chapter summary

This chapter has defined the empirical dataset used to study diversification across stocks, bonds, and gold from the perspective of a euro-area investor. The equity proxy is the EURO STOXX 50 Net Return Index, Bloomberg ticker SX5T Index. The bond proxy is the Bloomberg euro-area sovereign bond benchmark LEATTREU Index, and gold is measured using the euro-denominated XAUEUR BGN Curncy series. Together, these assets represent the main risky, defensive, and alternative components of the portfolio setting developed in the previous chapters.

The chapter has also explained the formal 2005-2025 sample window and the common overlapping sample of 5,224 daily observations used for estimation. Daily log returns were constructed from Bloomberg PX_LAST levels and aligned by date across the three assets. The data were then assigned to six regimes covering the pre-GFC period, the GFC, the euro sovereign debt crisis, the low-inflation / QE period, COVID-19, and the post-2021 inflation and tightening environment.

The preliminary statistics show that the three assets differ clearly in volatility and distributional shape. Returns are non-normal and fat-tailed, while stationarity tests support the use of log returns in the later dynamic models. The normalised level plot highlights the very different long-run paths of equities, bonds, and gold, and the return plot shows volatility clustering around crisis episodes.

The full-sample correlation matrix provides only a first indication of diversification. It shows weak negative correlations between stocks and both bonds and gold, and a modest positive correlation between bonds and gold. Yet these averages may conceal important variation across regimes. Chapter 4 therefore builds on this data foundation by modelling time-varying dependence, measuring portfolio risk across regimes, and comparing the defensive roles of euro-area government bonds and euro-denominated gold in a formal econometric framework.

Chapter 4. Methodology

4.1 Analytical strategy and chapter logic

Chapter 3 showed that the EURO STOXX 50 Net Return Index, the euro-area government bond benchmark and euro-denominated gold have different return profiles. Stocks are the most volatile, bonds move more smoothly, and gold follows a separate crisis-sensitive path. The descriptive results are useful as a starting point, but they do not show whether diversification protects the portfolio during the periods when protection is most needed. The methodology moves from simple summary statistics to tools that track co-movement and portfolio risk across regimes.

The empirical work proceeds in three steps. First, the thesis compares pairwise correlations within the regimes defined in Chapter 3. Second, it uses rolling correlations and DCC-GARCH to examine how dependence changes through time. Third, it translates these dependence patterns into portfolio outcomes by comparing a stock-only portfolio, a conventional stock-bond portfolio and a stock-bond-gold portfolio. This order keeps the analysis simple at the beginning and gradually moves towards the portfolio-risk question at the centre of the thesis.

This structure follows the argument developed in Chapters 1 and 2. The stock-bond literature, the ECB's discussion of the post-2021 diversification problem and the gold safe-haven literature all point to the same issue: average correlations can be misleading when relationships change during stress periods. The methods used in this chapter are selected to make those changes visible rather than to average them away.

4.2 Static dependence by regime

The first empirical step is to estimate pairwise correlations separately for the six regimes introduced in Chapter 3. This makes the correlation analysis consistent with the macro-financial periods used in the thesis. The literature suggests that stock-bond relationships depend on inflation, policy tightening and sovereign stress, while the role of gold may also differ from one crisis to another (Molenaar et al., 2024; Baur and Lucey, 2010; Choudhury et al., 2022). Regime correlations therefore give a first indication of whether bonds and gold behave differently across market environments.

This step is especially useful for H1 and H2. H1 expects bond-based diversification to weaken in higher-inflation regimes. H2 focuses on whether gold behaves as a hedge or safe haven in different episodes. A full-sample correlation would hide these differences, while regime-level estimates allow the comparison to be made before introducing a dynamic model.

Static regime correlations are still only a first step. They average all observations within each period and can miss shorter breakdowns inside a crisis window. The GFC, the sovereign debt crisis and COVID-19 all contain both calmer and more turbulent phases. For this reason, regime correlations are treated as a useful intermediate result rather than as the final answer. The next step adds the time dimension more directly.

4.3 Rolling correlations and the motivation for dynamic modelling

Rolling correlations are used as a visual bridge between regime averages and the formal dynamic model. They are calculated for the three asset pairs central to the thesis: stocks and bonds, stocks and gold, and bonds and gold. The purpose is not to treat rolling windows as the definitive test, but to illustrate how co-movement can vary over time.

This approach helps identify whether relationships evolve gradually or shift sharply around major events such as the GFC, the euro-area sovereign debt crisis, COVID-19, and the post-2021 inflation episode. If stock-bond or stock-gold correlations increase during these periods, diversification cannot be assumed to be a stable feature of the assets. This is particularly relevant during periods when investors rely most on defensive assets.

However, rolling correlations have limitations. Results depend on the window length chosen and may vary if the window is adjusted. They are descriptive and do not produce a full conditional covariance matrix. Consequently, rolling correlations are used as a diagnostic step before moving to DCC-GARCH, which models changing dependence in a more formal and rigorous way.

4.4 DCC-GARCH as the main dynamic dependence framework

DCC-GARCH is the main dynamic dependence model used in this thesis. It is appropriate because the research question requires both volatility and correlations to vary over time. Chapter 3 showed fat tails, volatility clustering and crisis-related instability in the return data, so a constant-correlation approach would be too restrictive. Since the thesis asks whether stocks, bonds and gold still reduce portfolio risk across regimes, the model has to capture changes in co-movement during both calm and stressed periods.

The framework has two parts. The GARCH component models the conditional variance of each return series, which is important because large financial-market shocks often cluster together. Bollerslev's (1986) GARCH model provides the basis for this part of the analysis. Engle's (2002) Dynamic Conditional Correlation model then extends the framework by allowing the correlation matrix to change through time. This is the key feature for the thesis,

because diversification depends not only on individual asset volatility but also on how the assets move together at each point in the sample.

Let r_t denote the vector of daily log returns for the three assets: euro-area stocks, euro-area government bonds, and euro-denominated gold. The return equation can be written as:

$$r_t = \mu + \varepsilon_t$$

where r_t is the vector of asset returns, μ is the vector of mean returns, and ε_t is the vector of residuals. The residuals are assumed to have a time-varying conditional covariance matrix H_t :

$$\varepsilon_t = H_t^{1/2} z_t$$

where z_t is a vector of standardised innovations. In the DCC-GARCH framework, the conditional covariance matrix is decomposed as:

$$H_t = D_t R_t D_t$$

where D_t is a diagonal matrix containing the conditional standard deviations of each asset, and R_t is the time-varying conditional correlation matrix. This decomposition is useful because it separates the modelling of individual asset volatility from the modelling of correlations between assets.

In the first step, the conditional variance of each asset is estimated using a univariate GARCH(1,1) specification:

$$h_{i,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1}$$

where $h_{i,t}$ is the conditional variance of asset i at time t , ω_i is the constant term, α_i measures the effect of recent shocks, and β_i captures volatility persistence. This specification is parsimonious and widely used in financial time-series analysis because it captures the main feature required for this thesis: volatility changes over time and tends to persist after large shocks.

In the second step, the standardised residuals from the univariate GARCH models are used to estimate the dynamic conditional correlation process. The DCC component can be written as:

$$Q_t = (1 - a - b)\bar{Q} + az_{t-1}z'_{t-1} + bQ_{t-1}$$

where Q_t is the time-varying covariance matrix of the standardised residuals, $\bar{Q}$ is their unconditional covariance matrix, a measures the short-run effect of new shocks on correlations, and b captures the persistence of correlations over time. The conditional correlation matrix is then obtained as:

$$R_t = \text{diag}(Q_t)^{-1/2} Q_t \text{diag}(Q_t)^{-1/2}$$

The model produces daily conditional correlations for the three asset pairs: stocks-bonds, stocks-gold and bonds-gold. These series are used to see whether diversification relationships remain stable or become weaker during crisis and inflation regimes.

DCC-GARCH is particularly relevant for H1 and H3. H1 expects the stock-bond relationship to be more favourable in low-inflation and non-crisis periods, but less favourable in the post-2021 inflation and tightening regime. H3 is concerned with the portfolio-level effect of that change. The conditional covariance matrix from the DCC-GARCH model provides the link between changing dependence and time-varying portfolio risk.

The use of DCC-GARCH also keeps the methodology proportionate to the scope of the thesis. A broader connectedness or spillover model could be useful for a larger financial-system study, but it would distract from the three-asset portfolio question. For euro-area stocks, euro-area government bonds and euro-denominated gold, DCC-GARCH provides enough structure to study changing dependence without making the methodology unnecessarily complex.

4.5 Portfolio construction and portfolio-risk evaluation

Because the thesis is about portfolio risk, the empirical analysis cannot stop at pairwise correlations or dynamic dependence estimates. Correlations show whether assets move together, but they do not show how an actual allocation behaves in terms of volatility, drawdowns and risk-adjusted performance. The key question is whether adding bonds and gold

to an equity position reduces risk in practice. The benchmark allocations used for this comparison are summarised in Table 4.1.

Table 4.1. Benchmark portfolio allocations

Portfolio	Stocks	Bonds	Gold	Purpose
A: Equity-only benchmark	100%	0%	0%	Baseline for measuring diversification benefits
B: Traditional stock-bond portfolio	60%	40%	0%	Tests the conventional bond-based diversification channel
C: Stock-bond-gold portfolio	60%	30%	10%	Tests whether gold adds incremental risk reduction

Source: Author's own portfolio design for the empirical analysis.

Three fixed-weight benchmark portfolios are used. The equity-only portfolio provides the baseline. The 60/40 stock-bond portfolio represents the traditional balanced allocation. The stock-bond-gold portfolio then tests whether a modest gold allocation adds protection beyond bonds alone.

The weights are fixed on purpose. The aim is not to design an optimal trading strategy, but to evaluate whether simple and easy-to-interpret diversification rules still work across regimes. Optimised portfolios would add another layer of model dependence and could make it harder to isolate the contribution of bonds and gold. Fixed weights keep the comparison clear: first equities alone, then stocks with bonds, and finally stocks with both bonds and gold.

