UNIVERSITY OF PIRAEUS

DEPARTMENT OF BUSINESS ADMINISTRATION

MBA TQM INTERNATIONAL

Financial Stress Index Construction: The Case of Greece

Master's thesis

MBA Total Quality Management International

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ΠΑΡΑΡΤΗΜΑ Δ: **ΥΠΕΥΘΥΝΗ ΔΗΛΩΣΗ** **ΕΚΠΟΝΗΣΗΣ ΔΙΠΛΩΜΑΤΙΚΗΣ ΕΡΓΑΣΙΑΣ**

ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ

ΤΜΗΜΑ ΟΡΓΑΝΩΣΗΣ ΚΑΙ ΔΙΟΙΚΗΣΗΣ ΕΠΙΧΕΙΡΗΣΕΩΝ

Μεταπτυχιακό Πρόγραμμα Σπουδών

στη «Διοίκηση Επιχειρήσεων – Ολική Ποιότητα» με διεθνή προσανατολισμό

ΒΕΒΑΙΩΣΗ ΕΚΠΟΝΗΣΗΣ ΔΙΠΛΩΜΑΤΙΚΗΣ ΕΡΓΑΣΙΑΣ

(περιλαμβάνεται ως ξεχωριστή [δεύτερη] σελίδα στο σώμα της διπλωματικής εργασίας)

Δηλώνω υπεύθυνα ότι η διπλωματική εργασία για τη λήψη του μεταπτυχιακού τίτλου σπουδών, του Πανεπιστημίου Πειραιώς, στη Διοίκηση Επιχειρήσεων - Ολική Ποιότητα με διεθνή προσανατολισμό με τίτλο:

Financial Stress Index Construction: The Case of Greece

έχει συγγραφεί από εμένα αποκλειστικά και στο σύνολό της. Δεν έχει υποβληθεί ούτε έχει εγκριθεί στο πλαίσιο κάποιου άλλου μεταπτυχιακού προγράμματος ή προπτυχιακού τίτλου σπουδών, στην Ελλάδα ή στο εξωτερικό, ούτε είναι εργασία ή τμήμα εργασίας ακαδημαϊκού ή επαγγελματικού χαρακτήρα.

Δηλώνω επίσης υπεύθυνα ότι οι πηγές στις οποίες ανέτρεξα για την εκπόνηση της συγκεκριμένης εργασίας, αναφέρονται στο σύνολό τους, κάνοντας πλήρη αναφορά στους συγγραφείς, τον εκδοτικό οίκο ή το περιοδικό, συμπεριλαμβανομένων και των πηγών που ενδεχομένως χρησιμοποιήθηκαν από το διαδίκτυο.

Παράβαση της ανωτέρω ακαδημαϊκής μου ευθύνης αποτελεί ουσιώδη λόγο για την ανάκληση του πτυχίου μου.

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Ονοματεπώνυμο ... Επίσκοπος Ιωάννης

Ημερομηνία ... 28/2/2024

Σελίδα 14

Abstract

This thesis develops and evaluates a Financial Stress Index (FSI) for Greece. The FSI is constructed using market-based variables that correspond to five segments of the Greek financial markets, namely, the money market, and bank, equity, bond, and foreign exchange markets. The variables are aggregated via the variance-equal weight method and transformed via the logistic sigmoid function to form a gauge of financial stress scaled from 0 to 1. Using observations from the past 22 years, our index covers the entire era of Greek participation in the eurozone. Furthermore, its daily frequency facilitates its use for responsive policy decisions in the rapidly changing financial environment that characterizes emerging markets, particularly in the European periphery. By validating the constructed FSI against known periods of financial stress, we conclude that it performs well in identifying major individual stress events.

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1 Introduction

In Finance, index construction is a broad area of study with important practical applications. For example, a stock index such as the S&P 500, offers a measure of the average level of share prices on the top 500 exchange-listed companies in the United States. In the same spirit, researchers are interested in a measure of the tensions that occasionally develop in the financial system, tensions that can lead to a financial crisis and have severe consequences for the economy. The Global Financial Crisis that started in 2007 in the United States and spread to the world highlighted the significance of early warning systems and intensified research of the so-called financial stress indexes (FSIs). These indexes would then be used by policy makers and practitioners in decision making by governments and firms.

This thesis falls within the realm of FSI construction, and the topic focuses on the case of Greece, a member state of the European Union. To briefly describe the thesis and motivate the topic, we start with the nature of FSI construction. Published research has used economic and market variables, such as the stock market level and volatility, that capture the sentiment of economic agents in a particular geographic area. These variables are then aggregated to form an FSI. Finally, the index is validated against a set of observed instances of extreme stress.

The existing literature on FSIs is rather thin, and there is only a handful of papers that study European FSIs. The broader FSI literature emphasizes on the common influences among markets, given the globalized nature of these markets. However, there are unique factors within each country leading to financial stress. These factors, for example, may be institutional, legal, or geopolitical, and they differentiate each financial crisis with respect to intensity and consequences for the markets and the economy. Greece is unique in several respects. Although it is a small market and naturally shares the same characteristics as other emerging markets, it is part of the European Union (EU). Eurozone's debt crisis right after the Global Financial Crisis highlights the importance of measuring the financial stress level of Greece, hence the significance of this thesis' topic.

Regarding the contribution of the present thesis to the financial literature, there is only one published paper on Greek FSI construction (Louzis and Vouldis, 2012), which however uses monthly observations for its variables, and refers to the 1998 to 2010 period. Our model uses more recent, daily data that span 22 years, from Greece's adoption of the euro to the present day. The thesis develops answers to the following research questions: How is a daily Financial Stress Index constructed for a developing European country such as Greece? How is such an index validated based on specific historical dates of market stress? Can the proposed index capture well known and unexplored stress events such as the COVID-19 and the Russia-Ukraine war periods?

Answering these questions will fill the gap in the literature and provide insights for researchers studying FSIs in general. Greece's unique position within the EU periphery and its relation to the Eurozone debt crisis provide an important opportunity to study the problem of measuring financial stress. Furthermore, the daily focus of this

research highlights the value of the constructed FSI for policy makers in Greece and the EU and for international financial practitioners.

The rest of the thesis is structured as follows: Section 2 reviews the literature regarding Financial Stress Indexes, Section 3 presents the methodology used for the construction of Greece's FSI, Section 4 evaluates the FSI by comparing it to known periods of high stress, and Section 5 summarizes the conclusions drawn.

2 Literature Review

The construction of a comprehensive measure of financial stress has attracted academic interest, especially after the onset of the Global Financial Crisis. This measure usually has the form of an index that results from the combination of a series of variables related to various financial phenomena. However, the discussion of Financial Stress Indexes requires the definition of the main concepts revolving around financial stress and financial indexes. In this section, we review the various definitions of financial stress, as well as the literature of Financial Stress Indexes.

2.1 Defining Financial Stress

"Financial stress" is an empirically perceived concept widely referred to throughout the literature. What is particularly interesting about this concept is that it lacks a universally accepted definition. Instead, academics have provided a plethora of definitions. Hakkio and Keeton (2009) broadly define financial stress as "an interruption to the normal functioning of financial markets". Monin (2017) uses a nearly identical definition: "We define financial stress to be disruptions in the typical functioning of financial markets". Illing and Liu (2006) provide a more specific definition: "Financial stress is defined as the force exerted on economic agents by uncertainty and changing expectations of loss in financial markets and institutions". They describe stress as a spectrum with values that increase with expected financial loss, risk, or uncertainty. The situations of extreme stress values are characterized as crises. Holló, Kremer, and Lo Duca (2012) emphasize systemic risk, defining systemic stress as "that amount of systemic risk which has already materialized". Others plainly describe financial stress as "financial instability" (Brave and Butters, 2011; Nelson and Perli, 2007).

In the absence of a generally accepted and concise definition, academics have associated financial stress with certain financial phenomena. Hakkio and Keeton (2009) propose the following: i) increased uncertainty about the fundamental value of assets, ii) increased uncertainty about the behavior of other investors, iii) increased asymmetry of information, iv) decreased willingness to hold risky assets (flight to quality), v) decreased willingness to hold illiquid assets (flight to liquidity). For the purposes of this research, we accept the definition provided by Hakkio and Keeton (2009) and will attempt to gauge financial stress via the five phenomena they propose.

2.2 Financial Index Construction

Financial index construction is a systematic process aimed at encapsulating a series of financial metrics to reflect the dynamics of complex financial markets. This process involves the methodical selection of constituent elements, typically equities, bonds, or other financial instruments and their aggregation into a representative composite by applying sophisticated statistical and mathematical frameworks. Financial indexes mirror the broader market's performance, and thus serve as essential

tools that facilitate informed decision-making for investors, researchers, and policymakers.

Financial Stress Indexes incorporate variables such as volatility indicators, credit spreads, correlations, and balance sheet data to assess the degree of market instability. Each variable measures one or more stress-related phenomena in a certain market of the financial system. For instance, the spread between high-yield and risk-free bond reflects investor fight to quality in the debt market. The aggregation of multiple variables representing various markets and stress-related phenomena enables FSIs to identify periods of heightened market instability by quantifying the level of stress. The importance of this feature lies in the FSI's capability to signal periods of high underlying stress in cases in which no apparent financial event signals the beginning of a crisis. Furthermore, FSIs can often be used to determine whether a financial shock may propagate into the wider economic system.

Most articles in the FSI literature follow a common structure that consists of roughly three steps:

1. First, a set of variables that reflect financial stress are selected.
2. Second, the variables are combined into a single index through a statistical or mathematical aggregation method.
3. Finally, the performance of the index is evaluated using a series of selected crises.

Our review of the FSI literature focuses on each individual step in the above procedure.

2.3 Variable Selection

The variables are mostly selected subjectively, in a manner that reflects each country's financial stress (Kliesen, Owyang, and Vermann, 2012). They typically include economic fundamentals, yields, interest rate spreads, stock market indicators, volatility indicators, and foreign exchange indicators. Illing and Liu (2006) construct a daily FSI for Canada using variables that cover the equity, bond, and foreign exchange markets, as well as the banking sector. For the banking sector, they use the beta coefficient, which is the ratio of the covariance of the banking index over the variance of the market index. For the foreign exchange and equity markets, they use a hybrid volatility-loss measure, namely, CMAX, which is the ratio of the current exchange rate to the maximum of its value over the previous one or two years. The Canada–U.S. 90-day treasury bill spread is used to proxy credit risk in the debt markets, which in turn is a function of expected loss. Liquidity is measured by the bid-offer spread on 90-day Government of Canada treasury bills, as well as the spread between short-term bond yields of Canadian government bonds and the 90-day commercial paper rate. An increased bid-offer spread for the risk-free, frequently traded 90-day treasury bills signals a decrease in liquidity, as investors demand a higher premium for executing trades quickly. An increased spread between the commercial paper rate and the treasury bill rate is an indication of increased funding risk; risk-averse investors shift from bank

bonds to government bonds, causing the market price of the former to drop, thus widening the spreads. Given the selected variables, the authors use three approaches: The first is standard in the literature, the second is refined where possible, and the third extracts volatility measures via a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model on the price series.

Hakkio and Keeton (2009) of the Federal Reserve Bank of Kansas City created the monthly Kansas City Financial Stress Index (KCFSI) that consists of eleven variables. The spread between the 3-month London Interbank Offered Rate (LIBOR) and the Treasury Bill rate is used to proxy credit risk. The 2-year interest rate swap spreads represent the difference between the fixed-rate payments and the floating rate payments in a two-party interest rate swap agreement; the floating rate payments are usually dependent on the LIBOR. The two variables reflect flight to liquidity and quality. The authors use the spread between off-the-run and on-the-run 10-year Treasury securities to capture investor flight to liquidity. Off-the-run securities are more difficult to liquidate, as their market is not as deep as that of on-the-run securities. Bond spreads (AAA/Treasury securities, BAA/AAA, high-yield/BAA) and consumer asset-backed security spreads are used as a proxy for flight to quality. During normal periods, asset-backed securities are relatively low-risk investments because the underlying loans are geographically dispersed and thus unlikely to simultaneously default. However, during periods of financial stress, investors demand higher premiums for holding such assets, a behavior reflected in consumer asset-backed security spreads. The authors also include the correlation between returns on stocks and Treasury bonds. An investor flight to quality (from stocks to bonds) can be observed when the correlation tends to turn negative. Uncertainty about the fundamental value of assets and the behavior of other investors is gauged through the implied volatility of stock prices (VIX) and the idiosyncratic volatility of bank stock prices (IVOL). The VIX is derived from the current prices of one-month, equity call and put options, and measures the expected average volatility in the next thirty days. The VIX is also known as the "fear index", as it is negatively correlated with the S&P 500 index. The IVOL is the standard deviation of unexpected daily returns of the banking stock index during a month, and thus it is a measure of the current volatility of the banking sector. Finally, Hakkio and Keeton (2009) capture the increased asymmetry of information by including the cross-section dispersion of bank stock returns. Increases in stock market returns that cannot be explained by movements in the overall market indicate asymmetry of information between investors and banks.

