# Financial stability measure and comparison of financial risk monitoring indicators

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22/02 Les Cahiers de Recherche

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# Financial stability measure
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Abstract: Financial stability is indispensable for government, demanding important devotion of resources while regularly searching for ways to enhance the capacity to anticipate and restrain future spells of instability. Policymakers need to control and assess financial stability to be capable of finding potential threats in the financial system and taking suitable macroprudential measures early on. The goal of this paper is to respond to the following questions: (1) How can we measure the financial stability in the euro area? (2) How does a financial cycle react to a subsequent shock on the different risk monitoring indicators, and to what extent does the effect vary across indicators? To respond to these questions, we first use the arithmetic mean of the uniform and principal component analysis using the expectation-maximization algorithm weighting method to construct an aggregate financial stability index (AFSI) for both the euro area and 11 member states. Second, we use the bivariate vector autoregression (VAR) model to compare the impact of risk monitoring indicators on the financial cycle. We find that AFSIs can be a "complement" and a useful tool for macroprudential policymakers in their exercise of financial stability surveillance, allowing policymakers to have a clear picture of financial stability by offering them the possibility to identify stability, instability, and crisis areas. Furthermore, they seem to offer a better estimation of the intuitive response of the financial cycle after a shock compared to other financial stability monitoring indicators, such as macro risk, market risk, and liquidity risk indexes.

Keywords: Financial Stability, Aggregate Financial Stability Index, Risk Monitoring, Euro Area, EM-PCA, VAR Model.

JEL Classification: B22, B23, C43, C51, E58, G01.

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I thank Christophe Bravard, Cyriac Guillaumin, Valérie Mignon and Faruk Ülgen for suggestions, constructive conversations and useful comments on earlier drafts.

**Mesure de la stabilité financière et comparaison des indicateurs de surveillance des risques financiers**.

Résumé : La stabilité financière est indispensable aux pouvoirs publics, qui doivent y consacrer des ressources importantes tout en recherchant régulièrement des moyens d'améliorer leur capacité à anticiper et à limiter les futures périodes d'instabilité. Les responsables politiques doivent contrôler et évaluer la stabilité financière afin d'être en mesure de détecter les menaces potentielles liés au système financier afin de prendre rapidement des mesures macroprudentielles appropriées. L'objectif de ce document de travail est de répondre aux questions suivantes : (1) Comment peut-on mesurer la stabilité financière dans la zone euro ? (2) Comment le cycle financier réagit-il à un choc ultérieur sur les différents indicateurs de suivi des risques, et dans quelle mesure l'effet varie-t-il selon les indicateurs ? Pour répondre à ces questions, nous utilisons d'abord la moyenne arithmétique uniformisée des poids obtenus à partir de l'analyse en composantes principales utilisant l'algorithme de maximisation de l'espérance pour construire un indice de stabilité financière agrégé (ISFA) pour la zone euro et les 11 États membres. Ensuite, nous utilisons un modèle VAR bivarié pour comparer l'impact des indicateurs de surveillance des risques sur le cycle financier. Nous constatons que les ISFA peuvent être un "complément" et un outil utile pour les responsables de la politique macroprudentielle dans leur exercice de surveillance de la stabilité financière, permettant aux décideurs d'avoir une image claire de la stabilité financière en leur offrant la possibilité d'identifier les zones de stabilité, d'instabilité et de crise. En outre, ils semblent offrir une meilleure estimation de la réponse intuitive du cycle financier après un choc par rapport aux autres indicateurs de surveillance de la stabilité financière, tels que les indices de risque macro, de risque de marché et de risque de liquidité.

Mots-clés : Stabilité financière, Indice de stabilité financière agrégé, Gestion des risques, Zone euro, Analyse PCA, Modèle VAR.

Classification JEL : B22, B23, C43, C51, E58, G01.

# 1. Introduction

The purpose of macro-prudential policymaking is to ensure and preserve financial stability by preserving and limiting systemic risk, namely, the risk of large-scale disruption in the provision of essential financial services, with serious consequences for the real sector[2] (hampering economic activity and reducing economic welfare).

Indeed, when something goes wrong in the financial markets, or when the condition of their key institutions becomes severely strained, the related pressures on households and businesses might have undesirable effects on the real economy because capital can be impeded from flowing to worthy investments, potentially causing a credit crunch (Nelson and Perli, 2005). Therefore, financial stability is indispensable for government, demanding important devotion of resources while regularly searching for ways to enhance the capacity to anticipate and restrain future spells of instability.

Given the increasing complexity of the underlying factors contributing to instability, and the severity of the potential effects of instability on the real economy, it is important for policymakers to have financial stability monitoring tools (see Haldane et al., 2007; IMF, 2008). These tools must seek to create a more systematic approach to monitoring the global financial infrastructure to improve the understanding of risks and conditions that affect financial institutions and other intermediaries, and ultimately to warn policymakers and market participants about potential risks.[3] With this goal in mind, Haldane et al. (2007), based on a model of probability, assessed for the Bank of England the impact of possible key threats to financial stability. Their assessment included global parameters and relied on qualitative analysis, and it sought to evaluate a set of risks in the form of a map, including credit risk, market risk, funding risk, income generation risk, and operational risk. Specifically, the map offers the related risks and conditions, and how much better or worse they are, but it does not determine whether or not they are a specific threat to global financial stability.

The Global Financial Stability Map, used by policymakers for financial stability surveillance, was therefore introduced, from a large number of economic, market, and survey-based indicators, by Dattels et al. (2010). The authors characterize financial stability in their analysis as a function of six aggregate indicators of risks and conditions, which are related to a variety of sub-indicators. Hence, the map seeks to appraise broad risks to financial stability arising from, and feeding back to, credit markets, the economy, market and funding liquidity, and leverage. However, the map does not

[2] See Bennani et al. (2017).
[3] See, for example, Dattels et al. (2010).

consider certain key sources of stability risks, such as operational risks or the microstructure of asset markets.[4]

Another kind of tool used by policymakers for the macroprudential supervision of financial risks are a set of indicators called "financial risk surveillance indicators," grouped into classes of risks. For instance, the European Systemic Risk Board (ESRB) uses in its risk dashboards a breakdown into eight major risk families,[5] which are the interlinkages and composite measures of systemic risk, macro risk, credit risk, funding and liquidity risk, market risk, profitability and solvency risk, structural risk, and risk related to central counterparties.[6] The aim of these indicators is to warn policymakers about the risk of inaction. For example, Alfaro and Drehmann (2009) show the utility to monitor GDP as a macro risk, by studying the stylized facts of GDP before a crisis in order to see the extent to which they can warn about a crisis.

Nevertheless, it seems that these indicators, as their name shows, only serve to prevent the risk of financial instability and the occurrence of a potential crisis. What happens when these indicators fail to prevent risk and a crisis happens? Do they still help? Can they help to predict the impact, magnitude or extent of a crisis in the financial system? Is there another kind of indicator that can help with this goal? The purpose of this paper is to answer these different questions.

Using the expectation-maximization principal component analysis (EM-PCA), and the methodology used in the literature by Cheang and Choy (2009) and taken up by Akosah et al. (2018), on the data of 11 euro area countries, we summarize information contained in 23 individual country variables[7] into a single aggregate financial stability index (AFSI). Then, we turn the 11 AFSI countries' data into a single aggregate index for the euro area. Lastly, we compare the impact of a financial shock, as measured by the AFSIs, on the financial cycle with the impact of a financial shock, as measured by some of the financial minoring risk indicators for both the 11 countries and the euro area, using a bivariate vector autoregression (VAR) model with impulse response function.

We find that AFSIs can be a "complement" and a useful tool for macroprudential policymakers in their exercise of financial stability surveillance, allowing policymakers to have a clear picture of financial stability by offering them the possibility to identify stability, instability and crisis areas. Furthermore, it seems to estimate better the intuitive response of a financial cycle after a shock

[4] See Dattels et al. (2010).
[5] The US Office of Financial Research in charge of risk analysis for the Financial Stability Oversight Council (FSOC) a more summary classification: macro risk, market risk, credit risk, funding and liquidity risk, and contagion and interconnexion risk (see Bennani et al., 2017).
[6] https://sdw.ecb.europa.eu/reports.do?node=1000005783.
[7] The variables regrouped into five sub-indexes (Financial Development Index, Financial Soundness Index, Financial Vulnerability Index, Monetary Condition Index and World Economic Climate Index).

compared to other financial stability monitoring indicators, such as macro risk, market risk, and liquidity risk indexes.

The remainder of this paper is structured as follows. Section 2 reviews previous relevant literature. Section 3 presents our empirical methodology. Section 4 describes the data, its statistical properties and the estimation. Section 5 presents our results and their implications. Section 6 concludes.

# 2. Literature review: financial stability and its measure

## 2.1. Financial stability definition

Before defining financial stability, it is important to mention the key principles that define it. Schinasi (2004) identifies five key principles for developing a working definition of financial stability.[8] First, financial stability is a broad concept, encompassing the different aspects of finance (and the financial system) – infrastructure, institutions, and markets. Second, financial stability not only implies that finance adequately fulfills its role in allocating resources and risks, mobilizing savings, and facilitating wealth accumulation, development, and growth; it should also imply that the systems of payment throughout the economy function smoothly (across official and private, retail and wholesale, and formal and informal payment mechanisms). Third, financial stability relates not only to the absence of actual financial crises but also to the ability of the financial system to limit, contain, and deal with the emergence of imbalances before they constitute a threat to themself or economic processes.[9] Fourth, financial stability must be formulated in terms of the potential consequences for the real economy. Disturbances in financial markets or in individual financial institutions need not be considered threats to financial stability if they are not expected to damage economic activity at large. The fifth and last principle in financial stability is thought of as occurring along continuum; an example that is more transparent is the health of an organism, which also occurs along a continuum.[10]

Starting from these key principles, we can see that the financial system is complex and its stability is built on expectations and dynamics and depends on many parts of the system working rationally well. This complexity of the financial system makes its modeling[11] sufficiently complicated, just as

[8] There are also many prerequisites for establishing a sound and stable financial system, such as: macroeconomic stability and a policy framework for maintaining it; an adequate – if not effective – framework for financial regulation, supervision and surveillance (implicitly mentioned in the text as infrastructure; well-established codes, standards and business practices), and more generally private incentive structures; and an enforceable legal system that supports productive private financial contracts.
[9] See Schinasi (2004) for more details.
[10] A healthy organism can usually attain a greater level of health and well-being, and the range of what is normal is broad and multi-dimensional.
[11] Existing models only attempt a stylized view, trying to elucidate the underlying mechanisms driving financial stability. See, for example, Aymanns et al. (2018) for more details.

it does the definition of its stability. Indeed, unlike price stability, which is based on a precise and transparent definition, there is no consensus comparable to financial stability. Many definitions of financial stability have been given by different economists (academics and central bankers) during the last few years (see Duisenberg, 2001; Large, 2003; Norwegian Central Bank, 2003). These studies on the definition of financial stability can be grouped into two classes. On the one hand, we have those who have tried to define financial stability by its opposite, namely, financial instability; and, on the other hand, there are the authors who have tried to directly define the concept of financial stability.

Studies of the first class include Mishkin (1999) and Ferguson (2002), who consider that there is financial stability in the absence of instability. Instability here occurs when shocks to the financial system interfere with the information flow so the financial system can no longer do its job of channeling funds to those with productive investment opportunities (Mishkin, 1999). According to Mishkin, this is justified by the fact that a decline in the ability of financial intermediaries, particularly banks, to engage in financial intermediation, and to make loans, leads directly to a decline in investment and aggregate economic activity. And this is because of the important role of these institutions in financial markets, which is to engage in information-producing activities that facilitate productive investment for the economy. For Davis (2002), financial instability is a forerunner of a financial crisis that leads to the collapse of the financial system and its incapacity to redistribute financial resources in the country.

The second class includes Schwartz (1986), Wellink (2002), Foot (2003), the Norwegian Central Bank (2003), Large (2003), Padoa-Schioppa (2003) and Schinasi (2004), whose studies have tried to define financial stability directly. Crockett (1997) had already defined financial stability as an absence of instability;[12] this author believes that financial stability is stability in financial markets and that instability comes from price movements, causing economic fundamentals. The Deutsche Bank (2003) asserts that the concept of financial stability widely represents a steady state in which the financial system efficiently performs its key economic functions, such as allocating resources and spreading risk, as well as settling payments, and it is able to do so even in the event of shocks, stress situations, and periods of profound structural change.[13] Schinasi (2004), based on the key

[12] For Crockett (1997), instability is a situation in which economic performance is potentially deteriorated by fluctuations in the price of financial assets or by an inability of financial institutions to meet their contractual obligations.

[13] It identifies two types of analysis that authorities need to identify potential risks as early as possible and to recognize the emergence of any undesirable developments. The first consists of taking into account the relevant developments in the real economy, on the international financial markets and at the systemically relevant intermediaries or groups of intermediaries. And the second type implies a critical assessment of the quality of the regulatory framework governing markets and intermediaries, as well as the soundness of the technical systems, with payment transactions and securities settlement, in particular, being necessary.

principles described above, defines financial stability as a condition in which an economy's mechanisms for pricing, allocating, and managing financial risks (credit, liquidity, counterparty, market, etc.) are functioning sufficiently well to contribute to the performance of the economy. Hesse and Čihák (2007) suggest that financial stability at the symmetrical level has a rapport with the absence of system-wide episodes in which the financial system fails to function and the resilience of financial systems to stress. Chant (2010) shows that financial stability must be seen through its absence (namely, through the polar category of financial instability). However, Agoraki et al. (2011) argue that the financial stability of banks depends on the different country-specific institutional characteristics.

Fundamentally, a financial system can be characterized as stable in the absence of excessive volatility, stress, or crises (Gadanecz and Jayaram, 2008). Although this narrow definition is relatively simple to formulate, it does not consider the positive contribution of a well-functioning financial system to the overall economic performance. Therefore, a broader definition is required, including the macroeconomic dimension to financial stability and the interaction between the financial sector and the real sector. In this context, the ECB (2007) defined financial stability as a condition in which the financial system, which includes intermediaries' financial institutions, markets and infrastructure, is able to cope with shocks and counterbalance the prospects for disruption of the financial intermediation process.

Borio and Drehmann (2009) assert that financial stability is the converse of financial instability. Finacial instability, here, is characterized by a situation in which normal-sized shocks to the financial system are sufficient to produce financial distress. Specifically, it is a situation in which the financial system is fragile. Strassberger and Sysoyeva (2016) point out that it is important to understand financial stability as a permanent capacity of the banking sector in relation to the continuous performance of its functions without adverse negative effects on the real sector. The ECB (2017) rethinks the question of financial stability by defining it as the state in which the banking sector can avert the build-up of systemic risk, but key risks continue to emanate from imbalances and vulnerabilities in the fiscal, macroeconomic, and financial sector domains. Bennani et al. (2017) define financial stability as a condition of the financial system whereby it shows resilience in the face of stressful episodes and financial or real shocks. Although this definition explicitly refers to the ability to withstand shocks, this is still appreciated, giving a static character to the definition adopted.

## 2.2. Financial stability measure

As we have seen above, financial stability, unlike price stability, is difficult to define. This characteristic makes its measurement difficult given the interdependence and complexity of the interactions between the different elements of the financial system and the real economy. However, during the past year, different researchers (academics and policymakers)[14] have fixed on various statistical indicators that embodied and illustrated the vulnerability of the financial system to gauge financial stability. The early warning system, macro-stress testing and financial stability indices are the quantitative methods used to evaluate financial stability. Yet, it is vital to note that while, on the one hand, each of these techniques has its advantages, weaknesses, and limits, on the other hand, approaches to the development of these measures have evolved over time as concerns have shifted from the microprudential dimension to the macroprudential dimension of financial stability.

### 2.2.1. Early warning Indicators

Initially developed in the literature for currency and balance of payment crises to banking crises,[15] the early warning system was established from potential leading indicators to forecast the probability of a financial crisis. In other words, the authors of this literature examine empirical regularities in the run-up to financial crises to allow officials and/or private market participants to identify vulnerabilities in advance and to take remedial action (Aikman et al., 2018). Honohan's work (1997) was one of the first essays to specify and evaluate a set of early warning indicators. Considering the antecedents of three types of crisis (macroeconomic crises driven by endogenous boom–bust financial cycles; microeconomic crises associated with weak management and fraud in individual banks; and crises in government-permeated banking systems), the author found that crises with macroeconomic origins tended to be associated with high rates of credit growth, elevated loan-to-deposit ratios, and high levels of foreign borrowing in advance.[16]

Subsequently, Kaminsky et al. (1998) and Kaminsky and Reinhart (1999) introduced the signal-extraction approach by predicting thresholds that minimize each indicator's noise-to-signal ratio (i.e., the ratio of the probability of false alarms to one, minus the probability of missing a crisis). The key advantage of this technique is its scalability: a large number of potential early warning indicators can be assessed. The authors point out that the real exchange rate, equity valuations, real interest rates and the money multiplier were the indicators with the lowest noise-to-signal ratios. Based on this approach, and counting the number of indicators that have crossed their thresholds

[14] See, for example, IMF (2006), Hawkins and Klau (2000), Nelson and Perli (2005), Gray et al. (2007).
[15] See, for example, Calvo et al. (1993), Eichengreen et al. (1996).
[16] A finding that aligns remarkably closely with current perspectives on the drivers of financial stability risks.

at any given time, Kaminsky (1999) developed a set of composite early warning indices. Out-of-sample crisis probabilities calculated from this framework increased substantially before the 1997 Asian crisis in Thailand, the Philippines and Malaysia, but not in Indonesia.

Borio and Lowe (2002a, 2002b) applied the Kaminsky et al. (1998) approach to banking crises. They focused on signals provided by cumulative increases in credit and equity prices, and they analyzed whether composite measures outperformed individual indicators viewed in isolation. They found that the best-performing indicator, on an individual basis, was a "credit gap," as given by a rolling Hodrick-Prescott filter. This indicator later received significant attention in the literature, encompassing as an anchor variable the countercyclical capital buffer (CCyB).[17] Moreover, it was shown that this indicator is particularly useful in forecasting crises on a 3-year horizon rather than near-term risks. The prime composite measure in their analysis, in terms of performance, was to weight together credit and asset price gaps, leading to a noise-to-signal ratio that was almost 50% lower than that obtained for the credit gap alone – a benefit achieved by reducing the number of false positive signals issued.

More traditional regression-based techniques were also employed in other papers to examine the covariance of financial crises. Papers that use this approach are Demirgüç-Kunt and Detragiache (1998), Eichengreen et al. (1996) and Frankel and Rose (1996) – see also Berg and Patillo (1999) for an application to currency crises. Using this approach, Demirgüç-Kunt and Detragiache (2000) developed tools for monitoring bank crisis risk. The first tool was an early warning system that issued a signal when the projected crisis probability exceeded a certain threshold, chosen to reflect policymakers' preferences over avoiding false alarms versus missing crises. The second was a rating system for bank fragility, which mapped crisis probability forecasts onto different fragility classes. And, in an out-sample forecasting exercise, Demirgüç-Kunt and Detragiache (1998) showed that, while these tools identified signs of fragility in Thailand and the Philippines in the run-up to the Asian crisis, they provided a more confident picture of risks in other Asian economies.

The downside of these models is, first, their inability to predict the *timing* of crises. Second, they do not give information about the shock's response ability (Vintu and Negotei, 2018). This is why, from the mid-2000s, interest in this approach began to fade. However, the advantages of these models lie in their ability to identify underlying vulnerabilities, which may persist for a substantial period of time before a crisis occurs (Chamon and Crowe, 2012). This insight also explains why there has been renewed interest in searching for indicators of financial stability risk over the past decade since the global financial crisis. Another group of papers in the recent literature adopt a

[17] See, for example, Drehmann et al. (2011).

multivariate approach to identifying build-ups in vulnerabilities for macroprudential policy purposes. These papers include Aikman et al. (2016), which gives a set of indicators of financial stability in the US financial system. Dattels et al. (2010) use a closely related approach for the purposes of constructing the IMF's risk monitoring system. Aikman et al. (2018) adopted a similar methodology[18] for assessing each indicator relative to its historical distribution, aggregating them into composite measures.

#### 2.2.2. Stress tests

Generally speaking, stress testing involves analysing how an object or system copes under pressure. Bank stress testing, also called microprudential stress testing, is designed to test the resilience of banks to severe but plausible shocks (Dent et al., 2016). In practice, this typically means modeling the impact of hypothetical adverse macroeconomic and financial market scenarios on bank profitability and balance sheets. The process of microprudential stress is conducted in three steps.[19] First, the regulator plans an initial stress, which designates a crisis narrative and associated set of exogenous shocks. This scenario is designed in such a way that it is adverse, plausible, and coherent (Siddique and Hasan, 2012). Second, when the scenario has been determined, its effect on the balance sheet of banks is determined to compute the post-stress regulatory capital ratio and profits. And, third, once the post-stress capital ratio has been determined, it is compared to a hurdle rate set by the regulator. If it does not meet this hurdle, the bank is said to have failed the stress test. In this context, the regulator commonly has the authority to require the bank to raise extra capital. Microprudential stress tests are thus used as a tool to recapitalize undercapitalized banks, thereby reducing their leverage and increasing their resilience.

