Ca' Foscari
University
of Venice

Master's Degree Programme –
Second Cycle
in Economics and Finance

Final Thesis

Connectedness in European Government Bonds: an Empirical Analysis

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Matriculation Number 849636

Academic Year

2020/2021

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Introduction

The process of European integration experienced a strong push forward in 2002 with the adoption of the euro as a common currency. This process has been surely a cultural one, with the first idealized discussions about the United States of Europe taking place since the eighteenth century, but also an economical and financial one. After a 40-years long preparatory process, the adoption of euro in the euro-zone set the beginning of a unified monetary policy, carried out by the European System of Central Banks led by the European Central Bank. Nonetheless, fiscal policies are still rather fragmented being for the most part dictated by national governments, which can cause some mismatching in the financial sector.

In this thesis we aim at studying the financial integration of a sample of ten countries of the euro-zone (Portugal, Belgium, the Netherlands, Italy, France, Germany, Spain, Finland, Austria and Ireland) by looking at the monthly yields of these counties for different maturities and by applying the generalized variance decomposition method in order to assess the connectedness among these nations.

We deem this to be a topic of increasing relevance in the European context due to how strong such integration has become in the last 20 years and, consequently, how relevant the monetary policies undertaken at the European level are for the economies of the member states and for the peoples of Europe.

The goal of our analysis is to analyze how, when and why connectedness shifted in Europe, in what direction and to which effect. We will look at the concept of connectedness as a whole but also individually, discussing how every country in the sample contributes to connectedness. We will start by describing the theoretical basis for our work. We then move one to discuss the most important events of the most troubled and, at least for the ends of our analysis, interesting countries, justifying why their yield curves look the way they do. When it comes to the bulk of our analysis, we will apply the methodology described earlier, performing what we will refer to as static analysis, to the entirety of our sample and then to specific sub-sample, defined by the most important economic events that took place in Europe in the last 20 years. Lastly, we will pursue a dynamic approach, assessing how connectedness changed over time in

the sample. We will show how useful connectedness is as a tool to analyze financial events, differentiating between crisis and stability periods, the different behavior of peripheric and core nations and the fragmented environment left behind by the sovereign debt crisis.

Chapter I

Methodology

The methodology used in our study applies the variance decomposition technique proposed by Diebold and Yilmaz in the paper "On the network topology of variance decompositions: Measuring the connectedness of financial firms". Given that the goal of this thesis is to evaluate the connectedness within a sample of yields of 10 countries, the bedrock of the study is based on a vector autoregressive model, a model well suited for interpreting a system composed by multiple time series.

1.1 VAR Model

The vector autoregressive model (VAR for short) is multidimensional version of an AR autoregressive model, extending the idea of autoregression to N time series, having the lagged values of all N series as regressors. If we consider a generic VAR model with p lags and two time series, the model is given by:

$$x_t^1 = c_1 + a_{11}x_{t-1}^1 + \dots + a_{1p}x_{t-p}^1 + b_{11}x_{t-1}^2 + \dots + b_{1p}x_{t-p}^2 + \varepsilon_{1t},$$

$$x_t^2 = c_2 + a_{21}x_{t-1}^1 + \dots + a_{2p}x_{t-p}^1 + b_{21}x_{t-1}^2 + \dots + b_{2p}x_{t-p}^2 + \varepsilon_{2t},$$

or

$$x_t = c + A_1x_{t-1} + \dots + A_px_{t-p} + \varepsilon_t$$

In matrix form, where x_t is the 2xp vector of variables, c is a 2xp vector of constants, A_1 is a 2x2 parameters matrix that multiplies the 1 lagged variables, ε_t is a 2x1 vector of errors.

The model we choose for our analysis is a one lagged VAR with ten series given by the yields of the ten countries. The choice of this model is dictated mainly by the AIC and the BIC but also by a simple reasoning surrounding the size of the model. AIC and BIC as matter of fact suggested different models. Out of the 4 models tested (VAR with lag ranging from 1 to 4) the AIC suggested that the best model was the VAR(4) , while the

BIC pointed towards the VAR(1). This is not surprising given the fact that the BIC penalizes more heavily models with a greater amount of parameters. In the end we choose the VAR(1), capitalizing on the benefits of having a simpler model to deal with. This will also allow us to perform more flexible analyses later on (see dynamic analysis) due to the fact that a smaller sample size is required for the estimation of a model with less lags.

When it comes to VAR models there are different types of models that we might be referring to such as structural VAR, or SVAR (a transformed VAR that aims at standardizing the errors), VARMA (a vectoral model that contains a moving average component in addition to the autoregressive one) and so on. Here we are sticking to the simple VAR, or reduced VAR, since it is the model used in our reference paper and has some interesting properties that we will discuss in the next section.

1.2 Variance decomposition and population connectedness

The idea of measuring the connectedness between the countries of our sample boils down to the question "how much the yields of country i influence the yields of country j?". This issue can be addressed by using the forecast error variance decomposition. In particular, introducing a wording that we will be using throughout the rest of the thesis, we define d_{ij}^{H} as the variance decomposition component from country i to country j with a H-step ahead forecast.

We will start by introducing the connectedness table, which is the bedrock of our study. Table 1 represents a generic connectedness table that includes N entities. We can decompose it in 4 parts: the upper-left contains all the individual bilateral variance decomposition components d_{ij}^{H} defined earlier; the upper-right part contains the total connectedness "from others"; the lower-left part contains the total connectedness "to others"; the bottom-left part contains the total connectedness. We now proceed to expand on these 4 components.

We refer to the connectedness table as $D^{H}=[\ d_{ij}^{H}\ ]$. The entities of this table in our case are the ten countries (Portugal, Netherlands, Belgium, Italy, France, Germany, Spain, Finland, Austria, Ireland), therefore N=10. In regard to the upper-left section, the off-

diagonal entries are the ones of most interest to us, since they represent the pairwise connectedness between two specific countries. In particular, we refer to these entries as $C^{H}_{i\leftarrow j} = d^{H}_{ij}$. Generally speaking, we have that $C^{H}_{i\leftarrow j}$ is different from $C^{H}_{j\leftarrow i}$. This is not surprising since the variance transmitted from a one country to another is not necessary the same as the variance that said country receives from that specific other country. It works in a similar fashion to import and export: the amount of goods exported by country a to country b is rarely the same as the amount exported by country b to country a. There is a total of N^2-N distinct pairwise directional connectedness measures (100-10=90 in our case).

We can now define the net pairwise connectedness as $C^{H}_{ij} = C^{H}_{j\leftarrow i} - C^{H}_{i\leftarrow j}$ to better understand the connectedness between two specific countries. There are $\frac{N^2-N}{2}$ of said net pairwise connectedness measures (45 in our case). What is to greater interest to us though are the elements in the upper-right and bottom-left parts of the table. These are the "from" and "to" others connectedness measures, respectively, and they are computed as the sum of all the off-diagonal elements of rows (from) and columns (to). We refer to them as:

$C^{H}_{j\leftarrow \cdot}=\sum_{j=1}^{N} d^{H}_{ij}$ with $j \neq i$, for the total connectedness from others and

$C^{H}_{\cdot\leftarrow j}=\sum_{i=1}^{N} d^{H}_{ij}$ with $i \neq j$, for the total connectedness to others.

The total amount of directional connectedness measures is equal to 2N (20 in our case). We can now compute the net total directional connectedness for a specific country as $C^{H}_{i} = C^{H}_{\cdot\leftarrow j} - C^{H}_{j\leftarrow \cdot}$ there are N net total directional connectedness measures. Lastly, we can define the total connectedness as:

$C^{H} = \frac{1}{N}\sum_{i,j=1}^{N} d^{H}_{ij}$ with $j \neq i$

There is obviously only 1 total connectedness measure.

Lastly, we compute every individual entry d^{H}_{ij} of the matrix D^{H} as:

$$d^{H}_{ij} = \frac{\sigma_{jj}^{-1} \sum_{h=1}^{H} (e_i' \Theta_h \Sigma e_j)^2}{\sum_{h=1}^{H} (e_i' \Theta_h \Sigma \Theta_h' e_i)}$$

Where e_i and e_j are two selector vectors with 1 in the i-th and j-th position respectively and 0 elsewhere, Θ_h is the coefficient matrix multiplying the H-lagged shock vector in the infinite moving-average representation of the non-orthogonalized VAR(1) model, Σ is the covariance matrix of the shock vector in the non-orthogonalized VAR(1) model, and σ_{jj} is the j-th diagonal element of Σ. Since shocks in the generalized variance decomposition method are not orthogonal by construction, the sums of the d_{ij}^{H} entries of the connectedness table don't necessarily add up to 1 along rows and columns. Therefore, we decide to rationalize them to one by taking $\tilde{d}_{ij}^{H}$ instead of d_{ij}^{H} as entries for our table, where $\tilde{d}_{ij}^{H}$ is computed as:

$$\tilde{d}_{ij}^{H} = \frac{d_{ij}^{H}}{\sum_{j=1}^{N} d_{ij}^{H}}$$

This way by construction we have that $\sum_{j=1}^{N} \tilde{d}_{ij}^{H}$=1 and $\sum_{i,j=1}^{N} \tilde{d}_{ij}^{H}$=N.

Table 1. Generic connectedness table

	X_1	X_2	. . .	X_N	From Others
X_1	$\tilde{d}_{11}^{H}$	$\tilde{d}_{12}^{H}$	. . .	$\tilde{d}_{1N}^{H}$	$\sum_{j=1}^{N} \tilde{d}_{1j}^{H}, j \neq 1$
X_2	$\tilde{d}_{21}^{H}$	$\tilde{d}_{22}^{H}$	. . .	$\tilde{d}_{2N}^{H}$	$\sum_{j=1}^{N} \tilde{d}_{2j}^{H}, j \neq 2$
. . .	. . .	. . .	. . .	. . .	. . .
X_N	$\tilde{d}_{N1}^{H}$	$\tilde{d}_{N2}^{H}$	. . .	$\tilde{d}_{NN}^{H}$	$\sum_{j=1}^{N} \tilde{d}_{Nj}^{H}, j \neq N$
To Others	$\sum_{i=1}^{N} \tilde{d}_{i1}^{H}$ *i≠1*	$\sum_{i=1}^{N} \tilde{d}_{i2}^{H}$ *i≠2*	. . .	$\sum_{i=1}^{N} \tilde{d}_{iN}^{H}$ *i≠N*	$\frac{1}{N} \sum_{i,j=1}^{N} \tilde{d}_{ij}^{H}$ *i≠j*

The technique that we will be using is the forecast error variance decomposition. This technique allows at a "microeconomic" level to unravel how much of the variance of entity i is caused by entity j, well in line with our goal to analyze and discuss how the yields of various countries influence each other. Using the words of Sims "Generally, if economically meaningful innovations can be found, forecast error variance decompositions provide information about the relative importance of different shocks for the variables described by the VAR model". In addition this method will allow us to look at connectedness at different time horizons, a useful tool to evaluate the robustness of our analysis and to give us more freedom in the way we conduct the study. We will follow the same approach used by the main reference for this work, that is the generalized variance decomposition method applied by Diebold and Yilmaz (2012) and firstly introduced by Koop et al. (1996) and Pesaran and Shin (1998).

The advantage of the generalized variance decomposition arises from overcoming the main shortcoming of the more traditional way to address dynamic analysis of vector autoregressive models pioneered by Sims (1980), namely the restriction regarding the ordering of variables. In particular, the traditional approach routinely uses orthogonalized impulse responses where such orthogonalization of the shocks of the VAR model is achieved via Cholesky decomposition before the impulse response or forecast error decomposition are computed. The result of this type of procedure causes each variable to be only affected by itself and the previous variables estimated, making the ordering of the variables a very pressing issue.