For each portfolio, daily returns are calculated as the weighted average of the daily returns of the three assets:

$$r_{p,t} = w_S r_{S,t} + w_B r_{B,t} + w_G r_{G,t}$$

where $r_{p,t}$ is the return of portfolio p on day t , $r_{S,t}$, $r_{B,t}$, and $r_{G,t}$ are the daily returns on stocks, bonds, and gold, and w_S , w_B , and w_G are their respective portfolio weights. For the stock-only portfolio, $w_S = 1$ and $w_B = w_G = 0$. For the 60/40 portfolio, $w_S = 0.60$, $w_B = 0.40$, and $w_G = 0$. For the stock-bond-gold portfolio, $w_S = 0.60$, $w_B = 0.30$, and $w_G = 0.10$.

Portfolio risk is evaluated with several complementary measures. The first is annualised volatility, which measures the average size of portfolio fluctuations and allows risk to be compared across portfolios and regimes on a yearly scale. It is calculated as:

$$\sigma_p^{ann} = \sigma_p^{daily} \sqrt{252}$$

where σ_p^{daily} is the standard deviation of daily portfolio returns and 252 represents the approximate number of trading days in a year. Annualised volatility is useful because it allows the risk of different portfolios and regimes to be compared on a common scale.

The second measure is maximum drawdown, which captures the largest peak-to-trough loss in the cumulative portfolio value. This measure is especially relevant in a crisis-focused thesis because investors do not experience risk only as average volatility; they also experience it through large losses. Maximum drawdown is defined as:

$$MDD_p = \min_t \left(\frac{V_{p,t}}{\max(V_{p,0}, \dots, V_{p,t})} - 1 \right)$$

where $V_{p,t}$ is the cumulative value of portfolio p at time t . Unlike volatility, maximum drawdown focuses directly on loss episodes. This is important because a portfolio can have moderate average volatility but still expose the investor to severe losses during crises.

The third measure is the Sharpe ratio, used here as a secondary indicator of risk-adjusted performance. Since the thesis is mainly comparative and does not focus on beating a specific cash benchmark, the Sharpe ratio is calculated using a zero risk-free rate:

$$SR_p = \frac{\bar{r}_p}{\sigma_p}$$

where $\bar{r}_p$ is the average portfolio return and σ_p is the standard deviation of portfolio returns. The Sharpe ratio is interpreted cautiously, because the central focus of the thesis is risk reduction rather than return maximisation.

In addition to realised portfolio returns and realised risk measures, the DCC-GARCH model provides a time-varying conditional covariance matrix that can be used to estimate

conditional portfolio risk. For a portfolio with weight vector w , conditional portfolio volatility is calculated as:

$$\sigma_{p,t} = \sqrt{w' H_t w}$$

where H_t is the conditional covariance matrix estimated by the DCC-GARCH model. This measure links the dynamic dependence framework directly to portfolio risk. It shows how the estimated risk of each portfolio changes over time as volatility and correlations shift across crises and regimes.

This portfolio framework connects the methodology directly to H1 and H3. If the 60/40 portfolio reduces volatility and drawdowns compared with the stock-only benchmark in low-inflation and non-crisis periods, the evidence supports the traditional diversification logic in H1. If the same benefit weakens in the post-2021 inflation and tightening regime, this would be consistent with a breakdown of bond-based diversification. The stock-bond-gold portfolio then shows whether gold adds a further layer of protection or whether its contribution also remains conditional.

4.6 Hedge and safe-haven evaluation for bonds and gold

Bonds and gold are treated as competing defensive assets because both may reduce equity risk, but they do not work through the same channel. In the safe-haven literature, a hedge is an asset that is uncorrelated or negatively correlated with another asset on average. A safe haven is more demanding: it should retain that property during periods of severe market stress (Baur and Lucey, 2010). This distinction is important because an asset can look useful in normal periods and still fail when equity losses become extreme.

The thesis evaluates hedge and safe-haven behaviour in two ways. First, it examines the average and regime-specific relationship between each defensive asset and stock returns. This shows whether bonds or gold tend to offset equity risk in calm periods, crisis periods and the post-2021 inflation regime. Second, it looks at behaviour during severe stock-market stress, using lower-tail equity observations to focus on the days when protection is most valuable.

This keeps the analysis tied to the main research question. The purpose is not to write a separate study of gold, but to compare whether euro-area government bonds or euro-denominated gold provide better protection inside a three-asset euro-area portfolio. Previous research shows that gold can be defensive, but that its role is conditional and episode-specific

(Baur and Lucey, 2010; Huang and Chang, 2021; Choudhury et al., 2022; Vieira et al., 2023). The comparison with bonds is therefore necessary rather than optional.

4.7 Linking methods to hypotheses

The methodology is organised around the three hypotheses. H1 is examined through regime correlations, rolling correlations, DCC-based stock-bond dependence and the comparison between the stock-only portfolio and the 60/40 stock-bond portfolio. If bond diversification weakens in high-inflation and tightening regimes, this should appear both in the dependence measures and in the realised portfolio-risk results.

H2 is addressed through the hedge and safe-haven evaluation of bonds and gold. The key comparison is between their usual relationship with stocks and their behaviour during severe equity-market stress. This turns the safe-haven literature into an empirical test rather than leaving it as a theoretical discussion.

H3 is tested through the DCC-GARCH estimates and the portfolio-risk measures, especially in the post-2021 inflation regime. If conditional correlations rise and portfolio risk increases even after gold is included, the results would support the view that diversification has become weaker in the recent macro-financial environment.

4.8 Scope limitations of the empirical methodology

The methodology is deliberately focused. It does not include a full connectedness framework, a high-dimensional spillover model, a large set of optimised portfolios or a country-by-country sovereign bond decomposition. These approaches would be useful for different research questions, but they would move this thesis away from its main portfolio-risk objective.

This narrower scope improves interpretability. With three assets and a clearly defined euro-area investor perspective, regime correlations, rolling dependence, DCC-GARCH and portfolio-risk measures are sufficient for answering the research question. The omitted methods are better treated as possible extensions for future work, especially if the analysis were expanded to include more asset classes or individual sovereign bond markets.

4.9 Chapter summary

This chapter has set out the empirical route used to answer the research question. It starts with regime-specific static correlations, uses rolling correlations to visualise changing co-movement, and then applies DCC-GARCH as the main framework for time-varying dependence among stocks, bonds and gold. The chapter also explains why portfolio-risk measures are needed in addition to pairwise correlations.

The chapter also shows how bonds and gold are evaluated as defensive assets and how each methodological block relates to the three hypotheses. The resulting design links dependence, regime shifts and portfolio outcomes in a clear sequence. Chapter 5 presents the empirical results in the same order, beginning with static and rolling dependence and then moving to portfolio risk and hedge and safe-haven analysis.

Chapter 5. Empirical Results

5.1 Introduction to the empirical results

Chapter 4 developed the empirical strategy used to test the three hypotheses of this thesis. This chapter applies that strategy to the euro-area dataset described in Chapter 3. The aim is to move from the design of the study to the evidence itself: whether a portfolio built from the EURO STOXX 50 Net Return Index, euro-area government bonds, and euro-denominated gold still reduces risk across crisis and macro-financial regimes.

The chapter follows the same order as the methodology. It begins with regime-specific correlations, because the full-sample correlations in Chapter 3 only gave a broad average over very different periods. The GFC, the euro sovereign debt crisis, COVID-19, and the post-2021 inflation and tightening regime are not interchangeable market environments. A separate regime view is therefore needed before drawing conclusions about diversification.

The analysis then moves to rolling correlations and DCC-GARCH conditional correlations. Rolling correlations provide a visual check of how relationships change through time, while the DCC-GARCH model gives a more formal measure of time-varying dependence. These steps are especially useful because diversification usually matters most when markets are already under stress.

The second half of the chapter turns from dependence to portfolio outcomes. Three benchmark allocations are compared: a stock-only portfolio, a 60/40 stock-bond portfolio, and a 60/30/10 stock-bond-gold portfolio. The main indicators are annualised volatility, maximum drawdown, and DCC-based conditional portfolio volatility. The Sharpe ratio is also reported, but the main focus remains risk reduction rather than return maximisation.

The final empirical block looks directly at the defensive role of bonds and gold during the worst equity-market days. This lower-tail analysis is needed because an asset can look useful on average while failing to protect the portfolio when equity losses are most severe. The chapter closes by linking the results back to H1, H2, and H3.

5.2 Regime-specific static correlations

The first step is to estimate correlations within each regime. This keeps the empirical analysis close to the logic developed in Chapters 1 and 2: the stock-bond relationship, the role of gold, and the usefulness of diversification can all change with the macro-financial environment. One full-sample coefficient would hide those differences.

Table 5.1. Regime-specific correlations between stocks, bonds and gold

Regime	Stock-Bond	Stock-Gold	Bond-Gold
Pre-GFC	-0.1274	0.2210	-0.0206
GFC	-0.4404	-0.1070	0.0643
Euro sovereign debt crisis	-0.0141	-0.1325	0.0468
Low-inflation / QE	0.0439	-0.0993	0.2132
COVID-19	0.0547	0.1043	0.2369
Post-2021 inflation / tightening	0.0266	-0.0972	0.1824

Source: Author's calculations based on Bloomberg Terminal daily log returns for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data last updated: 31 December 2025.

Table 5.1 shows that the relationships between the three assets are not stable over time. The stock-bond correlation is mildly negative before the GFC and strongly negative during the GFC. It then moves close to zero during the euro sovereign debt crisis and becomes slightly positive in the later regimes. The GFC is the clearest example of traditional bond diversification working strongly: the stock-bond correlation is -0.4404, the most negative value in the table.

The later regimes give a more cautious message. In the Low-inflation/QE period, the stock-bond correlation is 0.0439. In the Post-2021 inflation and tightening regime, it is 0.0266. Both values are low and positive. The static evidence therefore confirms regime dependence, but it does not show a sharp post-2021 rise in stock-bond co-movement. H1 cannot be judged from this table alone.