Microprudential stress tests have three main advantages. First, they allow market participants to obtain clear insights into the opaque balance sheet of the evaluated financial institutions (Bookstaber et al., 2014). Second, they help financial institutions to ameliorate their own risk management. Stress tests require banks to have a global view of their own risk management practices by forcing them to appraise their resilience to a variety of novel scenarios. Thus, more banks are now engaged in serious internal stress tests. And, finally, it is shown that microprudential stress tests are an effective mechanism to recapitalize banks (Armour et al., 2016). For example, the stress test forced European banks to increase their capital by 260 billion euros between 2011 and 2016 (Arnold and Jenkins, 2016).

[18] The methodology involves identifying indicators in distinct risk categories.
[19] See, for example, Aymanns et al. (2018).

In spite of their strengths, microprudential stress tests also have their weaknesses. The first and most important them is that microprudential stress tests ignore the fact that economies are complex systems and thus they fail to capture systemic risk (Aymanns et al., 2018). By considering institutions individually, they ignore the interconnections and interactions between financial institutions that serve to propagate and amplify distress, and the losses that result from adverse scenarios are substantially underestimated (Bookstaber et al., 2014). As argued by Bernanke (2015), the majority of losses in the last financial crisis can be traced back to such interactions, as opposed to the initial shock emerging from credit losses in subprime mortgage loans. Second, it was shown that the value of the information that microprudential stress tests provide is increasingly being questioned. As argued by Glasserman and Gowtham (2015), their outcomes have converged. This makes it possible to wonder, on the one hand, what the information produced by the stress tests is actually worth (Hirtle et al., 2016); and, on the other hand, to realize that the value of such information is decreasing over time (Candelon and Sy, 2015).

These weaknesses of microprudential stress tests, and their inability to appropriately account for systemic risk, have led to the development of a specific type of stress test focused on this goal, called the macroprudential stress test, which seeks to appraise the resilience of the whole financial system rather than one specific institution.[20] Macroprudential stress tests expand microprudential stress tests by incorporating contagion effects between interconnected financial institutions that can arise following the initial scenario. That implies that, on the one hand, the regulators must not only appraise the effect of the initial shocks on the individual balance sheets but also apprehend how the balance sheets are interlinked; on the other hand, they should analyze the consequences of these interlinkages and the ability of financial distress to propagate throughout the system (Aymanns et al., 2018).

To sum up, unlike the early warning system, which allows prediction of the likelihood of a financial crisis (especially a currency crisis) but doesn't give information about the ability of the shock response, stress testing proposes more faithful analysis, which can estimate the financial system's resistance to adverse macroeconomic scenarios. As shown in several studies, stress tests can find out the source of risk and vulnerabilities of the investigated banking sector or the overall financial sector. Studies based on stress tests include Schmieder et al. (2011), Buncic and Melecký (2012), Jakubík and Sutton (2011), Bennani et al. (2017), and Aymanns et al. (2018). Čihák (2007), using an Excel-based exercise with institution-by-institution data, illustrates that stress tests are complementary to other tools for financial stability analysis, in particular, the financial soundness

[20] See, for example, Alessandri et al. (2009) and Henry and Kok (2013).

indexes developed by the IMF (2006). Recently, Kohn and Liang (2019) assessed the impact of stress tests based on features of the stress test program that differentiate stress tests from regulatory capital requirements. They found that the stress tests appear to offset some procyclicality in capital ratios, driven by not only the macroeconomic scenarios but also the requirement to pre-fund shareholder payouts, which rise as the economy expands. Their review also proposes that there are many other questions that could be pursued on stress tests even if they conclude that these remain an effective risk management tool.

### 2.2.3. Aggregate financial indexes

Aggregate financial indicators, which cover a large part of the definition of financial stability, are another quantitative method used for measuring the stability of the financial system, besides the aforementioned early warning systems and stress testing. An example of such indicators is the IMF's (2006) set of financial soundness indicators. This quantitative method is used by Hawkins and Klau (2000), Nelson and Perli (2005) and Gray et al. (2007) to inspect market pressure, external and banking system vulnerabilities. For instance, Nelson and Perli (2005) used this method to compute a "financial fragility index" for the US financial system. They showed that the fragility composite index may allow an estimation of the probability that the financial system is, or is not, in a state of shock. The construction of their index includes two steps. First, the authors group information contained in 12 individual variables into 3 indicators that refer to *t* volatility and correlation. Second, a logit model is used to predict the statistical likelihood that financial markets behave in a similar way at any time to that recorded during the previous financial crisis. The Swiss National Bank (2006), by combining market data with balance sheet data, also adopted this method to build a similar pressure indicator for banking.

Likewise, country-specific financial stability indexes have been constructed, including: Illing and Lui (2003) for Canada; Morales and Estrada (2010) for Colombia; Albulescu (2010) for Romania; Sales et al. (2012) for Brazil; Sere-Ejembi et al. (2014) for Nigeria; and Arzamasov and Penikas (2014) for Israel. Islami and Kurz-Kim (2013), using some financial variables that have a causal relationship with the real economy, constructed a single composite financial stress indicator, the aim of which is to predict developments in the real economy in the euro area. They concluded that their indicator can serve as an early warning indicator for negative impacts of financial stress on the real economy. Jakubík and Slacik (2013) developed a comprehensive financial instability index, which measures the level of financial market stress in some key Central, Eastern, and South-eastern

European (CESEE) countries,[21] using a broad range of indicators, from money, to bonds, equity and foreign exchange markets. It is obvious that their index understands developments in money, foreign exchange, and equity and bond markets, and thus reflects sentiments in all of the relevant financial market segments in the countries considered. Koong et al. (2017), using a large set of financial and market-based variables, developed a financial stability index to measure financial stability in Malaysia. The authors adopted a series of forecasting tests and assumed that their index predicted the Malaysian business cycle, as well as delivering well regarding the financial downturns in Malaysia. Akosah et al. (2018) developed for Ghana a composite quantitative indicator to measure the performance of the financial system since the adoption of inflation targeting in 2017. Meanwhile, Loloh (2015) developed an aggregated financial soundness indicator for Ghana, while Kočišová (2014) constructed an aggregated banking system stability index for 10 selected countries (the Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, the Slovak Republic and Slovenia) that joined the European Union in 2004. However, Illing and Lui (2003) give a good description of how one might strive to build a composite financial stability index. They point out the choice of relevant variables, which must reflect the structure of the country's financial system.

The key advantages of this quantitative method reside in the calculation's simplicity and cover a large definition of financial stability by combining macroeconomics and financial variables. Also, the relevant index of this method offers the analysts the possibility to compare different financial systems in terms of stability and also allows them to observe the financial stability dynamics (Albulescu, 2008), offering the possibility to outline the stability, instability, and crisis areas. In terms of disadvantages, the technique includes several stages: the selection of individual indicators, the selection of the method for their normalization, and identification of a weighting method (which relies on the retained criteria and on the established weights). This method is used in this paper to develop a financial aggregate index for the euro area. In addition to the aforementioned advantages, unlike the two previous methods ("early warning systems" (EWS) and "stress testing"), this technique allows us to make comparisons between different periods and systems, offering a clear picture of the stability level of development (Vintu and Negotei, 2018). The following section presents the details of its steps.

The central banks' desire to monitor and analyze financial stability's threats and risks has led to the publication of financial stability reports. Studies related to this topic, including Gadanecz and Jayaram (2008), Oosterloo et al. (2007) and Čihák (2007), provide comprehensive surveys of the

[21] The study includes nine selected countries in emerging Europe (including the Czech Republic, Hungary, Poland, the Slovak Republic, Bulgaria, Croatia, Romania, Russia and Ukraine).

financial stability reports and the underlying indicators. Oosterloo et al. (2007), in particular, underline three principal motivations for the publication of financial stability reports. They point out that financial stability report publications, first, increase the transparency of the authorities responsible for financial stability; second, they contribute to financial stability; and, third, they fortify cooperation between the various participants implicated to maintain financial stability. From a general point of view, the greater part of financial stability presented in the financial stability reports center on various market segments. Basically, the focus relies upon the economy conditions and the areas of inspected vulnerabilities (Gadanecz and Jayaram 2008).

In fact, many emerging market economies widely focus on capital inflows, the balance of payment situation, and exchange rate movement, while developed economies center on their banks' exposure to emerging markets. Banking ratios are also broadly appraised in most reports. However, there is no common use of composite indicators in published financial stability reports. But there are some common areas when it comes to the specific variables used in the financial stability reports (Akosah et al., 2018).

Besides, in order to evaluate the risks and conditions that impact financial stability, the financial stability map was first introduced by Haldane et al. (2007) for the Bank of England and then by Dattels et al. (2010) for the USA. The aim of the map was to complement existing attempts, in addition to the IMF's widest surveillance and financial stability initiatives (Global FSR, 2007). As mentioned by Dattels et al. (2010), the map sought to understand a range of potential sources of instability and contagion between diverse segments of the financial markets and non-linear relations across inherent factors. It contained four risks and two conditions. The four risks comprised macroeconomic risks, emerging market risks, credit risk, and market risk; and the two conditions included monetary and financial conditions, and risk appetite.[22] Concerning the map's performance, the authors concluded that the map generally warned that risks were very low, whereas conditions were very loose, suggesting higher risks to financial stability in the period ahead.

However, it is evident from the survey of literature that no aggregate financial stability index has been introduced for the euro area. The only such index developed for the euro area is the financial stability risk index introduced by Deghi et al. (2018) using the partial quantile regression method. Therefore, this paper develops an aggregate financial stability index for the euro area using carefully

[22] The monetary and financial conditions are assessed by the availability and cost of funding linked to global monetary and financial conditions, such as the real short-term interest rate, G-3 excess household and corporate liquidity, Goldman Sachs global financial conditions index, growth of custodial reserve holdings at the Federal Reserve Bank of New York, and G-3 Bank lending condition). Meanwhile, the risk appetite is evaluated by the willingness of investors to take on additional risk by adjusting exposure to the riskier asset classes, the consequent potential for increased losses, and the implications for the functioning of broader financial markets.

picked macroeconomic variables (both external and internal) and bank-balance-sheet data (completed with financial soundness and monetary conditions indicators). Thus, the paper offers a contribution to the debate on financial stability concerns for the euro area economy.

# 3. Empirical methodology

The methodology adopted to construct our quarterly aggregate financial stability index (AFSI) is as follows: we first compute for each country in our sample (eleven countries) the five sub-indexes (Financial Development Index (FDI), Financial Soundness Index (FSI), Financial Vulnerability Index (FVI), Monetary Conditions Index (MCI), World Economic Climate Index (WECI)), and we then aggregate them into a single AFSI. Then, we make an aggregation of the set AFSIs to obtain the euro area aggregate financial stability index. The weights allocated to both our AFSIs and AFSI sub-indexes are the arithmetic mean of weights based on both uniform and principal component methods using the expectation-maximization algorithm. We start by estimating the monetary condition sub-index and then we estimate the other sub-index.

## 3.1 Monetary conditions sub-index

In a small open economy, the monetary condition index (MCI) is defined as the weighted average of the real interest rate and the real exchange rate compared to their equilibrium values (Batini and Turnbull, 2000), as follows:

$$mci_t = \beta r_t + (1 - \beta)(-z_t) \tag{1}$$

where $r_t$ indicates the real interest rate in percent (p.a) at time *t*. The real interest rate is defined as the difference between the nominal interest rate $i_t$ and the expected inflation rate $E_t(\pi_{t+1})$. So, we define the real interest rate $r_t$ as: $r_t = i_t - E_t(\pi_{t+1})$. $z_t$ indicates the real exchange rate (in ln*100)[23]: $z_t = s_t + p_t^* - p_t$, where $s_t$ is the nominal exchange rate (local currency per unit of foreign currency), $p_t$ indicates the domestic price level, and $p_t^*$ the foreign price level.

The monetary condition sub-index composition reflects the assumption of a small open economy. Not only the interest rate but also the exchange rate are important components that define the monetary stance – whether it is loose and stimulates demand, or whether it is tight and constrains demand. Therefore, the sub-index captures the impacts of monetary policy on aggregate demand and, as a consequence, on the output via two of the most important policy transmission channels -- the interest rate and exchange rate channels. The real interest rate impacts decisions to substitute between consumption today and saving today to consume in the future and to borrow funds to

[23] ln indicates logarithmic terms.

finance investment and consumption expenditure. Meanwhile, the real exchange rate impacts the substitution or shift in demand between domestically and foreign-produced goods, as it captures changes in relative prices.

The parameter $\beta$ means that the weight here is positive and comprises between 0 and 1 ($\beta \in [0,1]$). Thus, we can see that the higher level of the real interest rate is consistent with the higher monetary condition index. A higher interest rate means a higher cost of borrowed money to finance consumption and investment, or larger incentives to save and postpone consumption, which, in turn, leads to constrained aggregate demand and output. The real exchange rate enters the equation with a minus sign because of its definition. The nominal exchange rate is a direct quote, which is the number of units of domestic currency per one unit of foreign currency. Therefore, the real exchange rate is determined in terms of foreign prices, converted to domestic currency, and relative to domestic price level. Depreciation of the domestic currency vis-a-vis foreign currency would correspond to a larger, more positive, or less negative value of the real exchange rate. More depreciated domestic currency, all other things being equal, gives exporters more domestic currency per one unit of foreign currency. Then a weaker, in real terms, domestic currency, should stimulate demand for domestically reproduced goods and services. Therefore, this implies more accommodative monetary conditions. So, a larger value of the real exchange rate then indicates more accommodative conditions. To obtain the correct impact of the real exchange rate in this definition on output, we add minus before the real exchange rate.

It is important to notice that although the MCI is defined here in real terms, it can also be defined in nominal terms. The advantages of favoring the real-term approach, rather than the nominal one, are as follows: first, macro-econometric models are based on real-term variables (Guillaumin and Vallet, 2017). Second, in the medium term, when inflationary effects can pass through the output gap, it can be difficult to interpret the nominal variables. Moreover, it has been shown that the evolution of nominal variables conducts more ambiguous information than real variables.[24]

Nevertheless, using MCI as a monetary stance measurement has some disadvantages. First, the index specification assumes that the interest rate and exchange rate are both monetary policy instruments, which is not always the case. Bindseil (2004) shows that, in practice, they can be operational targets. Second, even if the MCI were an operational target, it would not be appropriate in the case where non-policy variables might play a role in determining changes in both the interest rate and exchange rate (Eika et al., 1996; Ericsson et al., 1998).

[24] See, for example, Aubert (2003) for literature review.

In the next section, we will present the estimating methodology of the rest of the sub-index.

## 3.2 The other four sub-index

We estimate the rest of our sub-indexes using the statistical normalization approach introduced by Cheang and Choy (2009) and taken up by Akosah et al. (2018). All of our variables are normalized using the z-score to ensure that the overall index is not dominated by any individual variable. Underlying the normalization of variables is the concept of "stationarity," or the notion that the mean and variance of each variable does not vary over time (Brave and Butters, 2011). For this to hold, some variables must first be altered with a stationarity-inducing transformation prior to estimation. For this reason, we do some stationarity tests and use some transformation before normalizing the data. The zero mean and one standard deviation, z-score, is given as follows:

$$\widetilde{X_t} = \frac{(X_t - \mu_X)}{\sigma_X} \tag{2}$$

where $\widetilde{X_t}$ is the normalized series of the interest variable. $X_t$ represents the value of interest variable at time *t*, $\mu_X$ and $\sigma_X$ denotes, respectively, the mean and standard deviation of *X*.

This step is followed by calculating weights for the selected variables. The empirical literature suggests two approaches for computing weights for the index: the uniform weighting (see, for exemple, Jakubík and Slacik, 2013 and Albulescu, 2010); and the principal component method. However, the uniform averaging index is likely to be influenced or swayed by the most dominant variable (Akosah et al., 2018). Thus, we use the principal component analysis (PCA) method[25] for computing the weights of our sub-indexes.

The mathematics behind PCA[26] is as follows. Let us denote $x_t$ the $1 \times N$ elements row vector of data at time *t*, and $X_t$ the stacked matrix of data vector, where each column of this vector contains $T$ observations of our sub-indicator normalized variable. The eigenvector-eigenvalue decomposition of the variance-covariance matrix[27] $X_T' X_T$ gives a set of weights referenced by the $1 \times N$ vector $W$ corresponding to the eigenvector associated with the largest eigenvalue of this matrix. These weights are used to compute a weighted sum of the $x_t$ at each point in time, such that the resulting index is obtained by:

$$I_t = X_t W \tag{3}$$

[25] In the line of, for example, Brave and Butters (2011) or Arzamasov and Penikas (2014).
[26] See Appendix A and Theil (1971) for more details on the PCA method.
[27] $X_T'$ represents the transpose of the matrix $X_T$.

Where $I_t$ represents the sub-index. In general, many missing values and frequency variations in the data set can cause problems and render PCA not feasible. An alternative method that avoids these problems is the approach proposed by Stock and Waston (2002), which presents how this issue can be addressed by an iterative estimation strategy that relies on the incomplete data methods of the expectation-maximization (EM) algorithm of Watson and Engle (1983). This algorithm uses the information from the balanced panel of indicators to make the best possible prediction of the unbalanced indicators. The algorithm begins by estimating PCA on a balanced subset of the data to obtain an initial estimate of the index. The data for each of the financial indicators is then regressed on this estimate of the index, and the results of each regression are used to predict the missing data. The index is re-estimated by PCA on both the actual and predicted data. This process continues until the difference in the sum of the squared prediction errors between iterations reaches the desired level of convergence. However, a criticism addressed by Brave and Butters (2011) to this approach is that the Stock and Watson EM algorithm is a purely static estimation method that does not incorporate information along the time dimension into the construction of the index. Furthermore, it is restricted by the initial balanced panel of indicators, given its reliance on PCA.

Because of missing values for some countries' variables, we use this method instead as a starting point. We use a similar approach to Arzamasov and Penikas (2014), and Akosah et al. (2018), by taking the arithmetic mean of all the principal factors generated from the PCA-based EM algorithm to make sure that the generated weights are all positive. The arithmetic mean of the different principal factors obtained after running the PCA-based EM algorithm is as follows:

$$w_{ij} = \frac{\sum_{\{i=1\}}^{\{n\}} f_{ij}}{k} \tag{4}$$

where $w_{ij}$ is the arithmetic mean of all principal factors, and *n* represents the total number of variables or sub-indexes implicated in the PCA-based EM algorithm.

Thus, the consolidated index for each of the four sub-indexes is calculated by the given equation:

$$\widetilde{w_{ij}} = \frac{w_{ij}}{\sum_{\{i=1\}}^{\{n\}} w_{ij}} \tag{5}$$

Where, $w_{ij}$ is the arithmetic mean of all principal factors, and *n* represents the total number of variables or sub-index implicated in the PCA-based EM algorithm.

Thus, the consolidated index for each our four sub-indexes is calculating by the given equation:

$$I_t = \omega\ (-X_t) \tag{6}$$

where $\omega$ represents the vector of the mean of weights obtained from the uniform and PCA-EM algorithm.[28] For each variable in the matrix $X_t$, the corresponding $\omega_{\mathrm{j}} = \frac{\frac{1}{n}+\widetilde{w_{ij}}}{2}$. $X_t$ is the matrix of the selected variables in the corresponding sub-index vector $I_t$. The minus sign before $X_t$ allows us to ensure that the selected indicators have the same directional effect on the aggregate index. Thus, an increase (respectively, a decrease) in a given sub-index leads to an amelioration (respectively, a deterioration) in financial stability.

The final step consists of aggregating into the single aggregate financial stability indicator (AFSI) the five sub-indexes for each country of our sample. The aggregation is obtained as follows:

$$AFSI_t = \sum_i \alpha_i I_{it} \tag{7}$$

with $i = 1, \dots, 5$. The five sub-indexes are, respectively, the Financial Development Index (FDI), the Financial Soundness Index (FSI), the Financial Vulnerability Index (FVI), the Monetary Conditions Index (MCI), and the World Economic Climate Index (WECI), where $\alpha_i$ represents the weight of the corresponding sub-index $I_{it}$. The weights allocated to our AFSIs are the arithmetic mean of weights based on both uniform and principal component methods using the expectation-maximization algorithm.

There are other ways to obtain the weights in equation (7). For example, the weights can be based on expert judgments and weights commonly used in the literature (see Cheang and Choy, 2009 and Akosah et al., 2018). Or, one can simply use the weights provided by the principal component, which mostly explains the variance (first principal component) of data (sub-indexes). In this paper, for robustness, we use the two methods, in addition to the methodology explained above, and we make a comparison. Using the existing literature, the weights used for the AFSIs are as follows: FDI = 5%, FSI = 35%, FVI = 20%, MCI = 30%, and WECI = 10%. We discuss these weights in the following section.

# 4. Data description and estimation

## 4.1. The selected variables and data issues

The first thing to do in the construction of an aggregate financial stability index is to identify the set of variables and conditions that might support threats to financial stability (Cheang and Choy, 2009). In order to construct our quarterly aggregate financial indicator, we use the traditional financial soundness indexes, as well as indicators from the external sector, monetary and financial

[28] We make restrictions on the factor loadings to satisfy $\frac{\omega'\omega}{N} = I$.

sector, balance of payments, foreign exchange and capital markets. The set of variables is presented in Table 1 and is carefully selected based on the condition that developments in those variables have potential influence on financial stability. Table 1 contains 23 variables[29] for our euro area financial stability index, and we collect quarterly data for 11 countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Spain and Portugal) from 2007Q1 to 2020Q4.