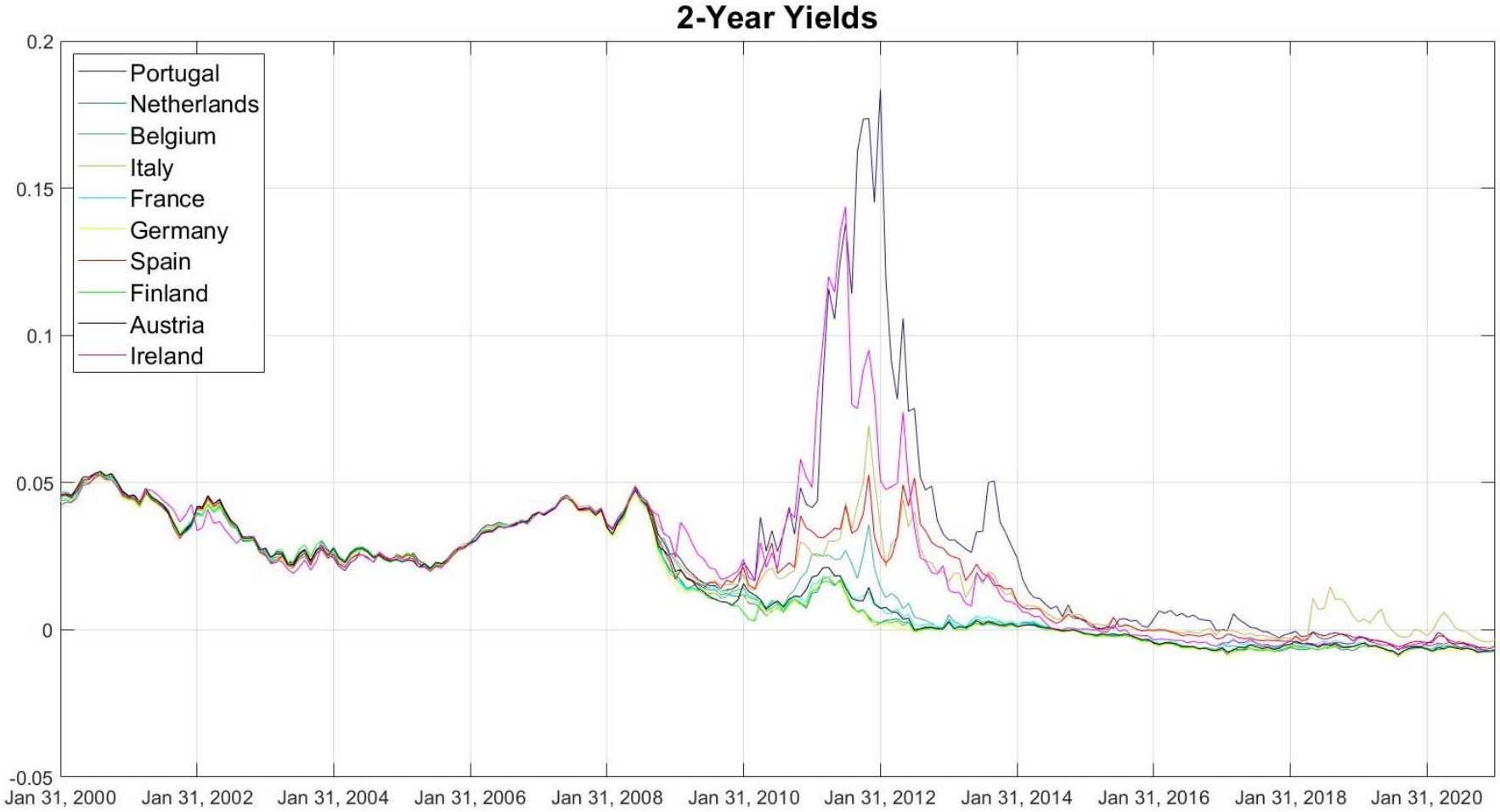
The generalized variance decomposition, on the other hand, effectively treats every variable as first in the ordering, making the issue of ordering inconsequential. This result is achieved not by the orthogonalization of shocks but allowing for correlated shocks while simultaneously accounting for the correlation among them observed historically, under normality assumptions.

Chapter II

Preliminary evidence

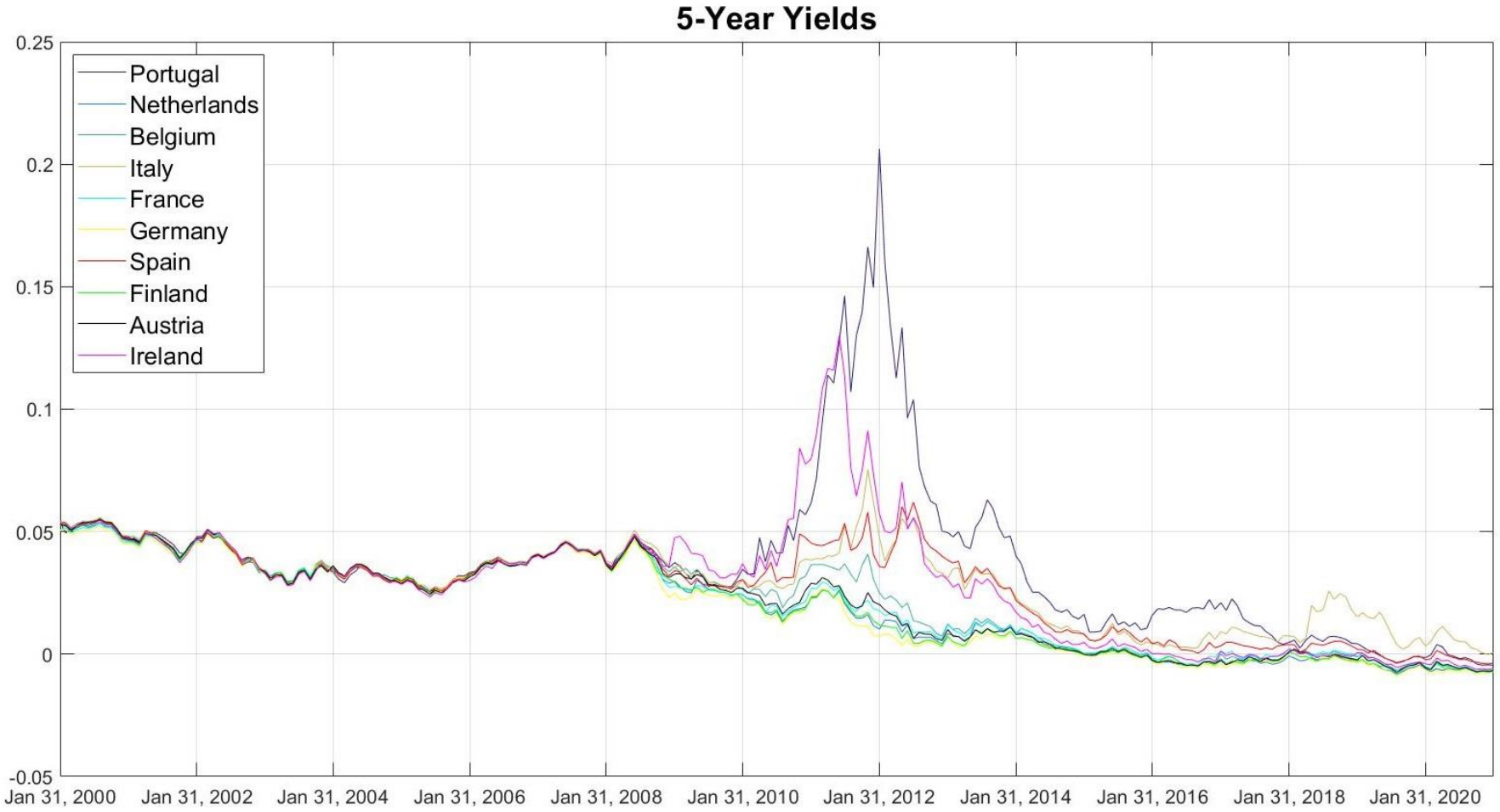
In this section we provide some preliminary evidence on the data. The next three graphs report the spot returns for the 10 countries (Portugal, the Netherlands, Belgium, Italy, France, Germany, Spain, Finland, Austria, Ireland) for maturities of 2, 5 and 10 years, from January 2000 to January 2021. The data are taken from the Bloomberg platform.

Graph 1. Monthly 2-year yields for the 10 countries analyzed (2000-2021)



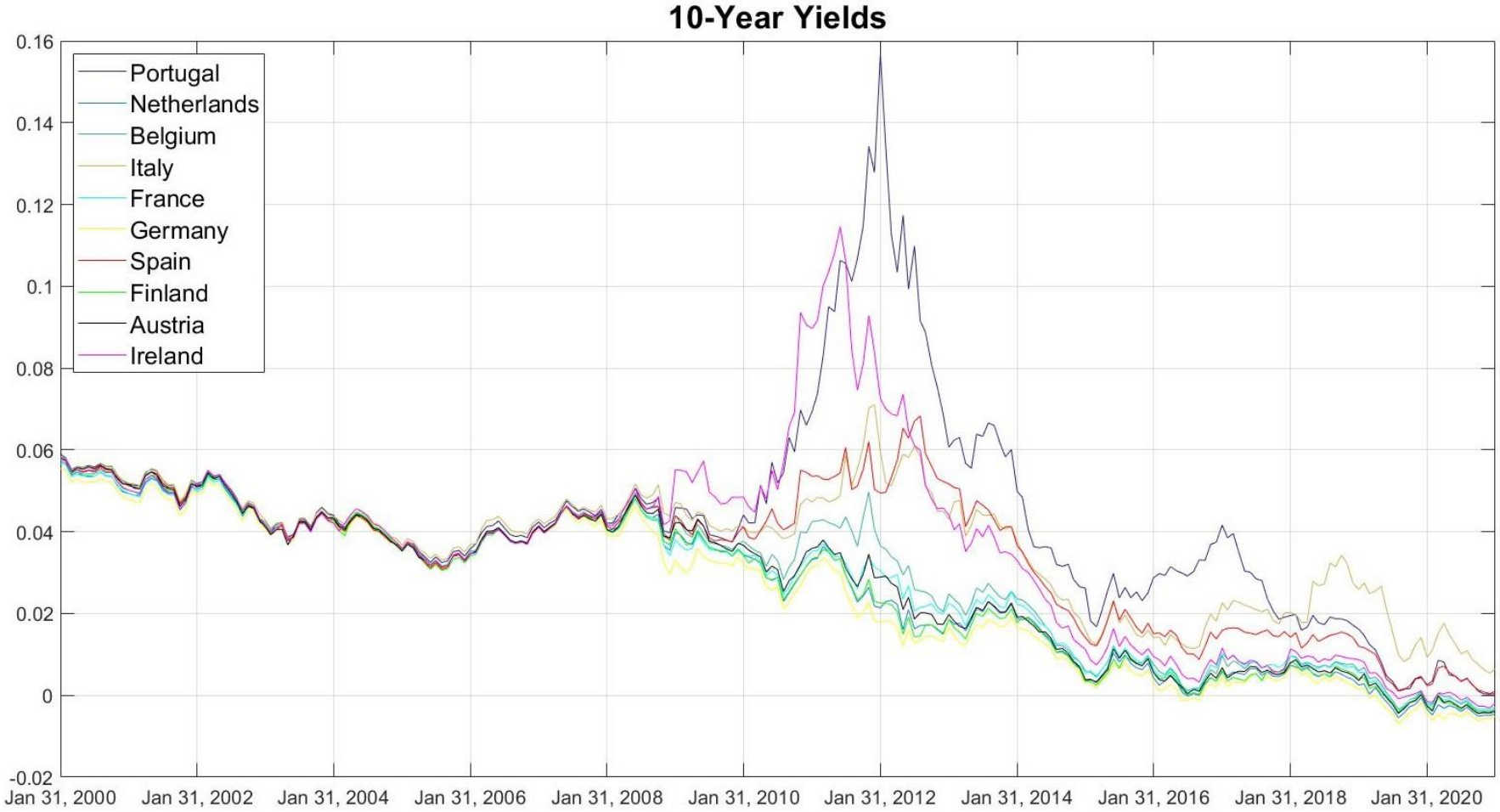
Source: Bloomberg (2000-2021)

Graph 2. Monthly 5-year yields for the 10 countries analyzed (2000-2021)



Source: Bloomberg (2000-2021)

Graph 3. Monthly 10-year yields for the 10 countries analyzed (2000-2021)



Source: Bloomberg (2000-2021)

In all three of these graphs we can distinguish three different periods. In this first period, which goes from January 2000 to December 2008, we can se how interests rates were overall constant despite some smaller trends in the interval. More interestngly, and more relevant to our analisys, during this period interest rates for all ten countries are extremely clustered. This is a result of the adoption of the euro, since every country had to comply to specific criteria, specifically regarding long-term interest rates on the national debt. This inevetably led to an homogenation of the interest rates. The second period goes from january 2009 to march 2015. This time period is more interesting since we can see the consequences of the 2007-2008 subprime crises and, more relevant to our analysis, the break out of the sovereign debt crisis. We can see a particular increase in the yields of peripheric countries, especially Ireland and Portugal, with Spain and Italy with yields not as high as the former two but still higher then the rest of the sample. We can mention how all of these countries, with the exception of Italy, went through a financial crises that led to the intervantion of international authorities or a period of political instability. The last period goes from april 2015 to january 2021. During this last period we can point out that Irish interest rates managed to converge towords the other core countries, while Italy, Spain and Portugal still face higher interests on their public debts with the Italian ones being particularly higher then the others since 2016. We now move on to discuss the episodes of the countries that present the most peculiar yield curves in the sample, highlighting the economic events that caused surges and drops in yields.