The stock-gold relationship is also uneven. It is positive in the Pre-GFC period, negative during the GFC and the euro sovereign debt crisis, negative again in the Low-inflation/QE period, positive during COVID-19, and negative after 2021. This pattern is consistent with the idea that gold can diversify equities in some periods but not in all of them. It is not a mechanical safe haven.

The bond-gold correlation is close to zero before and during the GFC, but it becomes positive in later regimes. The values reach 0.2132 in the Low-inflation/QE period, 0.2369 during COVID-19, and 0.1824 in the post-2021 regime. This matters because bonds and gold are both treated as defensive assets, yet they are not always independent from each other. Gold may still improve a portfolio, but its extra contribution depends on the regime.

Overall, the regime correlations support the use of a regime-based empirical design. They also show why the analysis needs to move further. Static correlations summarise each regime, but they do not show how quickly relationships change inside crisis periods.

5.3 Rolling correlation results

The rolling correlation analysis gives a more detailed view of changing dependence. A 252-day window is used, which roughly corresponds to one trading year. The purpose is not to replace the formal DCC-GARCH model, but to show whether the relationships between the assets evolve gradually or shift around crisis periods.

Figure 5.1. 252-day rolling correlations between stocks, bonds and gold



Source: Author's calculations based on Bloomberg Terminal daily log returns for SX5T Index, LEATTREU Index, and XAUEUR BGN Currency. Data last updated: 31 December 2025.

Figure 5.1 shows that the stock-bond relationship changes substantially over the sample. The correlation turns strongly negative around the GFC, which matches the static evidence in Table 5.1. During that episode, euro-area government bonds moved differently from equities and provided clear diversification. After the GFC, however, the relationship becomes less stable, moving closer to zero and turning positive in several periods.

For H1, this supports a qualified interpretation. Bonds do act as diversifiers, but their role is not fixed. The strongest defensive behaviour appears during the GFC, while later periods show a more mixed stock-bond relationship. The post-2021 period does not show a simple collapse of bond diversification, but it also does not reproduce the strong negative correlation seen in the GFC.

The stock-gold rolling correlation is also unstable. In several parts of the sample it is negative, suggesting useful diversification against equities. In other periods it moves close to zero or turns positive. This is consistent with H2 in a limited sense: gold can help, but its protective role changes over time and across shocks.

The bond-gold rolling correlation adds another important point. In later years it is often positive, especially around the Low-inflation/QE and COVID-19 periods. This means that gold does not always provide a fully separate defensive exposure from bonds. The three-asset portfolio may still be useful, but the contribution of gold has to be tested at the portfolio level rather than assumed from theory.

The rolling evidence therefore confirms the main limitation of static correlations. The asset relationships move over time, and the timing of those movements matters. The next section uses DCC-GARCH to estimate these changing correlations in a more formal framework.

5.4 DCC-GARCH conditional correlation results

Rolling correlations are useful visually, but they depend on the window length and do not formally model volatility clustering. The DCC-GARCH model addresses this limitation by estimating conditional correlations that can change over time together with asset volatility. This is the main dynamic dependence framework used in the thesis.

Table 5.2. DCC-GARCH parameter estimates

Parameter	Estimate	Interpretation
DCC alpha	0.0294	Short-run response of conditional correlations to new shocks
DCC beta	0.9456	Persistence of the conditional correlation process
DCC alpha + beta	0.9750	Overall persistence of the correlation process

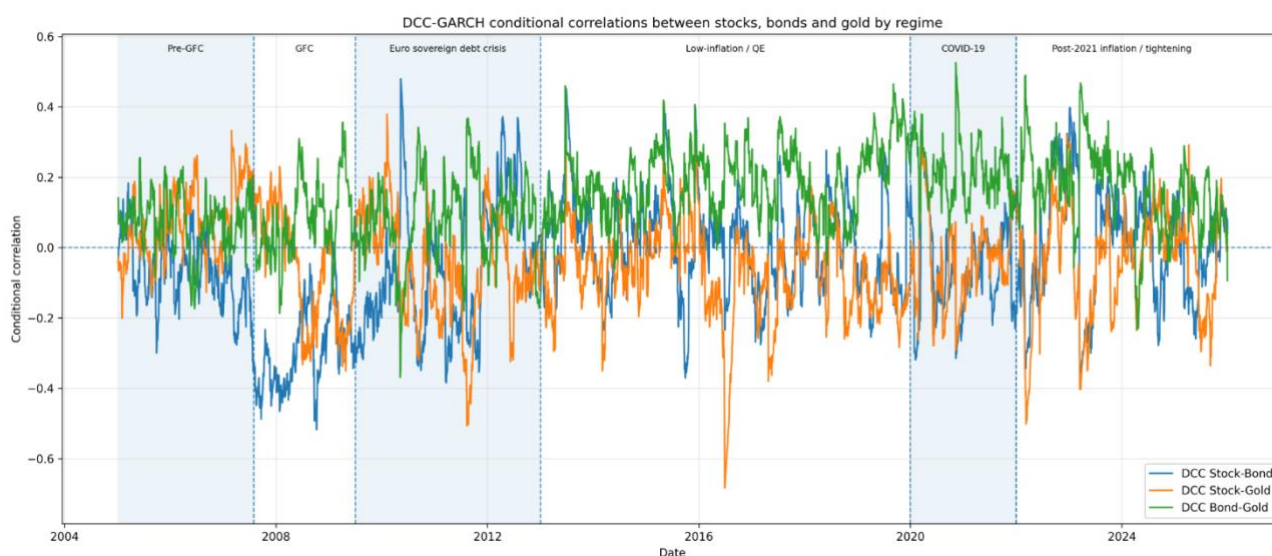
Source: Estimated by the author from daily log-return series constructed using Bloomberg data for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data accessed on 31 December 2025.

Table 5.2 reports the DCC parameters. The DCC alpha is 0.0294 and the DCC beta is 0.9456, giving alpha plus beta equal to 0.9750. The sum is close to one, which indicates a highly persistent correlation process. In practical terms, changes in co-movement do not disappear

immediately; once correlations shift, they tend to remain away from their previous level for some time.

This persistence matters for diversification. A temporary correlation spike may be uncomfortable, but a persistent shift can change portfolio risk over a longer period. The DCC results therefore justify using a dynamic model rather than relying only on static or rolling correlations. The univariate GARCH estimates are reported in Appendix A, while the main text focuses on the conditional correlations between the three assets.

Figure 5.2. DCC-GARCH conditional correlations between stocks, bonds and gold



Source: Estimated by the author from daily log-return series constructed using Bloomberg data for SX5T Index, LEATTREU Index, and XAUEUR BGN Currency. Data accessed on 31 December 2025.

Figure 5.2 confirms that the dependence between stocks, bonds, and gold is not constant. The stock-bond conditional correlation becomes most negative around the GFC, again showing the defensive role of bonds in that episode. After the GFC, it moves closer to zero. In the post-2021 inflation and tightening regime, it remains low and slightly positive rather than rising sharply.

This gives a balanced result for H1. The DCC evidence clearly supports the idea that the stock-bond relationship is time-varying. It does not, however, support the strongest version of the claim that stock-bond co-movement increased dramatically after 2021. The bond diversification channel changes across regimes, but it does not simply disappear.

The stock-gold conditional correlation is generally low and often negative after the GFC. This suggests that gold can contribute to equity diversification. At the same time, the

correlation is not consistently negative enough to describe gold as a stable safe haven. The DCC evidence is more consistent with a conditional role for gold: useful in some environments, weaker in others.

The bond-gold conditional correlation is mostly positive in the later part of the sample. This limits the interpretation of gold as a completely independent defensive asset. Gold may still improve a portfolio, but its added value depends on how much it diversifies equities relative to its positive relationship with bonds.

Table 5.3. Mean DCC conditional correlations by regime

Regime	DCC Stock-Bond	DCC Stock-Gold	DCC Bond-Gold
Pre-GFC	-0.0683	0.0673	0.0718
GFC	-0.2946	-0.0659	0.0799
Euro sovereign debt crisis	-0.0576	-0.0617	0.0799
Low-inflation / QE	0.0102	-0.0696	0.1812
COVID-19	-0.0603	-0.0352	0.2156
Post-2021 inflation / tightening	0.0127	-0.0369	0.1642

Source: Author's estimates using daily log returns derived from Bloomberg observations for SX5T Index, LEATTREU Index, and XAUEUR BGN Currency. Data accessed on 31 December 2025.

Table 5.3 summarises the conditional correlations by regime. The mean DCC stock-bond correlation is most negative during the GFC, at -0.2946. In the Low-inflation/QE regime it is 0.0102, and in the Post-2021 inflation and tightening regime it is 0.0127. These two values are very close to each other, which reinforces the earlier point: the post-2021 period shows weaker bond protection than the GFC, but not a large positive stock-bond correlation.

The stock-gold DCC correlations are negative in most regimes after the Pre-GFC period, but the magnitudes are modest. Gold therefore appears to provide some diversification against equities, without becoming a dominant or fully reliable hedge. Bond-gold correlations, by contrast, are positive in all regimes and become higher after the GFC. This is one reason why the portfolio results are needed: correlations alone do not tell us whether a small gold allocation improves actual portfolio risk.

Overall, the DCC-GARCH evidence supports the methodological argument of the thesis. Dependence is time-varying and persistent. It also points to a nuanced empirical answer: bonds and gold can diversify equity risk, but neither relationship is stable enough to justify a mechanical view of diversification.

5.5 Portfolio risk and performance results

The correlation results show how the assets move together, but the thesis question is ultimately about portfolio risk. The analysis therefore compares three fixed-weight portfolios: a stock-only benchmark, a 60/40 stock-bond portfolio, and a 60/30/10 stock-bond-gold portfolio. This comparison shows whether the dependence patterns documented above translate into lower volatility and smaller drawdowns for an investor.