The financial development index (Table 1) provides a measure of the level of financial system development. The ratio of market capitalization to GDP catches the development of the capital markets, while the ratio of total credit to GDP gives information on the ability of credit institutions to further their intermediation functions. Augmentations in the values of these indexes are expected to lead to ameliorations in the sub-index. Indeed, the Herfindahl–Hirschmann Index (HHI) in the sub-index represents the degree of concentration in the banking sector. It is calculated by the sum of the squares of all the bank's percentage share of deposits. An increase in the HHI is interpreted as a positive effect on stability.

The retaining variables for the financial soundness sub-index measure the solvency of credit institutions in the financial system. The ratio of non-performing loans (NPLs) to total loans shows the banks' loans quality, while the capital to assets ratio measures their level of capitalization. The aim of the ratio is to identify troubles with asset quality in the loan portfolio and the degree of credit risk. The increase in the ratio might reflect degradation in the quality of the credit portfolio, despite the fact that it is generally a retrospective indicator, in that NPLs are identified when problems occur. On the one hand, the ratio of NPLs net of provisions to capital provides an indication of banks' capital capacity to resist potential losses in NLPs. The ratio of liquid assets to total assets, as the so-called liquid assets ratio, gives a measurement of banks' capacity to face expected and unexpected demands for cash. The capital adequacy ratio denotes the buffer that a bank must have to face potential risks. In other words, it provides a measurement of banks' capacity to absorb unexpected losses and gives an indication of the banks' leverage.

On the other hand, the cost to income used to identify banks' profitability defines the efficiency at which the bank is being run. The lower the ratio is, the better it is for the bank, suggesting more profitability for the banks. The return on assets ratio provides a measure of the profitability or efficiency of the banks in using their assets. It also designates the buffer that a bank disposes of in order to face potential risks. The interest margin to gross income ratio and the non-interest

[29] For example, Albulescu (2008) used 18 variables; Morris (2011) used 19 variables; Cheang and Choy (2009) used 19 variables; Sere-Ejembi et al. (2014) used 18 variables; and Akosah et al. (2018) used 22 variables.

expenses to gross income ratio are comprised in the sub-index. Although the interest margin to gross income ratio measures the relative share of net interest earnings with gross income and reveals the importance of net interest income and the capacity to absorb losses, the non-interest expenses to gross income ratio measures the extent to which high non-interest expenses weaken earnings.

Table 1: Selected variables under each Sub-index

| Indicators | Subgroup |
|---|---|
| Market Capitalization/GDP<br>Total Credit/GDP<br>Herfindahl–Hirschmann Index (HHI) | Financial Development Index |
| Non-performing Loans to Total Gross Loans<br>Non-performing Loans Net of Provisions to Capital<br>Liquid Assets to Total Assets (Liquid Asset Ratio)<br>Regulatory Capital to Risk-Weighted Assets, percent (Capital adequacy ratio)<br>Customer Deposits to Total (Non-interbank) Loans<br>Cost to Income<br>Return on Assets<br>Non-Interest Expenses to Gross Income<br>Interest Margin to Gross Income | Financial Soundness Index |
| Inflation rate (CPI, year over year)<br>Ratio of Net Foreign Assets to Net Domestic Assets<br>Composite Index of Economic Activity<br>General Budget Balance (% GDP)<br>Current Account Balance (% GDP)<br>Ratio of Foreign Currency Assets to Foreign Currency Liabilities<br>Ratio of External Assets to Total Assets | Financial Vulnerability Index |
| Real Exchange Rate<br>Real Interest Rate | Monetary Condition Index |
| Economic Growth in G-20<br>Inflation Rate in G-20 | World Economic Climate Index |

Regarding the financial vulnerability sub-index, the set of indicators comprises macroeconomic variables, in addition to the funding structure of banking institutions. The sub-index indicates how well a financial system could react to given shocks. The inflation rate and general budget balance as a share of GDP are added as a signal of investor confidence in the economy since this may have implications for financial markets and financial stability. Moreover, the current account as a share of GDP reveals the country's exposure to external shocks. Meanwhile, the composite index of economic activity here gives the direction of global economic movements in future months. It helps businesses and investors to plan their activities around the expected performance of the economy and protects them from economic downturns. The ratio of foreign currency assets to foreign currency liabilities provides a measurement of the mismatch between foreign currency assets and liability. When the ratio is close to one, this indicates that there is a low risk of currency mismatch at the aggregate level. The foreign exchange rate covers banks' vulnerability to exchange movements in both directions. And, finally, the ratio of external assets to total assets measures the external position of the local bank sector.

The monetary condition sub-index comprises the real interest rate, calculated by the difference between the short-term interest rate and the inflation rate. The sub-index here supposes that the monetary conditions affect financial stability via the credit channel.

The world climate sub-index measures investors' confidence level in the financial system. The sub-index comprises two world macroeconomic indicators, which are world economic growth and world inflation rate.

Tables B.1 to B.11, in Appendix B, present unit root tests of the selected variables contained in Table 1 for each country of our sample. The results of these tests show that, for all countries, there are a few numbers of variables that are stationary in level. And they reveal that most variables are stationary in terms of differences. The variables that present a deterministic trend were regressed on the trend and the residuals of this regression were used for the analysis.

## 4.2. Estimation

For the 11 countries, the construction of the aggregate financial index for the euro area requires the following steps:

(i) estimate the monetary condition sub-index using equation (1),

(ii) estimate the financial development, financial soundness, financial vulnerability, and world economic climate sub-indexes using the EM-PCA method following equations (2), (4) and (6),

(iii) use PCA to summarize into a single indicator (aggregate financial stability index) the information contained in the variance of financial development, financial soundness, financial vulnerability, and monetary condition sub-indexes following equation (7),

(iv) use PCA to summarize into a single indicator (aggregate index for the euro area) the information contained in the variance of the 11 indicators obtained after step (iii).

For step (i), the estimation of the model in equation (1) requires calibration of parameter $\beta$. Generally, this parameter is within [0.3, 0.8] (must be in [0, 1]);[30] a lower value means that the economy is more open and that the exchange rate channel is relatively strong, while the interest rate channel is weaker. In this paper we fix the value of the parameter to 0.7 for all countries.

Steps (ii) and (iii) are detailed in the methodology section. In step (iv) the aggregate index of the euro area is obtained using equations (4) and (6) on the financial stability index estimated separately for each country.

# 5. Results

## 5.1 Aggregate financial stability indexes

The financial stability indexes that we computed based on the indicators listed in Table 1 are displayed in Figure C.1 in Appendix C. As mentioned above, the estimation period covers March 2007 to December 2020. The figure contains the indexes for Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Spain, Portugal, and an aggregate of the 11 countries.[31]

The different indexes' average is zero by construction. Therefore, a value of zero is interpreted as the average financial stability index for that country, whereas progressively larger positive values indicate progressively better-than-average conditions, and progressively more negative values indicate progressively worse-than-average conditions. Essentially, the average condition varies across countries. For instance, a value of zero for France corresponds to around -0.32%, while a value of zero in Ireland corresponds to around 0.02%. The shared region in the sample represents official recessions, as defined by NBER, CEPR, and ECRI. We identify three official recessions in our study period, which are the global financial crisis of 2008–9, the European debt crisis of 2011Q2, 2012Q3, and the COVID-19 pandemic crisis of 2020Q1, 2020Q2. Overall, we can see that the indexes fall sharply during recession and tend to reach relatively high values during good

[30] IMF, Monetary Policy Analysis and Forecasting online course.

[31] The resulting indexes are robust when we change the way we compute weights in equation (7). We present two alternative ways to obtain AFSI in Figure C.3 in Appendix C for robustness.

times for each country, and more particularly for the aggregate index of the 11 countries (see Figure 1). The dynamic of the aggregate index is very similar to the dynamic of the AFSI of the core countries, especially Germany, France, the Netherlands and Austria. This might lead one to believe that the financial stability of the euro area depends more on the financial stability of these countries.

Indeed, five distinct developments can be identified on the index dynamic. The first one is the period of financial strain following the global financial crisis (March 2007–December 2009); the second period sustains the amelioration in financial stability (March 2010–June 2011); the third period is characterized by a return to financial strain following the European debt crisis (September 2011–December 2012); the fourth period is marked by more stable financial conditions (March 2013–December 2018); and the last period sustains a return to financial stress following the COVID-19 pandemic crisis.

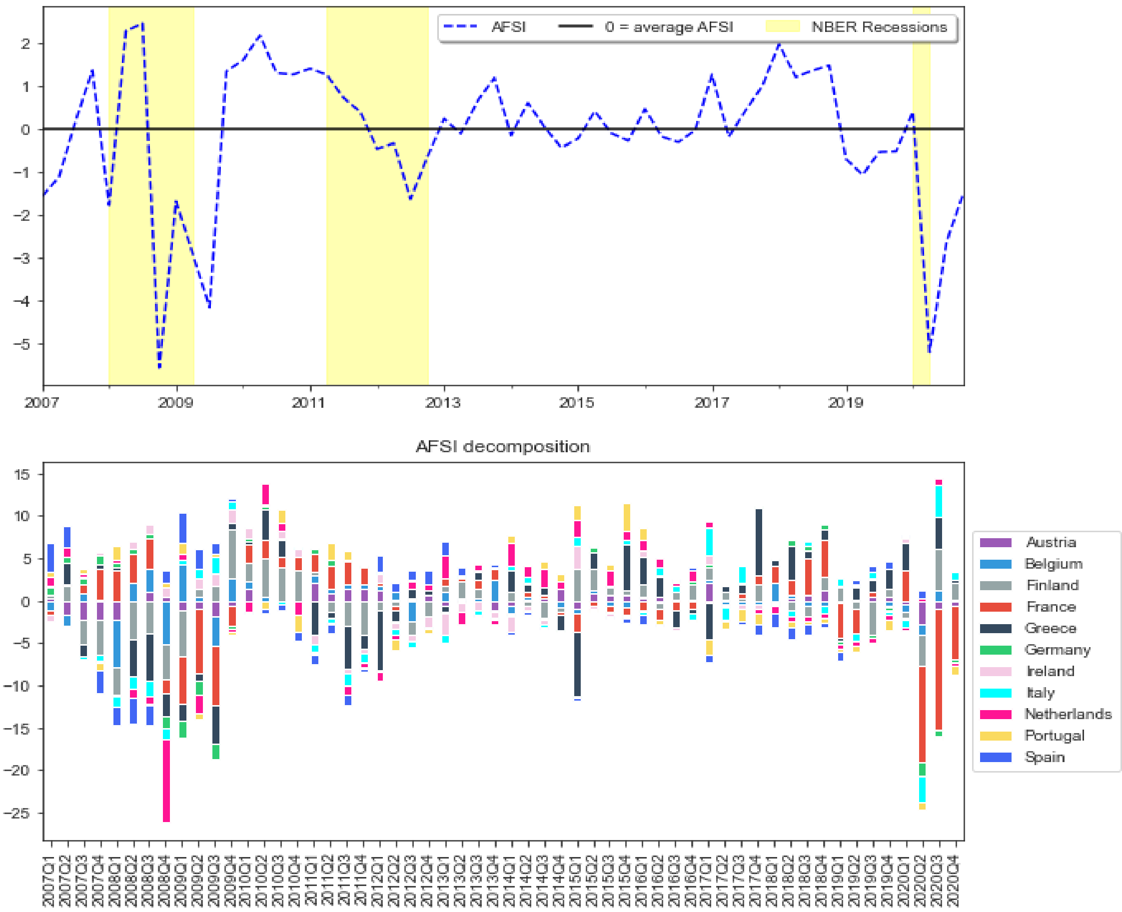
The first period is mainly characterized by considerable strain in banking sector stability, underpinned by deterioration in the AFSIs of all four core countries and some peripheral countries, especially Italy and Finland. The aggregate index for the euro area declines drastically, reaching its lowest level (-5.56% in December 2008) over the period of the study. Indeed, as we can see in the countries' AFSI decomposition, the world economic climate sub-index fell sharply within this period as a result of the worst recession affecting the world economy since the Great Depression in the 1930s. The crisis' impact through the euro area countries is also shown by declines in the financial vulnerability index (see Figures C.2.1 to C.2.11 in Appendix C). This is mainly due to the fall in current account balance, the ratio of foreign currency assets to foreign currency liabilities, and the ratio of external assets to total assets, which leads to deteriorating countries' terms of trade.

In addition, the financial soundness sub-index went down because of the decline in the real economy, which impacted the balance sheets of non-financial corporations and households, making the capacity to repay the contracted loans more difficult. This resulted in significant harm to banks' asset quality. For example, non-performing loans as a percentage of gross loans went up from 2.82% in March 2008 to 4.02% in March 2009 for France. Likewise, the financial development index declined because of tighter credit conditions, increasing concentration in the banking sector and a downbeat stock market fundamental (see, for example, France, Germany and Spain AFSI decomposition in Appendix C) as wary investors began to liquidate their shares.

The European debt crisis period was preceded by an improvement in financial stability in almost all countries, as can be seen in the aggregate index decomposition. The aggregate index increased until June 2010 when Greece's problems began. Then followed a substantial impairment of the financial stability of peripheral member states, especially Greece, where the crisis took root, and

Spain, Italy, Finland and Portugal. In Greece, for instance, the AFSI decomposition shows that financial soundness, financial vulnerability, and monetary condition indexes had already declined from June 2010. Monetary condition and financial soundness indexes remained deteriorated until March 2012. Meanwhile, the financial vulnerability index rose from 0.76% in June 2011 to 7.21% in June 2012, suggesting that agents became more optimistic about a resolution to the crisis, with the bond exchange taking place in Greece. The aggregate index finally became positive after December 2012.

**Figure 1: Aggregate Financial Stability Index and its decomposition for Euro area**




Source: Author' computation

The period before the COVID-19 pandemic crisis (March 2013–December 2018) was characterized by financial stability and improvement in the aggregate index. Then came a return to financial stress following the pandemic, a period that was marked by the deterioration of financial conditions, with the aggregate index declining sharply from 0.3% in March 2020 to -5.19% in June 2020. The decomposition of the aggregate index shows that all countries were affected, although the impact of the crisis differed from one country to another. Indeed, the crisis totally paralyzed the world economy.[32] As firms in the most affected sectors suddenly broken off to generate income, they were not able to pay their employees, banks, landlords and suppliers, leading the economy into a downward spiral. As a result, this reduced tax revenue, putting extra pressure on government finances and creating extreme volatility in the financial markets. To support the crisis, the European Central Bank, in coordination with the national central banks, decided to buy government bonds on the secondary market from the commercial banks, which in turn purchased them from their government upon issuance. This made it possible to maintain interest rates at a government low and to create room on commercial bank balance sheets to issue new loans to firms and households. As a consequence, this led the financial development sub-indexes of eurozone countries to increase (total credits to GDP increased, see countries' financial development indexes).

## 5.2 Financial cycle, financial risk monitoring indexes and aggregate financial stability index

In this section we present an application for our countries' aggregate financial stability indexes. The different AFSIs are compared to other financial monitoring risk indicators to illustrate their help in the financial monitoring exercise. Indeed, monitoring the risks to which the financial and non-financial sectors contribute, or are exposed, involves the authorities in financial stability using a set of indicators. These indicators are grouped into five classes of risk,[33] which are macroeconomic risk (GDP growth and its perspectives), the credit risk of non-financial agents (credit to households and non-profit institutions serving households as a percentage of GDP, for example), market risk (stock market index), liquidity, solvability and profitability risk (Eonia rate), and concentration, contagion, and interconnexion risk (economic activity concentration index). We find that for the eurozone countries over the last decade, when instability has been strictly related to the state of the financial system, as measured by AFSI, it has a potentially milder impact on financial cycles than when the instability is related to financial risk monitoring indicators.

### 5.2.1 Financial cycle estimation

One of the key goals of macro-prudential policymaking is assimilating the development of the financial cycle, since its analysis allows policymakers to have good comprehension, anticipation, and the ability to prevent the consequences of their turnarounds. The financial cycle has no clear and consensual definition. However, Borio (2014) points out that the financial cycle is related to self-reinforcing interactions between perceptions of value and risk, attitudes toward risk, and

[32] All economic sectors were affected: restaurants, hotels, bars, theatres, cinemas, and concert halls closed their doors and their income dried up. Events were cancelled, and the aviation and tourism industries came to an almost complete standstill. Demand for oil also largely dried up.
[33] See Bennani et al. (2017) for more details.

financing constraints, which translate into booms followed by busts. Financial crises are akin to financial cycle peaks, and so the cycle helps to identify financial distress risks in their build-up phase. From an empirical point of view, two important stylized facts of the financial cycle are established. The first shows that the financial cycle's frequency is lower than the traditional business cycle one.[34] And the second reveals that fluctuations in credit and property prices illustrate the financial cycle, both parsimoniously and effectively.[35]

In this paper we use these two variables (credit-to-GDP ratio and real house prices) to compute the financial cycle for the countries in our sample and the eurozone. The methodology used is as follows. First, we use the band-pass filter[36] to estimate both credit and house price cycles; and, second, we use PCA to combine the information from these two cycles into a summary index (financial cycle). The indexes obtained are summarized in Figure C.4 and attest to the previous findings in the literature.[37] Indeed, Figure C.4 shows the divergence between countries and a moderate financial cycle for the euro area as a whole.

#### 5.2.2 Financial risk surveillance indexes and financial cycle

There is as yet no "true" financial risk monitoring index to ensure financial stability. Macroeconomic indexes, the credit risk of non-financial agents' indexes, the market index, the liquidity, solvability, and profitability indexes, and the concentration, contagion, and interconnexion indexes are the set of indicators used by policymakers to monitor financial stability.

Macroeconomic conditions can help to anticipate cyclical downturns and must be monitored. The relevant indicators here are GDP growth and its prospects, production or business indices such as the Purchasing Manager Index (PMI), order book dynamics, consumer prices, and commodity prices. For instance, Alfaro and Drehmann (2009) study the stylized facts of GDP before crises in order to see the extent to which they can warn about a crisis. Studies on the uncertainty or the degree of disagreement[38] between macroeconomic forecasting professionals show that an increase in this indicator can be a signal of future macroeconomic downturns. Other indicators relate to

[34] Borio et al. (2012) show that the average length of financial cycles in a sample of seven industrialized countries since the 1960s has been around sixteen years, and that financial cycles normally have greater amplitude than business cycles. The length and amplitude of the financial cycle depend on the policies adopted (Borio et al., 2012), but the literature identifies a tendency for financial variables to evolve at a relatively slow pace.

[35] Borio et al. (2012). These variables tend to co-vary rather closely with one another, and the variability in the two series is dominated by low-frequency components.

[36] The band-pass filter allows us to decompose the time series into different components based on their different frequency ranges. For example, we can extract from the series the trend represented by the components with periodicities longer than the business cycle; estimate the gap represented by the components with business cycle periodicities; and obtain the noise represented by the components with shorter periodicities than the business cycle.

[37] See Merler (2015), for example.

[38] Uncertainty, or the degree of disagreement, is assessed by probability distributions, around growth forecasts, provided by surveys of macroeconomics forecasting professionals (Survey of Professional Forecaster).

export performance, which reflects the economic dynamism of a country such as the net external position or exchange rate.

Regarding the credit risk of non-financial agent monitoring, several indicators can be used. The first one that can be used is the indebtedness variable (bank loans), whereby the level of indebtedness can be measured as a percentage of GDP or in trend deviation. The Basel Committee in Banking Supervision (BCBS) recommends, especially, monitoring the total credit gap.[39] Previous studies have shown that this variable is a good leading indicator of banking crises (see Basel Committee in Banking Supervision, 2010; Drehmann and Juselius, 2014; Dembiermont et al., 2013). In the same way, the level of non-financial corporations' debt and the level of households and non-profit institutions serving household debt can be measured as a percentage of GDP or in trend deviation. The first one reveals the possible acceleration of aggregate counterparty risk, while the second is subject to specific monitoring, both in volume and in terms of the conditions for granting credit.

Regarding market risk, from a macroprudential point of view, it is essential to be able to control the proper functioning of the financial markets. In particular, phenomena of massive overvaluation, which could degenerate into financial crises, should be avoided. The issue is all the more important as this detection must be done as far upstream as possible to avoid market corrections that are too sudden, to which all agents are exposed and which could have systemic consequences (Bennani et al., 2017). Concretely, this surveillance is carried out on the stock markets, and more precisely on the level of stock market indices such as the CAC 40 in France, DAX 30 in Germany, or EURO STOXX 50 for the euro area. The experience has shown that an overvaluation of stock prices is often followed by a sudden readjustment, which can degenerate into a financial crisis. Table 2 (below) presents the set of stock market indices used in our analysis.

The liquidity risk for a financial agent is defined as the risk of not being able to use the usual means of refinancing to meet its commitments. For a bank, for instance, this risk materializes when it is unable to refinance itself in the short term (i.e., to renew short-term borrowing on the liabilities side of its balance sheet). Bank liquidity indicators primarily concern the interest rate conditions at which they refinance themselves on the interbank market. In the eurozone the Eonia rate is the interbank rate by reference.