2.1 Portuguese financial crisis

In the late 90s Portugal's commitment to join the eurozone led interest rates to an historical low, causing a decrease in private savings and an increase in consumption and investment. These phenomena paired with an expansionary fiscal policy produced a period of economic growth and low unemployment for the country. Public expenditure, however, was mostly directed at current expenditure, and investments were aimed at non-tradable uncompetitive sectors (telecommunication, electricity, healthcare). The result of all of this was an economic growth that was not sustainable in the long term and that was not capable of generating innovation, productivity and long-term

employment creation. Things started to get worst in the early 2000s, as the Portuguese economy started to feel the pressure of competition arising from central and eastern European countries in key sectors for its export compart, namely footwear and textile, alongside an increasingly higher deficit, drop in competitiveness, an abnormal increase in nominal wages and an increase in unemployment. From 2002 to 2008 Portugal attempted to address the situation through two phases of budget consolidation. The main goals of these two phases were to make public expenditure more sustainable, regain competitiveness through salary disinflation and higher productivity growth, invest in education, research and development, energy dependency, public administration. Despite the efforts of the country, however, Portugal was not able to overcome the rigidity of its labor market, which was posing a threat to competitiveness, unemployment and growth.

We can state that the Portuguese financial crises officially started with the financial crises of 2008. In response to the subprime crises the Portuguese government decided to increase public spending in an attempt to stimulate the economy and ended up increasing the budget deficit from 2.7 percent in 2008 to 9.3 percent in 2009. Despite the political stability of the country and the commitment to undergo fiscal consolidation, the increasing contagion risk caused by a deteriorating environment at the European level kept pushing up the cost of Portugal's sovereign debt. When in April 2011 both Fitch and Standard and Poor's de-ranked Portugal's rating from A+ and A to BBB- a bailout seemed inevitable. Under pressure from the European Central Bank, Portugal requested financial assistance through an IMF-EU programme in April 2011 which resulted in a bailout package of 78 billion euros approved in May 2011.

The Portuguese economic adjustment programme accorded between the Portuguese government the IMF and the EU was based on three pillars: fiscal consolidation, financial stability, structural transformation.

Regarding the first pillar, the programme aimed at improving the Portugal's government budget deficit from 9.1 percent in 2010 to 5.9 percent in 2011, 4.5 percent in 2012, and 3.0 percent in 2013. This was achieved through two avenues: spending cuts and revenue-increasing measures. Spending cuts resulted mainly in: a gradual reduction of the amount of people employed by the public sector alongside a reduction in wages;

reduction of funding and increase in efficiency of the healthcare and education sectors; reduction in unemployment benefits. Revenue-raising measures consisted primarily in raising of value-added tax rates, enlargement of the property tax and income tax bases, privatization and incrementation of health care services fees. In particular, privatizations helped to increase competitiveness in certain sectors and allowed the country to raise funds to reinvest in much needed public infrastructures projects.

The second pillar revolved around the financial sector that in Portugal (contrary to Ireland) didn't present a property bubble nor a significant holding of toxic assets, but was heavily levered. The goal of the programme was to reduce the leverage, strengthen regulatory supervision and ensure sufficient capitalization. As such, the Banco de Portugal, Portugal's central bank, mandated Core Tier 1 capital ratio targets of nine percent by the end of 2011 and ten percent by the end of 2012. Despite the efforts put into strengthening the regulatory and supervisory system, soon after the end of the adjustment programme Banco Espirito Santo SA filed for bankruptcy and required an intervention by the Portuguese central bank. This accident generated mistrust towards the entirety of the Portuguese banking system and the ability of the national authorities to properly monitor it.

Structural transformation was mainly focused on making the job market more competitive and on improving the business environment. Some of these reforms included easing employee protection, reducing compensation for overtime work, limiting the duration and amount of unemployment benefits, reducing barriers to entry in non-tradeable sectors in order to drive prices down, reform of the judicial system, increasing competition and easing the regulatory burden.

The economic adjustment programme ended in June 2014 and since then the country has been on a steady path for economic growth and reduction of public deficit as it can be seen in the yields graphs for all maturities. The spike in yields of 2013 was caused by Portugal re-entering the international capital markets for the first time since the bailout to auction its public bonds. The last significant increase in yields happened around the end of 2015 when the new government led by Antonio Costa, the leader of the national socialist party, won the elections. Costa run an electoral campaign based on social reforms and a loosening of the austerity policies. His pledge to reverse the austerity policies mandated by the European Union during the economic adjustment

programme raised concerns in the financial markets, given the still non-consolidated economic growth of the country, fiscal imbalances and the massive debt burden. Despite the expansionary fiscal policies implemented, Portugal still managed to reduce its debt to GDP ratio in the following years, causing interest rates to drop overtime.

2.2 Irish financial crisis

Ireland is the second country that asked for international financial support. The crises of Portugal and Ireland were for the most part different when it comes to the lead up to the crises, but they were similar in terms of solutions. During the 1990s and the early 2000s Ireland experienced a period of healthy economic growth. The growth of this period was accompanied by economic reforms, educational attainment and progress in regard to European integration, which benefitted Ireland in terms of labor-force participation, labor productivity, foreign direct investment and export. From the early 2000s up to 2007, Ireland's economy kept growing but during this period we also witnessed wages outgrowing productivity gains, which resulted in an increase in labor costs that eroded price-competitiveness causing the country to lose ground in exports and to increase the imports. In addition to these macroeconomic problems, the financial sector started to show the features that would have cause its collapse a few years later. Low interest rates and lax credit standards made it easier for both corporations and households to access credit, leading to a high private debt and an oversized and highly leveraged banking system. In 2008 the loan to deposit ratio was over 200%, forcing the banking system to rely on loans from international banks while the real estate market was overexpanding. The reliance of Irish banks on inter-bank lending and their high exposure to the property market were the main causes of vulnerability of the Irish banking sector that started to collapse after the burst of the real estate bubble in 2007. The downturn of the construction sector that came right after increased the loans losses for banks and trigger a credit crunch effect. The banking crisis trickle down to the rest of the economy with an increase in unemployment and a decrease in GDP starting from 2008, worsened by the recession experienced by all of Ireland trade partners. In order to address banks funding problems and potential capital shortfall, the Irish government issued a first round of state aids in the form of guarantees on bank liabilities in order to provide capital support. An agency challenged with the task to manage non-performing

assets was established as well. A first round of liquidity injections was issued for a value of 46 billion euros into five Irish institutions. Despite the efforts of the government, however, markets were still skeptical towards Irish banks and the public intervention casted doubts on the sustainability of the sovereign debt as well, given how linked it was with the banking system at this point. The central bank of Ireland kept providing emergency liquidity assistance to banks for a total amount of 140 billion euros by the end of 2010.

The shrink in fiscal revenue, exacerbated by the pro cyclical nature of the policies implemented during the previous decade, and the policies in support of the banking sector triggered the sovereign debt crisis for the country. Ireland implemented fiscal consolidation policies starting from the mid-2008 in order to counter the decrease in GDP and increase in fiscal deficit. Such policies had an immediate effect given the flexibility of the Irish economy triggering a regain in competitiveness and a decrease in the deficit. Despite all of this, however, markets were still skeptical about the solidity of the banking system and the sustainability of the sovereign debt, pushing the interest rates of the Irish debt to unsustainable levels.

Given the situation the Irish government decided to ask for financial assistance from the EU, Eu member states and the IMF in December of 2010. The economic adjustment programme was developed in close cooperation with the Irish authorities and attempted to build up on the Irish National Recovery Plan for 2011-2014, a programme already prepared by the government in 2010. The first priority of the programme was to provide enough liquidity to the banking system in order to keep it at float long enough for the national authorities to implement the necessary reforms and to break the vicious cycle that linked the sovereign debt to the national financial system. The overall package consisted of 85 billion euros. The directives contained in the economic adjustment plan for Ireland were similar to the ones that will later be implemented in Portugal, in particular: restoring viability of the financial sector; consolidating public finances; structural economic reforms.

With regard to the financial sector, the programme aimed at downsizing and reorganizing the banking sector via stabilization and recapitalization of troubled institution and merges of non-viable banks. Other measures were put in place to strengthen the supervisory and resolution framework, which had proven to be

inadequate during the crises. Fiscal policies were focused on building up on the policies already implemented by the Irish government in the lead up to the crisis. The goal of the programme was to contain the increase of public debt and decrease the public deficit. Lastly the structural economic reforms aimed at boosting employment, competition and growth. Generally speaking the impact of this part of the programme was limited in virtue of the relative flexibility of the Irish economy.

Ireland successfully exited the programme in December 2013 since it was deemed of not needing any further financial assistance. Since then the country has been experiencing an healthy and steady growth, so much so that in 2015 it had the greater increase in GDP growth in the European union (a stunning 26.3%). This is also reflected in the yields of the country that had been in line with the yields of the core European countries since 2016.

2.3 Spanish financial crisis

Spain presents an interesting case, being chronologically the last country that requested financial assistance and the biggest economy that did so.

During the three decades prior to the crisis Spain experienced a long period of stable growth, marked by the milestones of joining the European Union in 1986 and the adoption of the euro in 1999, with a consistent increase in GDP per capita, that overall double during this period, and a respectable GDP growth rate, that averaged at around 4% per year. We can focus particularly on the growth of the Spanish economy between 1999 and 2007. In this period, similarly to what happened in Portugal and Ireland, the low interested rates that resulted from Spain adopting the euro pushed a strong economic expansion driven by increased level of consumption and investment which fostered mainly the housing market. The boom in the housing market was accompanied by an increase in residential and commercial real estate prices, while the Spanish economy was experiencing low productivity growth rates that reduced the competitiveness of the country and generated sizeable account deficits. In addition to this, national banks were unable to meet the demands of the market just relying on savings rates, hence resorting to borrow money from foreign banks, so much so that in 2007 Spain was the second largest borrower in the world after the USA. In summary the

situation of the country right before the crisis was comparable in many aspects to the Irish situation: highly levered banks, with an overexposure to foreign markets and to a real estate and construction sector that was highly overprized, and a surging private sector indebtedness.

When the subprime crisis broke and financing conditions started to tighten, the country entered in recession. By mid-2008 GDP growth dropped, the fiscal deficit widened and unemployment peaked. In late 2008 the government intervened with a 11 billion euros stimulus plan aimed at creating jobs and support the sectors of the economy that got hit harder by the crisis. It also intervened in the financial sector by creating three institution that were supposed to give the authorities better tools to handle the crisis: the FAAF, a fund for the acquisition of non-toxic assets held by financial institutions, the debt guarantee programme of December 2008 and in 2009 the creation of the FROB, a government sponsored special purpose vehicle created to assist with potential recapitalization efforts as well as with the restructuring of the banking system. Overall the efforts of the government paid out, the economy stabilized in 2010 and the banking system held up.

Things got worst again in 2011 when the break out of sovereign debt crises in other peripheric European countries increased the contagion risk with negative repercussions on the most vulnerable economies of the union. The recession this time was projected to be less severe but to last longer and was accompanied by fiscal consolidation measures, such as: pension reforms; VAT increase; strengthening of capital standards and transparency for banks; increase the flexibility of the job market via hiring incentives and easing of dismissal costs and criteria. The economic downturn turned out deeper and longer than expected. The funding costs for Spain as well as Spanish banks significantly increased. These market conditions raised widespread concern that private and public resources would be insufficient to support the banking system with capital, despite some of the initial restructuring efforts in 2010 listed above. The strong job destruction after the burst of the housing bubble caused a rapid increase of the unemployment rate to 25% of active population, NPLs increased sharply, particularly those related to real estate and construction. In June of 2012, the Spanish government made an official request for financial assistance for its banking system to the Eurogroup for a loan of up to €100 billion. It was designed to cover the capital shortfall identified

in a number of Spanish banks, with an additional safety margin. In December of 2012 and January of 2013, the ESM disbursed a total of 41.3 billion euros, in the form of ESM notes, to the Fondo de Restructuración Ordenada Bancaria (FROB). The remaining €58.7 billion in the programme envelope was not needed and remained unused. The main goals of the programme were: remove doubts about the quality of the banks balance sheets, allowing them to carry out their financial intermediation function; facilitate an orderly downsizing of bank exposures to the real estate sector, restore market-based funding and reduce bank's reliance on central bank liquidity support; enhance risk identification and crisis management mechanisms pertaining to the Spanish banking sector in order to reduce the occurrence and severity of future financial crises.

Given the success in achieving its goals, Spain exited the financial support programme in November of 2013, just 18 months after it stared. There are a few things to point out about the Spanish case: Spain was the biggest country to request financial support, granting the country a higher leverage power during the bargaining with international authorities; the financial support programme was mainly focused on the banking sector given that the country was already undergoing a process of fiscal consolidation; the amount of money borrowed by Spain was ultimately lower than the amount of money borrowed by Portugal, Ireland and Greece, both in relative and absolute terms.

2.4 Italian financial crisis

The Italian case is quite peculiar since it is the only country that we have discussed so far that did not ask for a bail out from the international authorities.