Grimaldi (2010) identifies sixteen daily observed financial variables from the corporate bond, government bond, banking, equity, and money markets. The author uses corporate bond spread variables related to three different rating classes (AA, BBB, and high yield), as well as long-term European versus German government bond spread. The Dow Jones Euro Stoxx Financial index is selected as a proxy for stress in the banking sector stocks, as it can signal the development of bubbles and detect sudden crashes. Equity market stress is measured using share prices, actual earnings per share, and equity risk premium. Stock prices and actual earnings per share indicate equity market performance, while the equity risk premium reflects investor risk aversion. Stress in the money market is captured first by the spread between the EURIBOR (Euro

Inter Bank Offered Rate) and EONIA (Euro Over Night Index Average) rates. EURIBOR is a daily-published average of the borrowing cost of each bank from other banks in Europe. European banks that are short of cash report higher costs, and this liquidity premium is reflected in a higher EURIBOR. The EONIA functions as a benchmark risk-free interest rate. In addition, the spread between the European Central Bank's (ECB) main refinancing rate (the interest rate for banks borrowing from the ECB in the medium term) and the 2-year bond yield is used, because its downward trend indicates a worsening monetary liquidity. Finally, a series of volatility variables (long implied bond volatility, implied stock volatility) function as proxies for risk aversion.

Holló, Kremer, and Lo Duca (2012) create the Composite Indicator of Systemic Stress (CISS) for the Euro area. The authors focus on the most important segments of an economy's financial system: financial intermediaries, money markets, equities, bonds, and foreign exchange markets. Regarding the raw indicators, the authors also mainly use return volatilities and spreads. One volatility measure corresponds to each segment of the financial system, namely: realized volatility of the 3-month EURIBOR rate (money markets), realized volatility of the Datastream non-financial sector stock market index (equity markets), volatility of the German 10-year benchmark government bond index (bond markets), realized volatility of the idiosyncratic equity return of the Datastream bank sector stock market index over the total market index (financial intermediaries), and realized volatility of the euro exchange rate vis-à-vis the US dollar, the Japanese Yen and the British Pound, respectively (foreign exchange market). In a similar manner, the authors use two more variables for each segment. More specifically, for the money market, they use the interest rate spread between 3-month EURIBOR and 3-month French T-bills, as well as the Monetary Financial Institution's (MFI) emergency lending at Eurosystem central banks, divided by their total reserve requirements. These variables are a proxy to interbank lending liquidity, and central bank lending respectively. The bond market is represented by A-rated corporation/ government spreads and 10-year interest rate swap spreads, while the equity market by the CMAX for the non-financial sector and the stock-bond correlation. The CMAX interacted with the book-price ratio for the financial sector equity market index is used along the spreads between A-rated financial and non-financial corporations to reflect the stress in financial intermediaries.

Louzis and Vouldis (2012) create the Financial Systemic Stress Index (FSSI) for Greece in a monthly frequency using both market and balance sheet data. They select fourteen individual stress variables that correspond to different segments of the financial system. To capture stress in the fundamentals of the Greek economy, they employ the 10-year Greek-German bond spread, the yield realized volatility of the 10-year Greek bond, as well as the correlation between returns on Greek stocks and German bonds. For the banking sector, the authors use the banking index, its realized volatility, the idiosyncratic risk of bank stock prices (beta coefficient), and the BBB/German bond spreads. They also include balance sheet variables such as bank interest margin, which reflects bank profitability, deposit gaps and loan gaps. The latter two refer to the cyclical component of total deposits and loans respectively. Negative values reflect reduced bank liquidity and unwillingness to lend. For the equity markets,

the authors include the CMAX transformation of the General Index of Athens Stock Exchange, its realized volatility, and stock earnings per share. Finally, money market stress is calibrated through the 3-month EURIBOR/3-month German T-bill spread.

Monin (2017) describes the daily financial stress index developed by the Office of Financial Research (OFR). OFR was created following a mandate of the Dodd-Frank Act of 2010, and its purpose is to develop and maintain metrics and reporting systems for risks to financial stability. The author selects 33 stress indicators, aiming to cover five segments of the financial system (credit, equity valuation, funding, safe assets, and volatility) for the United States, other advanced economies, and emerging markets. In the credit category, there are measures of credit spreads (option adjusted), on securities such as US corporate and US high yield bonds, Euro area corporate bonds, and Japan corporate bonds, among others. The equity valuation category includes price-to-book ratios for the emerging market index, the Nikkei 225 index, the European stocks index, and the S&P 500 index. The funding category consists of spreads that reflect how easily financial institutions can fund their activities, such as the 2-year USD/EUR cross-currency swap spread, the 2-year US swap spread, 3-month EURIBOR-EONIA, and the3-month TED spread. For the safe assets category, the author uses the yields of the 10-year US Treasury note and the 10-year German bond, along with the spot exchange rates between gold, the USD, the Japanese Yen, and the Swiss Franc. In the volatility category, there are measures of implied and realized volatility from equity, credit, currency, and commodity markets, as follows: S&P 500 Volatility Index (VIX), Dow Jones EURO STOXX 50 Volatility Index (V2X), ICE Brent Crude Oil Futures volatility, Implied Volatility on 6-Month EUR/USD Options, Emerging Market Volatility Index, and NIKKEI Volatility Index, among others.

2.4 Variable Aggregation

Throughout the literature, we find several methods in which individual variables are combined into a single FSI. While in some cases all the variables are directly aggregated through a statistical or mathematical method, a common practice is the grouping of variables into thematic subindexes prior to aggregation (Holló, Kremer, and Lo Duca, 2012; Louzis and Vouldis, 2012; Song and Li, 2021; MacDonald, Sogiakas, and Tsopanakis, 2018).

Illing and Liu (2006) discuss and use four of the existing methods in the literature, namely, factor analysis, credit weights, variance-equal weights, and transformations based on cumulative distribution functions (CDFs). The variance-equal weights method assumes variables are normally distributed and standardizes each variable, subtracting the mean and dividing by the standard deviation, before summing them into a single index. This method, also used by Song and Li (2021) and MacDonald, Sogiakas and Tsopanakis (2018), gives equal importance to each variable. Holló, Kremer, and Lo Duca (2012) find the normality assumption problematic because financial variables of high frequency often do not follow normal distributions, and instead use an empirical CDF to transform the variables to order statistics in a manner that high ranking percentiles correspond to high stress. The aggregation methodology

they propose considers time-varying cross-correlations estimated recursively based on Exponentially Weighted Moving Averages (EWMA), thus assigning more weight on situations in which high stress is evident on several market segments simultaneously. The impact of each market segment on the overall stress is determined through portfolio-theoretical principles, based on its relative impact on economic activity, and more specifically on industrial production growth.

In the spirit of Holló, Kremer and Lo Duca (2012), Louzis and Vouldis (2012) use a multivariate Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model to capture the time-varying nature of the cross correlations between stress variables, which they find to be more sensitive than the EWMA model. They use principal component analysis in each of the areas above to find the first principal component which explains most of the variation within each set of raw stress indicators. This leads to five subindexes which are then scaled from 0 to 1 by using the logistic transformation. Subindex portfolio weights are deduced by examining their impact on the growth rate of an economic activity index, which in turn is the first principal component of five variables (unemployment, manufacturing index, exports, imports, and producer's price index).

Hakkio and Keeton (2009) and Monin (2017) use PCA to capture the co-movement of the variables. Hakkio and Keeton (2009) identify financial stress as the factor most influencing the eleven variables after standardization and compute it as the first principal component (the first eigenvalue) of the sample correlation matrix. The weights with which each variable enters the FSI are computed by the first eigenvector of the correlation matrix, that is, from each variable's loadings to the first principal component. Monin (2017) also standardizes the variables before applying a dynamic factor model with a single latent factor, which is a generalization of classical principal components analysis. This model re-estimates the indicator weights each time the FSI is calculated based only on information up to that date, which means that no re-estimation of the whole series is necessary. In addition, the index is easily decomposed into five constituent subindexes, corresponding to the five categories above.

Grimaldi (2010) creates two summary indexes, the first of which captures the level of the variables, while the other captures their rate-of-change. A logit model extracts the information contained in the two complimentary indexes, creating a binary variable (stress and no-stress). The FSI is the fitted probability from this model.

2.5 Index Evaluation and Identification of Stress Events

The most common evaluation method found in the literature is the comparison of the index time series with known periods of high financial stress. Illing and Liu (2006) construct a list of events drawn from reviews of Bank of Canada Annual Reports and Monetary Policy Reports. These events are subsequently graded on a 1-3 scale based on their severity in a survey of senior officials and economists at the Bank of Canada. The authors compare these events with periods in which the FSI exceeds the two-standard-deviation threshold and evaluate the various FSIs on their Type I and II errors. Following Illing and Liu (2006), Louzis and Vouldis (2012) identify periods of

stress by conducting a survey in which financial experts evaluate the level of stress each suggested event caused to the Greek financial system in a scale of 0 to 4. Using this scale, the events with an average score of over two are characterized as financial crises. The authors also evaluate the property of the FSSI as a leading stress indicator via a probit model.

Hakkio and Keeton (2009) find the standard deviation threshold proposed by Illing and Liu (2006) problematic, as new observations alter both the mean and the standard deviation. They stress that a period could be classified as high-stress before the addition of the new observations, and as low-stress afterwards. Instead, they propose a percentile approach, in which the 90^{th} percentile would signal high stress, as well as a benchmark approach. Instead of defining stress events, they compare the peaks of their FSI to known periods of financial stress, practically ensuring the FSI produces no Type II errors. This practice is also employed by Monin (2017) and Song and Li (2021).

In Grimaldi (2010), dating periods of stress in the European Union is mainly conducted by using a textual search of the ECB Bulletins. The frequency of positive and negative words is used to pinpoint major periods of financial stress in the EU from July 1999 to October 2009. The threshold between high and low stress periods is set by the yearly average of positive or negative words. To evaluate their FSI, the author first compares its values to the VSTOXX index and applies a loss function optimization method to minimize its Type I & II errors.

Holló, Kremer, and Lo Duca (2012) are skeptical of the event-based criterion, as it is likely to exclude periods of undelrying or developing systemic stress that are not directly associated with a specific triggering event. The authors also point out that the criterion requires crises to be well defined in terms of time, especially in cases of high-frequency FSIs. They evaluate their own FSI in the spirit of Hakkio and Keeton (2009), examining whether each peak is generally associated with a known crisis. To identify periods of extreme stress in the financial system, they apply two non-linear empirical frameworks: The first is an autoregressive Markov-switching model employed to capture the regime dependence of the FSI. The second approach is a bivariate threshold regression model that uses the growth in industrial production as an observable variable that reflects the real economy.

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3 FSI Construction Methodology

The literature review on Financial Stress Index construction reveals a wide spectrum of methods for selecting financial metrics, aggregating them into a single index, and evaluating the produced index. For the purposes of the present thesis, we compare the methods and preliminarily decide the preferable framework for the construction of a daily FSI for Greece.

3.1 Variable Selection and Data Description

Throughout the FSI construction literature, the types of variables used present a substantial overlap (Kliesen, Owyang, and Vermann, 2012). Academics use a variety of spreads, correlations, stock market indicators, and volatility indicators that derive, in their majority, from organized exchanges. Exchanges provide valuable information because their prices reflect investor sentiment and consumer expectations. Provided that these markets are efficient, they should immediately and correctly embody all the arriving information.

The guidelines of variable selection are dictated by the frequency of input data observations (i.e., quarterly, monthly, weekly, or daily). Although high-frequency data tend to be more volatile and prone to false signals (Kliesen, Owyang and Vermann, 2012), the related indexes are significantly more effective in real-time decision-making, as they reveal rapidly evolving economic conditions, a crucial element for a gauge of financial stress. For that reason, we employ daily variables. As noted earlier, this feature differentiates this thesis and fills the gap in the existing literature for Greece.