Table 5.4. Full-sample portfolio risk and performance

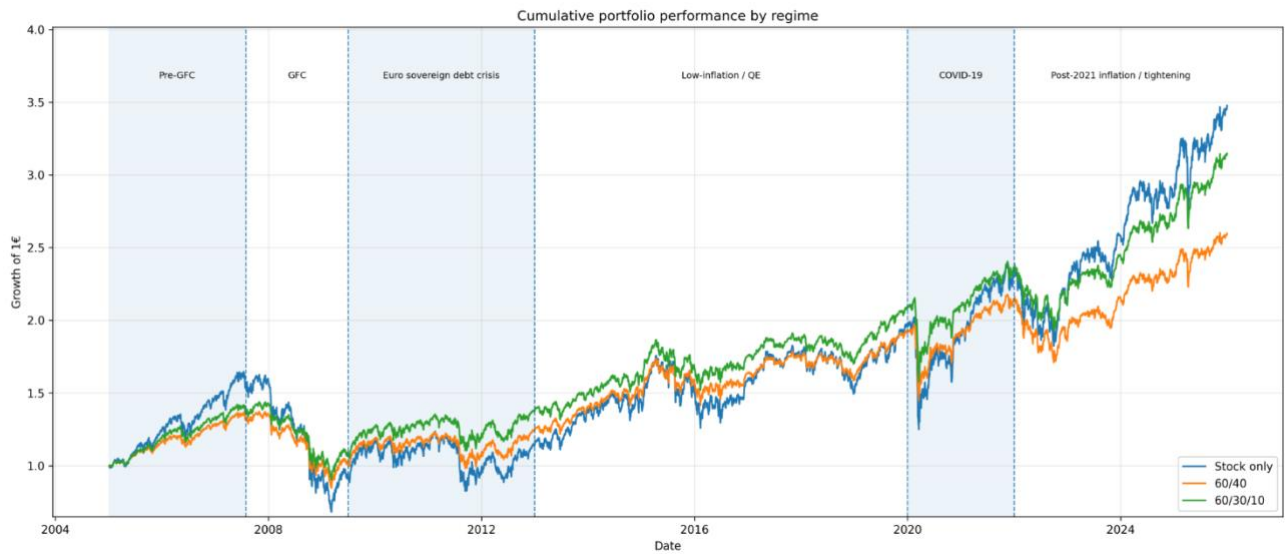
Portfolio	Annualised return	Annualised volatility	Maximum drawdown	Sharpe ratio
Stock-only	5.89%	21.00%	-58.58%	0.2806
60/40 stock-bond	4.51%	12.63%	-38.33%	0.3575
60/30/10 stock-bond-gold	5.42%	12.63%	-37.15%	0.4293

Source: Author's portfolio calculations using daily Bloomberg-based log returns for SX5T Index, LEATTREU Index, and XAUEUR BGN Currency. Data accessed on 31 December 2025.

Table 5.4 shows that diversification reduces risk over the full sample. The stock-only portfolio has annualised volatility of 21.00% and a maximum drawdown of -58.58%. The 60/40 stock-bond portfolio lowers volatility to 12.63% and improves maximum drawdown to -38.33%. This is a substantial reduction in risk relative to holding equities alone.

Adding gold produces a smaller but still visible improvement. The 60/30/10 portfolio has almost the same annualised volatility as the 60/40 portfolio, at 12.63%, but its maximum drawdown improves to -37.15%. Its Sharpe ratio is also higher, at 0.4293 compared with 0.3575 for the 60/40 portfolio. Since the thesis focuses on risk rather than return maximisation, the Sharpe ratio is treated as supporting evidence, not as the main criterion.

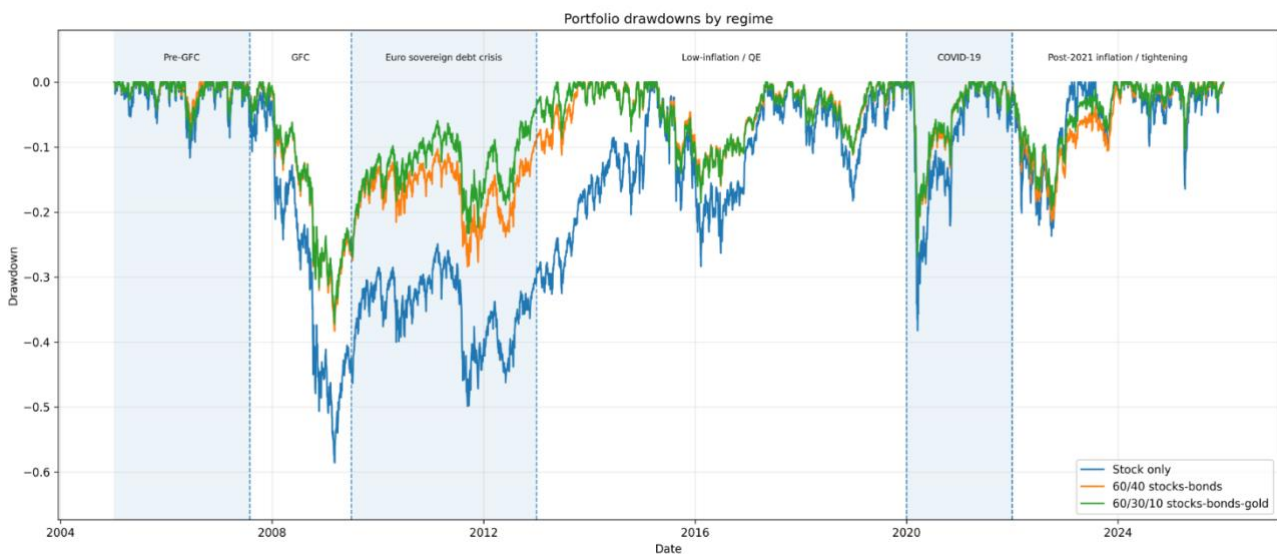
Figure 5.3. Cumulative performance of benchmark portfolios



Source: Author's portfolio simulation using daily Bloomberg-based log returns for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data accessed on 31 December 2025.

Figure 5.3 shows the cumulative paths of the three benchmark portfolios. The stock-only portfolio experiences the largest swings, especially around the main crisis episodes, but it also ends with the highest cumulative value over the full sample. The diversified portfolios follow smoother paths, and the 60/30/10 portfolio finishes above the 60/40 portfolio but below the stock-only benchmark. This confirms that diversification improves risk characteristics rather than maximising cumulative return.

Figure 5.4. Portfolio drawdowns across the sample



Source: Author's drawdown calculations using daily log returns constructed from Bloomberg series for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data accessed on 31 December 2025.

Figure 5.4 is more directly tied to the thesis question. The stock-only portfolio suffers the deepest drawdowns, particularly during the GFC, the euro sovereign debt crisis, and COVID-19. Both diversified portfolios reduce these losses substantially. The 60/30/10 allocation has a smaller full-sample maximum drawdown than the 60/40 allocation, but this advantage is not uniform across all regimes. Gold improves drawdown outcomes in the GFC, the euro sovereign debt crisis, and the Post-2021 inflation/tightening regime, while the 60/40 portfolio performs slightly better in some other periods. Gold therefore appears to complement bonds conditionally, but it does not transform the portfolio on its own.

Table 5.5. Portfolio risk and performance by regime

Regime	Portfolio	Annualised return	Annualised volatility	Maximum drawdown	Sharpe ratio
Pre-GFC	Stock-only	17.23%	13.34%	-11.65%	1.2916
Pre-GFC	60/40 stock-bond	11.04%	7.94%	-6.69%	1.3899
Pre-GFC	60/30/10 stock-bond-gold	12.46%	8.48%	-8.72%	1.4696
GFC	Stock-only	-26.98%	34.18%	-58.06%	-0.7895
GFC	60/40 stock-bond	-13.62%	19.72%	-38.33%	-0.6903
GFC	60/30/10 stock-bond-gold	-12.66%	19.80%	-37.15%	-0.6394
Euro sovereign debt crisis	Stock-only	5.77%	24.16%	-33.26%	0.2389
Euro sovereign debt crisis	60/40 stock-bond	5.45%	14.56%	-20.24%	0.3745
Euro sovereign debt crisis	60/30/10 stock-bond-gold	6.81%	14.41%	-18.44%	0.4724
Low-inflation / QE	Stock-only	7.69%	17.09%	-28.37%	0.4498
Low-inflation / QE	60/40 stock-bond	6.15%	10.42%	-18.40%	0.5905

Low-inflation / QE	60/30/10 stock-bond-gold	5.86%	10.35%	-18.58%	0.5662
COVID-19	Stock-only	8.72%	25.20%	-38.24%	0.3462
COVID-19	60/40 stock-bond	5.50%	15.32%	-26.47%	0.3590
COVID-19	60/30/10 stock-bond-gold	6.28%	15.52%	-26.80%	0.4050
Post-2021 inflation / tightening	Stock-only	9.83%	17.32%	-23.62%	0.5676
Post-2021 inflation / tightening	60/40 stock-bond	4.80%	10.80%	-20.98%	0.4445
Post-2021 inflation / tightening	60/30/10 stock-bond-gold	7.12%	10.64%	-19.06%	0.6685

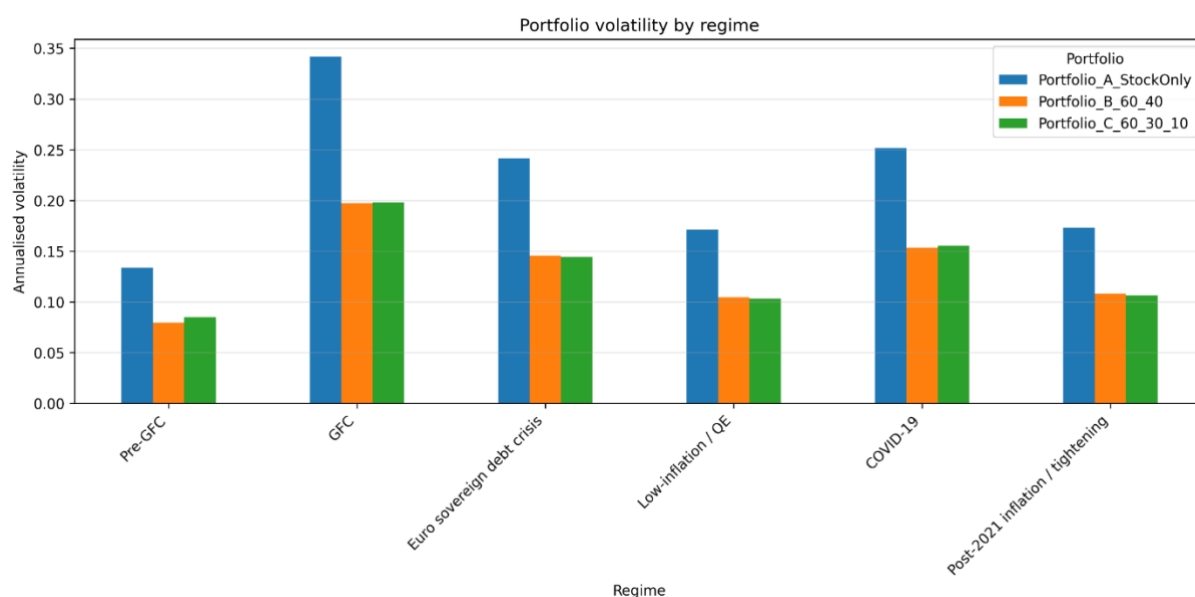
Source: Author's regime-level portfolio estimates using daily Bloomberg-based log returns for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data accessed on 31 December 2025.