When the subprime crisis broke out in 2007 the Italian financial system was not hit too hard by it since Italian banks had a low exposure to foreign banks and since they did not hold an unhealthy amount of toxic assets in their balance-sheets. The Italian financial crisis started in 2008 when the GDP decreased by 1.2 percent and since then the country seemed to be unable to firmly grasp a stable growth. In that year the effects of the global financial crisis had started to spread to the real economy causing a decrease in investments, disposable income and consumption in all of the western economies. Given how reliant the Italian economy is on exportations, the sudden contraction of

demand from foreign countries caused a decrease in GDP growth in both 2008 and 2009 (the contraction in 2009 was particularly dramatic, -5.5 percent).

The country seemed to have overcome the crisis in 2010 when it appeared that the worst part of the crisis was over and many European countries were on the path of recovery. The Italian GDP that year grew by 1.7 percent. The Italian economy however was hit again in 2011 by the breakout of the sovereign debt crisis that we already discussed in regard to Ireland, Portugal and Spain. Many factors in this phase contributed to an increase in interest rates for Italy: the weak recovery shown by the country in the previous year; the public debt that at this point had been consistently increasing since 2008 (from 102.3 percent in 2008 to 115.3 percent in 2010 as a ratio to GDP); the dubious political stability of the country; the concerns over a contagion effect that could have spread from the other peripheric countries to Italy.

The Italian sovereign debt crisis became obvious in June of 2011, after Greece, Ireland and Portugal had already asked for a bail out to the European authorities, when the interest rates on the debt started to increase, peaking in November of that year. The increase in the interest rates put under pressure the national banking sector since Italian banks held a huge amount of Italian debt in their balance-sheet triggering a capital and, potentially, liquidity crisis. The turmoil of the financial sector caused a credit crunch effect that soon trickle down to the real economy, exacerbating the crisis that businesses and households were already experiencing. Pressured by the financial markets and the European authorities, the then sitting government resigned in November of 2011.

The new government that took over, led by a substantially a-political figure, Mario Monti, set as a goal to implement fiscal consolidation policies and to invigorate the trust of financial markets towards the country. The fiscal policies adopted in this period were focused on tax increases, cuts to public spending and a pension reform. Overall the country managed to restore the trust of financial markets and the interest rates on its debt started to steadily decrease until they pretty much fell in line with the rest of the European countries in 2016. Despite the efforts of the government, however, the huge amount of debt and the lack of structural reforms for the economy continued to cause a spread between the interest rates of Italy and the rest of the core countries during the

post-crisis period. It is important to notice that such spread was not noticeable prior to 2007.

The interest rates of the Italian debt jumped up again in 2018. This time the increase can be attributed to internal political affairs. The results of the political election that took place in that year, in fact, led to the formation of a government made up of populist parties that run their electoral campaigns on policies focused on social reforms that implied an increase in public spending that raised concerns in the financial markets. Despite the efforts made by the neo-formed government to reassured European authorities and the financial markets that such policies would have led to an increase in consumption and GDP, the weak economic performances of the country in the previous years and the anti-european sentiment espoused by the leading parties in the government coalition led to an increase in the interest rates. This misalignment in the interest rates of Italy compared to the rest of the European countries persists to this day. It is important to point out that such misalignment this time is not caused by a financial crisis but by a political one.

2.5 Belgian financial crisis

Lastly we want to briefly talk about the situation in Belgium during the subprime crisis and the beginning of the sovereign debt crisis. Despite the fact that the country didn't go through an economic adjustment programme and did not ask for a bailout to international authorities, Belgium still presents very high yields for all maturities when compared to the other core nations (Germany, the Netherlands, France, Finland, Austria) and this will lead Belgium to play a peculiar role in the analysis that follow.

In the years prior to the breakout of the subprime crisis Belgium carried out a long and steady process of fiscal consolidation that resulted in the country registering an historical low in debt over GDP ratio in 2007, right before the crisis, equal to 87.3 percent. There's no reason to assume that such trend wouldn't have continued if the international economy didn't take the abrupt downturn that it did.

The crisis hit Belgium in 2008, due to the concomitance of three main events: a political crisis that started in 2007; an economical crisis caused mainly by the worsening of the

economy worldwide; a banking crisis that involved three of the biggest banks in the country, Fortis, Dexia and KBC.

The economic crisis really started to show its effects on the national economy towards the end of 2008, presenting the typical characteristic that we have discussed previously in regard to other nations: increase in prices; decrease in consumption; credit crunch; decrease in productive investments; decrease in export growth; increase of the unemployment rate. All of these factors contributed to a drop in GDP growth that peaked in 2009, years in which it decreased by more than 2 percent.

The bank crisis that involved the three troubled institutions mentioned above were all resolved via bailouts and nationalizations. Fortis was partially nationalized by the governments of Belgium, the Netherlands and Luxemburg (the bank was mainly active in the Benelux region) in September 2008. Each country acquired 49 percent of the shares of the division of the bank operating in the country. Dexia received a bailout from the Belgian and French government in September of 2008. The worsening of the asset position of the bank in later years, mainly due to the exposure to the Greek debt crisis and the Icelandic bank crisis, led to the nationalization of the bank by the Belgian government in 2011. KBC was supported by the Belgian government in three phases in October 2008, January and May 2009. These operations consisted of cash injection, acquisition of the bank shares by the Flemish government and bank guarantees offered by the federal government. In addition to this ad-hoc measures, initially the Belgian government guaranteed bank savings up to 20000 euros, to then later increase said limit to 100000 euros. The government also intervened to protect the savings of Belgian customers of Kaupthing Bank, an Icelandic bank hit by the Icelandic bank crisis.

Other than facing the bank crisis, the Belgian government stepped up its efforts to restore the soundness of public finances in 2010 when it outlined its fiscal consolidation programme through 2012. Unlike the other countries that we have discussed so far, Belgium focused more on revenue increase than spending cuts. Some of these measures were: reduce the fiscal deficit to no more than 3 percent from 2012 (this goal was only reached in 2015), reduction of public debt starting from 2011 (debt to GDP ratio started to decline from 2014); reduction on VAT rate on construction; implementation of new measures to stimulate employment; implementation of new taxes (tax on banks and

stock exchange companies, environmental tax); increased efforts to fight fiscal evasion; cuts on healthcare costs and personnel expenditure.

Belgian yields increased drastically in 2011. This was due to the breakout of the sovereign debt crisis in other European. The concerns over Belgian sovereign debt was funded upon the significant exposure that Belgian banks had toward the sovereign debt of the most troubled nations of the union and the possible triggering of a sovereign-private debt spiral in the nation as a result of the involvement that the country have had in the previous years in the private banking sector. The Belgian government reacted by issuing the staatsbon, government bond that could be easily purchased at banks marketed towards households with interested rates that were double the rates of standard savings (3.5,4 and 4.2 percent depending on maturity). The staatsbon initiative was a success and allowed the country to raise funds at rates that were more convenient than market rates. Yields started to drop in 2012 also thank to the stabilization of the political situation in the country.

2.6 ECB policies

In this section we aim at briefly discussing the policies implemented by the European Central Bank since 2007. We will talk about the Quantitative Easing programme defined as the monetary policy by which a central bank, in our case the ECB, purchases a consistent amount of government bonds or other financial assets in order to inject liquidity into the economy.

The ECB started to implement so called unconventionally monetary policies since 2007, aimed towards both public debt and private debt. Given how intertwined these two were especially during the sovereign debt crisis it should not surprise how polices aimed at the latter ended up influencing the former. These polices can be grouped into two categories: exceptional liquidity provisions (LTROs, FRFA and setting the deposit rates to zero); asset purchases (sovereign bond and covered bond purchase programmes). The goals of this policies were to provide liquidity to the banking system and to trigger the reduction of sovereign market distress. We will first focus on liquidity measures regarding the fixed-rate full-allotment procedure (FRFA) and the long-term refinancing operations (LTROs).

The ECB started to implement the FRFA in October 2008 and continued to do so until March 2010 for its LTROs. Soon after, however, the Greek sovereign debt crisis broke out forcing the ECB to reimplement said policy since May 2010 with the intention to offset liquidity risk in the market. Since before the FRFA started, in 2007 the ECB had engaged in the gradual lengthening of the LTROs up to one year. Three-year LTROs were offered for the first time in December 2011 and a second time in February 2012. The main objective of the ECB in this phase was to provide banks with enough liquidity to restore the smooth functioning of the interbank markets, allowing banks to carry out their function of conceding credit to businesses and households. Generally speaking, in fact, a liquidity crisis can cause a credit crunch effect that has consequences on the whole economy. In addition to this, these measures also reduced the counterparty risk premia that banks had to pay to other market participants. Despite the efforts of the ECB, the interbank market was still not functioning properly. Hence in July 2012 the ECB decided to lower the deposit rates to zero. Even if markets had anticipated a lowering of the deposit rates, dropping them to zero caught them by surprise and showed the commitment of the ECB to use unconventional tools in order to push private banks to lend money.

After the beginning of the Greek financial crisis, in May 2010 the ECB announced the implementation of the Securities Market Programme (SMP). The programme consisted of purchases of sovereign bonds in the secondary market and had the goal to ensure depth and liquidity in those market segments that were dysfunctional. The programme unofficially ended in January 2011 but the worsening of the sovereign debt crisis in the euro-area and the risk of contagion to Spain and Italy forced the ECB to resume the programme in August 2011. In the end the total amount of euro-zone government bonds purchased by the ECB through the SMP was worth 219.5 billion euros. During 2012 the sovereign debt crisis kept intensifying as the Spain banking system showed its weaknesses. As a response in July 2012 the then president of the ECB Mario Draghi held a speech in which he stated that the ECB would have done “whatever it takes to save the euro”. In September of that year the ECB announced a new sovereign bond purchase programme called Outright Monetary Transactions (OMT) and proceeded to end the SMP at the end of that year. The goal of this new programme was similar to the one of the SMP, that is to repair the monetary policy transmission mechanism and restore

homogeneous credit conditions throughout the euro-zone. Despite said similarity in goals, the two programmes differed on the condition to access the program. In particular, in order to access the OMT countries were required to comply with a full or precautionary macroeconomic adjustment programme set by the European Financial Stability Facility or the European Stability Mechanism. Other differences between the programmes related to the duration of the programmes and the maturity of the bond purchased. As of today, the ECB has not purchased any sovereign bonds within the OMT, most likely because no nation was willing to comply to said macroeconomic adjustment programmes. Nonetheless studies conducted on the efficacy of such policies found out that they "decreased the Italian and Spanish two-year government bond yields by about two percentage points, while leaving unchanged the bond yields of the same maturity in Germany and France". Moreover, "the scenario analysis suggests that the reduction in bond yields due to OMT announcements is associated with a significant increase in real activity, credit, and prices in Italy and Spain with relatively muted spillovers in France and Germany."

Generally speaking, the ECB has been implementing asset purchasing programmes (APP) since May 2009. In that date the ECB announced its first Covered Bond Purchase Programme (CBPP1), planning to purchase 60 billion euros of euro-denominated covered bonds issued in the euro-zone. This programme lasted until June 2010 and was followed by the CBPP2, that lasted for 1 year between October 2011 and October 2012 with a targeted total nominal amount of covered bonds purchase of 40 billion euros. The stated aim of the programme was to contribute to easing funding conditions for credit institutions and enterprises and to encouraging credit institutions to maintain and expand their lending to customers. These two programmes were followed by CBPP3. This programme started in October 2014 and ended in December 2018. It was restarted in November 2019 and it is currently running.

Other APPs are the corporate sector purchase programme (CSPP), the asset-backed securities purchase programme (ABSPP) and the public sector purchase programme (PSPP). The PSPP makes up the bulk of the ECB asset purchase programmes. It started in March 2015 and run until December 2019 and it was restarted in November 2019. The securities covered by this programme are nominal and inflation-linked central government bonds and bond issued by recognized agencies, regional and local

governments, international organizations and multilateral development banks located in the euro-area. The APP has direct effects on the yields of public and private sector securities. As the APP favors a downward shift in market yields, whose movements are inversely correlated to asset prices, credit supply conditions improve and investments are stimulated. The additional liquidity spurs investors to rebalance their portfolios towards assets yielding higher returns, for example those not directly covered under the central banks' interventions, thereby transmitting the monetary stimulus to the various private sector financing instruments. Finally, lower interest rates favor the depreciation of the exchange rate, providing a further boost to economic activity.

The last programme implemented by the ECB was the pandemic emergency purchase programme (PEPP). This programme was initiated in March 2020 to counter the serious risks to the monetary policy transmission mechanism and the outlook for the euro area posed by the coronavirus outbreak.