Following the work of Grimaldi (2010), Holló, Kremer, and Lo Duca (2012), and Louzis and Vouldis (2012), we categorize our variables into five large market segments: the money market, as well as the banking, equity, bond, and foreign exchange markets. The data is drawn from various sources, including Datastream, European Central Bank's Data Warehouse, and Athens Stock Exchange. The daily observations date from January 1, 2002, to December 29, 2023 (5,739 observations). The variables and their corresponding market segments are as follows:

Money Markets (One variable)

- Spread between the EURIBOR and the EONIA rates up to end of September 2021.
- Spread between the EURIBOR and the Euro Short-Term Rate (ESTR) from the beginning of October 2021.

Banking Markets (Two variables)

- Inverse CMAX on the FTSE/ATHEX Banks Index (daily closing prices).
- Conditional volatility of the FTSE/ATHEX Banks Index (daily closing prices), calculated via EWMA.

Equity Markets (Two variables)

- CMAX on the Datastream Non-Financials Index on the Athens Stock Exchange (daily closing prices).
- Conditional volatility of the Datastream Non-Financials Index on the Athens Stock Exchange (daily closing prices), calculated via EWMA.

Bond Markets (One variable)

- Spread of 10-year Greek government bond to 10-year German bonds.

Foreign Exchange Markets (One variable)

- Average Conditional volatility of the Euro exchange rate vs the US Dollar, the Japanese Yen, and the British Pound, calculated via EWMA.

The variables above are in line with those of the received literature, thus making our results directly comparable to the published research for Europe.

3.1.1 Money Markets

We gauge money market stress using the spread between EURIBOR and EONIA or ESTR. The EURIBOR, EONIA, and ESTR are all interest rate benchmarks used in the eurozone financial markets that represent different aspects of short-term interbank lending.

EURIBOR is a series of benchmark interest rates representing the average interest rates at which a panel of eurozone banks borrow from each other (European Money Markets Institute, 1998). It is calculated by the European Money Markets Institute (EMMI) each working day from interbank borrowing rates provided by a panel of eurozone banks for a variety of maturities. These rates are based on estimates rather than actual transactions. After excluding the highest and lowest 15% of the rates, the EMMI calculates and publishes the average of the remaining rates. The EURIBOR is employed as a reference rate for setting interest rates in corporate loans. It is also used in interest rate swaps, i.e., agreements where banks exchange fixed for floating interest cash flows based on a notional amount. Because it is an offered rate, the EURIBOR reflects the creditworthiness of each bank. During times of extreme stress in the banking sector such as the global financial crisis, interbank rates rise dramatically.

EONIA was the rate for unsecured overnight lending among euro area banks. It was calculated by the EMMI from data provided by a panel of European banks, based on actual transactions. From October 2019, the EMMI changed the methodology of the EONIA calculation and defined it as the ECB's ESTR plus a fixed spread of 0.085% until the EONIA was replaced by the ESTR. Therefore, for our thesis we use the ESTR as the risk-free rate from October 1, 2019, and the EONIA rate before that date.

The spread between EONIA (or ESTR) and EURIBOR can provide insights into the credit risk perception of banks in the interbank lending market. We employ this spread to reflect flight to quality and flight to liquidity. An increase in the spread can indicate that banks are becoming more selective in their lending, preferring to transact with institutions considered to have higher creditworthiness. As a result, the EURIBOR

may rise compared to the EONIA rate, contributing to a wider spread. In addition, an increase can indicate that investors are favoring more liquid and safer assets, such as those represented by the EONIA, which is considered a risk-free overnight rate. As demand for highly liquid assets rises, the EONIA rate may decrease relative to EURIBOR, leading to a wider spread.

3.1.2 Banking Markets

Bank stress is measured using the FTSE/ATHEX Banks stock price index, which is created and managed by the Financial Times Stock Exchange (FTSE), a global index provider in cooperation with Athens Stock Exchange. This index depicts, on a real time basis, the performance of the shares which constitute the Banks super sector according to the Industry Classification Benchmark (ICB) (Athens Exchange Group, 2024). At the end of 2023, the index included the four largest banks, namely, Alpha, NBG, Piraeus Bank, and Eurobank. We use the inverse CMAX on FTSE/ATHEX Banks index to capture investor loss in the bank stock markets, as well as increased uncertainty about the fundamental value of assets.

3.1.3 Equity Markets

For equity markets, we employ the Datastream Non-Financials Index on the Athens Stock Exchange to avoid a disproportionate representation of banks in the produced FSI. Stock indexes such as the ASE General index include and are heavily influenced by bank stocks. The General Index might miss a stressful event affecting non-financial stocks. For example, after June 2022, the ECB increased interest rates to combat inflation (Beningo et al. 2023). Banks largely benefited in the following months, as their expected revenues rose due to increased installments from loans (Agiomirgianakis et al., in press). However, non-financial companies were negatively affected as their investment activities were held back, leading to lower valuations of their stocks and bonds. Since we aim to define equity markets in a manner that avoids overlap with other markets, we exclude bank stocks.

We use the inverse CMAX on Datastream Non-Financials Index on the ASE to capture investor loss in the equity markets, as well as increased uncertainty about the fundamental value of assets.

3.1.4 Bond Markets

The spread between the yield to maturity of the Greek government, 10-year benchmark bonds to the respective yield of the German government bonds is a measure of the relative credit risk of Greek bonds compared to German bonds. Yield to maturity (YtM) is the average annual return an investor would earn if they bought the bond at its current market price and held it to its maturity. Supposing that Greek bond prices fall

while German bond prices remain the same, the Greek bond YtM would increase, thus widening the spread. A common explanation of the widening spread would be the increased credit risk on behalf of Greece, as investors flee the Greek bond market (or the emerging bond markets in general) to safe havens, i.e., countries with an outstanding debt credit rating. Consequently, the spread captures flight to quality, flight to liquidity and increased uncertainty about the fundamental value of Greek bonds.

The spreads between Greek and German bonds are also a measure of the long-term prospects of the Greek economy compared to top credit rating Eurozone economies. In addition, long-term bond yields are very sensitive to bond price changes (and vice-versa). Thus, if investors started selling Greek bonds for whatever reason, this would vividly show up in the spreads. Therefore, we can use the spread between Greek and German bonds as a variable capturing potential stress in the Greek credit market.

3.1.5 Foreign Exchange Markets

For the foreign exchange markets, we use the average volatility of the Euro against the USA dollar, the British Pound, and the Japanese Yen. Changes in these rates show several events that can affect the economy in every country and might lead to stress. For instance, if the USA central bank (the Federal Reserve) raises interest rates, then global investors take positions in American assets such as bonds, increasing demand for the dollar and its value compared to other currencies such as the Euro or the Yen. At the same time, demand for assets in Euro or Yen declines, leading to lower valuations and higher yields. We use this variable as a proxy for increased uncertainty about the fundamental value of assets and the behavior of other investors.

Furthermore, higher FX swings in these large economic areas, namely, USA, Eurozone, and Japan, could cause ripple effects in the global financial markets. They could affect trade balances, corporate profits, foreign investment, inflation, central bank policy responses, and investor sentiment (risk aversion levels). Therefore, we use our variable to capture the influence of the global financial environment on financial stress in Greece.

3.1.6 The CMAX Variable

Following Illing and Liu (2006) and Louzis and Vouldis (2012), we construct the CMAX variable for the banking and non-financial indexes. The CMAX is defined as the value of the index on day *n* divided by the maximum value the index had attained in the previous year, that is, 252 trading days:

$$CMAX_n = \frac{P_n}{max\left[P \in \left(P_{n-j},\ j = 0,\ \ldots,\ 252\right)\right]}$$

Apparently, this is a hybrid volatility-loss variable, showing how far the index is moving from its most recent peak. If it decreases significantly and persistently for a prolonged period, it indicates stress. To translate this decrease into stress increase, we invert the CMAX ratio before aggregation.

3.1.7 Estimating the Series Conditional Volatility

Computing daily volatility (i.e., the standard deviation or the variance of daily returns) can be done in various ways. Louzis and Vouldis (2012) use the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model, while Illing and Liu (2006) and Holló, Kremer, and Lo Duca (2012) use the Exponentially Weighted Moving Average (EWMA) model. We opt for the latter model due to its simplicity and ease of convergence of the optimization algorithm.

To explain the process used in this thesis, we employ the analysis in Hull (2018) and maintain his notation for clarity. Financial practitioners routinely compute daily returns u_i for day i, as

$$u_i = \frac{S_i - S_{i-1}}{S_{i-1}}$$

Suppose n is the most recent day of a data series for which we want to find the variance of returns. To compute the variance, the sample average return is set to zero, and the sum of squared returns is divided by the number of observations, m (and not $m - 1$). This leads to the variance estimator:

$$\sigma_n^2 = \frac{1}{m}\sum_{i=1}^{m} u_{n-i}^2$$

which is identical to the maximum likelihood estimator.

Although one can use this formula to construct a series of daily variances, practitioners understand that the most recent observations have more importance than older observations. Thus, in the summation of the variance formula, they arbitrarily put weights a_i which add up to 1, and make sure the weights of more recent observations are larger:

$$\sigma_n^2 = \frac{1}{m}\sum_{i=1}^{m} a_i u_{n-i}^2$$

In the EWMA model, a day's squared return is λ times the previous day's squared return, where λ is a parameter between 0 and 1. This means that the weights become exponentially smaller as we move further back in time. In this setup, it can be shown that the variance of each new day σ_n^2 is updated using the following recursive scheme:

$$\sigma_n^2 = \lambda \sigma_{n-1}^2 + (1-\lambda)\, u_{n-1}^2$$

The practical benefit of the EWMA model is that it needs only two numbers to estimate the next variance, once the parameter λ is estimated. Assuming normality of returns, the parameter λ is estimated by maximizing the logarithm of the likelihood function:

$$\sum_{i=1}^{m} \left[\frac{1}{\sqrt{2\pi v_i}} exp\left(\frac{-u_i^2}{2v_i} \right) \right]$$

where v_i denotes the variance σ_i^2. Taking logarithms, this is the same as maximizing

$$\sum_{i=1}^{m} \left[-\ln(v_i) - \frac{u_i^2}{v_i} \right]$$

Employing the Excel optimizer over the return series, gives us estimates for λ. Typically, a $\lambda \approx 0.95$ is a good approximation for a wide range of financial variables.

3.1.8 Variable Summary

We use the raw data series to produce our CMAX, volatility and spread variables. Their basic statistics are presented in Table 1.

Table 1: Statistics of the produced component variables.

Source Data	**Variable**	**Mean**	**St. Dev.**	**Min.**	**Max.**	**Median**
Datastream Non-Financials Index	Inverse CMAX	1.1911	0.2374	1.0000	2.4947	1.10
	Conditional Volatility	0.0126	0.0062	0.0040	0.0489	0.0108
FTSE/ATHEX Banking Index	Inverse CMAX	2.4181	3.2601	1.0000	43.091	1.52
	Conditional Volatility	0.0319	0.0202	0.0085	0.1272	0.0267
Euro vs Currencies (USD, JPY, GBP) Exchange Rates	Average Conditional Volatility	0.0055	0.0018	0.0026	0.0151	0.0051
EURIBOR, EONIA, ESTR	Spread	0.2090	0.2565	-0.8680	1.5610	0.1140
German 10-year Bond and Greek 10-year Bond yields	Spread	4.5597	6.0595	0.0600	38.0620	2.17

Notes: Period covered: 1-1-2002 to 29-12-2023. Total number of daily observations for each variable: 5.739. CMAX is the ratio of the current value of a stock index over its maximum in the last 1-year of trading. Conditional volatility is estimated by applying Maximum Likelihood on the daily returns, based on the Exponentially Weighted Moving Average (EWMA) model. Spread is the daily spread of the respective variables. EURIBOR is the Euro Interbank Offered Rate. EONIA is the Euro Overnight Index Average up to date 30-9-2019 and ESTR is the Euro Short-Term Rate from 1-10-2019 to 29-12-2023.