Table 5.5 confirms that the 60/40 portfolio reduces annualised volatility relative to the stock-only benchmark in every regime. This is an important result: bond-based diversification does not disappear after 2021. In the Post-2021 inflation and tightening regime, stock-only volatility is 17.32%, while the 60/40 portfolio has volatility of 10.80%. The risk reduction remains clear, although it is somewhat weaker than in the GFC and slightly weaker than in the Low-inflation/QE period.

The drawdown results tell a similar story. In the post-2021 regime, the stock-only maximum drawdown is -23.62%. The 60/40 portfolio improves this to -20.98%, and the 60/30/10 portfolio improves it further to -19.06%. Here the gold allocation becomes more visible. It does not strongly reduce average volatility, but it helps soften drawdowns in this period.

For H1, the evidence supports a qualified conclusion. Bonds still reduce risk, but the size of the benefit changes across regimes. For H2, the portfolio results suggest that gold adds incremental protection mainly through the full-sample maximum drawdown, selected regime drawdowns, and risk-adjusted performance, rather than through a large fall in average volatility.

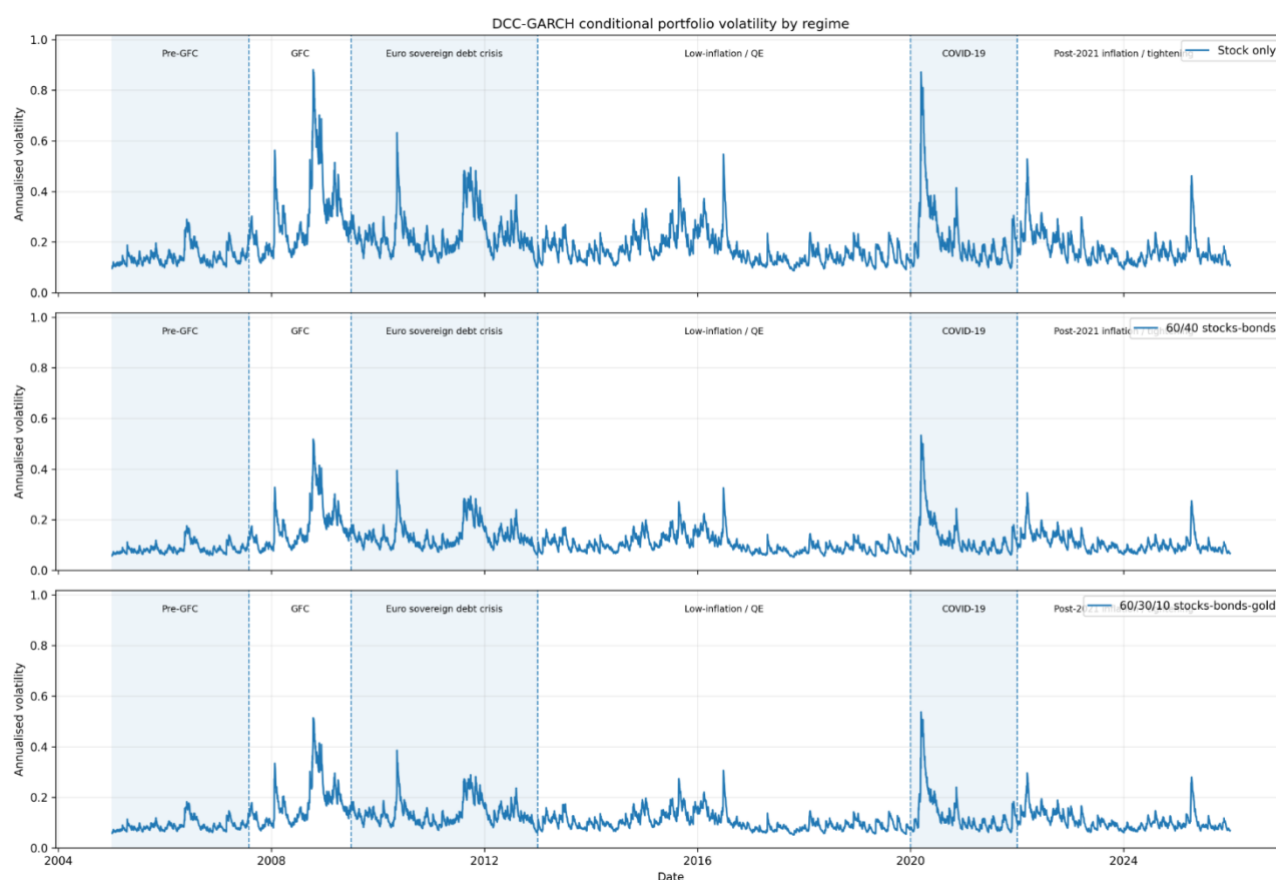
Figure 5.5. Annualised portfolio volatility by regime



Source: Author's volatility calculations using daily log returns derived from Bloomberg data for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data accessed on 31 December 2025.

Figure 5.5 visualises the same pattern. The stock-only portfolio is the most volatile allocation in every regime. The two diversified portfolios are consistently lower. The largest risk reduction comes from adding bonds, while the gold allocation produces smaller changes. In some regimes the 60/30/10 portfolio is slightly less volatile than the 60/40 portfolio; in others the difference is minimal.

Figure 5.6. DCC-GARCH conditional portfolio volatility



Source: Author's DCC-GARCH volatility estimates using daily Bloomberg-based log returns for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data accessed on 31 December 2025.

Figure 5.6 extends the portfolio analysis dynamically. The stock-only portfolio remains the riskiest allocation throughout the sample, with large spikes during the GFC and COVID-19. The diversified portfolios also become more volatile in stress periods, but their conditional volatility stays below the equity-only benchmark.

Table 5.6. DCC-based portfolio volatility and risk reduction by regime

Regime	N	Mean DCC vol. stock-only	Mean DCC vol. 60/40	Mean DCC vol. 60/30/10	Vol. reduction 60/40	Vol. reduction 60/30/10
Pre-GFC	650	14.27%	8.58%	8.86%	39.91%	37.94%
GFC	484	29.86%	17.47%	17.53%	41.49%	41.29%
Euro sovereign debt crisis	890	22.89%	13.77%	13.73%	39.85%	40.04%

Low-inflation / QE	1772	17.01%	10.34%	10.32%	39.20%	39.32%
COVID-19	512	21.55%	13.00%	13.05%	39.70%	39.46%
Post-2021 inflation / tightening	1020	17.15%	10.65%	10.59%	37.93%	38.26%

Source: Author's regime-level DCC-GARCH estimates using daily log returns constructed from Bloomberg data for SX5T Index, LEATTREU Index, and XAUEUR BGN Currency. Data accessed on 31 December 2025.

Table 5.6 confirms that the dynamic risk reduction remains positive in every regime. The 60/40 portfolio achieves its strongest DCC-based volatility reduction during the GFC, at 41.49%. In most regimes, the reduction is close to 39-40%. In the Post-2021 inflation and tightening regime, it falls to 37.93%, the weakest value in the table. The 60/30/10 portfolio performs slightly better in that regime, with a reduction of 38.26%.

These results provide the main empirical answer of the chapter. Diversification still reduces portfolio risk, but its strength is not constant. Bonds remain the main source of volatility reduction. Gold adds a modest improvement, especially through the full-sample drawdown result, selected regime drawdowns, and the post-2021 conditional risk comparison. The evidence therefore points away from both extremes: diversification has not failed, but it also does not work equally well in every regime.

5.6 Hedge and safe-haven results for bonds and gold

The portfolio results show that diversified allocations reduce risk, but they do not fully explain how bonds and gold behave during the worst equity-market days. A safe-haven asset should be evaluated precisely during those stress observations. This section therefore focuses on the lower tail of stock returns.

The analysis identifies the worst 10% and worst 5% of stock-return days and then measures the behaviour of bonds and gold during those days. This provides a direct test of whether the two defensive assets offered protection when equity losses were most severe.

Table 5.7. Safe-haven test during lower-tail equity returns

Stress definition	Asset	N	Mean return	Median return	Corr. with stocks	p-value	Significance
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Worst 10% stock-return days	Bonds	533	0.0520%	0.0903%	-0.0380	0.0022	***
Worst 10% stock-return days	Gold	533	0.1578%	0.1651%	-0.0124	0.0238	**
Worst 5% stock-return days	Bonds	267	0.0717%	0.1078%	-0.0153	0.0105	**
Worst 5% stock-return days	Gold	267	0.1709%	0.1329%	-0.0090	0.1632	Not significant

Source: Author's lower-tail return analysis using daily Bloomberg-based log returns for SX5T Index, LEATTREU Index, and XAUEUR BGN Currency. Data accessed on 31 December 2025.