Chapter III

Static analysis

In this section, we present and discuss the results obtained from the estimation of total connectedness for the full-length sample and for some particularly interesting sub-samples. We refer to this part as the static analysis. We will often separate countries in two groups: peripheric countries (Portugal, Ireland, Spain, Italy) and core countries (France, Germany, Finland, Netherlands, Austria, Belgium). Belgium presents some peculiarities being the only core country that experienced some serious financial turmoil during the sovereign debt crises.

3.1 Full-sample static analysis

We start by presenting the connectedness tables for the three maturities for the entire sample of data ranging from January of 2000 to January of 2021. The results are shown in Table 2 (2-year maturity), 3 (5-year maturity) and 4 (10-year maturity).

Table 2. 2-year full-length connectedness table. Total connectedness is highlighted in yellow.

	Portugal	Netherlands	Belgium	Italy	France	Germany	Spain	Finland	Austria	Ireland	From
Portugal	28.69	4.07	5.85	15.18	4.60	3.06	14.80	3.71	4.49	15.54	71.31
Netherlands	9.83	9.23	10.75	11.27	9.92	8.48	11.79	8.66	10.07	10.00	90.77
Belgium	15.20	7.25	9.22	12.87	7.85	6.33	13.07	6.76	8.01	13.46	90.78
Italy	20.06	5.47	7.91	15.49	6.26	4.53	15.20	5.07	6.30	13.70	84.51
France	11.46	8.72	10.32	11.81	9.43	7.91	12.22	8.17	9.53	10.43	90.57
Germany	10.02	9.25	10.69	11.14	9.91	8.50	11.65	8.68	10.04	10.12	91.50
Spain	18.33	5.67	8.12	14.92	6.35	4.74	15.20	5.26	6.50	14.89	84.80
Finland	9.82	9.33	10.78	11.18	10.02	8.59	11.67	8.77	10.14	9.70	91.23
Austria	11.71	8.43	10.16	11.86	9.05	7.60	12.31	7.89	9.24	11.75	90.76
Ireland	24.69	3.72	6.04	15.07	4.08	2.79	15.05	3.41	4.27	20.89	79.11
To	131.12	61.92	80.62	115.28	68.03	54.05	117.77	57.62	69.35	109.60	86.53
Net	59.81	-28.85	-10.16	30.77	-22.54	-37.46	32.97	-33.61	-21.41	30.48	

Source: Own production.

Table 3. 5-year full-length connectedness table. Total connectedness is highlighted in yellow.

	Portugal	Netherlands	Belgium	Italy	France	Germany	Spain	Finland	Austria	Ireland	From
Portugal	28.59	3.66	6.88	10.90	5.93	3.80	15.89	4.00	5.04	15.33	71.41
Netherlands	7.89	9.45	11.72	9.12	10.99	8.94	11.84	9.24	10.32	10.49	90.55
Belgium	12.37	7.61	10.53	10.16	9.47	7.24	13.60	7.56	8.74	12.72	89.47
Italy	16.37	5.81	9.37	12.18	7.80	5.47	15.82	5.85	7.05	14.27	87.82
France	10.48	8.54	11.08	9.46	10.31	8.18	12.55	8.46	9.58	11.36	89.69
Germany	7.54	9.78	11.84	8.69	11.31	9.33	11.31	9.59	10.64	9.97	90.67
Spain	16.02	5.79	9.28	11.55	7.73	5.44	15.94	5.78	6.99	15.48	84.06
Finland	8.03	9.61	11.77	8.90	11.20	9.18	11.46	9.47	10.51	9.87	90.53
Austria	8.63	9.18	11.52	9.08	10.79	8.72	12.02	9.01	10.11	10.95	89.89
Ireland	19.38	4.79	8.28	11.31	6.75	4.51	16.51	4.82	6.02	17.64	82.36
To	106.70	64.78	91.73	89.16	81.98	61.49	120.99	64.31	74.89	110.43	86.64
Net	35.30	-25.77	2.26	1.34	-7.71	-29.18	36.93	-26.23	-15.00	28.06	

Source: Own production.

Table 4. 10-year full-length connectedness table. Total connectedness is highlighted in yellow.

	Portugal	Netherlands	Belgium	Italy	France	Germany	Spain	Finland	Austria	Ireland	From
Portugal	14.89	7.14	11.14	9.13	8.71	6.97	13.23	7.70	9.08	12.01	85.11
Netherlands	4.83	10.93	12.67	7.31	11.76	10.45	10.01	11.06	11.95	9.03	89.07
Belgium	6.74	9.94	12.42	8.04	11.02	9.52	10.97	10.18	11.24	9.92	87.58
Italy	8.11	8.80	12.11	9.86	10.18	8.35	12.54	9.06	10.29	10.71	90.14
France	5.61	10.55	12.57	7.59	11.49	10.11	10.38	10.73	11.68	9.28	88.51
Germany	4.80	11.04	12.68	7.17	11.85	10.59	9.84	11.18	12.03	8.82	89.41
Spain	8.08	8.94	12.12	9.09	10.20	8.49	12.31	9.19	10.43	11.14	87.69
Finland	5.11	10.84	12.65	7.31	11.70	10.39	10.05	11.00	11.89	9.06	89.00
Austria	5.28	10.66	12.61	7.47	11.55	10.19	10.29	10.81	11.76	9.37	88.24
Ireland	9.56	8.28	11.85	8.95	9.56	7.84	12.69	8.57	9.91	12.79	87.21
To	58.11	86.19	110.41	72.08	96.54	82.31	100.00	88.49	98.50	89.34	88.20
Net	-26.99	-2.88	22.83	-18.06	8.03	-7.11	12.31	-0.52	10.26	2.13	

Source: Own production.

The first thing that we can notice is that total connectedness tends to be pretty much constant for all the maturities, with the longer maturities having a slightly higher degree of connectedness. Another important aspect is that the composition of said connectedness varies a lot among maturities, especially between the two shorter maturities (2 and 5 years) and the longer maturity (10 years).

We will start by describing the evidence that emerges from the shorter maturity yields. In Table 2 we can see a net split between the behavior of peripheric countries and core countries. The first glaring difference that appears is the net connectedness that tends to be positive for peripheric countries (ranging form 59.81 percent for Portugal to 30.77 percent for Italy) and negative for core countries (ranging from -37.46 percent for Germany to -10.16 percent for Belgium). It's not just the sign of connectedness to be opposite but also the scale of connectedness, with peripheric countries having an average net connectedness significantly higher than core countries in absolute value. This phenomenon is not really surprising given that connectedness behaves like a zero-sum game and peripheric countries are numerically inferior compared to core countries. Other differences between the two groups arise in regard to what we can define as "self-connectedness", that is component of variance for a specific country that is generated by the country itself. It is way higher than the mathematical average (10 percent in our case) for peripheric countries with Portugal leading the way with 28.69 percent, followed by Ireland with 20.89 percent, Italy (15.49 percent) and Spain (15.20 percent). For these countries self-connectedness is not simply high, but it is eighter the highest variance component or among the highest when we look at connectedness "to" others. In regard to connectedness "from" others we can see that Portugal plays a central role, being the biggest contributor to the variance of all the other peripheric nations. The situation is way more balanced for the core countries. The self-connectedness is around 9 percent for all of them, with the only outlier being Germany with 8.5 percent. When it comes to connectedness received from other countries these nations tend to present rather regular values. Looking at a country like Germany for example we see that the components of the connectedness "from" others are quite clustered, ranging between 11.65 to 8.49 percent. Moving to connectedness "to" others we see that core countries don't cause much variance toward peripheric counties. Peripheric countries are in fact always the four countries that receive the least amount of variance from core countries.

It is worth to highlight the peculiar situation of Belgium. Belgium is the core country with the highest value of net connectedness, it receives the highest amount of variance from peripheric countries than any other core country and at the same time it transmits the highest amount of variance to peripheric countries than any other core country. In a certain way Belgium can be seen as “the most peripheric core Country”. Overall the result obtained from the static analysis of the two years yields seems to be pretty clear: peripheric countries tend to increase total connectedness through an heavy contribution to the variance of other peripheric countries while having an average contribution to the variance of core nations and core countries tend to decrease total connectedness through a below-par contribution to the variance of peripheric nations and an average contribution to the variance of other core nations.

Moving on to the 5-year maturity we can notice that some things are starting to change even thou the central observations stay the same. In particular we can see that peripheric countries still have positive net connectedness while core countries have it negative. These values however are smaller for peripheric countries and greater for core countries when compared to the two years maturity. It appears that with the lengthening of maturities there is a convergence of the net connectedness values, implying an harmonization of the impact that the two groups of nations have on the total connectedness. The two glaring countries in this regard are Italy and Belgium. Italy presents values that are way more in line with the core countries when it comes to connectedness “to” others. Even thou it still transmits more variance to the other peripheric counties, Its “to” values have a way smaller range (8.69-12.18 percent) compared to the two years maturity. The country still presents the characteristics listed before for peripheric countries when it comes to connectedness “from” others. Similar observations can be made for Belgium, making it appear even more like a peripheric country. The comprehensive result of this changes is that both Italy and Belgium have an almost neutral impact on connectedness with a total “to” and “from” connectedness close to the total connectedness and a net connectedness close to zero. One last thing to point out is that every country experienced a slight increase in their self-connectedness.

This trend passes on to the 10-year maturity for core countries, as we can see in Table 4, and it is one of the trends that does so. In fact, we can notice that Table 4 is way

different than the previous two. As we said self-connectedness keeps increasing for core countries while it drastically decreases for peripheric countries. The drop is particularly harsh for Portugal, moving from 28.59 to 14.89 percent, and Ireland, from 17.64 to 12.71 percent, while it is a bit less significant for Italy and Spain, around 3 percent. One thing that persists, even if in a weaker fashion, for the 10-year maturity is the connectedness between peripheric countries. When it comes to connectedness "to" others peripheric countries still transmit their influence mostly to other peripheric nations. This phenomenon is particular significant for Portugal since the connectedness transmitted to others is on average four percentage points higher when it comes to other peripheric countries compared to core countries. The phenomenon is still present, even thou it is not as drastic, for Italy, Spain and Ireland. In regard to connectedness "from" others we can notice that this time peripheric countries are not just influenced by the other peripheric nations but also from some core countries, namely France, Belgium and in some cases Austria.

Lastly, we address the net connectedness generated by these countries. In this regard we can see a rather abrupt trend shift since now Portugal and Italy present a negative net connectedness, Ireland presents a small positive value and Spain remains consistent with the previous maturities showing a significant positive value. Generally speaking the role of pushing up the total connectedness has been taken over by some of the core countries, the aforementioned France, Belgium and Austria that, alongside Spain, present significant positive values for the net connectedness. The other core countries that we haven't mentioned so far, namely the Netherlands, Germany and Finland, show trends that are similar to the ones showed for shorter maturities, specifically lower connectedness, both from and to, peripheric countries when compared to the other core countries

3.2 Static analysis by segments

This section will act as a bridge between the static analysis and the dynamic analysis. Here we will break up the sample of data into three time intervals. The first interval goes from January 2000 to July 2009, including the period of time from the beginning of the sample until roughly two years after the breakout of the subprime crisis. During this

period yields were all extremely clustered with just some divergence towards the end, a sign that the subprime crisis was starting to show its effects on the yields of some nations and that the sovereign debt crisis was about to kick in. The second interval ranges from August 2009 to January 2015, covering the entirety of the sovereign debt crisis and ending when all the countries involved had already ended their economic adjustment programmes and were on the path of recovery. The third interval goes from February 2015 to January 2021. The third segment covers the post-crisis period including the minor financial turmoil experienced by Portugal and Italy. We will reserve this kind of discussion only for the 2 and 10 year yields since, as shown in the previous section, the results for the 5-year yields tend to be very similar to the 2-year ones.

3.2.1 2-year maturity

The connectedness table for the three intervals specified above are contained in the following tables.

Table 5. 2-year connectedness table, January 2000-July 2009. Total connectedness is highlighted in yellow.

	Portugal	Netherlands	Belgium	Italy	France	Germany	Spain	Finland	Austria	Ireland	From
Portugal	10.29	10.45	10.26	10.35	10.38	10.56	10.39	10.20	10.39	6.74	89.71
Netherlands	10.29	10.45	10.26	10.35	10.38	10.56	10.39	10.20	10.39	6.74	89.55
Belgium	10.29	10.45	10.27	10.35	10.38	10.56	10.39	10.20	10.39	6.73	89.73
Italy	10.28	10.44	10.26	10.35	10.37	10.56	10.39	10.19	10.39	6.76	89.65
France	10.29	10.45	10.26	10.35	10.38	10.56	10.39	10.20	10.39	6.74	89.62
Germany	10.29	10.45	10.27	10.35	10.38	10.57	10.39	10.20	10.39	6.72	89.43
Spain	10.29	10.45	10.27	10.35	10.38	10.56	10.39	10.19	10.39	6.74	89.61
Finland	10.29	10.45	10.26	10.34	10.38	10.56	10.39	10.20	10.39	6.74	89.80
Austria	10.29	10.45	10.27	10.34	10.38	10.57	10.39	10.20	10.40	6.71	89.60
Ireland	10.26	10.43	10.23	10.35	10.36	10.55	10.39	10.17	10.36	6.90	93.10
To	92.56	94.01	92.34	93.13	93.38	95.04	93.51	91.75	93.48	60.61	89.98
Net	2.85	4.45	2.61	3.48	3.76	5.61	3.90	1.95	3.87	-32.49	

Source: Own production.