Table 2: Stock Index series in the Euro area

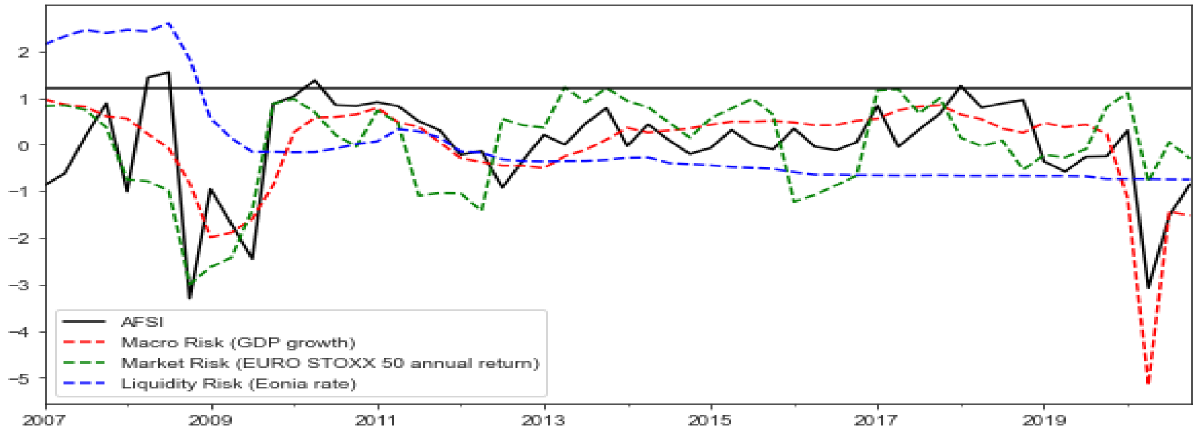
| Countries (country code) | Stock Index |
|---|---|
| Austria (AT) | ATX |
| Belgium (BE) | BEL 20 |

[39] The credit gap is defined as the deviation of the credit-to-GDP ratio from a one-sided filtered trend.

| | |
|---|---|
| Finland (FI) | OMX Helsinki 25 |
| France (FR) | CAC 40 |
| Germany (DE) | DAX |
| Greece (GR) | Athens General Composite |
| Ireland (IE) | ISEQ |
| Italy (IT) | FTSE MIB |
| Netherlands | AEX |
| Portugal (PT) | PSI 20 |
| Spain (ES) | IBEX 35 |

Figure 2 compares the AFSI developed here against some financial monitoring indicators[40] for the euro area. All indicators are de-meaned and standardized for comparison; they all fall during financial downturns. Their pairwise correlations range from approximately 0.13% between the financial stability index and liquidity risk index to over 30–35% between the financial stability index, market risk index, or macro risk index. The AFSI exceeds 1.2 standard deviation above its mean only two times but the peaks do not always correspond with the peaks of the other indexes, implying that these indicators as proxies of financial risk monitoring might carry slightly diverse information.

**Figure 2: AFSI for Euro area compared against other proxies for financial stability surveillance indicators**




Notes: The solid line represents the AFSI for Euro area compared against other proxies for financial stability surveillance indicators (macroeconomics risks, market risk and liquidity risk). All series are on the same scale (demeaned and standardized). The horizon line represents the 1.2 standard deviation limit. Source: Author' computation.

Many studies offer fascinating insights into particular aspects of boom–bust developments,[41] while others are based on indicators that can reflect the peaks of the financial cycle (Alfaro and Drehmann, 2009). In this paper we focus on analyzing the relationship between financial cycles and monitoring financial risk indicators. Based on the literature, suggesting that the peaks of

[40] We choose GDP as macroeconomic risk, stock market indexes as market risk, and the Eonia rate as liquidity risk.
[41] Especially those built on the bedrock of the dynamic stochastic general equilibrium approach.

financial cycles are closely related to the financial crisis, we suppose that these peaks correspond to the instant where shocks happen, thus leading to a financial downturn. To estimate the impacts of these shocks, we estimate a bivariate VAR with the financial cycle and each one of the monitoring financial risk proxies from Figure 2, separately. The bivariate VAR characterizes a parsimonious way to model the joint dynamics between these variables because of the short data set (quarterly data from March 2007 to September 2020). The reduced form of the bivariate VAR model estimated here can be represented as follows:

$$X_t = G_0 + G_1 X_{t-1} + G_2 X_{t-2} + \cdots + G_p X_{t-p} + e_t \tag{8}$$

where $e_t$represents the vector of residuals at time *t*. Moreover, $X_t$ is the vector of endogenous variables (monitoring financial risk proxy and the financial cycle). $G_0$ is a vector of constant terms, while $G_l\ (l = 1, \dots, p)$ is parameter vector for the endogenous variable $X_t$. The monitoring financial risk proxy is ordered first for each estimation. By doing this, we assume that the monitoring financial risk proxy is not affected contemporaneously (but only with a lag) by a shock to the financial cycle. Meanwhile, the financial cycle is affected contemporaneously by a shock to monitoring the financial risk indicator. For instance, if the monitoring financial risk proxy in our model is the liquidity risk index (the Eonia rate), this means that the Eonia rate is not impacted by a shock to the financial cycle; rather, a shock to the Eonia rate contemporaneously impacts the financial cycle. This representation is called Cholesky ordering, which is equivalent to a structural SVAR with a restriction on monitoring the financial risk proxy parameter. To illustrate this, let us assume that the structural model of our VAR is as follows:

$$X_t = B(L) u_t \tag{9}$$

where $u_t$ are structural economic shocks, white noise $E\left(u_{t-i} u'_{t-j}\right) = I$ for $i = j$ and $E\left(u_{t-i} u'_{t-j}\right) = 0$ for $i \neq j$. The impulse response function is $B(L) = B_0 + B_1 L + B_2 L^2 + \cdots$.

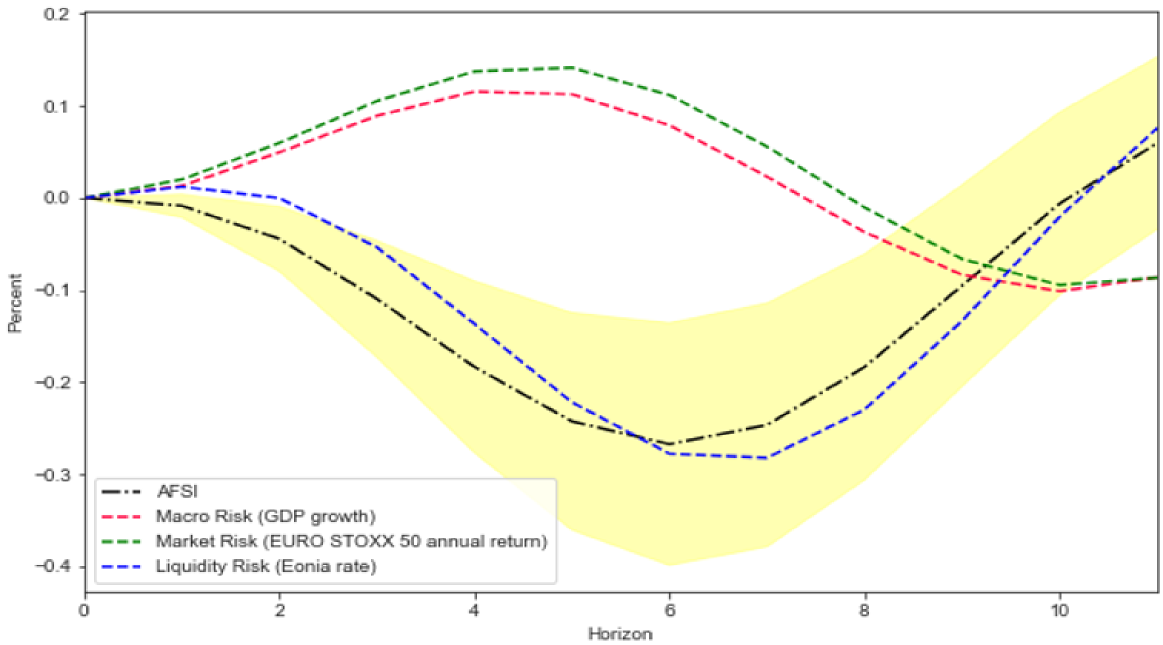
If $B(L)^{-1}$ exists, equation (9) can be approximated by a VAR model, as described by equation (8) or $G(L)X_t = e_t$. Thus, the VAR is estimated equation-by-equation to find the residuals $\widehat{e_t}$ and $\widehat{G_j}$. By taking the appropriate combination of the reduced form residuals $e_t$, we obtain the structural shocks $u_t = B_0^{-1} e_t$ and the structural IRF: $X_t = B(L) u_t$.

Here, we estimate equation (8), with the variables ordered as $[RiskInd_t\ FinCy_t]$ and estimate $\hat{\Sigma}$. The Cholesky decomposition $S$, of $\hat{\Sigma}$ is the unique lower triangular matrix, such that $SS' = \hat{\Sigma}$. The identified impulse response functions are $x_t = G(L)^{-1}Su_t$ and the structural shocks are $u_t = S^{-1}e_t$. The contemporaneous[42] response is:

$$Su_t = \begin{bmatrix} s_1 & 0 \\ s_2 & s_4 \end{bmatrix} \tag{10}$$

We estimate each VAR by selecting its length based on Akaike information criterion, and we use Cholesky IRF for our analysis. The euro area, as a whole, recursive impulse responses of the financial cycle to one-standard-deviation financial risk shock, as measured by the different proxies, where the risk indicator is ordered first, are represented in Figure 3. The shared area corresponds to +/- one standard error confidence interval for AFSI shock. As expected, the financial cycle decreases after the financial shock by between 0.24 and 0.28% when the financial risk is measured by AFSI and liquidity risk index, respectively. The result is not the same for macro and market risk indexes. These indexes fall to estimate the expected effect since they go up after the shock.

**Figure 3: Euro area financial cycle response to a 1 standard deviation shock in the different financial monitoring risk**




Note: The shared region represents the +/- one standard error confidence interval for the aggregate financial stability index.
Source: Author' computation.

We repeat the same exercise for the 11 countries of our sample and display the results in Figure C.5 in Appendix C. The financial cycle decreases after a financial shock, regardless of the index for Belgium, Finland, France, Germany and the Netherlands. However, we can see that when the

[42] See Ramey (2016) for more details.

instability shock is related to the financial condition alone, as measured by the AFSI, it has a potentially milder impact on the financial system. On the other hand, when the instability shock is related to the financial condition, as measured by the Eonia rate (liquidity risk indicator), its impact on the financial system appears stronger. For macro and market risk indexes, the impact appears to be small (see IRF for Finland, France, Germany and the Netherlands). The market risk indicator has a stronger effect on the financial cycle than other indexes for Belgium and Greece. Concerning Italy, the macro risk, market risk, and liquidity risk indexes fall to estimate the desirable intuition, since they go up after the shock. The market and liquidity risk indicators increase after the shock, before decreasing respectively, after one and two quarters, for Portugal and Spain.

To sum up, one can see that the result of this exercise is robust from one country to another. However, as robust as it is, it is clear that when the financial risk is measured by our AFSI, the reaction of the financial cycle to the shock is common for all countries (the financial cycle decreases after the shock before going up), even if the magnitude of the shock differs from country to country. This is consistent with the intuition behand this exercise. For the euro area as a whole, when instability is related to the state of the financial system alone, as measured by AFSI, it has a potentially milder impact on the financial cycle than when the instability is related to financial risk monitoring indicators.

In view of this result, it is obvious that the aggregate financial stability index can be a "complement" and a useful tool for macroprudential policymakers in their exercise of financial stability surveillance. Even though it allows policymakers to have a clear picture of financial stability by offering them the possibility to identify stability, instability, and crisis areas, it seems to estimate better the intuitive response of the financial cycle after a shock compared to other financial stability monitoring indicators, such as macro risk, market risk, and liquidity risk indexes.

# 6. Summary and concluding remarks

The purpose of this paper is to: (i) construct measure of financial stability indexes called aggregate financial stability indicators (AFSIs) for euro area countries; and (ii) assess their ability to be a monitoring financial stability tool, before and during a crisis, by comparing the response of the financial cycle to a shock, as measured by our AFSIs, with a shock measured by other financial monitoring risk indicators.

Our methodology is based on the approach proposed by Cheang and Choy (2009) and taken up by Akosah et al. (2018), with some differences. Our index includes a total of 23 variables from different markets, such as the equity market, credit market, money market, and the foreign exchange market, as well as other important macroeconomic indicators. The empirical normalization technique is used to normalize variables. The computed AFSIs are the weighted average of the composite sub-indices (financial development, financial soundness, financial vulnerability, monetary condition, and the world economic climate). The arithmetic mean of the uniform and principal component analysis using expectation-maximization algorithm weighting methods is used to assign weights to each variable to construct sub-indices, as well as to allocate weights to sub-indices to obtain the composite index. We use a set of euro area domestic and international events, which are ranked by NBER, CEPR, and ECRI as a benchmark to evaluate the appropriateness of our AFSI. The AFSIs are successful at closely tracking financial stability during these incidents, and they fall sharply during recession, tending to reach relatively high values during good times for each country, and more particularly for the aggregate index of the 11 countries.

The dynamic of the aggregate index is very similar to the dynamic of the AFSIs of the core countries, especially Germany, France, the Netherlands and Austria. This suggests that the financial stability of the euro area depends more on the financial stability of these countries. This seems obvious when one considers the economic and financial weight of these countries in the euro zone. This comparison attests to the comparative nature of the results of the methodology used, as highlighted by Albulescu (2008).

The comparison exercise of AFSIs to other financial monitoring risk indicators, using the VAR model impulse response to assess the dynamic of the financial cycle after a shock, measured by these different indicators, shows that the results are without a doubt robust from country to country because of the divergence of the financial cycle in the eurozone. However, the results show that when the financial risk is measured by our AFSIs, the reaction of the financial cycle to the shock is common for all countries (the financial cycle decreases after the shock before going up), even if the magnitude of the shock differs from country to country. For the euro area as a whole, when instability is related to the state of the financial system alone, as measured by AFSIs, it has a potentially milder impact on the financial cycle than when the instability is related to financial risk monitoring indicators. This paper thus contributes to the debate on the measurement of financial stability by highlighting another property of the results from the so-called aggregate financial indexes through this comparison analysis.

The results of this study suggest that the aggregate financial stability index can be a "complement" and a useful tool for macroprudential policymakers in their exercise of financial stability surveillance. Even though it allows policymakers to have a clear picture of financial stability by offering them the possibility to identify stability, instability, and crisis areas, it seems to estimate better the intuitive response of the financial cycle after a shock compared to other financial stability monitoring indicators, such as macro risk, market risk, and liquidity risk indexes. Thus, the European central bank (euro area countries' central banks) should use AFSIs based on our methodology to assess the euro area's financial system stability (countries' financial system stability), as well as being the basis for finding stabilization policies. The flexibility of our AFSI method structure can, with simple variations and extensions, readily incorporate sector-specific financial stability risks, depending on the specific concerns of policymakers in certain cases. Such risks could include crypto currency risks or natural disaster risks (see, for example, Avril et al., 2022).

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## Appendix A: The mathematics behind the principal component analysis (PCA)

Principal component analysis (PCA) is one type of unsupervised learning algorithm (dimension reduction algorithm) using in machine learning. Without trying to give a full primer on PCA, from an optimization viewpoint, the primary objective function is the Rayleigh quotient.[43] The matrix that figures in the quotient is (some multiple of) the sample covariance matrix. This objective function is as follows:

$$S = \frac{1}{n} \sum_{i=1\dots n} x_i x_i^T = \frac{X^T X}{n}$$

where each $x_i$ is a vector of $p$ features (variables) and X is the matrix, such that the $i$th row is $x_i^T$.

PCA seeks to solve a *sequence* of optimization problems. The first in the sequence is the unconstrained problem:

$$\text{maximize } \frac{u^T Su}{u^T u}, u \in R^p$$

Since $u^T u = \|u\|_2^2 = \|u\|\|u\|$, the above unconstrained problem is equivalent to the following constrained problem:

$$\text{maximize } u^T Su$$

$$\text{subject to } u^T u = 1$$

This is where the matrix algebra comes in. Since S is a symmetric positive semidefinite matrix (by construction), it has an eigenvalue decomposition of the form:

$$S = Q\Lambda Q^T$$

where Q is an orthogonal matrix (so $QQ^T = I$) and Λ is a diagonal matrix with non-negative entries $\lambda_i$, such that $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_p \geq 0$.

Hence, $u^T Su = u^T Q\Lambda Q^T u = w^T \Lambda w = \sum_{i=1}^{p} \lambda_i w_i^2$. Since u is constrained in the problem to have a norm of one, so is w, since $\|w\|_2 = \|Q^T u\|_2 = \|u\|_2 = 1$, by virtue of Q being orthogonal.

But if we want to maximize the quantity $\sum_{i=1}^{p} \lambda_i w_i^2$ under the constraints that $\sum_{i=1}^{p} w_i^2 = 1$, the best we can do is to set $w = e_1$, that is $w_1 = 1$ and $w_i = 0$ for $i > 1$.

[43] Also known as the Rayleigh–Ritz ratio, named after Walther Ritz and Lord Rayleigh.

Now backing out the corresponding $\mathrm{u}$, which is what we sought in the first place, we get:

$$\mathrm{u}^* = \mathrm{Qe}_1 = \mathrm{q}_1$$

where $\mathrm{q}_1$ denotes the first column of $\mathrm{Q}$, that is, the eigenvector corresponding to the largest eigenvalue of $\mathrm{S}$. The value of the objective function is also easily seen to be $\lambda_1$.

The remaining principal component vectors are then found by solving the sequence (indexed by $i$) of optimization problems:

$$\text{maximize } \mathrm{u}^T \mathrm{Su}$$

$$\text{subject to } \mathrm{u}^T \mathrm{u} = 1$$

$$\mathrm{u} = 0, \forall 1 \leq j < i$$

So, the problem is the same, except that we add the additional constraint that the solution must be orthogonal to all of the previous solutions in the sequence. It is not difficult to extend the argument above inductively to show that the solution to the problem is, indeed, $\mathrm{q}_i$ (with $i$ the eigenvector S).

The PCA solution is also often expressed in terms of the singular value decomposition of $\mathrm{X}$. To see why, let $\mathrm{X} = \mathrm{UDV}^T$. Then, $n\mathrm{S} = \mathrm{X}^T\mathrm{X} = \mathrm{VD}^2\mathrm{V}^T$ and so $\mathrm{V} = \mathrm{Q}$ (strictly speaking, up to sign flips) and $\Lambda = \frac{\mathrm{D}^2}{n}$.

The principal components are found by projecting $\mathrm{X}$ onto the principal component vectors. From the SVD formulation just given, it is easy to see that:

$$\mathrm{XQ} = \mathrm{XV} = \mathrm{UDV}^T\mathrm{V} = \mathrm{UD}$$

The simplicity of representation of both the principal component vectors and the principal components themselves, in terms of the SVD of the matrix of features, is one of the reasons why the SVD features so prominently in some treatments of PCA

# Appendix B: Unit root tests

Table B.1: Unit root tests for Austria

| | ADF | | | | PP | | KPSS | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First difference | | Level | | Level | |
| | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value |
| Composite Activity Indicator | -3.615* | 0.029 | -2.868* | 0.004 | -1.935 | 0.636 | 0.07* | 0.348 |
| Cost to Income | 1.098 | 0.929 | -1.022 | 0.279 | 0.515 | 0.828 | 0.048* | 0.597 |
| Total Credit / GDP | -1.999 | 0.287 | -6.391** | 0.000 | 1.234 | 0.944 | 0.14* | 0.06 |
| Current Account Balance | -2.638 | 0.085 | -5.162** | 0.000 | -2.058 | 0.262 | 0.483 | 0.044 |
| Customer Deposits to Total (Non-interbank) Loans | -2.222 | 0.198 | -1.394 | 0.152 | -3.209 | 0.083 | 0.99 | 0.003 |
| G20 GDP Growth Rate | -4.674** | 0.000 | -4.113** | 0.000 | -1.05 | 0.265 | 0.053* | 0.536 |
| G20 Inflation Rate | -3.05* | 0.03 | -4.138** | 0.000 | -1.763 | 0.399 | 0.05* | 0.573 |
| General Budget Balance | -3.376 | 0.055 | -7.349** | 0.000 | -1.202 | 0.21 | 0.654 | 0.017 |
| Herfindahl – Hirschmann Index (HHI) | -1.908 | 0.054 | -7.374** | 0.000 | -2.083* | 0.036 | 0.074* | 0.314 |
| Interest Margin to Gross Income | -3.045* | 0.031 | -5.974** | 0.000 | -2.942* | 0.041 | 0.63 | 0.019 |
| Interest Rate | -1.313 | 0.175 | -3.819** | 0.000 | -2.445* | 0.014 | 0.89 | 0.004 |
| Liquid Assets to Total Assets (Liquid Asset Ratio) | -2.469 | 0.123 | -7.26** | 0.000 | -4.088** | 0.001 | 0.104* | 0.146 |
| Market capitalization/GDP | 0.336 | 0.784 | -2.131* | 0.032 | -6.027** | 0.000 | 0.127* | 0.083 |
| Non-interest Expenses to Gross Income | -2.043 | 0.268 | -11.475** | 0.000 | -3.684* | 0.004 | 0.107* | 0.136 |
| Non-performing Loans Net of Provisions to Capital | -0.583 | 0.462 | -6.382** | 0.000 | -1.918 | 0.323 | 0.264* | 0.171 |
| Non-performing Loans to Total Gross Loans | -0.578 | 0.464 | -6.464** | 0.000 | -0.589 | 0.459 | 0.277* | 0.158 |
| Real Exchange Rate | 0.322 | 0.781 | -4.212* | 0.004 | 0.66 | 0.859 | 0.271* | 0.164 |
| Regulatory Capital to Risk-Weighted Assets, percent | -4.216* | 0.004 | -3.129* | 0.002 | -2.316 | 0.425 | 0.142* | 0.058 |
| Return on Assets | -2.627 | 0.087 | -3.8** | 0.000 | -4.508** | 0.001 | 0.318* | 0.12 |
| Ratio of external assets to total assets | -2.186* | 0.028 | -3.525** | 0.000 | -2.955* | 0.003 | 1.091 | 0.002 |
| Ration of Net Foreign Assets to Net Domestic Assets | -1.967* | 0.047 | -10.792** | 0.000 | -2.009* | 0.043 | 0.864 | 0.005 |
| Ratio of foreign currency assets to foreign currency liabilities | -0.656 | 0.431 | -7.665** | 0.000 | -2.104 | 0.243 | 0.217* | 0.237 |
| Inflation Rate (yoy) | -0.362 | 0.552 | -5.085** | 0.000 | -1.861 | 0.35 | 0.053* | 0.531 |
| Real Interest Rate | -1.073 | 0.256 | -7.5** | 0.000 | -1.244 | 0.196 | 0.782 | 0.008 |
| Real Effective Exchange Rate (log) | 0.431 | 0.809 | -4.35* | 0.003 | 0.625 | 0.852 | 0.269* | 0.166 |
| Monetary Condition Index | 1.256 | 0.946 | -7.376** | 0.000 | 2.008 | 0.99 | 0.104* | 0.147 |

Notes: ***, **, * indicates the rejection of the null hypothesis at 1%, 5% and 10% per cent level of significance respectively (t-statistic).
Null Hypothesis: ADF (Augmented Dicky-Fuller) and PP (Phillips-Peron) tests, the series has a unit root; KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, the series is stationnary.
Source: Author' computation.