Note: *** and ** indicate statistical significance at the 1% and 5% levels, respectively.

Table 5.7 shows that euro-area government bonds display relatively consistent defensive behaviour. During the worst 10% of stock-return days, bonds record an average return of 0.0520%, with a p-value of 0.0022. During the worst 5% of stock-return days, the average bond return remains positive at 0.0717%, with a p-value of 0.0105. The stress-period correlations with stocks are close to zero and slightly negative.

Gold also has positive average returns during equity stress, but the evidence is less stable. In the worst 10% of stock-return days, gold records an average return of 0.1578%, which is statistically significant at the 5% level. In the worst 5% tail, gold still has a positive average return of 0.1709%, but the p-value rises to 0.1632. The result is therefore not statistically significant in the more extreme stress definition.

This distinction is central for H2. Gold behaves defensively in the broader lower-tail sample, but its safe-haven evidence weakens when the equity-loss definition becomes more severe. Bonds provide smaller average stress-period returns, but their evidence is statistically more consistent across both thresholds.

Table 5.8. Bond-gold comparison during equity-market stress

Stress definition	N	Mean bond return	Mean gold return	Gold minus bonds	p-value	Significance
Worst 10% stock-return days	533	0.0520%	0.1578%	0.1057 pp	0.1279	Not significant

Worst 5% stock-return days	267	0.0717%	0.1709%	0.0991 pp	0.4097	Not significant
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Source: Author's bond-gold comparison using lower-tail daily log returns constructed from Bloomberg data for SX5T Index, LEATTREU Index, and XAUEUR BGN Curncy. Data updated on 31 December 2025.

Table 5.8 compares bonds and gold directly. Gold has higher average returns than bonds in both lower-tail samples, exceeding bonds by 0.1057 percentage points in the worst 10% of stock-return days and by 0.0991 percentage points in the worst 5% of stock-return days. However, neither difference is statistically significant. The results do not support a strong claim that gold is superior to bonds as a safe haven.

The safe-haven evidence is mixed but informative. Bonds look more statistically reliable, while gold delivers higher average returns during stress but with weaker statistical support. This supports a cautious interpretation of H2: gold has defensive properties, but they are conditional and should be viewed as a complement to bonds rather than a replacement for them.

5.7 Hypothesis testing summary

The previous sections reported the results in separate empirical blocks. This section brings them together and evaluates the three hypotheses stated in Chapter 1. The broader discussion of the implications is left for Chapter 6; the aim here is to summarise what the empirical evidence indicates.

Table 5.9. Summary of hypothesis testing

Hypothesis	Main empirical evidence	Conclusion
H1: Regime-dependent stock-bond diversification	Stock-bond correlations differ across regimes. The GFC shows a strongly negative correlation, while the Low-inflation/QE and Post-2021 regimes remain close to zero. The 60/40 portfolio reduces volatility in every regime, but the post-2021 reduction is somewhat weaker.	Partially supported
H2: Gold as a regime-dependent hedge and safe haven	Gold has low or negative stock correlations in several regimes and positive average returns during lower-tail equity days. Its safe-haven evidence is weaker in the worst 5% tail and it does not significantly outperform bonds during stress.	Partially supported
H3: Portfolio-level weakening of diversification	DCC-GARCH estimates show persistent time-varying correlations. Diversified portfolios remain less risky than equities alone. For the 60/40 portfolio, DCC-based risk reduction is lowest in the Post-2021 inflation/tightening regime; for the 60/30/10 portfolio, the post-2021 reduction is also weaker than in most regimes, although not the lowest overall.	Partially supported

Source: Author's own summary based on the empirical results of the thesis.

H1 is partially supported. The stock-bond relationship is clearly regime-dependent. Bonds provided strong diversification during the GFC, while later regimes show correlations closer to zero. The evidence does not show a sharp post-2021 increase in stock-bond correlation relative to the Low-inflation/QE period. At the same time, the portfolio results show that the 60/40 allocation still reduces volatility in every regime, with somewhat weaker risk reduction after 2021. Bonds therefore still work as diversifiers, but their contribution is not stable across regimes.

H2 is also partially supported. Gold has low or negative stock correlations in several regimes and positive average returns during lower-tail equity days. However, its safe-haven evidence weakens in the worst 5% equity-return tail, and the direct comparison with bonds does not show that gold is significantly stronger. Gold is best interpreted as a conditional defensive asset: useful in some periods, but not a guaranteed safe haven.

H3 is partially supported as well. The DCC-GARCH estimates show persistent time-varying correlations, and the DCC-based portfolio volatility results show that diversified portfolios remain less risky than the stock-only benchmark. The post-2021 regime has the weakest DCC-based volatility reduction for the 60/40 portfolio. This supports the idea that diversification became somewhat less powerful after the inflation and tightening shift, but not that it broke down completely.

Taken together, the evidence gives a nuanced answer to the thesis question. Diversification across euro-area stocks, euro-area government bonds, and euro-denominated gold still reduces portfolio risk. The effect, however, depends on the regime and on the type of defensive asset considered. Bonds remain the main source of volatility reduction, while gold adds a smaller and more conditional contribution, especially through drawdown and stress-period protection.

5.8 Chapter summary

This chapter presented the empirical results on diversification across euro-area stocks, euro-area government bonds, and euro-denominated gold. The analysis followed the sequence set out in Chapter 4: regime correlations, rolling correlations, DCC-GARCH conditional correlations, portfolio-risk results, and lower-tail safe-haven tests.

The regime-specific correlations showed that the relationships between the three assets are not stable. The stock-bond correlation was strongly negative during the GFC, but close to zero in later regimes. The stock-gold relationship also changed across periods, which supports the view that gold is not a constant hedge.

The rolling correlations and DCC-GARCH results confirmed the same point in a dynamic setting. Dependence between the assets changes through time, and the DCC estimates indicate strong persistence in conditional correlations. These results justify the move from static correlations to portfolio-risk analysis.

The portfolio evidence provides the main answer. The stock-only portfolio had the highest volatility and deepest drawdowns, but it also delivered the highest cumulative final value. The 60/40 stock-bond portfolio substantially reduced risk, while the 60/30/10 stock-bond-gold portfolio added a smaller and more conditional improvement, mainly through the full-sample maximum drawdown, selected regime drawdowns, a higher Sharpe ratio, and slightly better post-2021 conditional risk performance.

The lower-tail tests showed that both bonds and gold have defensive characteristics during severe equity-market losses. Bonds provided more statistically consistent safe-haven evidence, while gold produced higher average stress-period returns but weaker significance in the most severe tail. This supports the interpretation of gold as a conditional complement to bonds rather than a fully reliable substitute.

Overall, the results support the three hypotheses with some qualifications. Diversification continues to reduce risk for a euro-area investor, but the size of the benefit changes across regimes, crisis episodes, and the mix of bonds and gold. Chapter 6 discusses these findings in relation to the ECB's concerns about cross-asset correlations, the stock-bond regime literature, and the evidence on gold as a hedge and safe haven.

Chapter 6. Discussion

6.1 Introduction to the discussion

Chapter 5 presented the empirical results on diversification across euro-area stocks, euro-area government bonds, and euro-denominated gold. This chapter discusses what those results mean for the research question, the hypotheses, and the literature reviewed earlier. The aim is to highlight the key insights rather than to repeat the empirical results in full.

The results do not indicate a complete failure of diversification. Rather, they show that diversification continued to reduce risk, although the magnitude of this effect varied across regimes. Over the full sample, the equity-only portfolio had annualised volatility of 21.00% and a maximum drawdown of -58.58%. The 60/40 stock-bond portfolio reduced volatility to 12.63% and improved the maximum drawdown to -38.33%. The 60/30/10 stock-bond-gold portfolio kept volatility almost unchanged at 12.63%, but improved the maximum drawdown further to -37.15%. These results show clear risk reduction relative to equities alone, but they also show that the additional contribution of gold is mainly visible in downside-risk measures rather than in average volatility.

This interpretation matters because the thesis was motivated by the concern raised in the ECB Financial Stability Review that the post-2021 inflation environment made diversification more difficult. In that period, higher inflation, tighter monetary policy, and broad asset-price adjustments created conditions in which equities and bonds could suffer at the same time (ECB, 2022). The evidence in this thesis supports that concern in a moderate sense. The post-2021 regime weakened some diversification benefits, especially for the traditional 60/40 portfolio, but it did not eliminate them.

The discussion is organised around four main points. It first interprets the stock-bond results in relation to the regime-dependent correlation literature. It then discusses gold as a hedge and safe haven. The third part focuses on portfolio-risk implications. The fourth connects the results back to the ECB's post-2021 diversification concern before outlining the main limitations of the study.

6.2 Interpretation of stock-bond diversification results

The stock-bond results confirm that the relationship between equities and government bonds is not stable over time. The static stock-bond correlation was strongly negative during the global financial crisis, at -0.4404, but moved much closer to zero in later regimes. It was 0.0439 in the low-inflation/QE period and 0.0266 in the post-2021 inflation and tightening regime. The DCC-GARCH results tell the same broad story: the mean DCC stock-bond

correlation was -0.2946 during the GFC, but only 0.0102 during the low-inflation/QE regime and 0.0127 after 2021.

This pattern is consistent with Molenaar et al. (2024), who find that stock-bond correlations change with macroeconomic factors such as inflation, real rates, and sovereign creditworthiness. The euro-area evidence in this thesis supports a similar conclusion. The link between equity returns and sovereign bond returns varied across crisis periods, low-inflation conditions, and the post-2021 tightening environment.

At the same time, the results do not support a simple story of diversification collapse. The post-2021 stock-bond correlation did not rise sharply relative to the low-inflation/QE period. In correlation terms, the strongest version of H1 is therefore not fully confirmed. The evidence shows regime dependence, but not a dramatic post-2021 jump in stock-bond co-movement.