Table 6. 2-year connectedness table, August 2009-January 2015. Total connectedness is highlighted in yellow.

	Portugal	Netherlands	Belgium	Italy	France	Germany	Spain	Finland	Austria	Ireland	From
Portugal	35.26	1.18	3.87	19.82	2.48	0.03	15.03	0.73	1.78	19.82	64.74
Netherlands	26.22	2.44	5.85	17.55	3.60	0.53	14.14	2.07	3.17	24.43	97.56
Belgium	29.33	1.98	5.23	18.33	3.24	0.29	14.32	1.56	2.70	23.01	94.77
Italy	32.14	1.13	4.61	20.70	2.62	0.03	16.26	0.76	2.03	19.71	79.30
France	27.83	2.18	5.57	18.14	3.48	0.39	14.42	1.77	2.95	23.27	96.52
Germany	26.40	2.67	5.74	16.87	3.67	0.68	13.37	2.29	3.23	25.08	99.32
Spain	28.10	1.32	5.32	20.52	2.77	0.08	17.03	1.04	2.35	21.47	82.97
Finland	27.06	2.27	5.61	17.74	3.41	0.44	14.18	1.92	2.97	24.41	98.08
Austria	27.16	2.20	5.55	17.86	3.36	0.40	14.34	1.85	2.92	24.36	97.08
Ireland	31.58	1.38	4.36	19.24	2.49	0.09	15.05	1.04	1.99	22.78	77.22
To	255.82	16.32	46.49	166.06	27.65	2.28	131.11	13.11	23.17	205.57	88.76
Net	191.09	-81.24	-48.28	86.76	-68.87	-97.05	48.14	-84.97	-73.91	128.35	

Source: Own production.

Table 7. 2-year connectedness table, February 2015-January 2021. Total connectedness is highlighted in yellow.

	Portugal	Netherlands	Belgium	Italy	France	Germany	Spain	Finland	Austria	Ireland	From
Portugal	24.70	7.25	7.56	20.31	7.44	2.86	16.99	3.63	3.33	5.90	75.30
Netherlands	3.57	11.85	12.16	13.68	10.06	8.85	11.16	9.92	9.91	8.83	88.15
Belgium	5.04	11.29	11.94	14.39	10.09	8.06	12.20	9.06	9.12	8.82	88.06
Italy	4.94	6.91	7.63	41.77	4.71	2.57	17.53	5.32	3.94	4.69	58.23
France	5.51	11.40	11.99	13.39	10.38	8.26	11.94	9.02	9.22	8.87	89.62
Germany	3.62	11.97	12.34	12.10	10.43	9.32	10.78	10.07	10.29	9.07	90.68
Spain	8.93	9.98	10.72	17.56	9.29	6.19	14.68	7.27	7.16	8.23	85.32
Finland	3.19	12.08	12.46	11.79	10.39	9.42	10.67	10.32	10.45	9.23	89.68
Austria	3.24	11.79	12.28	13.41	10.15	8.98	11.10	10.00	10.10	8.94	89.90
Ireland	5.91	11.42	12.02	12.17	10.48	8.33	12.05	8.98	9.26	9.39	90.61
To	43.95	94.10	99.16	128.82	83.05	63.52	114.42	73.27	72.67	72.59	84.55
Net	-31.35	5.95	11.10	70.59	-6.57	-27.16	29.10	-16.41	-17.23	-18.02	

Source: Own production.

The results presented in Table 5 look very much like the hypothetical connectedness table that we described at the end of the previous section. The connectedness between any couple of countries is extremely clustered, fluctuating between 10.56 percent and 10.17 percent. Connectedness from and to others and net connectedness are similarly clustered, with the formers averaging at around 89.5 and 93 percent and the latter at around 4 percent. The only exception is given by Ireland, that presents a considerable negative net connectedness at -32.49 percent and connectedness to other countries values that average at 6.74 percent. It is also worth to point out that the divide, that was so prevalent when we analyzed the full sample earlier, between peripheric and core countries is completely absent here. The only data point that we can highlight is that the biggest economies in the sample (Germany, Netherlands, France, Spain and Italy) have higher net connectedness, even thou it is not that much higher than the rest of the sample. What emerges from Table 5 is that in the pre-crisis period connectedness was extremely stable, without any country exercising any influence on the others. The peculiar results of Ireland can be explain given the trend of its yield curve.

Moving on to Table 6, that comprises the sovereign debt crisis period, we can see the trends that characterized the full-length connectedness table for the 2-year yields. Not surprisingly, those trends are more emphasized here. In particular we can notice again the difference between the core countries and the peripheric countries. This time the connectedness to others of core countries is extremely smaller than the one of peripheric countries. This is particularly evident by looking at Germany, which has values lower than 1 percent for each connectedness. The other core countries show very small values as well, with Belgium presenting the greatest ones, ranging from 3.87 percent to 5.85 percent. Similarly to what was shown previously, these countries have a slightly higher connectedness to other countries when it comes to other core nations and a smaller one towards peripheric nations, even thou in this case the values are so small that this difference is not really significant. On the other hand, peripheric nations have a much higher connectedness to other countries, especially other peripheric counties. This time however the difference between the two seems to be less accentuated. Portugal is the country that presents the highest values for connectedness to others, ranging between 35.26 percent and 26.22 percent. Overall the results of Table 6 are in

line with the full-length connectedness table in terms of trends but thy are excessive in terms of magnitude. We can say that this interval of time is probably the most significant and influential for our analysis, at least for the 2-year maturity.

Lastly, we look at the last time period analyzed to notice that many of the trends identified in the previous time interval just don't hold anymore. Looking at net, total "to" and total "from" connectedness values it appears that the features that characterized the two groups of counties have disappeared. This is not true however if we consider the individual values that link any two countries. We start off by evaluating the core nations. When it comes to connectedness to others these countries still have the highest values towards other core countries, consistently with the results obtained earlier. This is particularly evident for Portugal and Italy since every core nation has the smallest values of connectedness to others towards these two countries. It is also very important to point out that this time Ireland behavior is completely in line with the other core countries. When it comes to variance that Ireland transmits to other nations, in fact, Spain, Italy, and Portugal are the least impacted. The values presented by Ireland in this regard are even smaller than some other core countries, like France, Netherlands and Belgium. The remaining peripheric countries keep showing for the most part the same tendencies that we have already described, that is high "to" connectedness among each other. This ca be justified considering that Spain, Portugal and Italy keep having higher yields than the rest of the sample. Lastly it is worth to point out that the two highest values that appear in Table 7 are Italy and Portugal self-connectedness (41.77 and 24.70 percent respectively). This can be justified in part by the isolation that peripheric countries experience in this period and partially by the fact that these two countries have gone through periods of individual financial instability caused by internal political struggle (in 2018 for Italy and in 2016 for Portugal). One conclusion that can be drawn by this last analysis is that even if yields rates have returned to a situation similar to the pre-crisis one, it appears that the impact of the sovereign debt crisis has changed the interaction between sovereign debts of peripheric and core countries, making the gap between the two groups hard to close.

3.2.2 10-year maturity

We now move on to discuss the connectedness tables for the three time intervals defined previously for the 10-year maturity yields. The connectedness tables are shown below.

Table 8. 10-year connectedness table, January 2000-July 2009. Total connectedness is highlighted in yellow.

	Portugal	Netherlands	Belgium	Italy	France	Germany	Spain	Finland	Austria	Ireland	From
Portugal	9.95	10.28	10.17	10.01	10.22	9.93	10.24	10.00	10.21	8.98	90.05
Netherlands	9.94	10.28	10.17	10.01	10.22	9.94	10.24	10.00	10.22	8.97	89.72
Belgium	9.95	10.28	10.17	10.01	10.22	9.93	10.24	10.00	10.21	8.98	89.83
Italy	9.96	10.28	10.17	10.02	10.21	9.91	10.24	9.99	10.21	9.01	89.98
France	9.94	10.28	10.17	10.01	10.22	9.94	10.24	10.00	10.22	8.97	89.78
Germany	9.93	10.29	10.17	10.01	10.23	9.95	10.24	10.01	10.22	8.94	90.05
Spain	9.95	10.28	10.17	10.01	10.22	9.92	10.24	9.99	10.21	8.99	89.76
Finland	9.94	10.29	10.17	10.01	10.23	9.94	10.24	10.01	10.22	8.96	89.99
Austria	9.95	10.28	10.17	10.01	10.22	9.93	10.24	10.00	10.22	8.98	89.78
Ireland	9.97	10.28	10.17	10.01	10.20	9.91	10.24	9.98	10.21	9.04	90.96
To	89.54	92.54	91.55	90.11	91.96	89.35	92.16	89.97	91.93	80.79	89.99
Net	-0.51	2.82	1.72	0.13	2.19	-0.70	2.40	-0.02	2.15	-10.18	

Source: Own production.

Table 9. 10-year connectedness table, August 2009-Jannuary 2015. Total connectedness is highlighted in yellow.

	Portugal	Netherlands	Belgium	Italy	France	Germany	Spain	Finland	Austria	Ireland	From
Portugal	25.06	1.08	8.55	14.68	3.08	1.04	20.13	1.50	3.51	21.38	74.94
Netherlands	5.98	8.67	13.69	7.31	10.87	8.42	11.63	9.05	11.45	12.93	91.33
Belgium	13.45	4.93	12.25	10.78	7.58	4.78	15.73	5.52	8.11	16.89	87.75
Italy	21.66	1.90	9.87	14.89	4.33	1.79	19.73	2.41	4.67	18.74	85.11
France	8.81	6.92	13.21	9.00	9.43	6.71	13.71	7.41	9.98	14.82	90.57
Germany	5.59	8.90	13.69	6.89	11.01	8.67	11.25	9.26	11.64	13.09	91.33
Spain	16.66	3.27	11.17	12.83	5.87	3.14	18.13	3.80	6.36	18.77	81.87
Finland	6.65	8.33	13.59	7.54	10.59	8.10	11.92	8.76	11.17	13.34	91.24
Austria	7.93	7.34	13.35	8.38	9.75	7.13	13.14	7.79	10.37	14.82	89.63
Ireland	17.63	2.98	10.77	12.17	5.42	2.90	17.90	3.50	6.03	20.70	79.30
To	104.36	45.65	107.90	89.58	68.50	44.01	135.14	50.24	72.92	144.78	86.31
Net	29.41	-45.68	20.15	4.48	-22.07	-47.32	53.27	-41.00	-16.71	65.49	

Source: Own production.

Table 10. 10-year connectedness table, February 2015-Jannuary 2021. Total connectedness is highlighted in yellow.

	Portugal	Netherlands	Belgium	Italy	France	Germany	Spain	Finland	Austria	Ireland	From
Portugal	9.34	9.31	11.37	9.62	10.65	7.92	11.20	9.40	9.98	11.21	90.66
Netherlands	6.71	10.44	11.67	8.01	11.26	9.25	10.31	10.41	10.81	11.12	89.56
Belgium	7.09	10.23	11.62	8.40	11.15	8.99	10.48	10.22	10.67	11.14	88.38
Italy	7.89	9.47	11.29	11.12	10.62	7.96	11.05	9.45	10.17	10.97	88.88
France	6.83	10.38	11.65	8.11	11.24	9.17	10.38	10.35	10.77	11.13	88.76
Germany	6.66	10.50	11.69	7.81	11.30	9.34	10.26	10.47	10.85	11.13	90.66
Spain	7.40	10.09	11.57	8.58	11.09	8.82	10.67	10.09	10.56	11.14	89.33
Finland	6.92	10.37	11.66	8.00	11.23	9.18	10.35	10.36	10.76	11.15	89.64
Austria	6.72	10.41	11.66	8.16	11.24	9.20	10.32	10.38	10.81	11.11	89.19
Ireland	7.40	10.13	11.61	8.41	11.10	8.88	10.56	10.13	10.59	11.20	88.80
To	63.63	90.89	104.17	75.10	99.65	79.38	94.91	90.88	95.17	100.10	89.39
Net	-27.03	1.33	15.79	-13.79	10.89	-11.28	5.58	1.25	5.98	11.30	

Source: Own production.

Table 8 presents similar characteristic to Table 5 discussed for the 2-year maturity yields. Individual connectedness between countries are very clustered and they don't show any particular trend. Total connectedness from and to others are clustered around 90 percent and net connectedness don't diverge to much from 0. The only difference between the 10-year and 2-year maturity relates to Ireland. This time Ireland connectedness to others averages at around 9 percent, as opposed to the 6.7 percent registered for the 2-year case. We can attribute this to the normalization effect that we have already observed for the longest maturity in the full-length sample discussion earlier.