Table B.2: Unit root tests for Belgium

| | ADF | | | | PP | | KPSS | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First difference | | Level | | Level | |
| | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value |
| Composite Activity Indicator | -2.937 | 0.151 | -1.134 | 0.233 | -2.474 | 0.341 | 0.067* | 0.376 |
| Cost to Income | 0.993 | 0.915 | 0.13 | 0.726 | -1.128 | 0.704 | 0.062* | 0.427 |
| Total Credit / GDP | -3.571* | 0.032 | -6.162** | 0.000 | -2.461 | 0.348 | 0.132* | 0.073 |
| Current Account Balance | -1.728 | 0.08 | -5.657** | 0.000 | -2.595* | 0.009 | 0.061* | 0.434 |
| Customer Deposits to Total (Non-interbank) Loans | -0.345 | 0.559 | -8.238** | 0.000 | -1.748 | 0.407 | 0.408* | 0.069 |
| G20 GDP Growth Rate | -4.674** | 0.000 | -4.113** | 0.000 | -1.05 | 0.265 | 0.053* | 0.536 |
| G20 Inflation Rate | -3.05* | 0.03 | -4.138** | 0.000 | -1.763 | 0.399 | 0.05* | 0.573 |
| General Budget Balance | -0.779 | 0.379 | -8.42** | 0.000 | -0.826 | 0.359 | 0.238* | 0.205 |
| Herfindahl – Hirschmann Index (HHI) | -1.661 | 0.091 | -7.951** | 0.000 | -1.751 | 0.076 | 1.052 | 0.002 |
| Interest Margin to Gross Income | -1.232 | 0.2 | -4.389** | 0.000 | -0.394 | 0.539 | 0.694 | 0.013 |
| Interest Rate | -1.313 | 0.175 | -3.819** | 0.000 | -2.445* | 0.014 | 0.89 | 0.004 |
| Liquid Assets to Total Assets (Liquid Asset Ratio) | -0.566 | 0.469 | -7.102** | 0.000 | -0.562 | 0.47 | 0.467 | 0.048 |
| Market capitalization/GDP | -1.97* | 0.047 | 0.061 | 0.704 | -0.84 | 0.354 | 0.105* | 0.142 |
| Non-interest Expenses to Gross Income | 0.114 | 0.995 | -7.686** | 0.000 | -5.217** | 0.000 | 0.257* | 0.18 |
| Non-performing Loans Net of Provisions to Capital | -0.198 | 0.615 | -3.435** | 0.001 | -0.205 | 0.612 | 0.369* | 0.087 |
| Non-performing Loans to Total Gross Loans | -0.196 | 0.615 | -7.682** | 0.000 | -0.219 | 0.607 | 0.309* | 0.128 |
| Real Exchange Rate | -2.982* | 0.037 | -5.109** | 0.000 | -1.818 | 0.371 | 0.221* | 0.23 |
| Regulatory Capital to Risk-Weighted Assets, percent | -4.991** | 0.000 | -2.996* | 0.003 | -3.887* | 0.002 | 0.587 | 0.024 |
| Return on Assets | -2.824 | 0.055 | -2.622* | 0.008 | -5.87** | 0.000 | 0.77 | 0.009 |
| Ratio of external assets to total assets | -1.645 | 0.094 | -6.705** | 0.000 | -1.953 | 0.308 | 0.414* | 0.066 |
| Ration of Net Foreign Assets to Net Domestic Assets | -4.221* | 0.004 | -5.763** | 0.000 | -2.442 | 0.357 | 0.09* | 0.208 |
| Ratio of foreign currency assets to foreign currency liabilities | -0.957 | 0.306 | -8.65** | 0.000 | -0.837 | 0.355 | 0.89 | 0.004 |
| Inflation Rate (yoy) | -0.738 | 0.396 | -4.45** | 0.000 | -1.766 | 0.397 | 0.05* | 0.57 |
| Real Interest Rate | -2.251* | 0.023 | -5.988** | 0.000 | -1.614 | 0.101 | 0.13* | 0.078 |
| Real Effective Exchange Rate (log) | -3.028* | 0.032 | -5.331** | 0.000 | -1.818 | 0.371 | 0.22* | 0.232 |
| Monetary Condition Index | 0.67 | 0.861 | -5.899** | 0.000 | 0.888 | 0.899 | 0.09* | 0.21 |

Notes: ***, **, * indicates the rejection of the null hypothesis at 1%, 5% and 10% per cent level of significance respectively (t-statistic).
Null Hypothesis: ADF (Augmented Dicky-Fuller) and PP (Phillips-Peron) tests, the series has a unit root; KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, the series is stationnary.
Source: Author' computation.

Table B.3: Unit root tests for Finland

| | ADF | | | | PP | | KPSS | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First difference | | Level | | Level | |
| | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value |
| Composite Activity Indicator | -3.149 | 0.095 | -3.472** | 0.001 | -1.709 | 0.747 | 0.778 | 0.008 |
| Cost to Income | 2.658 | 0.999 | -1.042 | 0.268 | 0.907 | 0.902 | 0.083* | 0.247 |
| Total Credit / GDP | -3.985* | 0.009 | -4.104** | 0.001 | -2.601 | 0.279 | 1.048 | 0.002 |
| Current Account Balance | -2.116* | 0.033 | -7.817** | 0.000 | -2.144* | 0.031 | 0.543 | 0.031 |
| Customer Deposits to Total (Non-interbank) Loans | -3.975* | 0.01 | -9.254** | 0.000 | -2.102 | 0.244 | 0.131* | 0.075 |
| G20 GDP Growth Rate | -4.674** | 0.000 | -4.113** | 0.000 | -1.05 | 0.265 | 0.053* | 0.536 |
| G20 Inflation Rate | -3.05* | 0.03 | -4.138** | 0.000 | -1.763 | 0.399 | 0.05* | 0.573 |
| General Budget Balance | -8.843** | 0.000 | -4.816** | 0.000 | -1.714 | 0.082 | 0.565 | 0.027 |
| Herfindahl – Hirschmann Index (HHI) | -2.259 | 0.457 | -3.484** | 0.001 | -2.182 | 0.5 | 0.759 | 0.009 |
| Interest Margin to Gross Income | -2.211 | 0.202 | -4.049** | 0.000 | -3.389* | 0.011 | 0.42* | 0.064 |
| Interest Rate | -1.313 | 0.175 | -3.819** | 0.000 | -2.445* | 0.014 | 0.89 | 0.004 |
| Liquid Assets to Total Assets (Liquid Asset Ratio) | 0.82 | 0.888 | -0.929 | 0.317 | -3.551* | 0.034 | 0.133* | 0.072 |
| Market capitalization/GDP | -3.105 | 0.105 | -4.042* | 0.008 | 1.89 | 0.987 | 0.086* | 0.231 |
| Non-interest Expenses to Gross Income | -3.6* | 0.006 | -5.554** | 0.000 | -6.675** | 0.000 | 0.144* | 0.055 |
| Non-performing Loans Net of Provisions to Capital | -1.966 | 0.302 | -8.037** | 0.000 | -2.395 | 0.382 | 1.018 | 0.002 |
| Non-performing Loans to Total Gross Loans | 0.338 | 0.785 | -4.083** | 0.000 | 0.787 | 0.883 | 0.126* | 0.085 |
| Real Exchange Rate | -2.187 | 0.211 | -5.661** | 0.000 | -0.466 | 0.51 | 0.751 | 0.01 |
| Regulatory Capital to Risk-Weighted Assets, percent | 0.652 | 0.857 | -2.077* | 0.036 | -2.072 | 0.562 | 0.122* | 0.093 |
| Return on Assets | -4.016* | 0.008 | -1.854 | 0.061 | -1.651 | 0.093 | 0.446* | 0.055 |
| Ratio of external assets to total assets | -2.657 | 0.082 | -6.857** | 0.000 | -2.353 | 0.155 | 0.082* | 0.256 |
| Ration of Net Foreign Assets to Net Domestic Assets | -2.466* | 0.013 | -5.587** | 0.000 | -2.519* | 0.011 | 0.063* | 0.415 |
| Ratio of foreign currency assets to foreign currency liabilities | -4.01** | 0.000 | -1.693 | 0.086 | -2.162 | 0.22 | 0.066* | 0.382 |
| Inflation Rate (yoy) | -2.159* | 0.03 | -5.41** | 0.000 | -1.379 | 0.156 | 0.054* | 0.515 |
| Real Interest Rate | -1.524 | 0.12 | -6.548** | 0.000 | -1.701 | 0.084 | 0.453* | 0.053 |
| Real Effective Exchange Rate (log) | -2.227 | 0.197 | -4.393** | 0.000 | -0.493 | 0.499 | 0.756 | 0.009 |
| Monetary Condition Index | 0.176 | 0.74 | -6.652** | 0.000 | -2.548 | 0.305 | 0.085* | 0.239 |

Notes: ***, **, * indicates the rejection of the null hypothesis at 1%, 5% and 10% per cent level of significance respectively (t-statistic).
Null Hypothesis: ADF (Augmented Dicky-Fuller) and PP (Phillips-Peron) tests, the series has a unit root; KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, the series is stationnary.
Source: Author' computation.

Table B.4: Unit root tests for France

| | ADF | | | | PP | | KPSS | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First difference | | Level | | Level | |
| | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value |
| Composite Activity Indicator | -2.705 | 0.234 | -4.169** | 0.001 | -2.445 | 0.356 | 0.134* | 0.071 |
| Cost to Income | -0.29 | 0.58 | -1.411 | 0.147 | -1.752 | 0.405 | 0.077* | 0.29 |
| Total Credit / GDP | 2.911 | 1 | -4.843** | 0.000 | 4.073 | 1 | 1.199 | 0.001 |
| Current Account Balance | 0.066 | 0.706 | -7.488** | 0.000 | 0.416 | 0.805 | 0.121* | 0.096 |
| Customer Deposits to Total (Non-interbank) Loans | -5.337** | 0.000 | -2.78* | 0.005 | -2.568 | 0.1 | 0.131* | 0.074 |
| G20 GDP Growth Rate | -4.674** | 0.000 | -4.113** | 0.000 | -1.05 | 0.265 | 0.053* | 0.536 |
| G20 Inflation Rate | -3.05* | 0.03 | -4.138** | 0.000 | -1.763 | 0.399 | 0.05* | 0.573 |
| General Budget Balance | -3.405 | 0.051 | -7.491** | 0.000 | -0.466 | 0.51 | 0.304* | 0.132 |
| Herfindahl – Hirschmann Index (HHI) | -1.797 | 0.069 | -7.35** | 0.000 | -2.253 | 0.188 | 1.006 | 0.002 |
| Interest Margin to Gross Income | -2.876* | 0.048 | -4.456* | 0.002 | -2.016 | 0.28 | 0.518 | 0.036 |
| Interest Rate | -1.313 | 0.175 | -3.819** | 0.000 | -2.445* | 0.014 | 0.89 | 0.004 |
| Liquid Assets to Total Assets (Liquid Asset Ratio) | -2.767* | 0.006 | -4.958** | 0.000 | -2.078* | 0.036 | 0.137* | 0.065 |
| Market capitalization/GDP | -2.566 | 0.296 | -2.471 | 0.123 | -5.494** | 0.000 | 0.141* | 0.059 |
| Non-interest Expenses to Gross Income | -2.333 | 0.162 | -3.536** | 0.000 | -3.896* | 0.002 | 0.374* | 0.085 |
| Non-performing Loans Net of Provisions to Capital | -1.68 | 0.088 | -7.862** | 0.000 | -0.163 | 0.627 | 0.606 | 0.022 |
| Non-performing Loans to Total Gross Loans | -3.314* | 0.014 | -2.902* | 0.004 | -0.369 | 0.549 | 0.625 | 0.019 |
| Real Exchange Rate | -0.855 | 0.348 | -5.328** | 0.000 | -1.187 | 0.215 | 1.006 | 0.002 |
| Regulatory Capital to Risk-Weighted Assets, percent | -1.433 | 0.566 | -13.581** | 0.000 | -4.192* | 0.005 | 0.137* | 0.065 |
| Return on Assets | -3.09* | 0.027 | -3.603** | 0.000 | -3.387* | 0.011 | 0.104* | 0.148 |
| Ratio of external assets to total assets | -2.831 | 0.186 | -4.831** | 0.000 | -3.241 | 0.077 | 0.526 | 0.034 |
| Ration of Net Foreign Assets to Net Domestic Assets | -1.753 | 0.076 | -9.303** | 0.000 | -1.863 | 0.06 | 0.392* | 0.076 |
| Ratio of foreign currency assets to foreign currency liabilities | -3.782* | 0.003 | -9.506** | 0.000 | -3.825* | 0.003 | 0.13* | 0.076 |
| Inflation Rate (yoy) | -3.316* | 0.014 | -2.904* | 0.004 | -1.272 | 0.188 | 0.077* | 0.287 |
| Real Interest Rate | -2.212* | 0.026 | -6.44** | 0.000 | -2.052* | 0.038 | 0.764 | 0.009 |
| Real Effective Exchange Rate (log) | -0.797 | 0.372 | -5.181** | 0.000 | -1.163 | 0.223 | 1.007 | 0.002 |
| Monetary Condition Index | -0.001 | 0.684 | -6.54** | 0.000 | 0.002 | 0.685 | 0.114* | 0.115 |

Notes: ***, **, * indicates the rejection of the null hypothesis at 1%, 5% and 10% per cent level of significance respectively (t-statistic).
Null Hypothesis: ADF (Augmented Dicky-Fuller) and PP (Phillips-Peron) tests, the series has a unit root; KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, the series is stationnary.
Source: Author' computation.

Table B.5: Unit root tests for Germany

| | ADF | | | | PP | | KPSS | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First difference | | Level | | Level | |
| | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value |
| Composite Activity Indicator | -5.526** | 0.000 | -4.476** | 0.000 | -2.272 | 0.45 | 0.064* | 0.402 |
| Cost to Income | 0.945 | 0.908 | -1.089 | 0.25 | -2.968* | 0.038 | 0.121* | 0.096 |
| Total Credit / GDP | 0.009 | 0.687 | -4.224** | 0.000 | 1.355 | 1.000 | 0.743 | 0.01 |
| Current Account Balance | -0.13 | 0.639 | -8.03** | 0.000 | -1.428 | 0.569 | 0.744 | 0.01 |
| Customer Deposits to Total (Non-interbank) Loans | -3.143 | 0.096 | -2.995* | 0.003 | 0.406 | 0.802 | 0.116* | 0.108 |
| G20 GDP Growth Rate | -4.674** | 0.000 | -4.113** | 0.000 | -1.05 | 0.265 | 0.053* | 0.536 |
| G20 Inflation Rate | -3.05* | 0.03 | -4.138** | 0.000 | -1.763 | 0.399 | 0.05* | 0.573 |
| General Budget Balance | -2.601 | 0.279 | -4.522** | 0.000 | -1.644 | 0.095 | 0.111* | 0.124 |
| Herfindahl – Hirschmann Index (HHI) | -2.634 | 0.086 | -7.882** | 0.000 | -2.629 | 0.087 | 0.116* | 0.11 |
| Interest Margin to Gross Income | -0.855 | 0.348 | -1.83 | 0.064 | -0.404 | 0.535 | 0.078* | 0.286 |
| Interest Rate | -1.313 | 0.175 | -3.819** | 0.000 | -2.445* | 0.014 | 0.89 | 0.004 |
| Liquid Assets to Total Assets (Liquid Asset Ratio) | -1.215 | 0.206 | -7.005** | 0.000 | -1.571 | 0.498 | 0.138* | 0.063 |
| Market capitalization/GDP | 1.693 | 0.979 | -1.507 | 0.124 | -4.189* | 0.005 | 0.072* | 0.327 |
| Non-interest Expenses to Gross Income | -2.609 | 0.276 | -4.556** | 0.000 | 1.106 | 0.93 | 0.728 | 0.011 |
| Non-performing Loans Net of Provisions to Capital | -2.068* | 0.037 | -2.095 | 0.549 | -0.9 | 0.329 | 1.03 | 0.002 |
| Non-performing Loans to Total Gross Loans | -3.411** | 0.001 | -0.557 | 0.981 | -1.318 | 0.174 | 1.109 | 0.001 |
| Real Exchange Rate | -2.069 | 0.257 | -5.618** | 0.000 | -0.939 | 0.313 | 0.833 | 0.006 |
| Regulatory Capital to Risk-Weighted Assets, percent | -2.286 | 0.177 | -2.824* | 0.005 | -2.097 | 0.246 | 0.948 | 0.003 |
| Return on Assets | -0.617 | 0.448 | -3.309** | 0.001 | -0.654 | 0.432 | 0.252* | 0.186 |
| Ratio of external assets to total assets | -2.24 | 0.192 | -1.633 | 0.097 | -1.494 | 0.127 | 0.563 | 0.028 |
| Ration of Net Foreign Assets to Net Domestic Assets | -1.433 | 0.142 | -5.842** | 0.000 | -2.609 | 0.091 | 0.097* | 0.175 |
| Ratio of foreign currency assets to foreign currency liabilities | -1.625 | 0.098 | -5.485** | 0.000 | -1.631 | 0.097 | 0.135* | 0.067 |
| Inflation Rate (yoy) | -1.336 | 0.168 | -3.682** | 0.000 | -1.298 | 0.179 | 0.063* | 0.421 |
| Real Interest Rate | -1.621 | 0.099 | -7.851** | 0.000 | -1.706 | 0.083 | 0.836 | 0.006 |
| Real Effective Exchange Rate (log) | -2.09 | 0.249 | -5.607** | 0.000 | -0.885 | 0.335 | 0.832 | 0.006 |
| Monetary Condition Index | -0.137 | 0.637 | -7.43** | 0.000 | -0.194 | 0.616 | 0.115* | 0.113 |

Notes: ***, **, * indicates the rejection of the null hypothesis at 1%, 5% and 10% per cent level of significance respectively (t-statistic).
Null Hypothesis: ADF (Augmented Dicky-Fuller) and PP (Phillips-Peron) tests, the series has a unit root; KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, the series is stationnary.