3.2 Variable Aggregation

The variable aggregation step in the FSI construction process is characterized by a wide differentiation in methodology. We find several variations of sophisticated methods involving PCA, CDF, credit weights, multivariate GARCH, logit models, etc. Comparing these methods raises a fundamental question: does the application of more complex approaches guarantee superior results? Illing and Liu (2006) note that the credit-weighted standard-variable index, one of the simplest indexes outperforms the other 12 constructed in the same paper. Holló, Kremer, and Lo Duca (2012) use credit weights for their subindexes and state that the application of equal weights produces similar results. Park and Mercado (2014) find that the variance-equal weight method tends to capture more stressful periods than PCA. McDonald, Sogiakas and Tsopanakis (2018) and the International Monetary Fund (2009) also opt for the same method due to its simplicity of calculations and its effective representation of the prevailing financial conditions.

The variance-equal weight method has been criticized for assuming normality of the variables, as non-normal data may produce increased outliers, which may in turn alter the mean and standard deviation to the point that new observations significantly influence past FSI values (Hakkio and Keeton, 2009; Holló, Kremer, and Lo Duca, 2012). However, all FSI construction methods include crude assumptions, as they attempt to sum disparate metrics. The goal of an FSI is to portray a relative magnitude of financial stress rather than a precise value. Considering the above, we opt for the variance-equal weight method for the purposes of this thesis.

The variables are initially standardized by subtracting their mean and dividing by their standard deviation. Standardizing the variables creates the basis of equal weighting. However, it also produces negative values that reduce the practicallity of the index. The European Central Bank (2009b) and Louzis and Vouldis (2012) address this problem by transforming the standardized indexes using the logistic sigmoid function:

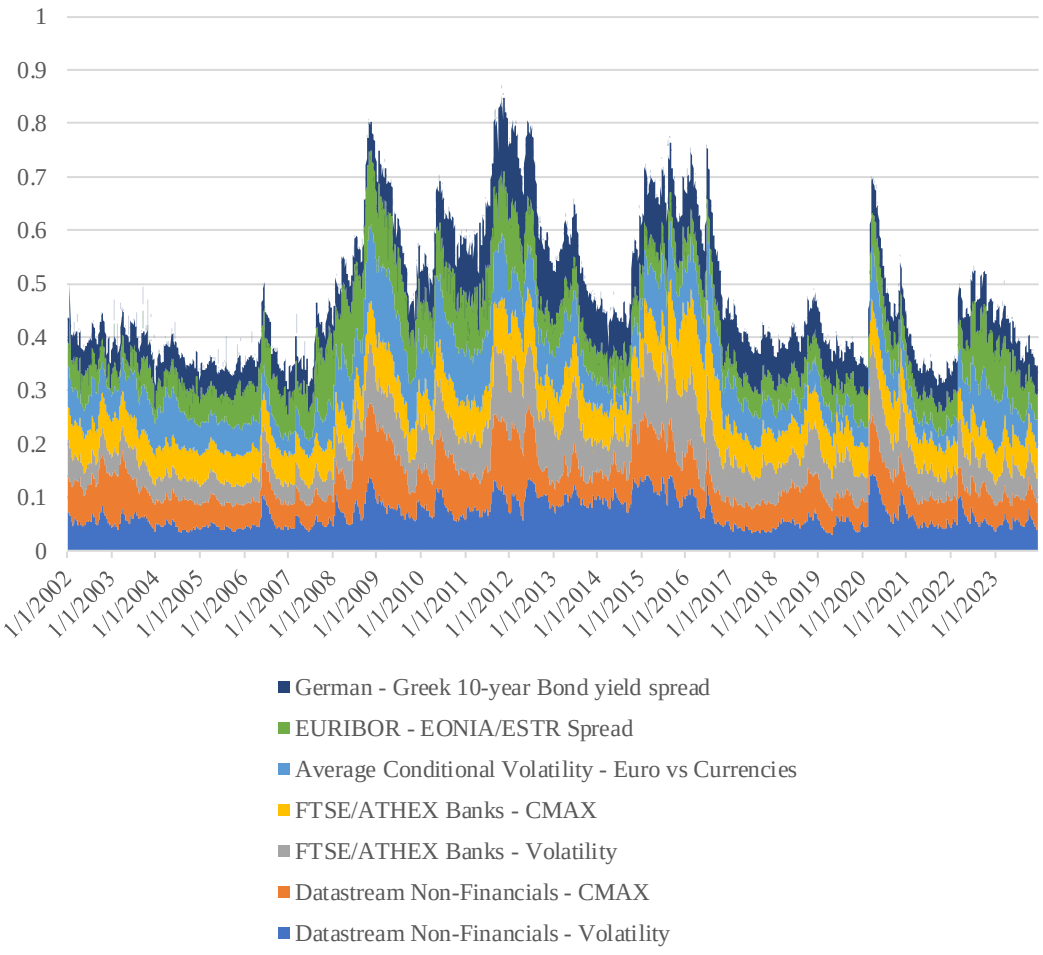
$$y = \frac{1}{1 + exp(-x)}$$

where y is the transformed variable. Naturally, the resulting variable is bound within the (0, 1) interval. We employ this transformation method due to its simplicity of application and its effectiveness in describing outlier values within a narrow interval.

Once the seven variables are standardized and transformed, we apply equal weight factors. The weight factor of each equals one seventh, or 0.143. The products are summed into a single, daily FSI. Figure 1 shows a graph of the resulting index, and Figure 2 portrays the intertemporal contribution of index components.

Figure 1. The daily Greek FSI from January 2002 to December 2023.

Figure 2. Intertemporal contribution of index components.



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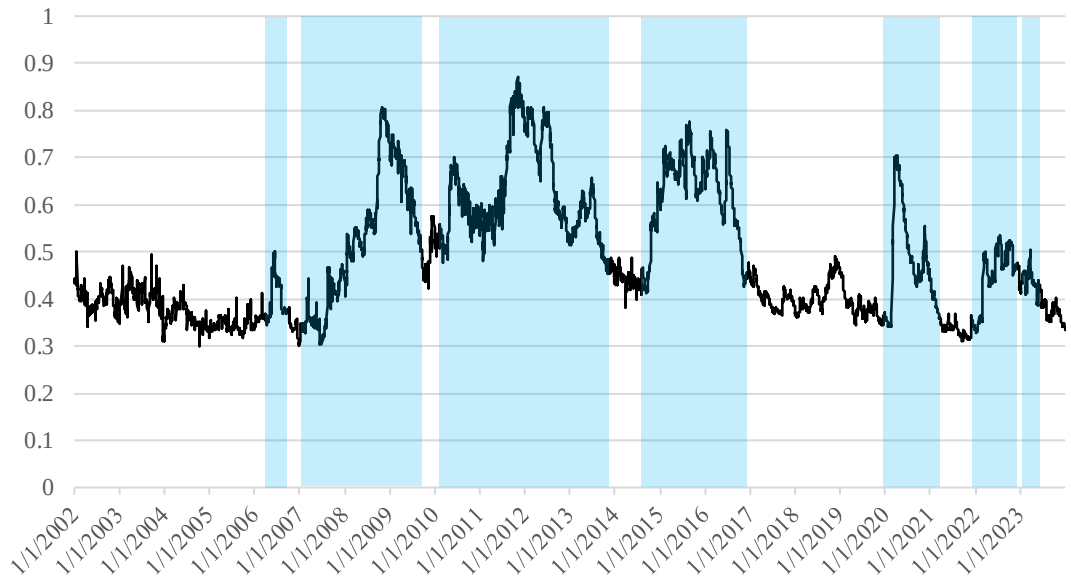
4 Index Evaluation and Identification of Stress Events

The literature provides variety of FSI evaluation methods, ranging from the comparison of real stress events with high FSI values to the calibration of stress impact on the economy through regression models. The definition of a critical stress level is vulnerable to criticism related to the addition of new values (Hakkio and Keeton, 2009). It also results in periods of above-the-threshold values, which requires a more precise definition of real stress events in terms of time, especially in cases of high-frequency FSIs (Holló, Kremer, and Lo Duca, 2012). Thus, for the purposes of this thesis, using value thresholds to strictly define crisis periods will be avoided altogether. We are more interested in the daily level of underlying stress rather than assigning a binary condition system of crisis or no crisis to an entity as complex as the Greek economy. Following Hakkio and Keeton (2009), we assess our FSI by comparing its peaks to known periods of financial stress, ensuring it produces no Type II errors.

For a more comprehensive comparison of high stress values and their corresponding events, the former are grouped into high stress periods (Figure 3). For each period, we briefly describe the succession of financial events.

Figure 3. Selected high stress periods.



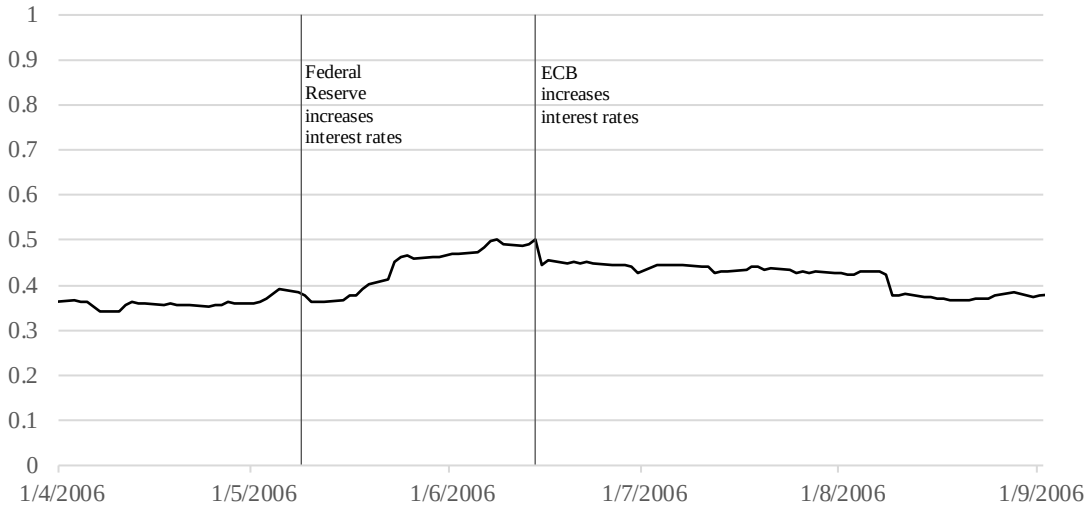
4.1 Worldwide Uncertainty About Interest Rate Increases (April - June 2006)

In April and May 2006, a rise in commodity prices along with an increased capacity utilization rate, and a tightening of labor markets prompted considerable investor speculation about acceleration of inflation rate (International Monetary Fund, 2006). These concerns led to a synchronized policy tightening on behalf of central banks. In May 10, the Federal Reserve announced its 16th consecutive increase of interest rate, which would reach 5%, and vaguely hinted further policy firming (La Monica, 2006). While in April the ECB had hinted a reluctance to intervene, in June 15, it increased its policy rates from 2.5 to 2.75%, marking the third consecutive increase (Trichet, 2006).

The synchronized policy tightening created uncertainty, as the increased cost of funding sparked doubt about the optimistic projected growth claimed by central banks (Trichet, 2006; International Monetary Fund, 2006). Equity markets plunged, with the Eurofirst index dropping more than 9% compared to its peak value earlier in May. The G7's attempts to intervene in global economic imbalances were perceived to indicate an intention to depreciate the US dollar, causing volatility in the foreign exchange markets. The withdrawal of liquidity resulted in increased investor risk aversion and a steep decline in high-risk asset prices, especially in emerging markets. Risk aversion also became evident in credit default swap markets, where foreign investor flight to quality concentrated investments in the more developed domestic markets and away from emerging markets.

Greece, as an emerging European market, was not immune to the above international developments. In May 2006, the Greek equity market suffered a severe decline, with the Athens General Composite index dropping 9.34% and the FTSE/ATHEX-20 index dropping 9.59%. The market value of major component companies of the FTSE/ATHEX-20 index such as the Agricultural Bank of Greece, Intracom, Eurobank, and the National Bank of Greece decreased by 18.6, 18.3, 15.4, and 15.4%, respectively. Our index increased 44.4% from a low of 0.36 on May 1, 2006, eventually reaching a peak of 0.52 on June 14, 2006 (Figure 4). This vast increase can be attributed to our FSI's capability of capturing the high volatility in equity and foreign exchange markets that characterized that certain period.

Figure 4. The daily Greek FSI from April 2006 to September 2006.



4.2 The Global Financial Crisis (2007-2009)

The global financial crisis (GFC) refers to the period of extreme stress in global financial markets and banking systems between mid-2007 and early 2009 (Reserve Bank of Australia, 2023). This period has been studied extensively, and therefore there is ample evidence about its origins, as well as the channels and mechanisms through which it evolved and spread worldwide, severely affecting all markets, including Greece.