Table 9 presents the connectedness table during the sovereign debt crisis period. Here we can see the well-known trends that we have already discussed, namely a sharp divide between peripheric and core countries, higher connectedness to others for peripheric countries, positive net connectedness values for peripheric countries and negative ones for core countries. There are however a few peculiarities in this table compared to the 2-year one for the same time period. Firstly this time core countries present higher connectedness values towards other nations (both peripheric and core nations). Just to provide an example, Germany, that only presented value lower than 1 percent in the 2-year scenario, now only has values greater than 1 percent, peaking at 8.67 percent. On the other hand peripheric countries present lower values, especially Portugal and Italy. Secondly, looking at core countries, we can notice that the divide between the connectedness to others of these nations towards core countries and peripheric countries is greater than what it used to be in 2-year case. Taking the Netherlands as an example the average connectedness to others in the 10-year case for peripheric and core countries are around 2.3 percent and 7.5 percent respectively (5.2 percentage points spread), while the same values for the 2-year case were 1.4 percent and 2.3 percent (0.9 percentage points spread). Another difference is given by the magnitude of the net connectedness values, way greater in the 2-year scenario. Generally speaking this table presents similar characteristic to the 2-year full-length sample and the second 2-year segment table. It is important to notice however that while the connectedness table related to the sovereign debt crisis in the 2-year case was a good approximation of the full-length 2-year connectedness table, that is not the case for the 10-year yields.

Table 10 displays the post-crisis connectedness for the ten years maturity. Here we find some of the trends that we discussed in the 2-year case, particularly more clustered values for connectedness to others for each individual country, for net connectedness and for total connectedness from and to others. Noticeably we can see that again Ireland presents values in line with the other core countries. Contrary to the 2-year scenario, this time Spain too presents values similar to the core nations. The same can not be said for Portugal and Italy, that still present the typical characteristic of peripheric countries that we have discussed many times at this point. This time however such tendencies are not that sharp. One trend that we pointed out for the 2-year case for this time period was the strong self-connectedness of Portugal and Italy. This trend is still present in the 10-year case but is nowhere near as strong. Generally speaking we can affirm that in the post-crisis period the data shows a strong tendency to normalization, similar to the pre-crisis situation, that was not as evident in the two years case.

Chapter IV

Dynamic analysis

The next step in our analysis concerns a dynamic study of connectedness. We will repeat the analysis that we did previously for the full sample and for some specific time-intervals within the sample, but this time we will apply it to a rolling window of 48 observations rolling through the whole sample. This type of approach will give us a better understanding of how connectedness changed over time in a dynamic fashion. There are two main reasons why we picked 48 as the window width (we remind that we are using monthly data, therefore 48 observations are equivalent to 4 years): firstly 4 years is a time-span long enough to ignore minor, irrelevant trends that we are not interested in reporting on and that generate a sort of "background noise" that tends to make the data schizophrenic; secondly 4 years is short enough to catch in a clear and defined manner the most significant trends. The time horizon H is 8, as it was for the static analysis. This part will be divided in three sections: in the first one we will discuss how total connectedness changed over time; in second part we will report on total connectedness "to" and "from" others for each nation, as well as net connectedness; in the third part we will make a robustness assessment by repeating the analysis for different time horizons H and for different window length.

4.1 Total connectedness

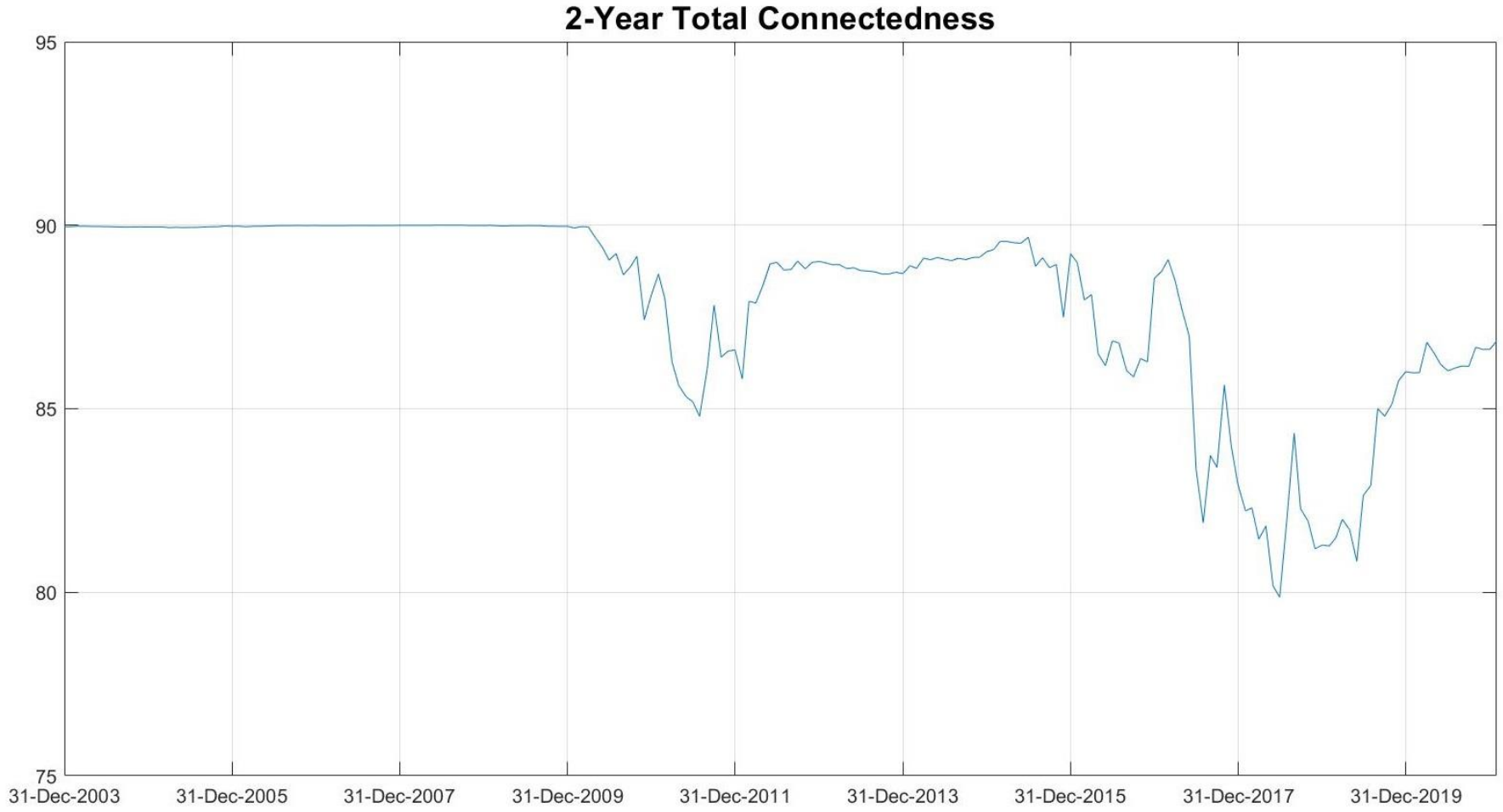
In this section we will discuss how total connectedness changed over time for the three different maturities considered. In order to achieve this we will also use the support of the dynamic total connectedness "to" others. The choice of using connectedness "to" others instead of "from" others is mainly dictated by convenience, since the formers tend to be clearer and easier to read. Notice that every country tends to have a specular behavior in the two plots (meaning that if Portugal, for example, has a crescent trend in a certain time interval in the connectedness "to" others plot, it will have a descendent trend in the same time interval in the connectedness "from" others plot, and vice versa), making it redundant to report both. Lastly, we will look at the total connectedness trends through both mathematical and economic lens, meaning that we will partially

link such trends to the most relevant financial happenings of the time period considered and partially to the mathematic outputs of the model.

4.1.1 2-year yields

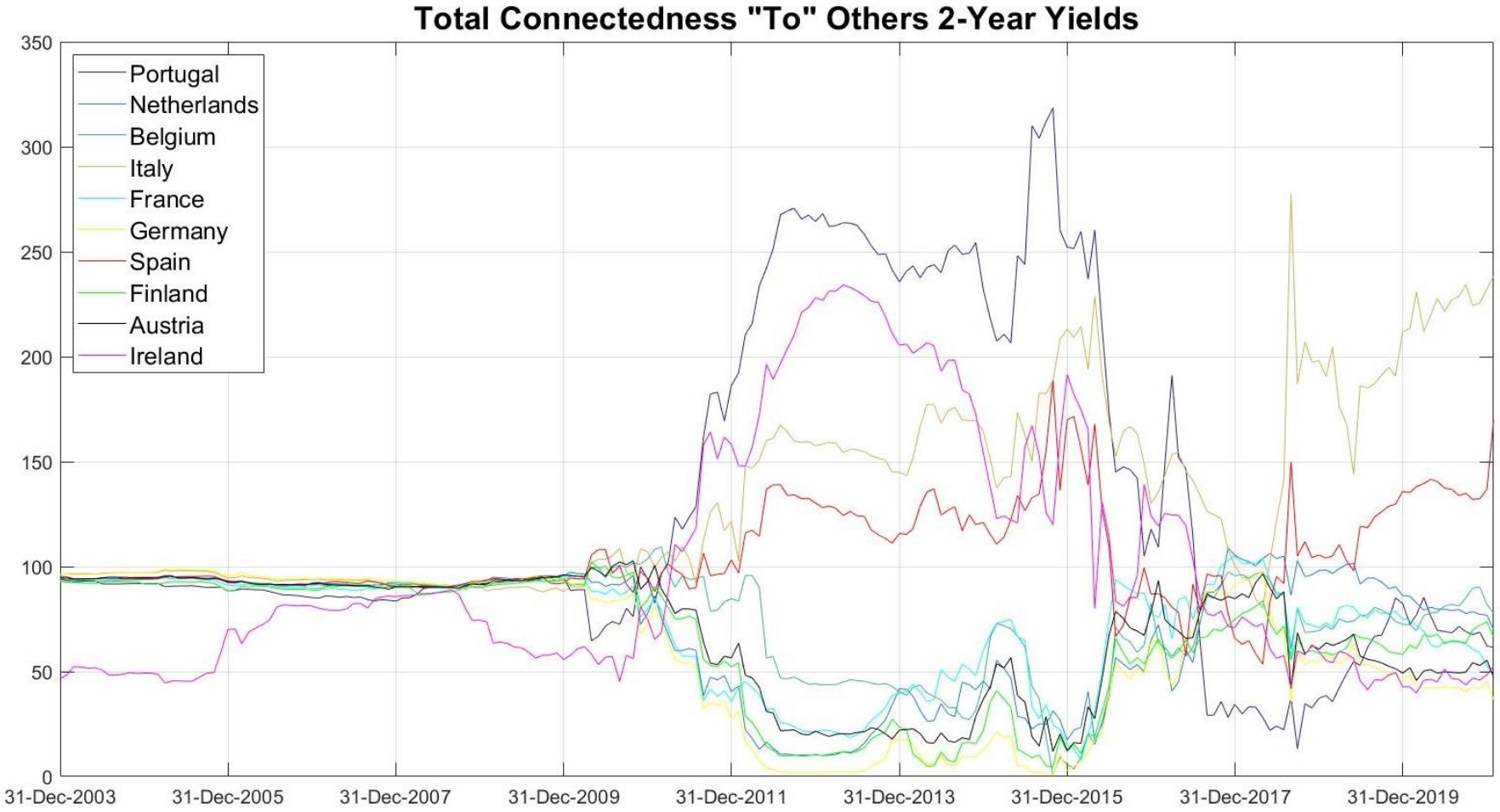
We start the analysis, as usual, with the 2-year yields. The two graphs below show the total connectedness and the total connectedness "to" others for each individual country.

Graph 4. 2-year total dynamic connectedness.



Source: Own production.

Graph 5. 2-year total dynamic connectedness “to” others for each individual country.



Source: Own production.

The first noticeable trait of the total connectedness, shown in Graph 4, is that it does not oscillate that much. Throughout the entire time interval connectedness only ranges between 90 percent and 80 percent. When we look at the total connectedness "to" others for each country, however, we see that values are extremely volatile. In the case of Portugal these values range between 320 percent and 20 percent. This difference in the two graphs can be explained by noticing that usually all the nations in the sample tend to act in a coordinated manner to balance each other, which results in an overall stability of the total connectedness. This point will become clearer as we discuss the specifics of the graphs.