The portfolio evidence gives a more useful interpretation. The 60/40 portfolio reduced volatility in every regime, including after 2021. In the post-2021 inflation and tightening regime, volatility fell from 17.32% for the equity-only portfolio to 10.80% for the 60/40 portfolio. However, the DCC-based risk reduction for the 60/40 portfolio was 37.93% in this regime, the lowest value across the six regimes. This is why H1 is best interpreted as partially supported: bonds remained useful diversifiers, but their contribution was not equally strong in all macro-financial environments.

For investors, this distinction is important. The results do not imply that euro-area government bonds should no longer be used for diversification. They suggest instead that the defensive role of bonds can become less reliable when inflation uncertainty, bond-market volatility, and equity-market stress occur together. A bond allocation may still reduce portfolio risk, but the size of that benefit should not be treated as fixed.

The euro-area setting makes this conclusion more nuanced. Unlike U.S. Treasuries, euro-area government bonds are not a single homogeneous safe asset. A broad euro sovereign benchmark contains issuers with different fiscal positions and spread dynamics. The euro sovereign debt crisis showed that government bonds can themselves become a source of risk in a monetary union. The fact that bonds still reduced risk in this thesis is therefore meaningful, but their defensive role should be read within this institutional context.

6.3 Interpretation of gold as a hedge and safe haven

The results also support a conditional interpretation of gold. Gold provided diversification against equities in several regimes, but the evidence was not uniform. The static stock-gold correlation was negative during the GFC (-0.1070), the euro sovereign debt crisis (-0.1325), the low-inflation/QE period (-0.0993), and the post-2021 regime (-0.0972). During COVID-19, however, the static stock-gold correlation was positive at 0.1043. The DCC results were also mostly low or negative after the pre-GFC period, but not strongly negative enough to describe gold as a stable hedge in every environment.

This result is generally aligned with the hedge and safe-haven literature. Baur and Lucey (2010) separate a hedge, which is weakly or negatively related to another asset in normal conditions, from a safe haven, which offers protection mainly during periods of financial stress. The findings of this thesis indicate that gold can serve as a diversifier and sometimes as a safe haven, but not in a stable or unconditional way.

The lower-tail tests make this point clearer. During the worst 10% of equity-return days, gold had a positive average return of 0.1578% and the result was statistically significant at the 5% level. During the worst 5% of equity-return days, gold's average return was still positive at 0.1709%, but the p-value was 0.1632, so the result was not statistically significant. Gold therefore looked defensive in the broader stress sample, but the evidence weakened in the more severe tail.

Bonds showed more statistically consistent safe-haven behaviour. Their average return was 0.0520% during the worst 10% of equity days and 0.0717% during the worst 5% of equity days, with both results statistically significant. Gold had higher average returns than bonds in both stress samples, but the differences were not statistically significant: the gold-minus-bond return difference had p-values of 0.1279 in the worst 10% sample and 0.4097 in the worst 5% sample. The evidence therefore does not support the claim that gold is clearly superior to bonds as a safe haven.

This result fits the more recent literature. Choudhury, Kinatader and Neupane (2022) show that the safe-haven behaviour of gold and sovereign bonds can vary across crisis episodes. Vieira et al. (2023) similarly emphasise that gold's hedging and safe-haven properties differ across markets and stress conditions. The findings of this thesis are consistent with that view. Gold is useful, but it is not a universal crisis asset.

The results suggest that gold is better understood as a complement to bonds.

The results suggest that gold is better understood as a complement to bonds. It can improve the portfolio's downside profile, especially through the full-sample drawdown result, selected regime drawdowns, and stress-period performance, but its effect on average volatility is modest. This explains why the 60/30/10 stock-bond-gold portfolio improved some risk measures without completely changing the overall risk profile. Its contribution is useful, but limited, especially because it does not materially reduce average volatility.

6.4 Portfolio-risk implications

The portfolio results are the most important evidence in the thesis because the research question is about portfolio risk. Correlations are useful, but they do not fully answer whether diversification works in practice. A portfolio can have low average correlations and still suffer large drawdowns during crises. For this reason, the move from dependence analysis to portfolio-risk analysis was necessary.

The full-sample results show that diversification worked in a basic risk-reduction sense. The 60/40 portfolio reduced annualised volatility from 21.00% to 12.63% and improved maximum drawdown from -58.58% to -38.33%. This confirms that euro-area government bonds remained the main stabilising asset in the portfolio. The 60/30/10 portfolio had almost identical volatility, at 12.63%, but improved the maximum drawdown further to -37.15% and produced a higher Sharpe ratio than the 60/40 portfolio. The gain from gold was therefore real, but smaller than the main effect from adding bonds.

The regime-level results tell the same story with more detail. During the GFC, the equity-only portfolio had volatility of 34.18% and a maximum drawdown of -58.06%. The 60/40 portfolio reduced these figures to 19.72% and -38.33%, while the 60/30/10 portfolio reported volatility of 19.80% and a maximum drawdown of -37.15%. In the post-2021 inflation and tightening regime, the stock-only portfolio had volatility of 17.32% and a maximum drawdown of -23.62%. The 60/40 portfolio reduced these to 10.80% and -20.98%, while the 60/30/10 portfolio reduced them further to 10.64% and -19.06%.

These numbers show two things at the same time. First, diversification did not fail after 2021: both diversified portfolios remained less risky than the equity-only benchmark. Second, the benefit was more conditional. The DCC-based risk reduction of the 60/40 portfolio was lowest in the post-2021 regime, at 37.93%, while the 60/30/10 portfolio performed slightly better at 38.26%. This supports the interpretation that gold added some incremental protection when the traditional stock-bond channel became less powerful.

The use of the EURO STOXX 50 Net Return Index also improves the consistency of the portfolio comparison. Since the equity proxy includes reinvested net dividends, it is more comparable with the total-return sovereign bond benchmark than a price-only equity index would be. The portfolio results therefore reflect a more complete measure of euro-area equity investment performance.

For H3, the conclusion is partial rather than absolute. The DCC-GARCH results show that conditional correlations are time-varying and persistent, with DCC alpha plus beta equal to 0.9750. The portfolio results show that diversification benefits continued after 2021, but were weakest for the 60/40 portfolio in that regime. Diversification still worked, but its strength depended on the regime and on whether gold was added to the bond allocation.

6.5 Relation to the ECB post-2021 diversification problem

The ECB's Financial Stability Review provides the main macro-financial motivation for the thesis. The ECB argued that the more inflationary post-pandemic environment increased cross-asset correlation risk and created challenges for diversification strategies (ECB, 2022). In 2022, many balanced portfolios experienced pressure on both the equity and bond sides, which raised doubts about the traditional role of government bonds as a defensive asset.

The findings partly support this concern. The traditional 60/40 portfolio still reduced risk in the post-2021 regime, but the DCC-based volatility reduction was the lowest among all regimes. Conditional portfolio risk also remained elevated after the inflation and tightening shock. In this sense, the post-2021 environment did make diversification more difficult.

At the same time, the results do not show a complete collapse of diversification. Stock-bond correlations remained close to zero rather than becoming strongly positive. The 60/40 portfolio continued to reduce volatility and drawdowns relative to the stock-only benchmark. The 60/30/10 portfolio improved the post-2021 drawdown further, from -20.98% for the 60/40 portfolio to -19.06%. This qualifies the ECB-related concern: the issue is not that diversification disappeared, but that its protection became less reliable.

The post-2021 regime should therefore be understood as a stress test for diversification. The traditional stock-bond portfolio still worked, but less strongly than in some earlier periods. Gold improved some downside-risk measures, but it did not fully offset the weaker environment for bond-based diversification.

For euro-area investors, the implication is straightforward. Diversification remains valuable, but it should be evaluated across regimes rather than inferred from long-run averages.

A portfolio that looks well diversified in a low-inflation environment may provide less protection when inflation shocks, rate increases, and bond-market repricing affect several asset classes at the same time.

6.6 Limitations of the empirical findings

The findings should be interpreted in light of several limitations. The first concerns the equity proxy. The thesis uses the EURO STOXX 50 Net Return Index, which is appropriate for dividend-adjusted euro-area equity performance. However, it covers only 50 large-cap companies and does not represent the entire euro-area equity market. Thus, the results should be interpreted as relevant to large-cap euro-area equities, not all European stocks.

A related point is that a net return index assumes a specific treatment of dividends after withholding taxes. While more suitable than a price index for portfolio analysis, it does not capture the individual tax circumstances of all investors. Consequently, the results are best viewed as benchmark evidence rather than realised returns for a specific investor.

Second, the bond proxy, a broad euro-area government bond benchmark, captures diversified sovereign exposure but does not distinguish between core and peripheral bonds. This matters because the euro sovereign debt crisis showed that sovereign risk is not uniform across member states. A more detailed study could separate German Bunds, French government bonds, Italian government bonds, Spanish government bonds, and other sovereign issuers.

A third limitation is the restricted asset universe. The thesis focuses only on stocks, government bonds, and gold. This is appropriate for the title and keeps the empirical design manageable, but it excludes other assets that may matter for diversification, such as corporate bonds, inflation-linked bonds, cash, real estate, or broader commodity indices. Including these assets could provide a broader view of portfolio resilience.

The fourth limitation is methodological. DCC-GARCH is suitable for modelling time-varying correlations in a three-asset framework, but it is not the only possible method. Other approaches, such as copula models, quantile regressions, or connectedness frameworks, could capture different aspects of dependence and tail risk. These methods were not used because they would move the thesis away from its focused portfolio-risk question.

The fifth limitation concerns portfolio construction. The thesis uses fixed-weight benchmark portfolios. This makes the results transparent and easy to interpret, but it does not represent an optimised investment strategy. The analysis also does not include transaction costs,

taxes, rebalancing costs, or investor-specific constraints. The portfolios should therefore be understood as analytical benchmarks rather than practical investment recommendations.

Finally, the post-2021 inflation and monetary-tightening regime is relatively short compared with the full sample. While the findings for this period are informative, they should not be treated as definitive forecasts for future stock-bond-gold relationships. Future regimes may produce different patterns of inflation, monetary policy, and cross-asset dependence.