Table B.6: Unit root tests for Greece

| | ADF | | | | PP | | KPSS | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First difference | | Level | | Level | |
| | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value |
| Composite Activity Indicator | -0.142 | 0.992 | -4.681** | 0.001 | -0.544 | 0.982 | 0.926 | 0.004 |
| Cost to Income | -2.178 | 0.214 | -1.455 | 0.136 | -1.458 | 0.554 | 0.193* | 0.282 |
| Total Credit / GDP | -2.469 | 0.123 | -2.187* | 0.028 | -2.699 | 0.074 | 0.331* | 0.111 |
| Current Account Balance | -1.678 | 0.088 | -7.701** | 0.000 | -1.747 | 0.076 | 0.852 | 0.006 |
| Customer Deposits to Total (Non-interbank) Loans | -1.224 | 0.203 | -6.375** | 0.000 | -1.155 | 0.226 | 0.714 | 0.012 |
| G20 GDP Growth Rate | -4.674** | 0.000 | -4.113** | 0.000 | -1.05 | 0.265 | 0.053* | 0.536 |
| G20 Inflation Rate | -3.05* | 0.03 | -4.138** | 0.000 | -1.763 | 0.399 | 0.05* | 0.573 |
| General Budget Balance | -2.351 | 0.406 | -5.061** | 0.000 | -2.146 | 0.52 | 0.801 | 0.007 |
| Herfindahl – Hirschmann Index (HHI) | -1.454 | 0.136 | -7.735** | 0.000 | -1.738 | 0.411 | 0.108* | 0.133 |
| Interest Margin to Gross Income | -0.639 | 0.438 | -7.543** | 0.000 | -0.714 | 0.407 | 0.493 | 0.041 |
| Interest Rate | -1.658 | 0.092 | -3.426** | 0.001 | -3.001* | 0.003 | 0.878 | 0.005 |
| Liquid Assets to Total Assets (Liquid Asset Ratio) | -0.577 | 0.464 | -5.77** | 0.000 | -0.363 | 0.551 | 0.136* | 0.067 |
| Market capitalization/GDP | -3.722* | 0.004 | -2.841* | 0.004 | -7.573** | 0.000 | 0.355* | 0.096 |
| Non-interest Expenses to Gross Income | -2.898* | 0.046 | -8.08** | 0.000 | -2.704 | 0.073 | 0.118* | 0.102 |
| Non-performing Loans Net of Provisions to Capital | -2.183 | 0.212 | -8.47** | 0.000 | -0.416 | 0.53 | 0.143* | 0.056 |
| Non-performing Loans to Total Gross Loans | -0.159 | 0.629 | -2.872* | 0.004 | -1.574 | 0.497 | 0.959 | 0.003 |
| Real Exchange Rate | -1.16 | 0.224 | -2.346* | 0.018 | -0.961 | 0.304 | 0.145* | 0.053 |
| Regulatory Capital to Risk-Weighted Assets, percent | -3.13 | 0.099 | -5.946** | 0.000 | -2.11 | 0.541 | 0.089* | 0.213 |
| Return on Assets | -4.012** | 0.000 | -11.14** | 0.000 | -4.329** | 0.000 | 0.051* | 0.555 |
| Ratio of external assets to total assets | -1.934 | 0.051 | -3.986** | 0.000 | -2.207* | 0.026 | 0.093* | 0.193 |
| Ration of Net Foreign Assets to Net Domestic Assets | -2.139* | 0.031 | -5.959** | 0.000 | -2.578* | 0.01 | 0.088* | 0.221 |
| Ratio of foreign currency assets to foreign currency liabilities | -0.348 | 0.557 | -6.507** | 0.000 | -0.56 | 0.471 | 0.472 | 0.047 |
| Inflation Rate (yoy) | -1.889 | 0.056 | -5.3** | 0.000 | -1.471 | 0.132 | 0.133* | 0.071 |
| Real Interest Rate | -4.562** | 0.001 | -5.793** | 0.000 | -2.145* | 0.031 | 0.1* | 0.162 |
| Real Effective Exchange Rate (log) | -1.255 | 0.193 | -6.14** | 0.000 | -1.11 | 0.242 | 0.145* | 0.053 |
| Monetary Condition Index | -2.002 | 0.6 | -5.928** | 0.000 | -2.234 | 0.471 | 0.12* | 0.099 |

Notes: ***, **, * indicates the rejection of the null hypothesis at 1%, 5% and 10% per cent level of significance respectively (t-statistic).
Null Hypothesis: ADF (Augmented Dicky-Fuller) and PP (Phillips-Peron) tests, the series has a unit root; KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, the series is stationnary.
Source: Author' computation.

Table B.7: Unit root tests for Ireland

| | ADF | | | | PP | | KPSS | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First difference | | Level | | Level | |
| | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value |
| Composite Activity Indicator | -3.385 | 0.053 | -7.409** | 0 | -2.283 | 0.444 | 1.077 | 0.002 |
| Cost to Income | -4.307* | 0.003 | -3.324* | 0.014 | 0.493 | 0.823 | 0.093* | 0.194 |
| Total Credit / GDP | -0.222 | 0.606 | -7.327** | 0.000 | -0.209 | 0.61 | 0.274* | 0.161 |
| Current Account Balance | -2.549* | 0.01 | -6.183** | 0.000 | -2.506* | 0.012 | 0.086* | 0.228 |
| Customer Deposits to Total (Non-interbank) Loans | -4.251** | 0.001 | -1.234 | 0.2 | -1.578 | 0.495 | 0.14* | 0.06 |
| G20 GDP Growth Rate | -4.674** | 0.000 | -4.113** | 0.000 | -1.05 | 0.265 | 0.053* | 0.536 |
| G20 Inflation Rate | -3.05* | 0.03 | -4.138** | 0.000 | -1.763 | 0.399 | 0.05* | 0.573 |
| General Budget Balance | -1.381 | 0.155 | -7.355** | 0.000 | -1.508 | 0.123 | 0.329* | 0.113 |
| Herfindahl – Hirschmann Index (HHI) | 0.862 | 0.895 | -1.976* | 0.046 | -1.471 | 0.839 | 0.713 | 0.012 |
| Interest Margin to Gross Income | -4.271* | 0.003 | -9.522** | 0.000 | -4.378** | 0.000 | 0.081* | 0.265 |
| Interest Rate | -1.313 | 0.175 | -3.819** | 0.000 | -2.445* | 0.014 | 0.89 | 0.004 |
| Liquid Assets to Total Assets (Liquid Asset Ratio) | -2.636 | 0.263 | 0.772 | 0.88 | -2.512 | 0.322 | 0.104* | 0.145 |
| Market capitalization/GDP | -3.123* | 0.025 | -2.196* | 0.027 | -0.913 | 0.323 | 0.214* | 0.242 |
| Non-interest Expenses to Gross Income | -3.955* | 0.01 | -6.171** | 0.000 | -4.598** | 0.000 | 0.078* | 0.283 |
| Non-performing Loans Net of Provisions to Capital | -0.91 | 0.325 | -3.094* | 0.002 | -0.708 | 0.409 | 0.466 | 0.049 |
| Non-performing Loans to Total Gross Loans | -0.868 | 0.342 | -2.141* | 0.031 | -0.69 | 0.417 | 0.298* | 0.137 |
| Real Exchange Rate | -1.196 | 0.212 | -4.758** | 0.000 | -1.528 | 0.119 | 1.065 | 0.002 |
| Regulatory Capital to Risk-Weighted Assets, percent | 1.407 | 0.96 | -6.816** | 0.000 | 1.425 | 0.961 | 1.087 | 0.002 |
| Return on Assets | -1.2 | 0.21 | -7.015** | 0.000 | -1.932 | 0.051 | 0.132* | 0.073 |
| Ratio of external assets to total assets | -2.604 | 0.278 | -9.482** | 0.000 | -2.594 | 0.282 | 0.766 | 0.009 |
| Ration of Net Foreign Assets to Net Domestic Assets | -2.013* | 0.042 | -3.149* | 0.002 | -3.781** | 0.000 | 0.213* | 0.244 |
| Ratio of foreign currency assets to foreign currency liabilities | -1.294 | 0.181 | -1.771 | 0.073 | -1.786 | 0.07 | 0.135* | 0.069 |
| Inflation Rate (yoy) | -5.351** | 0.000 | -4.478** | 0.000 | -2.236* | 0.024 | 0.065* | 0.397 |
| Real Interest Rate | -2.611* | 0.009 | -5.063** | 0.000 | -1.909 | 0.054 | 0.06* | 0.451 |
| Real Effective Exchange Rate (log) | -1.149 | 0.228 | -4.752** | 0.000 | -1.606 | 0.102 | 1.081 | 0.002 |
| Monetary Condition Index | -3.883* | 0.013 | -4.166** | 0.000 | -1.514 | 0.122 | 0.076* | 0.297 |

Notes: ***, **, * indicates the rejection of the null hypothesis at 1%, 5% and 10% per cent level of significance respectively (t-statistic).
Null Hypothesis: ADF (Augmented Dicky-Fuller) and PP (Phillips-Peron) tests, the series has a unit root; KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, the series is stationnary.
Source: Author' computation.

Table B.8: Unit root tests for Italy

| | ADF | | | | PP | | KPSS | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First difference | | Level | | Level | |
| | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value |
| Composite Activity Indicator | -3.158* | 0.023 | -3.667** | 0.000 | -2.383 | 0.147 | 0.341* | 0.105 |
| Cost to Income | -0.312 | 0.571 | -0.566 | 0.469 | -1.075 | 0.725 | 0.069* | 0.356 |
| Total Credit / GDP | 0.411 | 0.804 | -3.991** | 0.000 | 0.523 | 0.83 | 0.396* | 0.074 |
| Current Account Balance | -2.523 | 0.317 | -7.35** | 0.000 | -2.557 | 0.3 | 0.114* | 0.116 |
| Customer Deposits to Total (Non-interbank) Loans | 1.32 | 0.952 | -3.499** | 0.000 | -4.521** | 0.000 | 0.732 | 0.011 |
| G20 GDP Growth Rate | -4.674** | 0.000 | -4.113** | 0.000 | -1.05 | 0.265 | 0.053* | 0.536 |
| G20 Inflation Rate | -3.05* | 0.03 | -4.138** | 0.000 | -1.763 | 0.399 | 0.05* | 0.573 |
| General Budget Balance | -9.163** | 0.000 | -5.899** | 0.000 | -1.071 | 0.257 | 0.124* | 0.089 |
| Herfindahl – Hirschmann Index (HHI) | -2.53 | 0.108 | -8.413** | 0.000 | -2.653 | 0.082 | 0.636 | 0.018 |
| Interest Margin to Gross Income | -0.567 | 0.469 | -15.831** | 0.000 | -1.992 | 0.29 | 0.96 | 0.003 |
| Interest Rate | -1.313 | 0.175 | -3.819** | 0.000 | -2.445* | 0.014 | 0.89 | 0.004 |
| Liquid Assets to Total Assets (Liquid Asset Ratio) | -2.577 | 0.098 | -2.063* | 0.037 | -2.089 | 0.249 | 0.603 | 0.022 |
| Market capitalization/GDP | -2.62 | 0.271 | -1.58 | 0.107 | -6.062** | 0.000 | 0.475 | 0.046 |
| Non-interest Expenses to Gross Income | -3.101* | 0.027 | -6.795** | 0.000 | -5.85** | 0.000 | 0.09* | 0.207 |
| Non-performing Loans Net of Provisions to Capital | -2.69 | 0.076 | -2.236* | 0.024 | -0.479 | 0.505 | 0.301* | 0.135 |
| Non-performing Loans to Total Gross Loans | -2.645 | 0.084 | -1.513 | 0.122 | -1.696 | 0.433 | 0.332* | 0.111 |
| Real Exchange Rate | -0.673 | 0.424 | -5.704** | 0.000 | -1.156 | 0.226 | 0.106* | 0.138 |
| Regulatory Capital to Risk-Weighted Assets, percent | -2.783 | 0.203 | -9.855** | 0.000 | -7.99** | 0.000 | 0.113* | 0.118 |
| Return on Assets | -2.139* | 0.031 | -9.244** | 0.000 | -5.157** | 0.000 | 0.253* | 0.185 |
| Ratio of external assets to total assets | -3.608* | 0.029 | -7.711** | 0.000 | -3.747* | 0.019 | 0.811 | 0.007 |
| Ration of Net Foreign Assets to Net Domestic Assets | -3.019* | 0.003 | -11.117** | 0.000 | -3.664** | 0.000 | 0.577 | 0.025 |
| Ratio of foreign currency assets to foreign currency liabilities | -0.383 | 0.543 | -3.888** | 0.000 | -0.44 | 0.521 | 0.356* | 0.095 |
| Inflation Rate (yoy) | -1.782 | 0.071 | -3.88** | 0.000 | -1.289 | 0.182 | 0.065* | 0.394 |
| Real Interest Rate | -2.221* | 0.025 | -5.622** | 0.000 | -1.964* | 0.047 | 0.424* | 0.063 |
| Real Effective Exchange Rate (log) | -1.346 | 0.165 | -4.72** | 0.000 | -1.152 | 0.227 | 0.103* | 0.15 |
| Monetary Condition Index | -0.085 | 0.655 | -6.584** | 0.000 | -2.181 | 0.5 | 0.124* | 0.089 |

Notes: ***, **, * indicates the rejection of the null hypothesis at 1%, 5% and 10% per cent level of significance respectively (t-statistic).
Null Hypothesis: ADF (Augmented Dicky-Fuller) and PP (Phillips-Peron) tests, the series has a unit root; KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, the series is stationnary.
Source: Author' computation.

Table B.9: Unit root tests for Netherlands

| | ADF | | | | PP | | KPSS | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First difference | | Level | | Level | |
| | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value |
| Composite Activity Indicator | -2.63 | 0.266 | -4.36* | 0.003 | -1.804 | 0.703 | 1.068 | 0.002 |
| Cost to Income | -1.144 | 0.23 | -0.736 | 0.398 | -2.43 | 0.133 | 0.122* | 0.095 |
| Total Credit / GDP | -2.739 | 0.068 | -1.353 | 0.163 | 0.364 | 0.792 | 0.555 | 0.029 |
| Current Account Balance | -2.21 | 0.203 | -3.314** | 0.001 | -1.839 | 0.361 | 0.123* | 0.092 |
| G20 GDP Growth Rate | -4.674** | 0.000 | -4.113** | 0.000 | -1.05 | 0.265 | 0.053* | 0.536 |
| G20 Inflation Rate | -3.05* | 0.03 | -4.138** | 0.000 | -1.763 | 0.399 | 0.05* | 0.573 |
| General Budget Balance | -0.96 | 0.304 | -7.368** | 0.000 | -1.126 | 0.236 | 0.454* | 0.052 |
| Herfindahl – Hirschmann Index (HHI) | -1.471 | 0.132 | -7.415** | 0.000 | -1.659 | 0.452 | 0.112* | 0.12 |
| Interest Margin to Gross Income | -3.972* | 0.002 | -8.649** | 0.000 | -7.552** | 0.000 | 0.176* | 0.32 |
| Interest Rate | -1.313 | 0.175 | -3.819** | 0.000 | -2.445* | 0.014 | 0.89 | 0.004 |
| Liquid Assets to Total Assets (Liquid Asset Ratio) | -1.656 | 0.092 | -5.274** | 0.000 | -2.616 | 0.09 | 0.076* | 0.298 |
| Market capitalization/GDP | -2.202 | 0.489 | -3.139* | 0.024 | -5.724** | 0.000 | 0.112* | 0.119 |
| Non-interest Expenses to Gross Income | -0.359 | 0.553 | -1.565 | 0.111 | -7.953** | 0.000 | 0.134* | 0.07 |
| Non-performing Loans Net of Provisions to Capital | -2.556 | 0.102 | -5.935** | 0.000 | -0.285 | 0.582 | 0.461* | 0.05 |
| Non-performing Loans to Total Gross Loans | -3.486* | 0.008 | -5.296** | 0.000 | -3.236* | 0.018 | 0.269* | 0.166 |
| Real Exchange Rate | -2.41 | 0.139 | -6.011** | 0.000 | -1.702 | 0.43 | 0.568 | 0.027 |
| Regulatory Capital to Risk-Weighted Assets, percent | 2.351 | 0.997 | -7.657** | 0.000 | 2.116 | 0.993 | 0.13* | 0.077 |
| Return on Assets | -3.593* | 0.006 | -8.359** | 0.000 | -3.679* | 0.004 | 0.1* | 0.164 |
| Ratio of external assets to total assets | -2.827 | 0.055 | -7.044** | 0.000 | -2.826 | 0.055 | 0.192* | 0.283 |
| Ration of Net Foreign Assets to Net Domestic Assets | -2.84 | 0.183 | -7.361** | 0.000 | -2.845 | 0.181 | 0.979 | 0.003 |
| Ratio of foreign currency assets to foreign currency liabilities | -0.89 | 0.333 | -4.311** | 0.000 | -2.567 | 0.1 | 0.577 | 0.026 |
| Inflation Rate (yoy) | -1.079 | 0.253 | -7.226** | 0.000 | -2.209 | 0.203 | 0.085* | 0.235 |
| Real Interest Rate | -1.304 | 0.178 | -7.272** | 0.000 | -1.431 | 0.142 | 0.762 | 0.009 |
| Real Effective Exchange Rate (log) | -2.385 | 0.146 | -5.94** | 0.000 | -1.702 | 0.43 | 0.566 | 0.027 |
| Monetary Condition Index | 0.59 | 0.845 | -7.72** | 0.000 | 0.864 | 0.896 | 0.106* | 0.138 |

Notes: ***, **, * indicates the rejection of the null hypothesis at 1%, 5% and 10% per cent level of significance respectively (t-statistic).
Null Hypothesis: ADF (Augmented Dicky-Fuller) and PP (Phillips-Peron) tests, the series has a unit root; KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, the series is stationnary.
Source: Author' computation.

Table B.10: Unit root tests for Portugal

| | ADF | | | | PP | | KPSS | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First difference | | Level | | Level | |
| | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value |
| Composite Activity Indicator | 0.163 | 0.736 | -6.088** | 0.000 | -1.58 | 0.800 | 0.396* | 0.074 |
| Cost to Income | -4.137* | 0.006 | -3.108* | 0.002 | -0.251 | 0.595 | 0.146* | 0.052 |
| Total Credit / GDP | -0.585 | 0.461 | -2.414* | 0.015 | -0.36 | 0.553 | 0.731 | 0.011 |
| Current Account Balance | -2.43* | 0.015 | -2.257* | 0.023 | -1.624 | 0.099 | 0.934 | 0.004 |
| Customer Deposits to Total (Non-interbank) Loans | 4.209 | 1.000 | -7.449** | 0.000 | 2.842 | 1.000 | 0.141* | 0.06 |
| G20 GDP Growth Rate | -4.674** | 0.000 | -4.113** | 0.000 | -1.05 | 0.265 | 0.053* | 0.536 |
| G20 Inflation Rate | -3.05* | 0.03 | -4.138** | 0.000 | -1.763 | 0.399 | 0.05* | 0.573 |
| General Budget Balance | -0.954 | 0.307 | -7.506** | 0.000 | -0.958 | 0.305 | 0.518 | 0.036 |
| Herfindahl – Hirschmann Index (HHI) | -1.344 | 0.166 | -7.361** | 0.000 | -1.646 | 0.094 | 0.982 | 0.003 |
| Interest Margin to Gross Income | -2.521 | 0.111 | -9.947** | 0.000 | -2.528 | 0.109 | 0.252* | 0.186 |
| Interest Rate | -1.313 | 0.175 | -3.819** | 0.000 | -2.445* | 0.014 | 0.89 | 0.004 |
| Liquid Assets to Total Assets (Liquid Asset Ratio) | -2.218 | 0.48 | -6.555** | 0.000 | -2.138 | 0.525 | 0.994 | 0.003 |
| Market capitalization/GDP | -2.233 | 0.194 | -2.356 | 0.403 | -5.173** | 0.000 | 0.121* | 0.096 |
| Non-interest Expenses to Gross Income | -4.128** | 0.001 | -2.789* | 0.005 | -3.951* | 0.002 | 0.323* | 0.117 |
| Non-performing Loans Net of Provisions to Capital | -0.574 | 0.465 | -6.108** | 0.000 | -1.653 | 0.456 | 0.528 | 0.034 |
| Non-performing Loans to Total Gross Loans | -0.542 | 0.479 | -3.167* | 0.002 | -0.532 | 0.483 | 0.576 | 0.026 |
| Real Exchange Rate | -1.709 | 0.083 | -2.202* | 0.027 | -1.472 | 0.547 | 1.042 | 0.002 |
| Regulatory Capital to Risk-Weighted Assets, percent | -2.046 | 0.576 | -3.616* | 0.005 | -2.373 | 0.394 | 0.128* | 0.08 |
| Return on Assets | -2.27* | 0.022 | -6.3** | 0.000 | -3.208** | 0.001 | 0.231* | 0.215 |
| Ratio of external assets to total assets | -1.593 | 0.105 | -6.535** | 0.000 | -1.839 | 0.063 | 1.023 | 0.002 |
| Ration of Net Foreign Assets to Net Domestic Assets | -1.741 | 0.078 | -1.823 | 0.065 | -6.691** | 0.000 | 1.023 | 0.002 |
| Ratio of foreign currency assets to foreign currency liabilities | -1.678 | 0.088 | -7.689** | 0.000 | -1.977* | 0.046 | 1.099 | 0.002 |
| Inflation Rate (yoy) | -2.19* | 0.027 | -4.329** | 0.000 | -1.708 | 0.083 | 0.049* | 0.595 |
| Real Interest Rate | -2.632* | 0.008 | -2.871* | 0.004 | -1.803 | 0.068 | 0.136* | 0.067 |
| Real Effective Exchange Rate (log) | -1.011 | 0.284 | -6.374** | 0.000 | -1.47 | 0.548 | 1.044 | 0.002 |
| Monetary Condition Index | 0.577 | 0.842 | -4.011** | 0.000 | -0.007 | 0.682 | 0.103* | 0.152 |

Notes: ***, **, * indicates the rejection of the null hypothesis at 1%, 5% and 10% per cent level of significance respectively (t-statistic).
Null Hypothesis: ADF (Augmented Dicky-Fuller) and PP (Phillips-Peron) tests, the series has a unit root; KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, the series is stationnary.
Source: Author' computation.