In the mid-2000s, the US housing market experienced a sharp rise in home prices, reaching an excess of 30% compared to the early 2000s in January 2006 (Emmons, 2021; Claessens et al., 2010). The housing market boom was fueled by a rapid credit growth caused by low interest rates and loose lending criteria. Subprime mortgages were extended, as banks were confident that housing prices would continue to climb indefinitely, and that their profits would be secured either through loan interests, or through foreclosures. The US subprime mortgage market increased from just over 10% of the total mortgage market in 2000 to over 20% in 2006, amounting to an estimated value of between $300 and $400 billion (European Central Bank, 2008). These predatory lending practices generated undiversified portfolios, maximizing default correlations, and thus increasing systemic risk.

At the same time, the securitization of various assets through complex financial derivatives accelerated the surge of the mortgage market and other asset markets. Derivatives such as mortgage-backed securities (MBS) allowed banks to sell illiquid loans, transfer credit risk to third parties and enabled risk distribution. Using special purpose vehicles (SPVs), banks could remove assets with a high risk-weighted capital requirement from their balance sheet, thus allowing for additional lending. The SPVs' portfolio usually consisted of residential mortgage-backed securities (RMBS), including those backed by US sub-prime mortgages (European Central Bank, 2007). This "shadow banking system" changed the traditional role of banks as intermediaries

and fueled unregulated systemic risk. By mid-2007, the MBS outstanding value had reached $6.5 trillion (Fuster et al., 2022).

The rapid development of the derivatives market enabled the proliferation of repackaging and dispersion of debt into the global markets. Structures of multiple-layered collateralized debt obligations (CDO) emerged, of which the underlying asset was another CDO. Investors and institutions seeking greater leverage used such structured products to extract additional returns (European Central Bank, 2007). Rating these financial instruments was deficient at the time, with repackaged speculative-grade debts receiving triple-A rating in certain occasions.

In early 2007, the housing market began reversing. Large groups of overleveraged subprime borrowers were particularly vulnerable to financial shocks, and the sudden increase in monthly payments initiated a cycle of defaults and foreclosures. The reintroduction of newly foreclosed houses into the market led to further deterioration in prices. High loan-to-value mortgages allowed even moderate price declines to push many households into negative equity (Claessens et al., 2010). Banks abruptly tightened loan standards, sparking a chain reaction of reductions in consumer spending, decline in corporate profitability, and increase in unemployment. The propagation of the housing market crash into the real economy resulted in even more defaults and signaled a new recession, exceeding what was to be a plain correction in housing prices.

The first financial intermediaries to be affected by the housing market crash were those directly exposed to subprime mortgages and RMBSs. The complex derivative market began to collapse under the new wave of defaults. The extensive repackaging of debt prohibited any attempt to backtrace debts to their initial borrowers, thereby rendering intermediaries across the globe uncapable of evaluating their securities. Due to the criticism received for their poor assessment of borrowers' creditworthiness, major rating agencies abruptly downgraded the rating of multiple assets. As a result, banks resorted to fire sales of securities, causing liquidity issues, as security prices plummeted.

In Germany, IKB, a bank specialized in financing small and medium-sized companies operated an SPVs called Rhinebridge, which had invested heavily in the US subprime market (IKB, 2008). In July 2007, several banks questioned IKB's creditworthiness, and thus became unable to obtain sufficient sources of liquidity. This led to leading to a swift rescue by the state-owned KfW bank, other lenders, and taxpayers. The estimated rescue costs amounted to almost €8 billion, exceeding the bank's equity about fivefold (Odenius, 2008). In France, BNP Paribas managed three investment funds exposed to the US subprime market. On 9 August 2007, the bank announced its temporary suspension of redemptions, declaring that "The complete evaporation of liquidity in certain market segments of the U.S. securitization market has made it impossible to value certain assets fairly regardless of their quality or credit rating" (Potter, 2010).

Northern Rock, one of the top five mortgage lenders in the UK that relied heavily on interbank borrowing, also faced liquidity problems as the interbank market froze due to fears over subprime mortgages (Shin, 2009). On September 13, 2007, the

Bank of England agreed to provide emergency funding to Northern Rock as a lender of last resort, but BBC leaked the news, sparking panic among depositors. The next day, thousands of customers queued outside Northern Rock branches to withdraw their money, causing the first bank run in the UK since 1866. The bank's share price plunged by more than 30%. On September 17, the UK government announced its guarantee of all Northern Rock deposits.

Bear Stearns, a US investment bank heavily involved in the subprime RMB market, was under severe pressure after being forced to pay $3.2 billion to bail out its SPV hedge funds the previous year and marking losses for the first time in 80 years (Shorter, 2008). On March 10, several trading partners stopped trading with Bear Stearns to reduce indirect exposure to its failing assets. On March 11, 2008, the rating agency Moody's downgraded many of Bear's mortgage-backed securities causing a shortage of short-term liquidity. From March 10 to March 13, the company's cash reserves reduced from $18 billion to $2 billion, as clients demanded collateral for defaulting debts supported by MBSs. On March 13, the Federal Reserve offered a short-term "discount window" loan through JP Morgan. In June, the US Securities and Exchange Commission charged the managers of the two SPV hedge funds with fraud for dishonest reports of the funds' performance (Securities and Exchange Commission, 2008).

The rapidly deteriorating confidence among investors and creditors mounted financial strains related to liquidity, while the propagation of consecutive financial shocks resulting from defaults took its toll on the worldwide economy for the following year. The authorities' response to the unraveling crisis proved inadequate in various aspects. Interventions (e.g., recapitalizations) lacked scope, as they excluded financial institutions such as investment banks and insurance corporations, were uncoordinated at the international level, and were slow to cover the regulatory gap of the unattended "shadow banking system" (Claessens et al., 2010). Individual country responses were incapable of matching the scale and magnitude of the crisis.

Financial stress climaxed in 2008 with the simultaneous collapse of two major financial institutions. Lehman Brothers, a major US investment bank that had accumulated several mortgage agencies, reported severe losses and write-downs, resulting in consecutive price devaluations in the equity markets (Fender and Gyntelberg, 2008). On September 9, a large investor (Barclays) withdrew from negotiations regarding a capital injection due to solvency concerns, and the next day quarterly results were released, exposing the company's deteriorating performance (Wearden and Teather, 2008). Investor speculation about a potential bailout caused the stock market to plummet. Indeed, Lehman Brothers desperately attempted to secure a bailout loan from the Federal Reserve but was rejected because it was believed to lack adequate collateral. On September 15, 2008, the company filed for Chapter 11 bankruptcy protection, with $639 billion in assets and $619 billion in debt, marking the largest bankruptcy filing in U.S. history at the time. The emanating financial shock propagated throughout the world, affecting equity, bond, and money markets, resulting in investor flight to quality. The market affected the most was the credit default swap market, with the spread of the benchmark US investment grade CDS index (CDX)

increasing by 42 basis points on September 15 alone and the US high-yield spreads by 118 basis points.

American International Group (AIG), a leading insurance company with consolidated total assets of slightly more than $1 trillion as of June 30, had issued CDSs with a gross notional exposure of $441 billion (Federal Reserve, 2008). On September 15, major rating agencies downgraded AIG's rating, causing a series of collateral calls from CDS counterparties that brought the company to the brink of bankruptcy. Such an event would trigger bankruptcies of financial institutions with buyer positions in CDS contracts across the world. Due to the company's enormous size, its bankruptcy would also severely damage intermediaries invested in AIG debt, stock, and securities. As a response, on September 16, the Federal Reserve announced an $85 billion emergency loan to AIG, in exchange for a 79.9% equity stake and the right to replace its management and veto its decisions.

The collapse of Lehman Brothers and AIG had profound and lasting consequences for the global economy. It sparked a loss of confidence and trust among financial institutions, leading to a freeze in credit markets and a liquidity crisis. It also exposed the fragility and interconnectedness of the financial system, revealing the risks of excessive leverage, complex derivatives, and poor regulation of the shadow banking system. It triggered massive selloffs in stock markets, a contraction in economic activity, and a surge in unemployment that prompted unprecedented policy responses from governments worldwide.

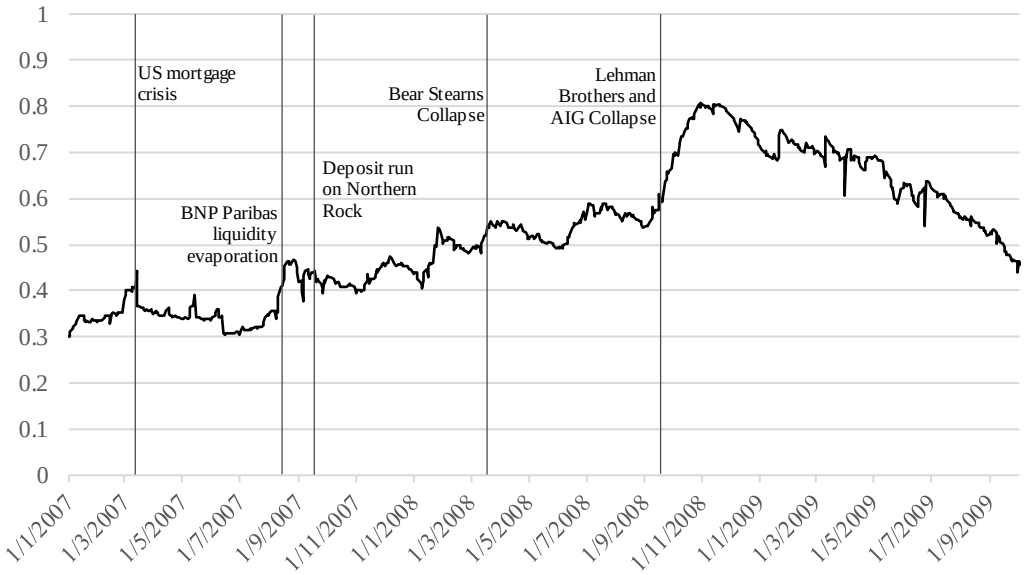
Greece also suffered from the rapid succession of financial shocks that impacted the global economy. Throughout the crisis, increases in risk aversion caused financial institutions to reduce their exposure to emerging markets. Investor flight to liquidity and quality caused severe declines in Greek equity markets. In 2008, the ASE General Index sustained an annual loss of 65.5%, while the sectorial indexes of banks and insurance companies sustained losses of 73.97% and 71.67%, respectively (Hellenic Capital Market Commission, 2009). The market capitalization of ASE listed companies and Exchange Traded Funds (ETFs) registered a total annual decrease of 65.1%. Investor movement towards safe havens widened the Greek-German bond spread, reaching 299 basis points on February 17, 2009, from an average of 80 basis points in 2008.

From a macroeconomic perspective, negative effects began appearing in 2009. Real GDP growth was negative (-1.2%), as compared to a 2% increase in 2008 and a 4.5% increase in 2007 (Hellenic Capital Market Commission, 2010). Real gross fixed capital formation suffered a 18.8% decrease in 2009. This drop can be attributed to the substantial reduction of investment in equipment by 25% and the contraction of the construction sector by 13%. Competitiveness in trade was also impaired, with the real exports of goods and services were estimated to have suffered a major decrease of 16%. Finally, unemployment marked a significant increase from 7.5% in 2008 to 9% in 2009.

During the 2007-2009 period, our index spikes in mid-March 2007 for the first time, reaching a value of 0.44, compared to the 0.3 value in the beginning of 2007 (Figure 5). This spike corresponds to the burst of the US mortgage market bubble. The next spike is observed in August 2007, with a slightly higher value of 0.46, marking

however a greater leap of nearly 50% from 0.31. This jump can be attributed to the liquidity problems caused by MBSs, similar to those faced by IKB and BNP Paribas in July and August. The index almost immediately dives to 0.38 before spiking back to 0.44 following the deposit run on Northern Rock. The next identifiable peak corresponds to Bear Stearns' near collapse in March 2008, where the index reaches an unprecedented value of 0.54. From this point on, the index remains above 0.5 until September 2009. Stress escalates even further in September 2008, when the index breaks the 0.6 threshold for the first time and briefly reaches a maximum of 0.8 in early November. During this period, the simultaneous collapse of Lehman Brothers and AIG occurred. In mid-November, the index retracts from the 0.8 area and enters a steady decline, while remaining at remarkably high values.