6.7 Chapter summary

This chapter interpreted the empirical findings from Chapter 5. The results show that diversification across the EURO STOXX 50 Net Return Index, euro-area government bonds, and euro-denominated gold still reduces portfolio risk. The evidence is not consistent with a complete breakdown of diversification, but it also does not support the idea that diversification works with the same strength in every regime.

The stock-bond results support a regime-dependent interpretation. Bonds remained useful diversifiers, but their risk-reduction benefit was somewhat weaker in the post-2021 inflation and tightening regime. Gold added a conditional layer of protection, mostly through downside measures: the full-sample drawdown result, selected regime drawdowns, and positive lower-tail returns. However, its safe-haven evidence was less statistically consistent than that of bonds.

Overall, the findings suggest a cautious conclusion. Diversification still reduces risk, but its effect changes across regimes. Bonds remain the main stabilising asset in the portfolio, while gold works better as an additional layer of protection than as a substitute for bonds. The post-2021 regime did not destroy diversification benefits, but it made them more conditional and less reliable than in some earlier periods.

The final chapter concludes the thesis by answering the research question directly, summarising the hypotheses, and outlining possible directions for further research.

Chapter 7. Conclusion and Further Research

7.1 Conclusion

This thesis examined whether diversification across euro-area stocks, euro-area government bonds, and euro-denominated gold still reduces portfolio risk before, during, and after major market crises. The study was motivated by the concern that the post-2021 inflation and tightening environment made traditional diversification less reliable, especially after a period in which both equities and bonds came under pressure.

The empirical analysis used three core proxies: the EURO STOXX 50 Net Return Index (SX5T) for euro-area equities, a broad euro-area government bond benchmark, and gold priced in euro. The sample covered the period from 2005 to 2025 and was divided into six regimes: Pre-GFC, GFC, euro sovereign debt crisis, Low-inflation/QE, COVID-19, and Post-2021 inflation/tightening. This regime structure allowed the thesis to examine whether the same portfolio logic held across very different market conditions.

The main conclusion is that diversification has not disappeared, but its effectiveness is conditional. Over the full sample, the stock-only portfolio had annualised volatility of 21.00% and a maximum drawdown of -58.58%. The 60/40 stock-bond portfolio lowered volatility to 12.63% and improved the maximum drawdown to -38.33%. The 60/30/10 stock-bond-gold portfolio had almost the same volatility, at 12.63%, but improved the maximum drawdown further to -37.15%. These results show that diversified portfolios reduced risk relative to equities alone. This should be read as a risk-reduction result, not as evidence that diversified portfolios produced the highest return.

The evidence supports a cautious yes: diversification reduced risk, but it did not deliver the same level of protection in every regime. Bonds remained the main source of portfolio risk reduction, while gold added a smaller and more conditional contribution, mainly through the full-sample drawdown result, better outcomes in selected regimes, and stress-period behaviour. Diversification still worked for a euro-area investor, but it should not be treated as a stable property that holds with the same strength in all macro-financial environments.

7.2 Answer to the research question

The research question asked whether diversification across EURO STOXX 50 net-return equities, euro-area government bonds, and euro-denominated gold still reduces portfolio risk before, during, and after major market crises, once regime-dependent stock-bond correlations and the time-varying hedge and safe-haven properties of gold are taken into account.

The evidence suggests that the answer is broadly yes, although only in a risk-reduction sense. Diversification across the three assets continued to reduce portfolio risk compared with an equity-only position. Government bonds remained the most important stabilising asset, especially in terms of volatility reduction. Gold contributed as well, but more modestly. Its clearest effect appeared in the full-sample maximum drawdown and in some lower-tail equity-market episodes rather than in a large reduction of average volatility.

The post-2021 inflation and tightening regime did not eliminate diversification benefits. In that period, the 60/40 portfolio still reduced volatility relative to the stock-only benchmark, from 17.32% to 10.80%. However, the DCC-based results showed that the post-2021 regime had the weakest volatility reduction for the 60/40 portfolio, at 37.93%. The 60/30/10 portfolio performed slightly better in this regime, with a DCC-based risk reduction of 38.26%. This suggests that gold improved the post-2021 allocation slightly, although the overall risk profile remained close to that of the 60/40 portfolio.

The evidence therefore does not support the view that diversification failed after 2021. A more accurate interpretation is that diversification became more regime-dependent. The traditional stock-bond allocation still reduced risk, but its protective strength was less reliable in the inflation and tightening environment than in some earlier periods.

7.3 Summary of hypotheses

The first hypothesis expected euro-area government bonds to provide stronger diversification in low-inflation and non-crisis regimes, while their risk-reduction benefit would weaken in the post-2021 inflation regime. The results support this hypothesis only partly. The stock-bond relationship clearly changed across regimes: it was strongly negative during the GFC, but much closer to zero in later periods. At the same time, the post-2021 stock-bond correlation did not rise sharply relative to the Low-inflation/QE period. The static correlations were 0.0439 in the Low-inflation/QE regime and 0.0266 in the Post-2021 regime, while the DCC averages were also very close, at 0.0102 and 0.0127 respectively. The weakening of diversification was therefore more visible in portfolio-risk measures than in the correlation coefficients alone.

The second hypothesis expected gold to behave as a regime-dependent hedge and occasional safe haven, but not as a uniform source of protection. The results are also mixed for H2. Gold had low or negative correlations with equities in several regimes and produced positive average returns during lower-tail equity days. During the worst 10% of stock-return days, gold had a positive average return of 0.1578% and the result was statistically significant

at the 5% level. In the worst 5% tail, gold still had a positive average return of 0.1709%, but the result was not statistically significant. Bonds showed more statistically consistent safe-haven evidence across both stress definitions. Gold should therefore be interpreted as a useful complement to bonds, not as a guaranteed replacement for them.

The third hypothesis expected portfolio-level diversification benefits to weaken after major crises and especially after the post-2021 inflation regime shift. The evidence for H3 is again mixed, but it is stronger at the portfolio-risk level than at the correlation level. The DCC-GARCH results showed persistent time-varying correlations, with the sum of DCC alpha and beta equal to 0.9750. Diversified portfolios remained less risky than the stock-only benchmark across regimes. The post-2021 period produced the weakest DCC-based volatility reduction for the 60/40 portfolio, while for the 60/30/10 portfolio the post-2021 reduction was weaker than in most regimes, but not the lowest overall. This supports the idea that the inflation and tightening shift made diversification less reliable, without implying a complete breakdown.

Taken together, the hypotheses are supported in a qualified form. The results do not show that bonds, gold, or diversified portfolios provide constant protection. They show that protection is still present, but it is not stable across all conditions. Its strength depends on the regime, the type of shock, and the way bonds and gold behave alongside equities.

7.4 Limitations

Several limitations should be noted. First, the thesis uses the EURO STOXX 50 Net Return Index as the equity proxy. This is appropriate for a portfolio-risk study because it includes reinvested net dividends and is more comparable with the total-return bond benchmark than a price index would be. However, it still represents only 50 large-cap euro-area companies. The results should therefore be interpreted as evidence for large-cap euro-area equity exposure rather than for the full European equity market.

Second, the bond proxy is a broad euro-area government bond benchmark. This is useful for capturing diversified sovereign bond exposure, but it does not distinguish between core and peripheral euro-area bonds. This matters because the euro sovereign debt crisis showed that sovereign risk differs across member states. A more detailed study could separate German, French, Italian, Spanish, and other government bond markets.

Third, the asset universe is deliberately limited to stocks, government bonds, and gold. This keeps the thesis focused and consistent with the research question, but it excludes other possible diversifiers such as corporate bonds, inflation-linked bonds, cash, real estate, and

broader commodity indices. Including these assets could produce a fuller picture of portfolio resilience.

Fourth, the methodology relies on static correlations, rolling correlations, DCC-GARCH, portfolio-risk measures, and lower-tail safe-haven tests. These methods are suitable for a three-asset bachelor thesis, but they do not capture every aspect of dependence. More advanced methods, such as connectedness analysis, copulas, or quantile regressions, could provide additional evidence on spillovers and tail dependence.

Finally, the portfolio analysis uses fixed-weight benchmark portfolios. This makes the results transparent and easy to compare, but it does not represent an optimised investment strategy. The analysis also does not include transaction costs, rebalancing costs, investor-specific taxes, or practical constraints. The portfolios should therefore be understood as analytical benchmarks rather than direct investment recommendations.

7.5 Further research

Future research could extend this thesis in several directions. A first extension would be to compare the EURO STOXX 50 Net Return Index with broader European equity benchmarks, such as the STOXX Europe 600 or MSCI EMU indices. This would show whether the results are specific to large euro-area blue-chip firms or whether they also hold for broader equity exposure.

A second extension would be to analyse euro-area government bonds in more detail. Instead of using one broad benchmark, future studies could distinguish between core and peripheral sovereign bonds. This would be especially useful for understanding how fragmentation risk affects the defensive role of government bonds in the euro area.

A third extension would be to broaden the asset universe. Inflation-linked bonds, corporate bonds, cash, oil, broader commodity indices, and real estate could be added to examine whether a wider portfolio provides stronger protection in inflationary regimes. This would also allow a more complete assessment of diversification after the post-2021 regime shift.

Future research could also use more advanced dependence methods. Connectedness models could show how shocks are transmitted between asset classes, while copula or quantile-based approaches could focus more directly on tail dependence. These methods were outside the scope of this thesis, but they would be useful for a more detailed study of crisis-period diversification.

Finally, the post-2021 regime should be revisited when more data become available. This regime is central to the thesis, but it is still relatively short compared with the full 2005-2025 sample. Additional years of data would make it possible to assess whether the weaker 60/40 performance observed after 2021 is temporary or part of a more persistent change in the stock-bond-gold relationship.

Overall, this thesis concludes that diversification has not disappeared for euro-area investors. Bonds remain the main source of portfolio risk reduction, while gold provides additional but more limited protection. The effectiveness of a stock-bond-gold portfolio depends on the regime and should be evaluated dynamically rather than assumed from long-run averages.

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