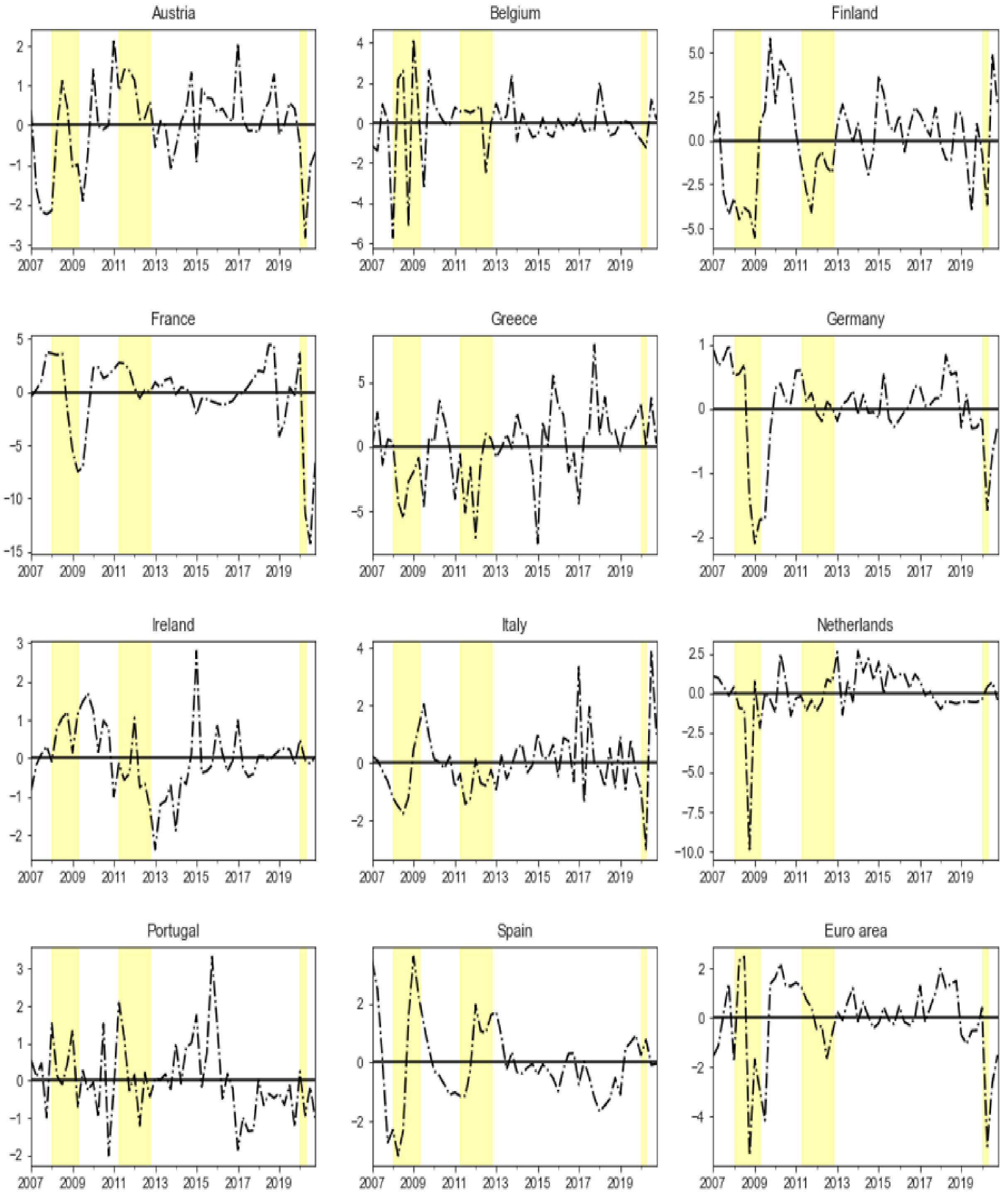
Table B.11: Unit root tests for Spain

| | ADF | | | | PP | | KPSS | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First difference | | Level | | Level | |
| | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value | t-statistic | p-value |
| Composite Activity Indicator | -2.198 | 0.491 | -4.349** | 0.000 | -1.953 | 0.627 | 0.657 | 0.016 |
| Cost to Income | 0.884 | 0.899 | -2.839* | 0.004 | 1.014 | 0.918 | 0.071* | 0.338 |
| Total Credit / GDP | -3.669* | 0.005 | 1.628 | 1.000 | -0.677 | 0.422 | 1.028 | 0.002 |
| Current Account Balance | -2.518* | 0.011 | -1.445 | 0.139 | -2.601* | 0.009 | 0.964 | 0.003 |
| Customer Deposits to Total (Non-interbank) Loans | -2.057 | 0.262 | -4.449** | 0.000 | -1.88 | 0.341 | 0.934 | 0.004 |
| G20 GDP Growth Rate | -4.674** | 0.000 | -4.113** | 0.000 | -1.05 | 0.265 | 0.053* | 0.536 |
| G20 Inflation Rate | -3.05* | 0.03 | -4.138** | 0.000 | -1.763 | 0.399 | 0.05* | 0.573 |
| General Budget Balance | -1.028 | 0.277 | -2.46* | 0.013 | -0.94 | 0.313 | 0.242* | 0.199 |
| Herfindahl – Hirschmann Index (HHI) | -2.077 | 0.254 | -2.713 | 0.231 | -2.106 | 0.242 | 1.021 | 0.002 |
| Interest Margin to Gross Income | -3.386* | 0.011 | -8.21** | 0.000 | -3.198* | 0.02 | 0.191* | 0.287 |
| Interest Rate | -1.313 | 0.175 | -3.819** | 0.000 | -2.445* | 0.014 | 0.89 | 0.004 |
| Liquid Assets to Total Assets (Liquid Asset Ratio) | -1.512 | 0.825 | -6.579** | 0.000 | -0.858 | 0.96 | 0.68 | 0.014 |
| Market capitalization/GDP | -1.828 | 0.064 | -1.466 | 0.133 | -3.611* | 0.006 | 0.034* | 0.822 |
| Non-interest Expenses to Gross Income | -2.432 | 0.363 | -3.029* | 0.002 | -3.23 | 0.079 | 0.118* | 0.102 |
| Non-performing Loans Net of Provisions to Capital | -0.606 | 0.452 | -3.776** | 0.000 | -2.439 | 0.131 | 0.295* | 0.14 |
| Non-performing Loans to Total Gross Loans | -0.982 | 0.295 | -1.686 | 0.087 | -1.878 | 0.343 | 0.312* | 0.125 |
| Real Exchange Rate | -1.143 | 0.23 | -4.166** | 0.000 | -1.567 | 0.5 | 0.126* | 0.085 |
| Regulatory Capital to Risk-Weighted Assets, percent | -3.673* | 0.024 | -9.079** | 0.000 | -3.836* | 0.015 | 1.186 | 0.001 |
| Return on Assets | -2.759* | 0.006 | -7.839** | 0.000 | -2.667* | 0.007 | 0.139* | 0.062 |
| Ratio of external assets to total assets | -3.08 | 0.111 | -9.174** | 0.000 | -2.99 | 0.135 | 0.715 | 0.012 |
| Ration of Net Foreign Assets to Net Domestic Assets | -0.147 | 0.633 | -7.348** | 0.000 | -0.147 | 0.633 | 0.574 | 0.026 |
| Ratio of foreign currency assets to foreign currency liabilities | -2.69 | 0.076 | -7.254** | 0.000 | -2.632 | 0.086 | 0.145* | 0.053 |
| Inflation Rate (yoy) | -1.013 | 0.283 | -2.752* | 0.006 | -1.573 | 0.109 | 0.065* | 0.391 |
| Real Interest Rate | -2.445* | 0.014 | -5.948** | 0.000 | -2.037* | 0.04 | 0.104* | 0.148 |
| Real Effective Exchange Rate (log) | -0.826 | 0.359 | -4.725** | 0.000 | -0.594 | 0.457 | 0.125* | 0.087 |
| Monetary Condition Index | -0.044 | 0.67 | -6.28** | 0.000 | -2.284 | 0.443 | 0.086* | 0.232 |

Notes: ***, **, * indicates the rejection of the null hypothesis at 1%, 5% and 10% per cent level of significance respectively (t-statistic).
Null Hypothesis: ADF (Augmented Dicky-Fuller) and PP (Phillips-Peron) tests, the series has a unit root; KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, the series is stationnary.
Source: Author' computation.

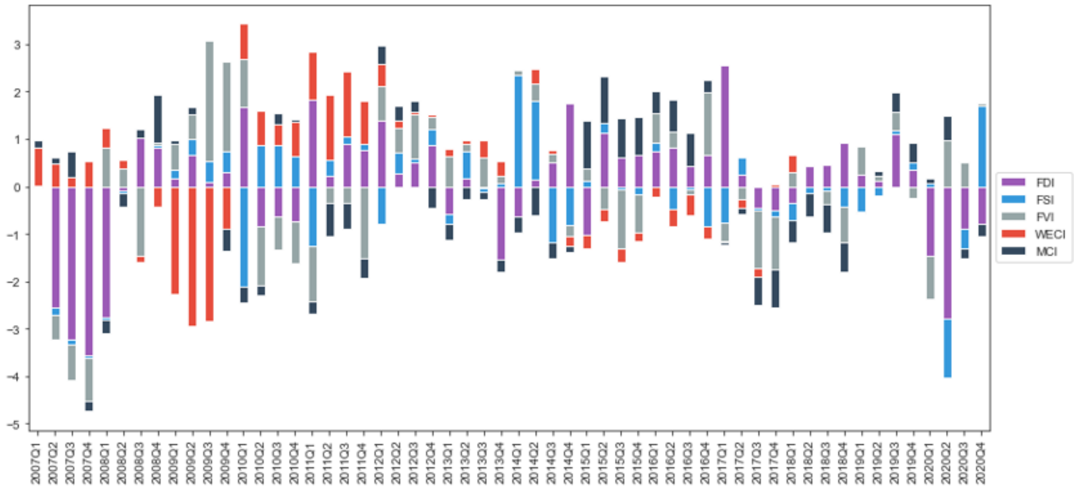
## Appendix C: Aggregate Financial Stability Indexes

**Figure C.1: Aggregate Financial Stability Indexes for Euro Area countries**



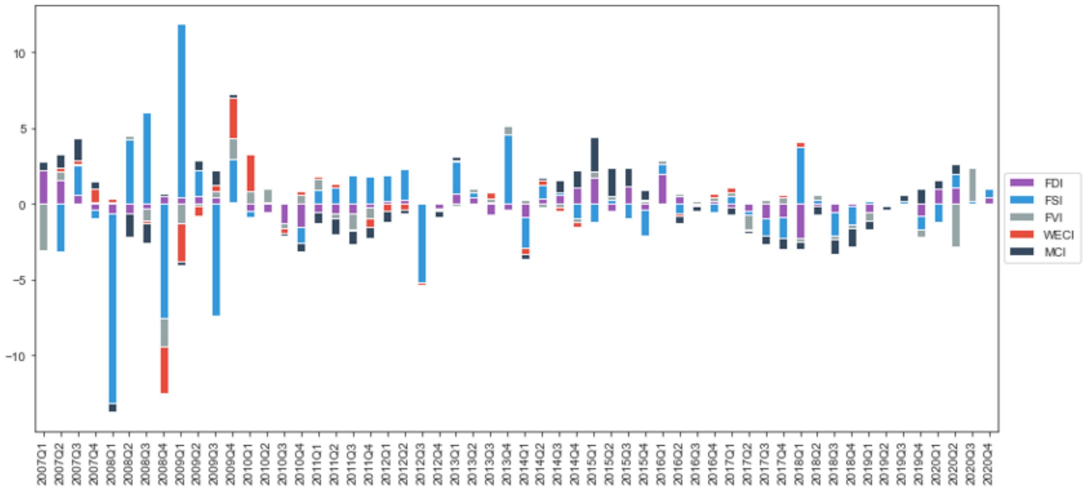

Notes: 0 = average financial stability. The shared regions correspond to respectively the global financial crisis of 2008-2009, the European debt crisis and the pandemic crisis Covid-19.
Source: Author' computation.

**Figure C.2.1: AFSI decomposition for Austria**



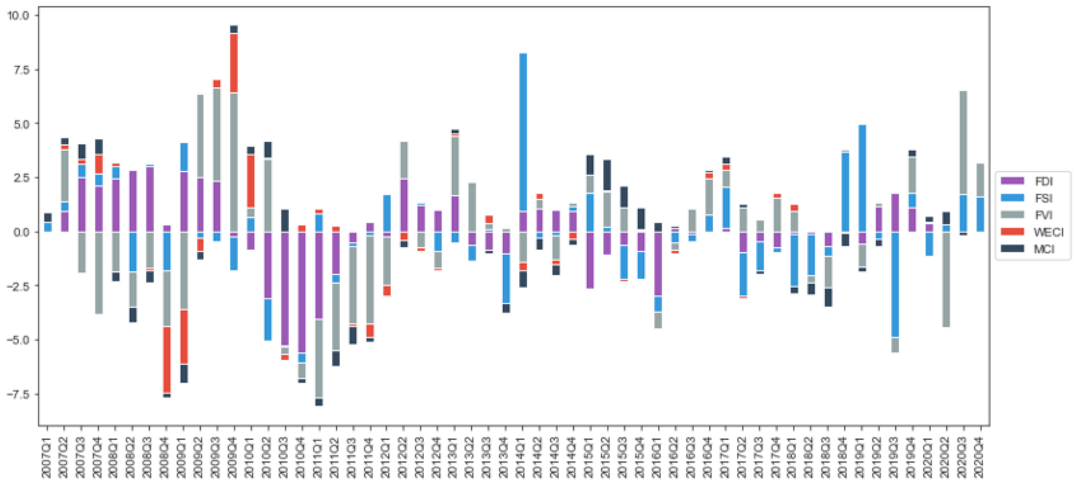

Note: FDI: Financial Development Index, FSI: Financial Soundness Index, FVI: Financial Vulnerability Index, WECI: World Economic Climate Index and MCI: Monetary Condition Index. Source: Author' computation.

**Figure C.2.2: AFSI decomposition for Belgium**



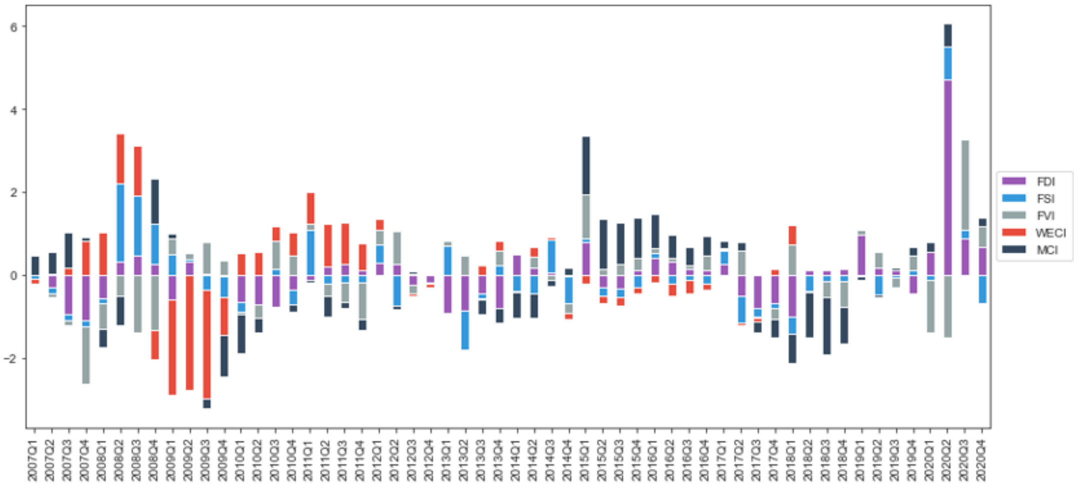

Note: FDI: Financial Development Index, FSI: Financial Soundness Index, FVI: Financial Vulnerability Index, WECI: World Economic Climate Index and MCI: Monetary Condition Index. Source: Author' computation.

**Figure C.2.3: AFSI decomposition for Finland**



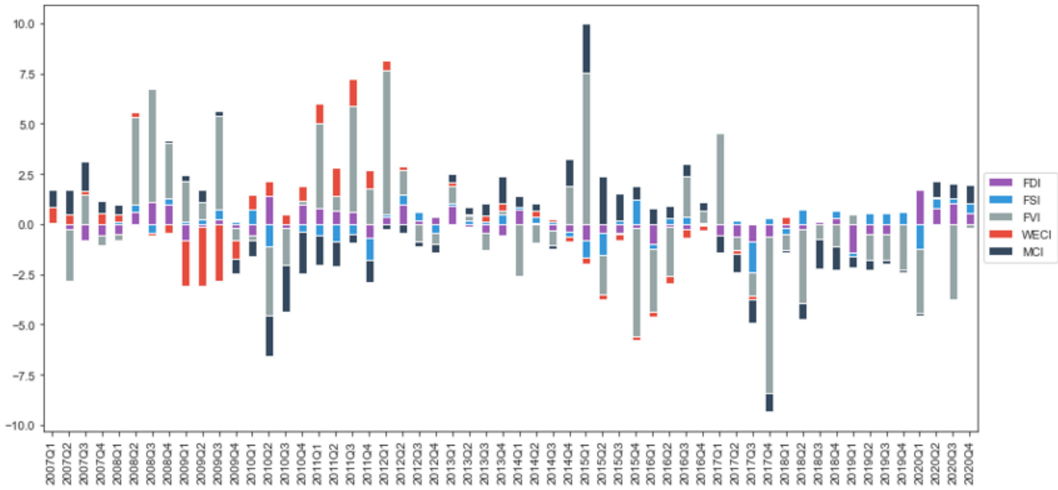

Note: FDI: Financial Development Index, FSI: Financial Soundness Index, FVI: Financial Vulnerability Index, WECI: World Economic Climate Index and MCI: Monetary Condition Index. Source: Author' computation.

**Figure C.2.4: AFSI decomposition for France**



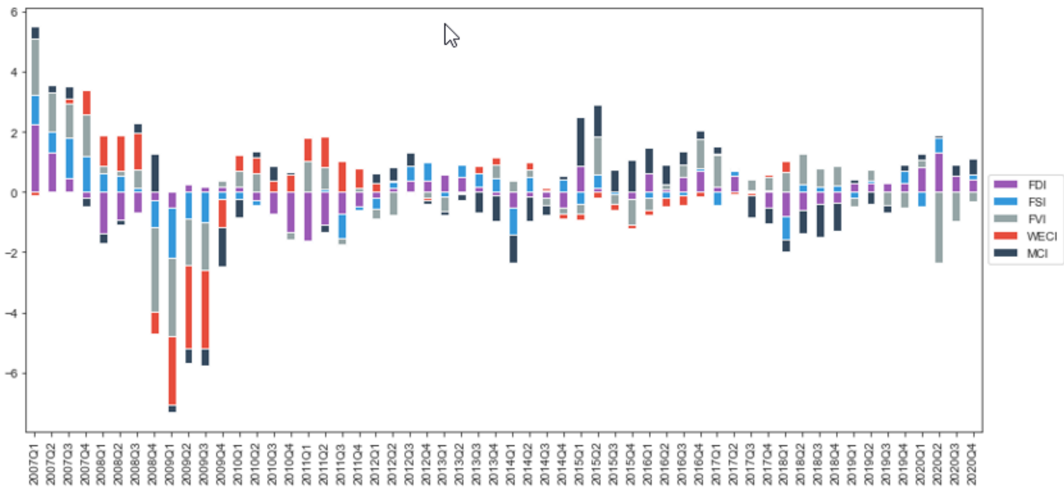

Note: FDI: Financial Development Index, FSI: Financial Soundness Index, FVI: Financial Vulnerability Index, WECI: World Economic Climate Index and MCI: Monetary Condition Index. Source: Author' computation.

**Figure C.2.5: AFSI decomposition for Greece**



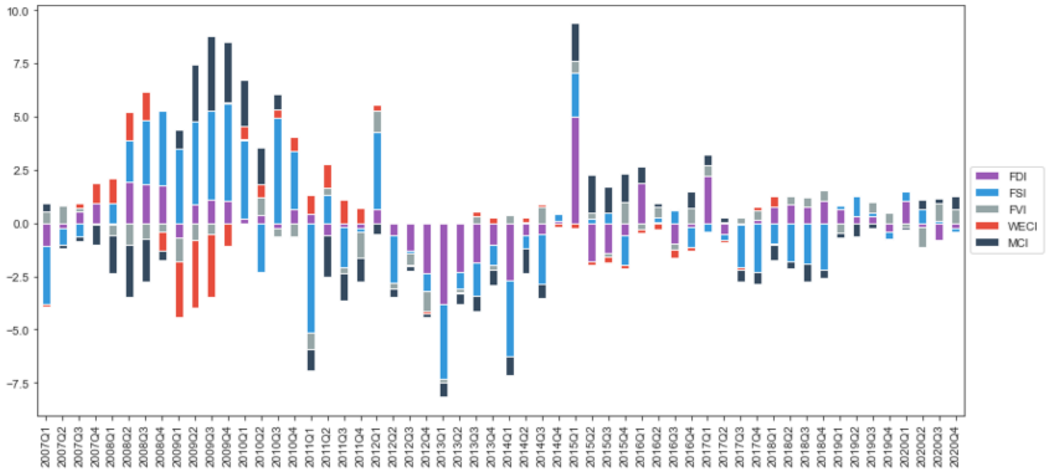

Note: FDI: Financial Development Index, FSI: Financial Soundness Index, FVI: Financial Vulnerability Index, WECI: World Economic Climate Index and MCI: Monetary Condition Index. Source: Author' computation.