Figure 5. The daily Greek FSI from January 2007 to October 2009.



4.3 The Greek Sovereign Credit Crisis (2009-2013)

Following the Global Financial Crisis, Europe faced another severe crisis that was triggered by high levels of public debt and deficit spending in some of the eurozone countries, especially Portugal, Ireland, Italy, Greece, and Spain. The crisis was exacerbated by the Global Financial Crisis of 2007-2008 and the Great Recession of 2008-2012, which reduced economic growth and tax revenues, and increased unemployment and social spending.

The sovereign debt of Greece, which held a central position in the development of the crisis, progressively accumulated over an extended period. Back in 1974, Greece's debt-to-GDP ratio was at a reasonable 18% (Baltas, 2013). Due to increased volatility in growth, high inflation, successive currency devaluations and structural weaknesses, the ratio reached 58% in 1986. Since 1981, Greece was a member of the European Union, thus accessing European funding at significantly lower interest rates.

At the time, Greek governments secured votes by opening obsolete job positions in the public sector with disproportionately high salaries, and by offering various allowances or other social benefits. Greece's irrational public spending was entirely supported by foreign funds that progressively accumulated a massive debt. By 1996, the debt-to-GDP ratio reached 113%. Borrowing only intensified after the country's entry into the euro January 2001, as it lowered inflation and enabled even lower interest rates. Public spending climaxed during the 2004 Athens Olympics, which cost €9 billion without including the supporting transport projects (The Guardian, 2004).

The consequences of Greece's accumulation of debt began unfolding in late 2009. On October 20, the newly elected government's finance minister, George Papakonstantinou, announced the 2009 fiscal deficit would be 12.7% of GDP, more than double the previous government's projection of 6%, and more than four times the limit set by the EU's Stability and Growth Pact (Gibson et al., 2012). Two days later, Fitch, a major credit rating agency downgraded Greece's Long-term foreign currency and local currency issuer default ratings from "A" to "A-" (Fitch Ratings, 2009). In November, Ireland revealed a fiscal deficit of 11.6% of GDP, also exceeding the EU limit. In the same month a state-owned Dubai conglomerate asked its creditors for a six-month debt moratorium. To address the ever-increasing concerns of investors and the EU creditors, the Greek finance minister reassured that "there will not be a point where the EU will need to come to the rescue of Greece" (BBC, 2009). Still, in December 2009, Standard and Poor and Fitch downgraded Greece's credit rating to "BBB+" (Trading Economics, 2009).

The year 2010 marked the development of the recession for Greece, as budget deficits remained unimproved and confidence in the markets was deteriorating. On January 8, 2010, the European Commission condemned Greece for falsifying its public finance data (Kosmidou et al., 2015). On February 11, Greece enforced a series of austerity measures imposed by the EU, sparking country-wide riots and strikes (BBC, 2012). These measures proved inadequate, and the government soon began investigating bailout options. Rumors about the potential default of Greece sparked turbulence in the markets, causing Standard and Poor's rating to drop to "BB+" on April 9. On April 23, 2010, the Greek Government formally requested a bailout from the International Monetary Fund, the European Central Bank, and the European Commission, collectively known as the "Troika" (Kosmidou et al., 2015). The conditions set by Troika for the €110 billion package included further austerity measures aimed at reducing the deficit to 3% of GDP by the end of 2014. The bailout package deal was later known as the "First Memorandum". In May, the EU and the IMF created a €750 billion rescue fund, known as the European Financial Stability Facility (EFSF), to provide loans to eurozone countries in financial distress. ECB announced the Securities Market Program (SMP), through which it would purchase government bonds of affected countries to lower interest rates and mitigate market pressure (European Central Bank, 2010).

In the meantime, rating agencies progressively downgraded European periphery countries' ratings while Italy and Spain negotiated minor austerity packages with the EU. In November 2010, Ireland became the second eurozone country to request a bailout from the EU and the IMF, receiving €85 billion in exchange further fiscal

consolidation and banking restructuring. Portugal followed in May 2011, receiving €78 billion in exchange for budget cuts and economic reforms. On May 15, violent protests against austerity measures emerged in Spain (Kosmidou et al., 2015).

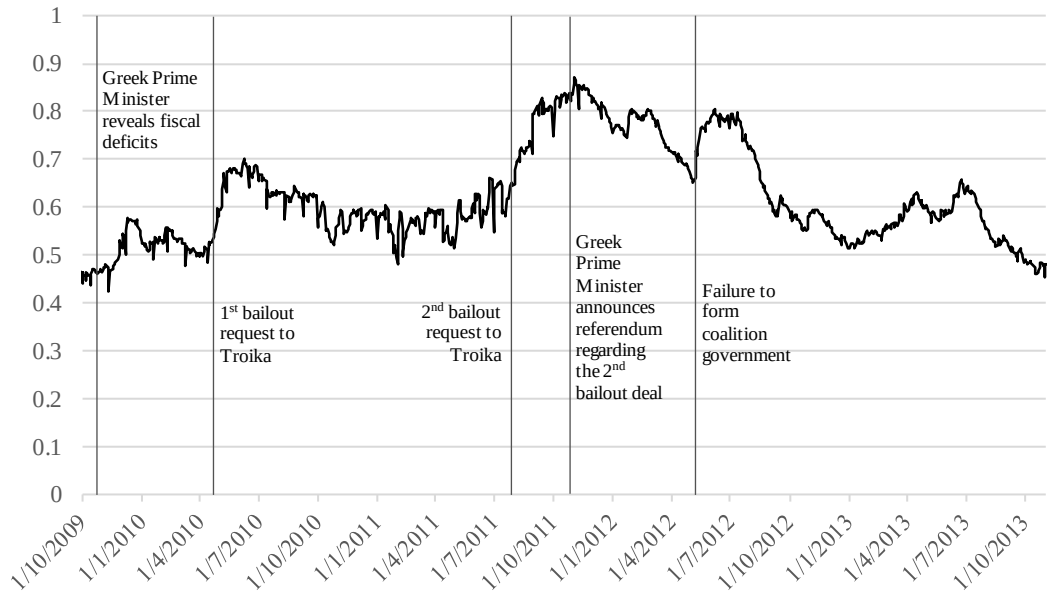
Despite EU's efforts, the Greek economy continued spiraling uncontrollably, as was discovered in an EU/IMF audit in June 2011 (Kosmidou et al., 2015). At an emergency summit with the EU on July 21, a second bailout package of €109 billion was agreed upon, committing Greece to even harsher austerity measures, including reduction in salaries and public sector layoffs. The agreement was concluded on October 27 and involved a significant debt restructuring that would write off 50% of Greek debt. However, on October 31, due to immense political pressure from opposing parties in the Greek Parliament, the Greek Prime Minister, George Papandreou, announced a referendum on the bailout plan to gather popular support. This announcement caused the Greek-German bond spreads to jump from the already alarming value of 2,163 basis points to 2,898 basis points on November 3, when the Prime Minister was strongly advised to recall the referendum, otherwise Greece would not receive the next instalment. Indeed, George Papandreou cancelled the referendum and resigned shortly afterwards.

On February 12, 2012, the second bailout plan, later known as the "Second Memorandum", was finally approved. The EU members were forced to return any profits from trading Greek bonds until 2020, and the debt write-off was increased to 53.5% from 50%, ultimately reducing Greece's debt by €172 billion (Kosmidou et al., 2015). In March, while public unrest was mounting, the majority of Greece's corporate creditors agreed to the terms of the debt restructuring deal, reducing the expected estimate of the debt-to-GDP ratio from 198% to 160.5%. That mediocre improvement can be attributed to the need of banks to recapitalize, which led to more, temporary debt. New EU requirements also demanded Greek banks to raise their core tier1 capital ratio to at least 9% by September 2012 and to 10% by June 2013. Moreover, the debt that was subject to the restructuring deal was only a fraction of Greece's total debt. Still, the fact bondholders suffered from substantial losses made Greek markets even less attractive to investors.

Negative sentiment and uncertainty escalated further, when on May 6, 2012, two-thirds of Greek voters backed parties opposed to the second bailout deal, and yet no governing coalition could be formed. Rumor spread that Greece would leave the eurozone, defaulting on its debts. Standard and Poor reported there was "at least" a one-in-three chance of Greece exiting the eurozone in the coming months (Lopez, 2012). Concerned from these rumors, European Commission spokeswoman Pia Ahrenkilde Hansen, stated that Brussels "hopes and expects that the future government of Greece will respect the engagement that Greece has entered into" (BBC, 2012). Indeed, on May 17, a three-party coalition aligned with the second bailout terms was formed. However, banks had depleted one-third of their deposits since 2010, and on May 14 alone, Greeks withdrew €700 million exerting immense pressure on the banking system (Ray, 2023). In the next month, Spain and Cyprus marked the fourth and the fifth countries requesting financial aid from the EU (Kosmidou et al., 2015).

During the 2009-2013 period, our index spikes in November-December 2009 for the first time reaching a value of 0.57 (Figure 6). The mounting financial stress of late 2009 can be attributed to the Greek Prime Minister's revelations about the country's fiscal deficits, as well as the following downgrades from major rating agencies. The next peak, spanning from April to July 2010, corresponds to the request of a bailout on behalf of the Greek government. For these months, the index sustains a value of 0.66 and nearly breaks the 0.7 threshold on June 16. The index then presents an unprecedented volatility up to July 2011, where it starts increasing, following the agreement of the second bailout package in July 21. The index reaches its total maximum of 0.87 on November 2, after the Greek Prime Minister's announcement of the referendum regarding the implementation of the second bailout deal. The index remains above 0.75 until March 2012. The failure to form a coalition government on May 6 relates to a steep rise in the index values, from 0.65 on May 2 to 0.8 on June 5. The index maintains values near 0.8 until mid-July 2012 and mostly remains under 0.6 afterwards. It only falls below 0.5 on October 2013 for an extended period for the first time after November 2009.

Figure 6. The daily Greek FSI from October 2009 to October 2013.



4.4 The Third Memorandum and the Deposit Runs on Greek Banks (2014-2016)

The first two Memoranda, although successful in the direct reduction of Greece's debt-to-GDP ratio, failed to address the structural problems of Greek banks, sparking discussion about the scenario of a third bailout package. The capital base of Greek banks consisted, to a significant degree, of low-quality assets, such as non-performing loans (Louri and Migiakis, 2019). The value of these assets suffered successive declines and were particularly illiquid, leaving banks vulnerable to deposit runs. By February 2014, the Troika was already considering offering Greece a third bailout.

In late 2014, political turmoil in Greece intensified uncertainty among investors. Once again, the danger of a sudden change of ruling party was looming, and this time such change was certain to bring an anti-austerity party, Syriza, to power, as it appeared dominant in the polls (Smith, 2014). In his attempt to quell the political instability of the county, the Greek Prime Minister Antonis Samaras called for early elections and warned that Greece might exit the eurozone (Grexit) should Syriza win. The results were opposite to what the Prime Minister had hoped for. Greek-German bond spreads broke the 900 basis point threshold for the first time since July 2013 and the ASE General Index retreated 12.6% in December alone. In the snap elections of January 25, 2015, Syriza emerged victorious, reflecting widespread discontent among Greek voters regarding the austerity measures and economic reforms imposed as part of Greece's bailout agreements with the Troika. Spreads spiked from 809 basis points on January 23 to 1,034 on January 28. In February, the new government secured a four-month extension of its financial bailout from the eurozone after agreeing to a series of reforms regarding tax evasion and corruption and vowing to comply to the austerity measures dictated by the Second Memorandum (Traynor, 2015). The new deadline was set at the end of June 2015.

In February 2015, the ECB declared Greek bonds as unacceptable collateral for future loans, thus preventing Greek banks from using the Eurosystem open market operations to raise liquidity at very low rates (Andruszkiewicz et al., 2020). For the following months, liquidity pressures intensified as the news sparked a wave of cash withdrawals. Private sector deposits declined 26% from November 2014 to July 2015. The government responded with the closure of the Athens Stock Exchange on June 25 and with capital controls on June 28, imposing a €420 weekly limit on withdrawals (Amadeo, 2020).

In the meantime, Greece struggled to negotiate a new arrangement with its international creditors. On June 25, Troika submitted an agreement plan involving a third bailout package on the condition of further austerity measures. The next day, the Greek Prime Minister Alexis Tsipras announced the government's decision to hold a referendum regarding the bailout terms, mounting uncertainty about Greece's future in the eurozone (Andruszkiewicz et al., 2020). On June 30, Greece failed to meet the deadline of an €1.7 billion instalment, marking the first default of a developed nation on a payment to the IMF (Kindreich, 2017). Greek-German bond spreads widened from 996 basis points on June 26 to 1,406 basis points on July 3. The financial shock also

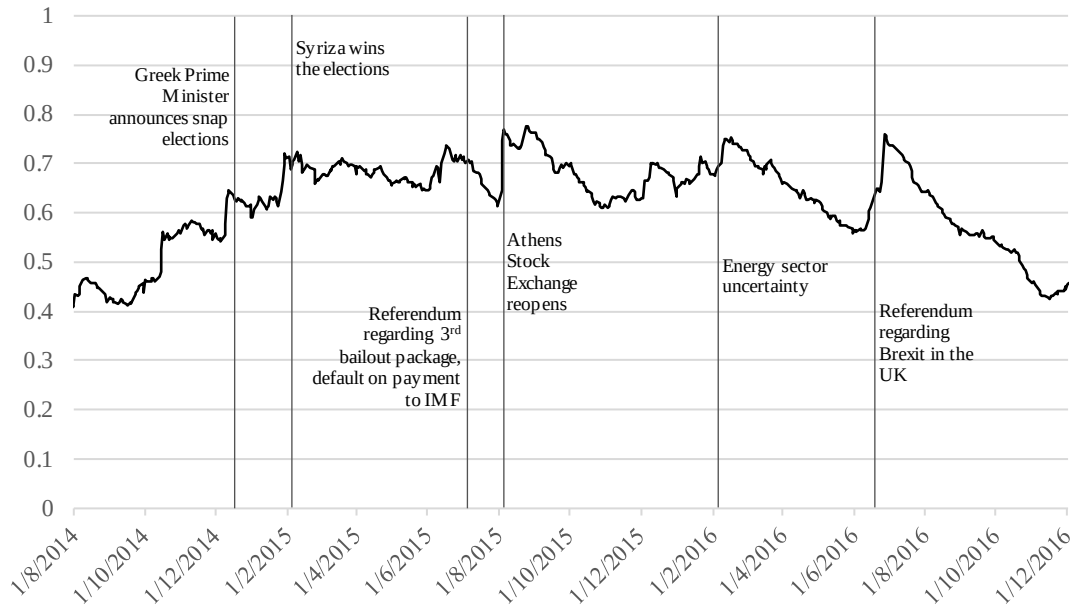
affected global markets: US stocks suffered the greatest losses in 2015, with the NASDAQ index immediately dropping 2.4% (Sisolak, 2015). On July 5, Greek voters overwhelmingly rejected the bailout terms in the referendum, with over 61% voting "No", causing spreads to reach 1,869 basis points on July 8. Following the referendum, Greece returned to the negotiating table with its creditors. Despite the "No" vote, the Greek government ultimately reached a controversial agreement with creditors on July 13th, 2015, paving the way for a third bailout program of €86 billion, known as the third memorandum (Andruszkiewicz et al., 2020). Two days later, the Greek parliament approved the new austerity measures.

On August 3, the Athens Stock Exchange reopened after five weeks. Since its value had remained unaltered during a particularly stressful period, it sustained a steep correction. The FTSE/ATHEX Banks index dropped 30% during the opening day and a total of 63.8% during the first three days of operation. For comparison, the Datastream ASE Non-Financials Index, dropped 12.8% and 9.5%, respectively.

In February 2016, financial markets across the world were characterized with high volatility and uncertainty (Hellenic Capital Market Commission, 2017). Declines in oil prices, fire sales of energy company stocks, and the deterioration of Chinese economy sparked fears about the return of recession, as was observed through the recent investor flight to safe assets such as gold. The stock markets suffered losses worldwide, with the ASE General index retreating 7.87% and major Greek bank stocks receding up to 29.2% on February 2. The total daily transaction volume in the ASE reached €97 million. In June 2016, the United Kingdom was planning a referendum regarding its exit from the European Union (known as Brexit), which adversely affected worldwide, and especially European markets. The shockwaves reached the already vulnerable Greek financial system. As a result, the ASE General index plummeted 17,2% from May 30 to July 4.

Our index breaks the 0.6 threshold, reaching a value of 0.65 for the first time in December 2014, when the Greek Prime Minister Antonis Samaras called for early elections (Figure 7). The index does not drop below 0.6 for nearly a year and a half. Following the victory of Syriza in the elections of January, it breaks the 0.7 threshold, reaching 0.72 on January 29, 2015. It breaks the 0.7 threshold again and reaches similar values in late June, prior to Alexis Tsipras' referendum and Greece's default on the IMF payment. The index then drops to 0.63 shortly after the Third Memorandum of July 13, before spiking up to 0.74 in early August. This abrupt spike can be attributed to the reopening of the Athens Stock Exchange. Worldwide uncertainty due to oil price drops caused our index to remain above 0.7 during February and early March 2016 and to briefly reach a value of 0.74. The most intense jump occurs at the time of the Brexit referendum in the UK. The index increases from 0.56 on June 2 to 0.74 on July 1. It only drops below 0.5 in late October 2016.

Figure 7. The daily Greek FSI from August 2014 to December 2016.



4.5 The COVID-19 Pandemic (2020-2021)

The COVID-19 pandemic caused abrupt disruptions to daily life, profoundly impacting the global financial system and virtually all aspects of economic activity. The unprecedented lockdown measures, combined with the unpredictable expansion of the virus sparked worldwide uncertainty, and governments were constantly faced with dilemmas between risking public health and preventing economic deterioration.

The escalation of concerns regarding COVID-19 was astonishing. In December 2019, an unknown, extremely contagious virus emerged in Wuhan, China (World Health Organization, 2023). On January 21, 2020, the first human case in the US occurred. On January 30, The World Health Organization declared the COVID-19 outbreak a Public Health Emergency of International Concern.

In mid-February, fears of COVID-19 becoming a global pandemic triggered massive selloffs, severely damaging equity and credit markets. Stocks experienced the most sudden drop in history, with the S&P 500 index plunging 20% in only 16 trading days (European Central Bank, 2020). The magnitude of turbulence in financial markets was evident in increases in volatility. On March 18, 2020, the VIX index, gauging option-implied volatility in the US equity market, reached an all-time high following the ECB's announcement of the pandemic emergency purchase program for euro area sovereign bonds. At the same time, expectations of increased high-yield corporate debt defaults caused rapid sales of the respective securities, which in turn pressured market liquidity. Constant withdrawals forced funds to sell assets with great haste. By June, Standard and Poor's downgrades reached 1,800, including 200 energy sector firms (Bank for International Settlements, 2021).

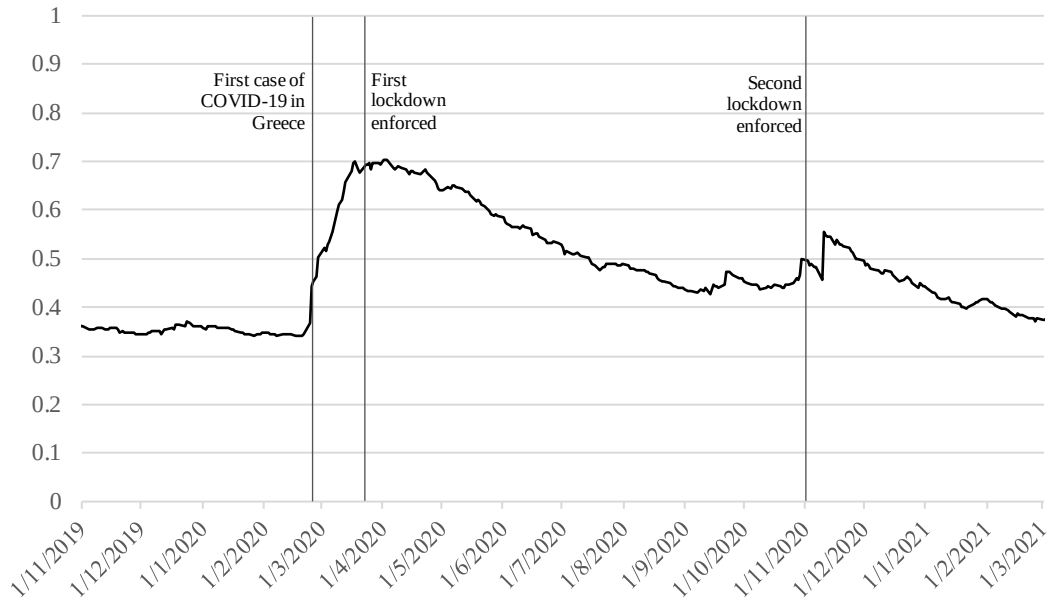
At the onset of this crisis, banks maintained increased capital buffers compared to the Global Financial Crisis. European banks doubled their loan loss provisions during the first quarter of 2020. Central banks provided a swifter response as well, which included direct transfers, tax reliefs or guarantees on non-performing corporate and household loans (European Central Bank, 2020). These provisions were aimed at halting the downward spiral of equity and credit markets and maintaining liquidity at sufficient levels.

The protracted lockdowns took their toll on the worldwide economy. The sectors affected the most were travel services, automobiles, and energy, which faced additional pressure from the sharp decline in oil spot and futures prices (European Central Bank, 2020). Economic activity indexes suffered losses from 40% for grocery and pharmaceuticals to 70% for retail, recreation, and transit from early March to mid-April (Bank for International Settlements, 2021). Cargo and passenger transports were also severely limited. Containerized sea freight in the major port terminals of China reported a 24% year-on-year decline, while scheduled flights were reduced more than 60% globally. Unemployment spiked within a month of lockdowns with an estimated 90 million workers losing their jobs in India. Global GDP is estimated to have contracted by 3.6% in 2020 (Hellenic Capital Market Commission, 2021).

The public health crisis of COVID-19 and the entailing economic recession inevitably affected Greece. GDP shrunk by 8.2% year-on-year, while the quarterly percentage decrease amounted to 15.6% and 9.4%, respectively (Hellenic Capital Market Commission, 2021). Greece's obligation to achieve its macroeconomic targets regarding a 3.5% primary surplus was suspended. Private consumption receded by 5.2%, imports of goods and services by 6.8%, and exports by 21.7%. The Greek financial markets were also adversely affected due to a lack of visibility on the duration of lockdowns, which intensified investor uncertainty. The ATHEX Composite Share Price Index marked an 11.75% yearly loss in 2020, while the greatest loss recorded that year was the FTSE/ATHEX-CSE Banking Index, suffering a staggering -41.37% loss.

The first case of COVID-19 in Greece was diagnosed on February 26, 2020 (National Public Health Organization, 2020). Our index performs the most abrupt leap in its 22-year history, increasing from a nearly five-month long steady value of 0.35 to 0.7 within a month (Figure 8). After remaining slightly below 0.7 for a month, it then follows a steady decline to 0.45 over a six-month period. On March 23, a nation-wide lockdown was enforced, following a record of 695 confirmed cases and 17 deaths. In May 2020, lockdown restrictions were lifted in an effort to save the revenues from summer tourism. On November 5, Greek Prime Minister Kyriakos Mitsotakis announced the second lockdown, beginning the next day. The index reaches a minor peak of 0.55 in November 10 and begins declining afterwards, dropping below 0.4 in early February 2021.

Figure 8. The daily Greek FSI from November 2019 to March 2021.



4.6 The Invasion of Ukraine (2022)

Global recovery from the COVID-19 pandemic in terms of economic activity and financial stability was disrupted by the Russian invasion of Ukraine in early 2022. This unanticipated event marked the first large-scale armed conflict in Europe since World War II and sparked fears of escalation to a global conflict. Especially the first months after the invasion, significant shifts in the balance of global economy occurred that inevitably affected financial markets.

Prior to the invasion, tensions had been mounting between Russia and Ukraine, raising concerns due to Russian military build-up near the Ukrainian border. On February 24, 2022, Russian President Vladimir Putin decreed the independence of two eastern Ukraine regions (Bown, 2023). The west answered with a series of sanctions prohibiting new investments in, exports to, or imports from the contested regions. Other sanctions included asset freezes and travel bans for the Russian elite. On February 24, Russian President Vladimir Putin announced the launch of a "special military operation", aimed at securing Russian minorities in East Ukraine. The news sparked panic, which translated into high volatility in global financial markets.