**Figure C.2.6: AFSI decomposition for Germany**



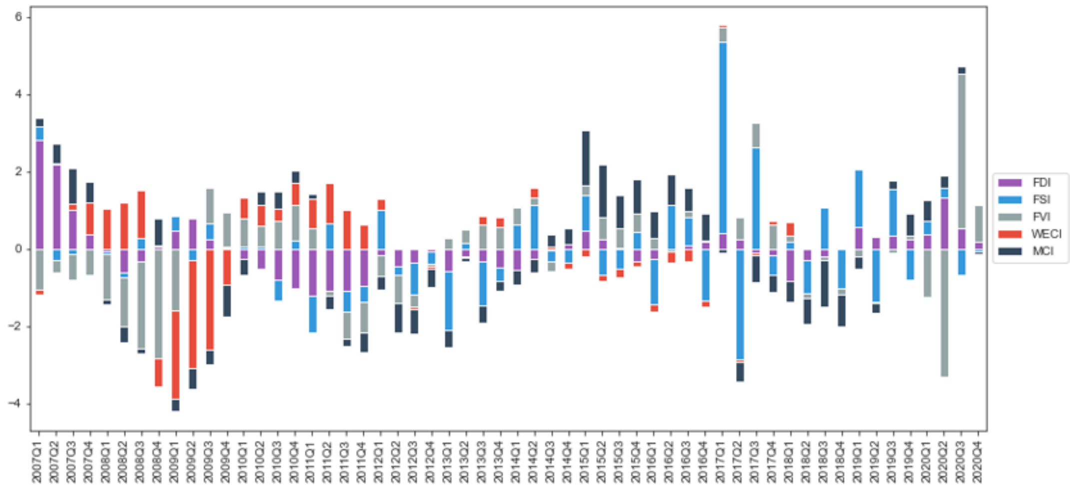

Note: FDI: Financial Development Index, FSI: Financial Soundness Index, FVI: Financial Vulnerability Index, WECI: World Economic Climate Index and MCI: Monetary Condition Index. Source: Author' computation.

### Figure C.2.7: AFSI decomposition for Ireland



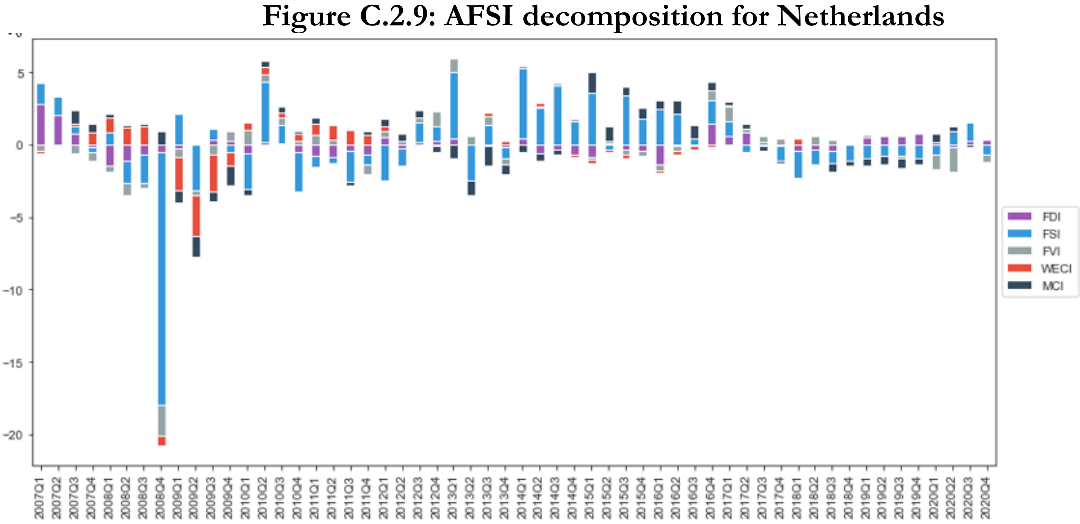

Note: FDI: Financial Development Index, FSI: Financial Soundness Index, FVI: Financial Vulnerability Index, WECI: World Economic Climate Index and MCI: Monetary Condition Index. Source: Author' computation.

### Figure C.2.8: AFSI decomposition for Italy



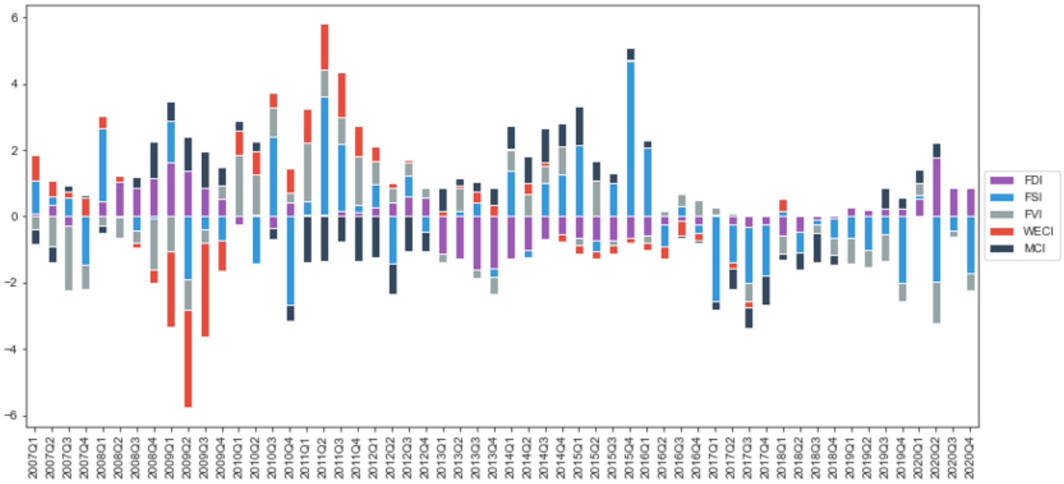

Note: FDI: Financial Development Index, FSI: Financial Soundness Index, FVI: Financial Vulnerability Index, WECI: World Economic Climate Index and MCI: Monetary Condition Index. Source: Author' computation.

### Figure C.2.9: AFSI decomposition for Netherlands



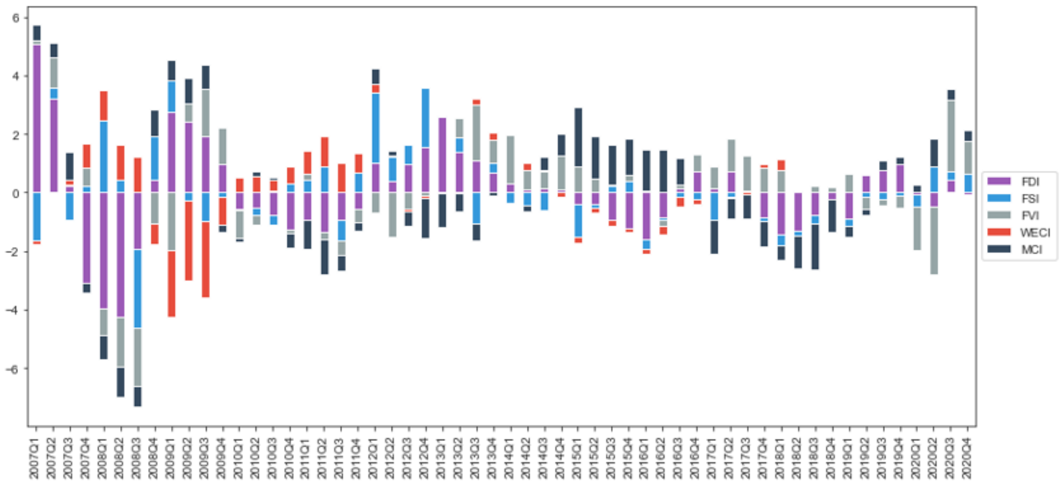

Note: FDI: Financial Development Index, FSI: Financial Soundness Index, FVI: Financial Vulnerability Index, WECI: World Economic Climate Index and MCI: Monetary Condition Index. Source: Author' computation.

Figure **C.2.10: AFSI decomposition for Portugal**



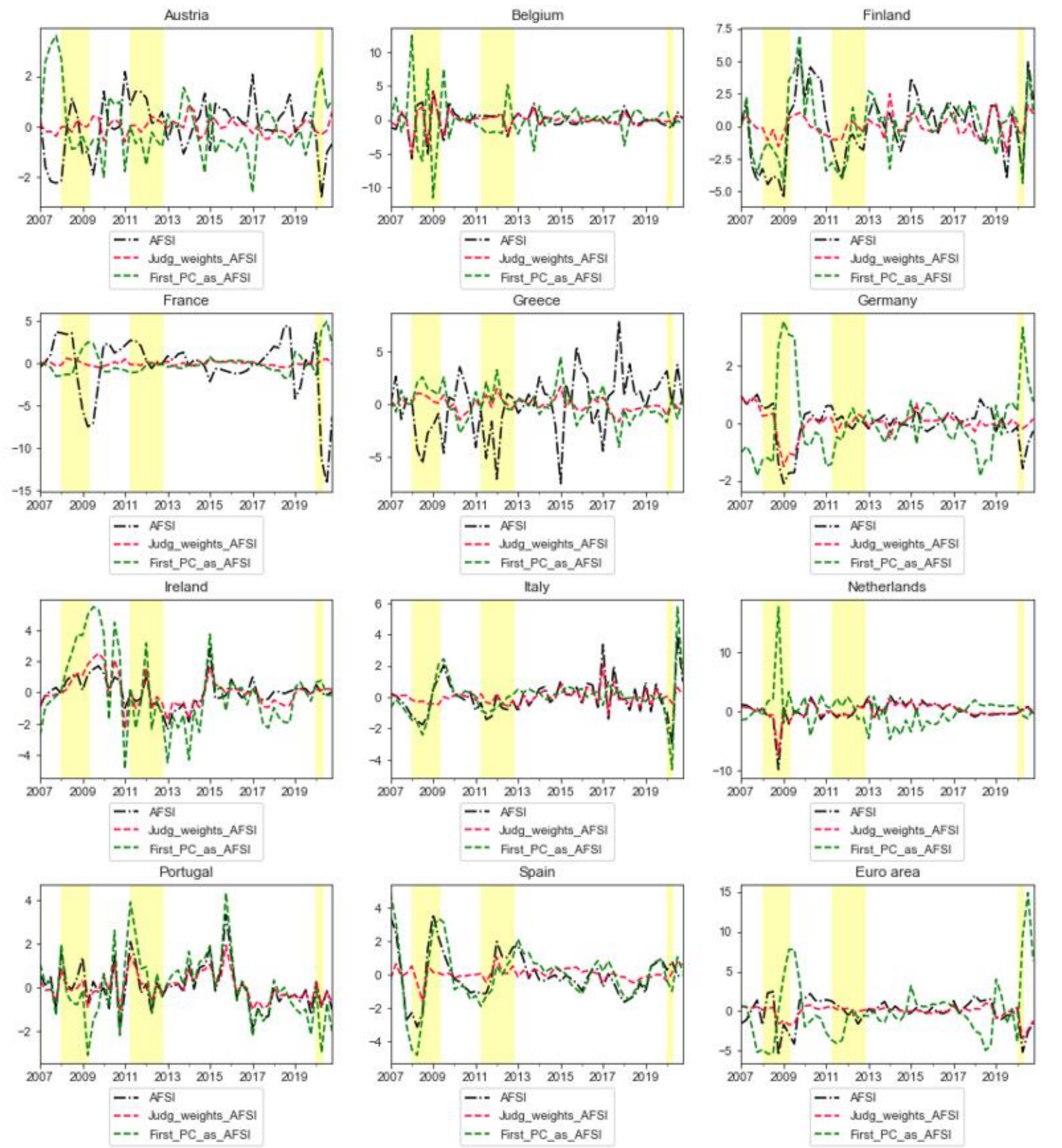

Note: FDI: Financial Development Index, FSI: Financial Soundness Index, FVI: Financial Vulnerability Index, WECI: World Economic Climate Index and MCI: Monetary Condition Index. Source: Author' computation.

**Figure C.2.11: AFSI decomposition for Spain**




Note: FDI: Financial Development Index, FSI: Financial Soundness Index, FVI: Financial Vulnerability Index, WECI: World Economic Climate Index and MCI: Monetary Condition Index. Source: Author' computation.

**Figure C.3: Robustness, AFSIs by different methods for Euro Area countries**




Notes: The shared regions correspond to respectively the global financial crisis of 2008-2009, the European debt crisis and the pandemic crisis Covid-19.

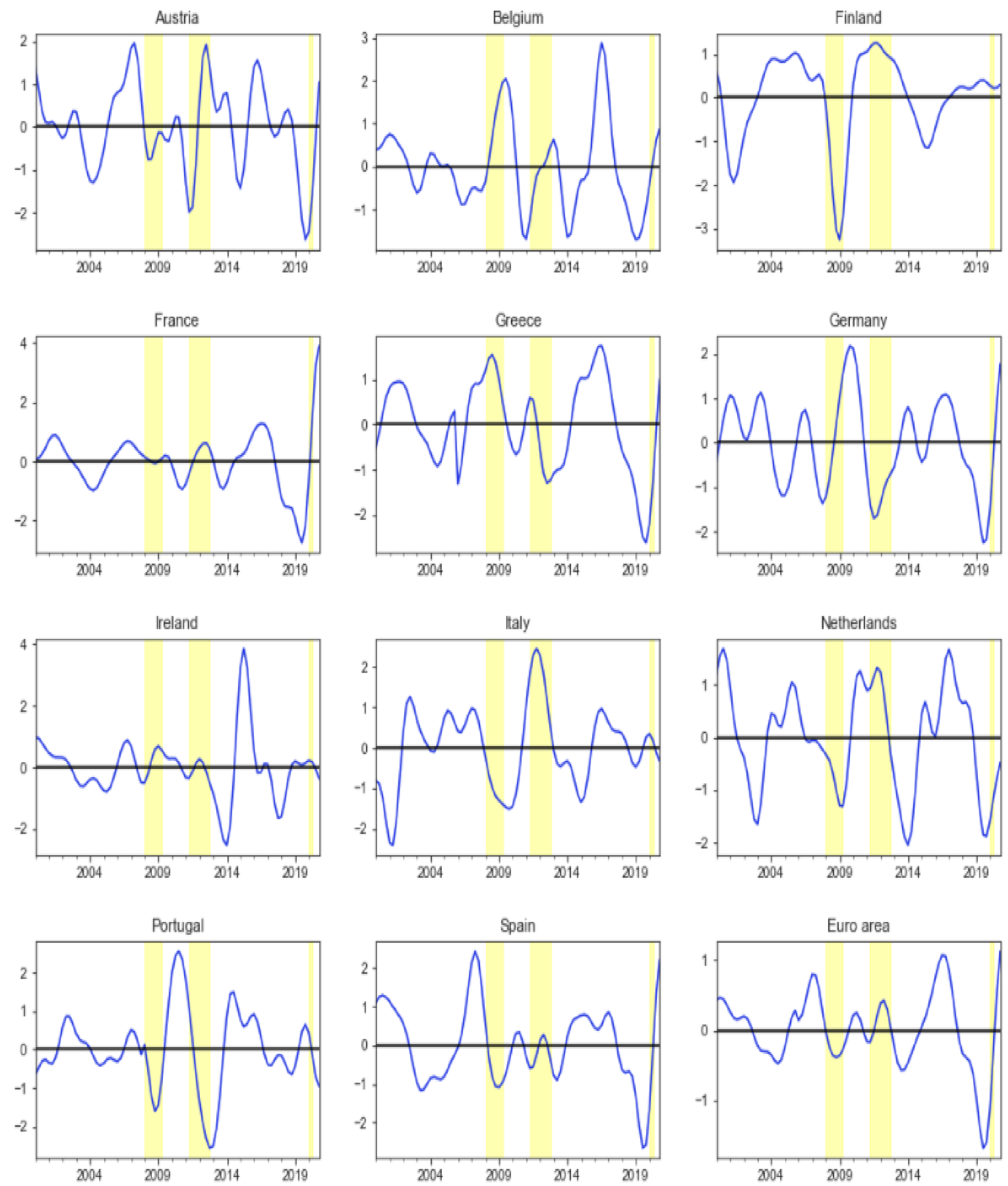
Source: Author' computation.

- The **black line** is the AFSI obtaining by the arithmetic mean of weights based on both uniform and principal component (see section 3.2 above).
- The **green line** represents the AFSI obtaining using the principal component which have the higher variance.
- The **red line** corresponds to the AFSI obtaining by fixing weights in the following equation:

$$AFSI_t = \alpha_1 FDI + \alpha_2 FSI + \alpha_3 FVI + \alpha_4 MCI + \alpha_5 WECI$$

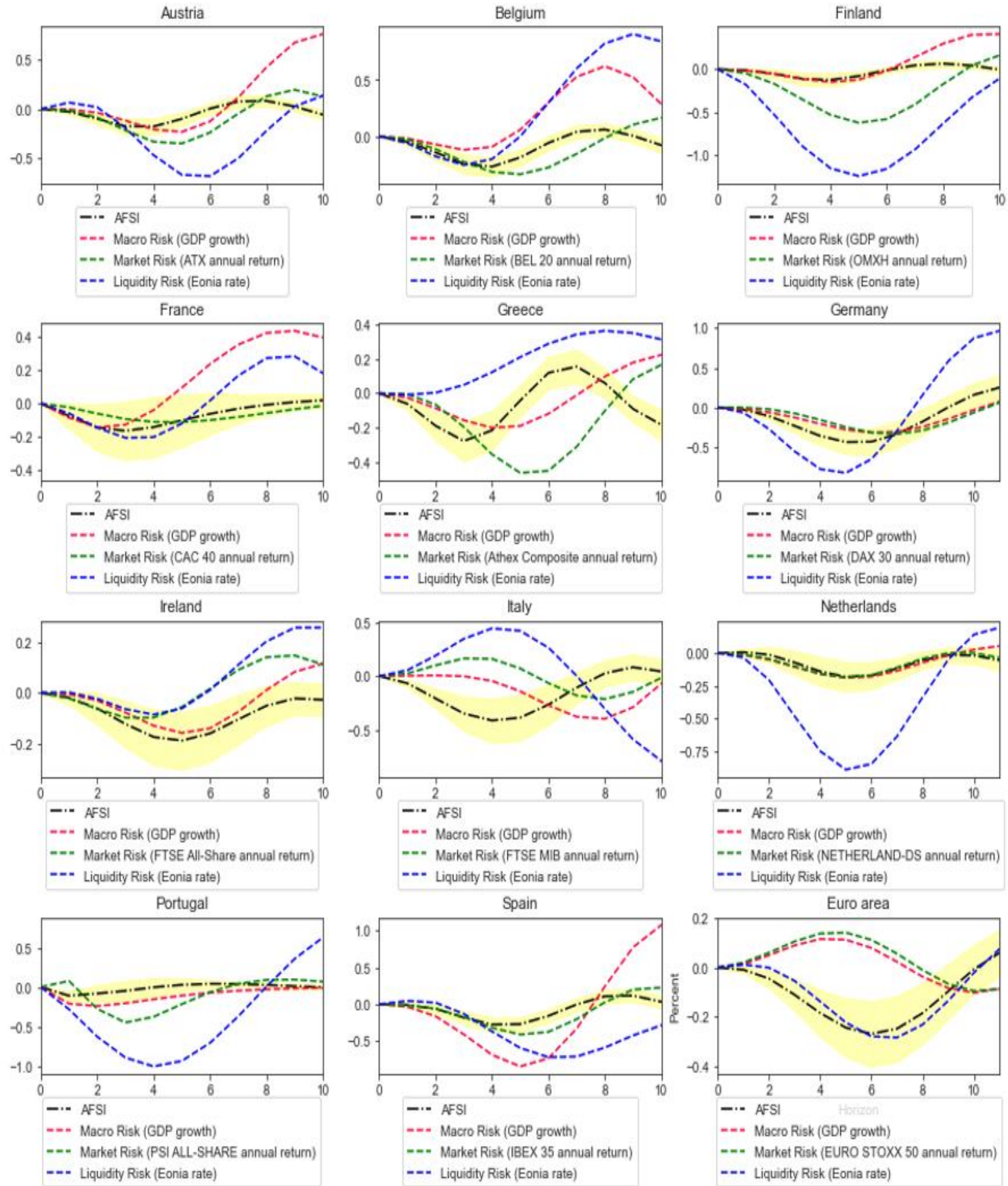
Where $\alpha_1$= 5%, $\alpha_2$= 35%, $\alpha_3$=20%, $\alpha_4$=30% and $\alpha_5$=10%. This weighting follows Cheang and Choy (2009).

**Figure C.4: Financial Cycles for Euro Area countries**




Notes: These cycles are measured by a frequency (Band-Pass) filter capturing medium-term cycles in credit-to-GDP ratio and real house prices. The Band-Pass filter is another type of univariate filter which allows to extract from a time series a part composed of any given range of frequencies. For example, we can extract from the time series the trend represented by the components with periodicities longer than the business cycle. We can estimate the gap represented by the components with business cycle periodicities.
The shared regions correspond to respectively the global financial crisis of 2008-2009, the European debt crisis and the pandemic crisis Covid-19.
Source: Author' computation.

**Figure C.5: Financial cycle response to a 1 standard deviation shock in the different financial monitoring risk**




Notes: The shared region represents the +/- one standard error confidence interval for the aggregate financial stability index. Source: Author' computation.

- The **black line** represents the response of financial cycle to one standard deviation shock of aggregate financial stability index (AFSI), obtaining by the arithmetic mean of weights based on both uniform and principal component (see section 3.2 above), as financial monitoring risk.
- The **red line** represents the response of financial cycle to one standard deviation shock of GDP growth rate (Macro risk) as financial monitoring risk.
- The **green line** represents the response of financial cycle to one standard deviation shock of stock market annual return (Market risk) as financial monitoring risk.
- The **blue line** represents the response of financial cycle to one standard deviation shock of Eonia rate (Liquidity risk) as financial monitoring risk.