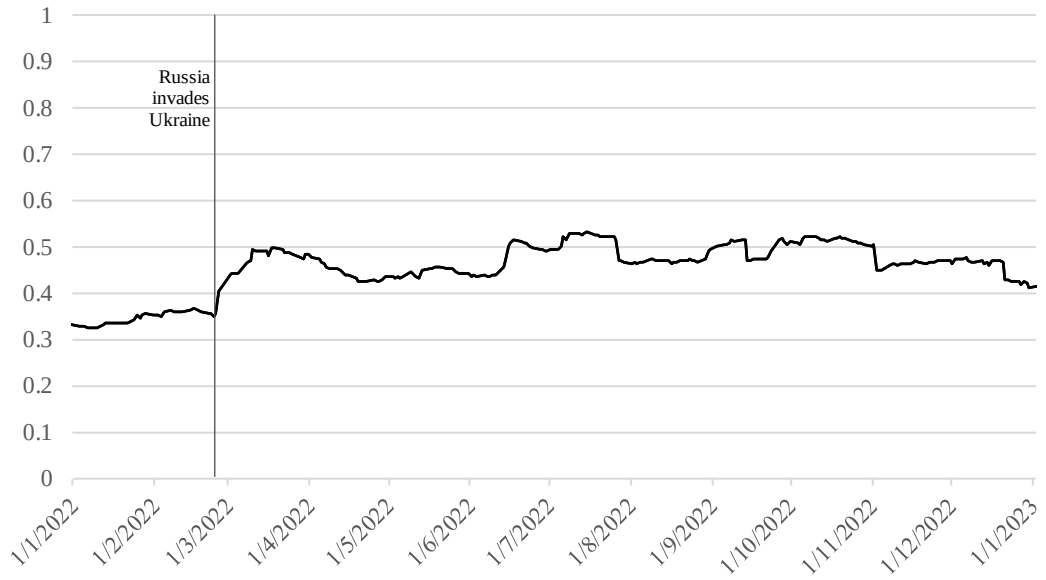
During the following days, the West limited imports from and exports to Russia, initially targeting key Russian industries in the defense sector, and prohibited transactions with the Central Bank of Russia (Bown, 2023). At this point it became evident that an escalation of sanctions would include oil and natural gas, which would severely damage supply. At the time, Russian oil accounted for 12% and natural gas for 17% of global production (Bank for International Settlements, 2023). The US and Canada were the first to ban imports of Russian petroleum in mid-March (Bown, 2023). European countries followed nearly a year later due to their dependence on Russian imports.

The spike in petroleum and commodity prices that resulted from the sanctions significantly contributed to the mounting inflationary pressures developing since late 2021 (European Central Bank, 2022). Average petroleum prices increased by 39.8%, from $69.42 per barrel in 2021 to $97.05 per barrel (Hellenic Capital Market Commission, 2023). Global inflation increased from 4.7% in 2021 to 8.8% in 2022 (International Monetary Fund, 2023). To mitigate this problem, central banks intervened by increasing their interest rates. The Federal Reserve's increases in 2022 amounted to 4.25 percentage points and ECB's to 2.5 percentage points (Hellenic Capital Market Commission, 2023). High commodity costs also compressed profitability in the corporate sector. Major firms hastily exited Russia, with more than 160 firms completely withdrawing and more than 180 suspending their operations in Russia (International Monetary Fund, 2022). Investor flight to quality caused high-yield spreads to widen, and crypto-assets were devaluated by 70% year-on-year.

The occurring energy crisis and inflation also became evident in Greece. Greece was exposed to the war in Ukraine through energy imports from Russia, which accounted for 30% of its total energy consumption (OECD, 2022). As a result, retail electricity prices increased by 79% in the year up to April 2022. For the first nine months of 2022, ever-increasing energy prices were the most important contributor to inflation, while in the fourth quarter, food and service prices dominated inflationary pressures (Hellenic Capital Market Commission, 2023). Greek households experienced a sudden change in the cost of living, despite the government rising minimum wages by 2% and 7% in January and May, respectively (OECD, 2022). Consumer price inflation reached a 25-year high, with the average Harmonized Index of Consumer Prices (HICP) surging 9.3% (Hellenic Capital Market Commission, 2023). To combat these issues, Greece was to receive €31.16 billion in subsidies and loans through the European Recovery and Resilience Facility by 2026. The increase of the country's indebtedness was followed by a 5.9% yearly GDP increase.

The invasion of Ukraine caused our index to increase from 0.35 to 0.5 within 10 days (Figure 9). For the rest of the year, its values fluctuate from 0.42 to 0.53.

Figure 9. The daily Greek FSI from January 2022 to January 2023.



4.7 Deposit Runs in the US and Switzerland (March 2023)

In March 2023 the simultaneous collapse of three US regional banks and a major Swiss bank was prevented with timely government interference. The occurring uncertainty created financial turbulence that was also evident in Greece.

Silicon Valley Bank's deposit base expanded rapidly, as it was heavily invested in startup firms in the tech industry during the pandemic-era tech boom (International Monetary Fund, 2023). The bank reinvested these funds into long-term Treasury bonds and mortgage bonds to generate reliable returns amid low interest rates. As investments in startups were limited in 2022, Silicon Valley faced liquidity problems and depositors began withdrawing. On March 8, 2023, the bank announced a $1.8 billion loss on the sale of securities that had lost significant value due to aggressive interest rate increases by the Federal Reserve. The bank revealed plans to raise over $2 billion to strengthen its balance sheet. The next day, negative investor sentiment caused Silicon Valley Bank's shares to plummet by 60%. Depositors, primarily venture capital firms and tech startups, began withdrawing their funds, exceeding one-fourth of the bank's deposit base, and reaching $42 billion. On March 10, 2023, the rapid withdrawal of funds pushed Silicon Valley Bank to the brink of collapse. The bank was closed and placed under Federal Deposit Insurance Corporation (FDIC) receivership to protect depositors (International Monetary Fund, 2023).

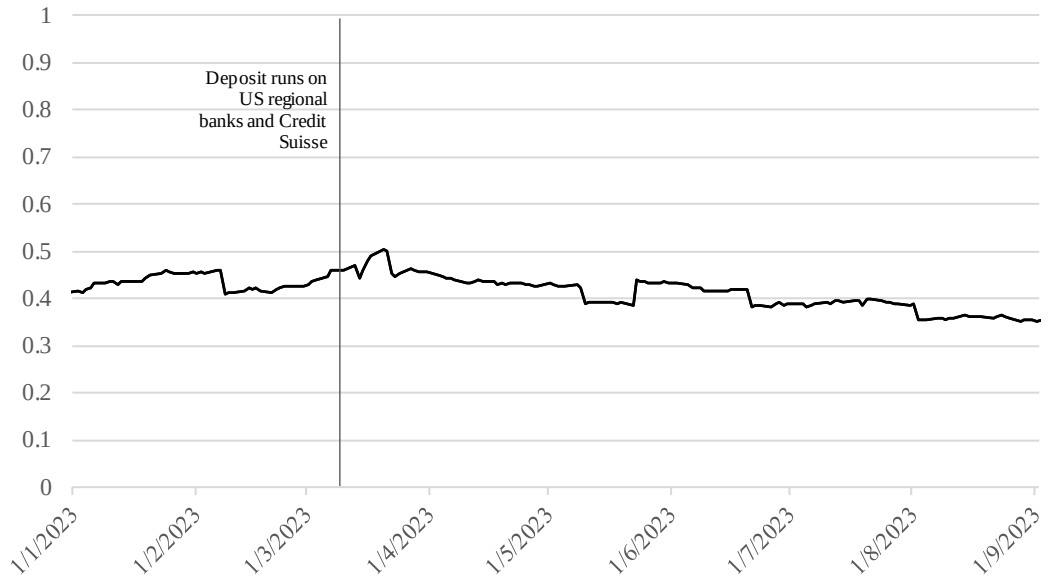
The deposit run on Silicon Valley turned the attention of investors towards banks with similar funding structures, such as Signature Bank, Silvergate Bank, and First Republic. In late 2022, 30% of Signature Bank's deposit base consisted of crypto-assets and suffered a 40% decline between March 8 and 10 (International Monetary Fund, 2023). Similar to Silicon Valley, the bank was placed under FDIC receivership on March 12. Silvergate Bank, another bank heavily invested in crypto assets that

experienced exponential growth, with total assets increasing from less than $1 billion in 2017 to more than $16 billion at the end of 2021 (Federeal Reserve, 2023). However, it faced liquidity issues following the plummet in cryptocurrency prices in November 2022, due to insufficient risk hedging. On March 8, Silvergate announced its intent to voluntarily liquidate, triggering a mass withdrawal of deposits. First Republic was also affected by the wave of withdrawals, which exceeded $100 billion (Son, 2023). Its stock price suffered a 90% loss in March alone and a 95% loss in 2023.

Credit Suisse was one of Switzerland's leading financial institutions, second only to UBS. Its total assets under management amounted to 1.6 trillion CHF at the end of 2021 (Credit Suisse Group, 2022). In the previous years, Credit Suisse faced a series of scandals and management shifts. In 2021, insufficient risk management led to a nearly $1 billion loss, following the collapse of U.S. family investment fund Archegos Capital and British finance firm Greensill Capital (Credit Suisse, 2021). Rumors that Credit Suisse was expecting a failure prompted clients to withdraw a total of 110 billion CHF in the fourth quarter of 2022 (Daga, 2023). On March 14, upon delivering its delayed 2022 balance sheet, the bank revealed its greatest annual losses since the Global Financial Crisis, reaching 7.29 billion CHF. The next day, the Saudi National Bank, a substantial investor, denied further funding due to state regulations, causing a 24% drop in Credit Swiss equity (Menon, 2023). Thus, Credit Suisse turned to the Swiss National Bank for short term liquidity, announcing a 54 billion CHF loan later that day. News of the rescue loan caused the bank’s shares to rebound by 20%.

The near collapse of the four banks shocked financial markets. European bank stocks plummeted, as the event damaged investor confidence, with the EURO STOXX Banks Index receding 18.5% and the FTSE/ATHEX Index 16.1% in the first half of March. However, broader implications regarding liquidity and solvency of financial intermediaries were largely mitigated by the swift response of central banks (International Monetary Fund, 2023). Our FSI exhibited a minor increase from the 0.45 area to 0.5 on March 21, prior to a steady decline to 0.35 (Figure 10).

Figure 10. The daily Greek FSI from January 2023 to July 2023.



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5 Concluding Remarks: Significance, Limitations, and Delimitations

In this thesis, we have constructed a daily Financial Stress Index for Greece with a 22-year timespan, using variables that cover equity, bond, foreign exchange, and interbank money markets. The variables have been aggregated via the variance-equal weight method and transformed via the logistic sigmoid function. The combination of these techniques has proved valuable in its simplicity of conveying a relative magnitude of financial stress on a 0 to 1 scale. The constructed index performs well in identifying known crises, and the major individual episodes in them.

The thesis contributes to the international literature on financial index construction in the following ways. First, to our knowledge, it is the only FSI that focuses entirely on Greece after a 10-year literature gap following Louzis and Vouldis (2012). Second, by focusing on Greece, it provides further evidence on the behavior of FSIs in developing countries, and particularly those in the European Union. Third, the construction of a high frequency FSI for this country allows financial practitioners and policy makers to apply it to decision-making and forecasting situations. Finally, the index, using observations from the past 22 years, is comprehensive as it covers the entire era of Greek participation in the eurozone.

The thesis shares the same limitations concerning FSIs in general. More specifically, the construction of an FSI depends solely on financial markets, while there are other economic factors that could provide useful information about the state of stress in an economy. However, these factors can be easily incorporated into our FSI as states of nature, which however do not change between successive observations. For example, a macroeconomic indicator such as the purchasing managers index (PMI) for Greece, which is measured at lower frequency (monthly) can be added to our daily FSI components, to account for the background economic expectations which apparently influence the daily financial activity of the securities and foreign exchange markets.

Regarding the thesis delimitations, the thesis focuses on a single country, namely, Greece. As stated from the beginning of this thesis, there is a wide variability in the effect of various events on market stress depending on the geographic region under study. Therefore, any research on FSI construction and deployment should be analyzed at the country level. Nevertheless, despite the confinement of the proposed research to a single country, its conclusions are to have broader implications for the field of financial stress, partly due to the uniqueness of Greece as a country of the EU periphery, which came to the forefront during the Eurozone debt crisis.

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