In the first part of Graph 4, up to the beginning of 2010, we can see that connectedness was very stable at around 90 percent, with just a few, almost imperceptible shifts. This is noticeable also in Graph 5, in which every country oscillates between 100 and 90 percent with the only exception being Ireland, which presents values constantly lower than the rest of the sample. We already pointed out this phenomenon in the by-segment analysis that we did earlier. In this first part we can see the balancing effect that we mention earlier. As a matter of fact the whole sample presents higher values when Ireland presents its lowest values, namely in the December 2003 - June 2006 and the September 2008 – August 2010 periods, and lowest values when Ireland is at its highest, between July 2006 and August 2008. The next section concerns the subprime crisis and the sovereign debt crisis periods. This is a good time to notice that there is a certain lag between shocks in yields and changes in connectedness due to the length of the window used. Divergence in returns began to show by the end of 2009 but we start to see a drop in total connectedness towards the beginning of 2010 and in the connectedness "to" others graph this shock becomes discernable only at the beginning of 2011. During this time, connectedness "to" others increased drastically for peripheric countries, as it decreased for core countries. We can also notice that Belgium is the core country with the highest values of connectedness until the end of 2013. This is consistent with the results obtained in the static analysis that pointed to an unusual behavior of the country. Economically speaking Belgium had to face a financial crisis during this period, even if it was not as severe as the ones faced by the peripheric countries, and its yields were higher than the rest of the core countries. In terms of total connectedness, there was a

dip in June 2011 followed by a period of stabilization that led to an equilibrium at around 88-89 percentage points between April 2012 and June 2015. We can infer that the impact on total connectedness of core countries was greater than the one of peripheric nations in this period.

In Graph 5 we can see an attempt at convergence at the beginning of 2015 that reverted right after. Looking at the yields curve and considering that all the observation from 2011 to 2015 played into this, we can deduce that this was caused both by the stabilization of yields that took place in 2014, as a consequence of Portugal, Ireland and Spain exiting their economic adjustment programmes, and the increase in yields of core nations that took place in 2011, caused by the exacerbation of the sovereign debt crisis in Europe. This first convergence barely had an impact on total connectedness, that presents a slight uptick at this time.

As yields of core countries decreased between the beginning of 2011 and the beginning of 2012, the divide between the connectedness of core and peripheric countries widened again. Finally, mid-way through 2016, connectedness for all countries begin to converge again in a more lasting manner since we entered the post-crisis period and yields started to be more stable from this moment on. As we have mentioned in previous sections, even if yields have been generally speaking stable after 2014, the new situation in which Europe finds itself is more fragmented and yields are not as clustered as they were before the crisis. This is reflected in the connectedness “to” others graph since the sample tends to be more clustered than during the sovereign debt crisis period but less clustered compared to the pre-crisis period. Exceptions to this rule are Portugal, Italy and Spain. Italy presents a very high connectedness to others since July 2018. This divergence was caused by the increase in yields that Italy experience since April 2018 as a consequence of its internal political turmoil. The increase in connectedness of Spain and Portugal can be explained in relation to the behavior of Italy. As we have discussed earlier, in this last period, connectedness among Spain, Italy and Portugal is considerably strong. We can infer that the increase in Italy yields pushed up the connectedness of Spain and Portugal as well.

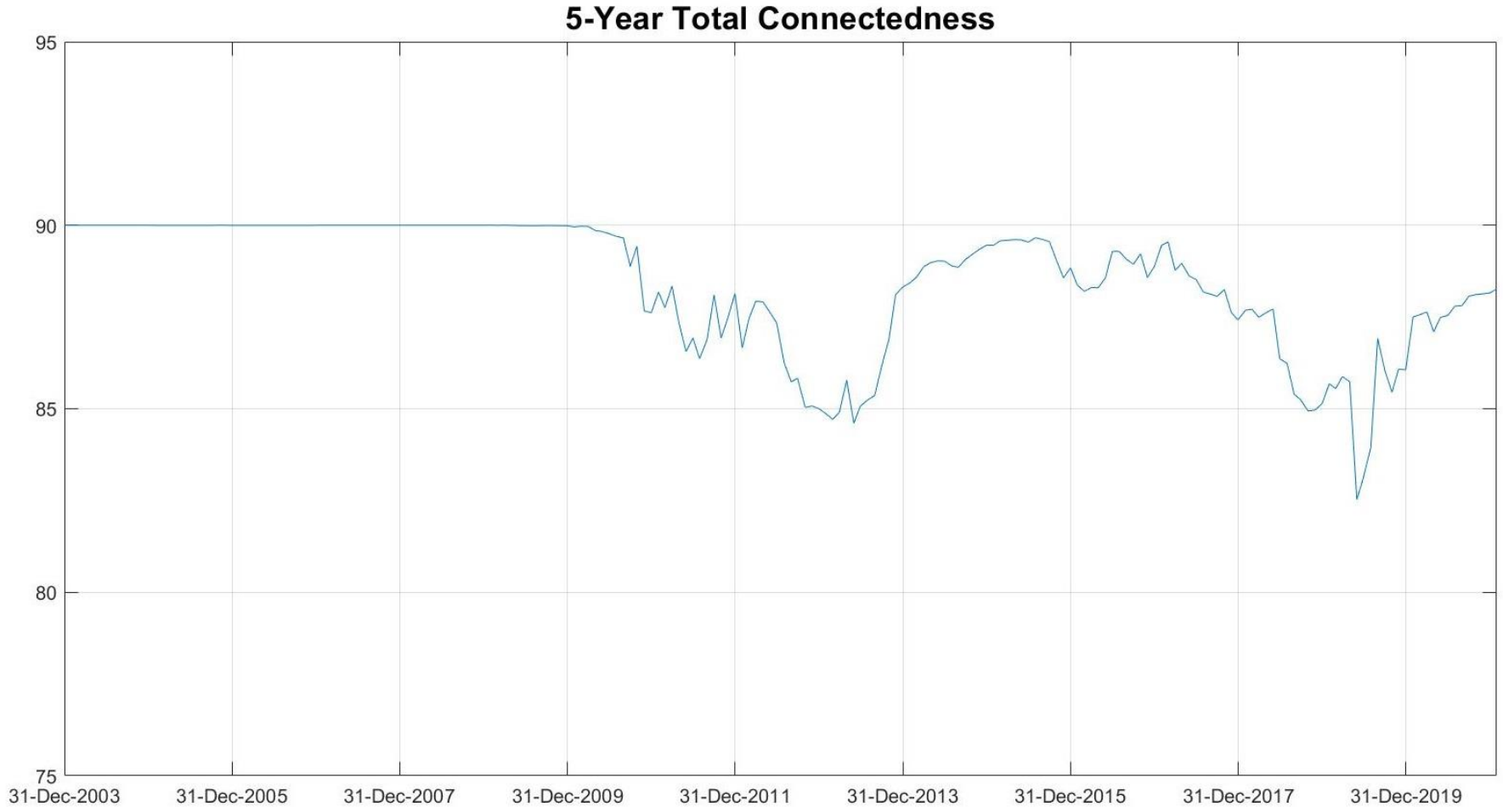
In terms of total connectedness we can see a constant decrease that peaked in May 2018. It seems that the post-crisis equilibrium resulted in decrease that was later

inverted with the increase of connectedness “to” others by Italy, Portugal and Spain as we just described.

4.1.2 5-year yields

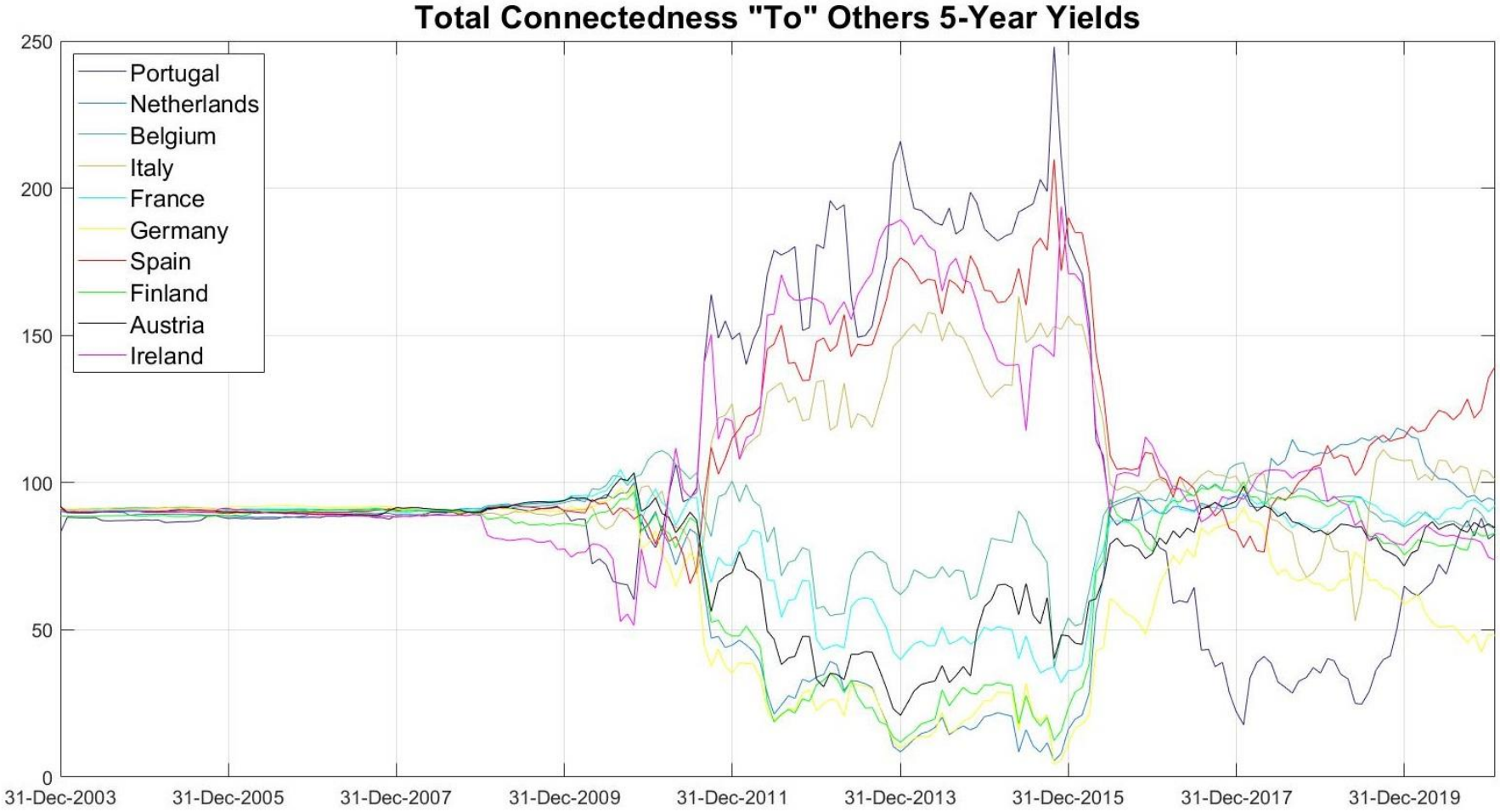
In this section we will talk about total connectedness and total connectedness “to” others for 5-year maturity yields in a similar fashion to what we just did for the 2-year yields. Since most trends are shared between the two maturities, we will specifically point out the peculiar traits of the 5-year maturity and briefly hint at the shared ones. The two graphs below show total connectedness and total connectedness “to” others for each individual country for the maturity that we are currently discussing.

Graph 6. 5-year total dynamic connectedness.



Source: Own production.

Graph 7. 5-year total dynamic connectedness “to” others for each individual country.



Source: Own production.

At a glance we can see that overall the macro-trends shown in the two graphs are the same ones shown in the graphs for the 2-year maturity. The first difference that we can point to is the lower volatility of the 5-year connectedness. Total connectedness ranges between 90 and 82.5 percent here, while the same range in the 2-year case was 90-80 percent. Even for individual countries the range is smaller, with Portugal (just to be consistent with our previous example) ranging between 250 and 20 percent. This is not surprising given the smaller volatility of the 5-year yields compared to the 2-year ones.

Going through the timeline we see that the pre-crisis period is extremely stable, just like in the 2-year case. Even the fluctuations presented by Ireland previously are not present here until 2009, year in which Ireland and Austria (this last one only since the beginning of 2010) started to diverge from the rest of the sample showing lower connectedness. Noticeably the sovereign debt crisis period was shorter in this case. The divergence in connectedness begins at around the same time in July of 2011, but it ends mid-way through 2016, as opposed to the 2-year case in which convergence became effective only one year later. Additionally, during the crisis peripheric countries appear to be more clustered and core countries less clustered compared to the 2-year scenario. In particular Belgium and, to a lesser degree, France and Austria, are rather isolated from Germany, Finland and the Netherlands, which have lower and more clustered connectedness. We can say that this time the distinction between peripheric and core nations is more blurred. The small bottleneck that we noticed in the previous analysis is way smoother and less noticeable here.

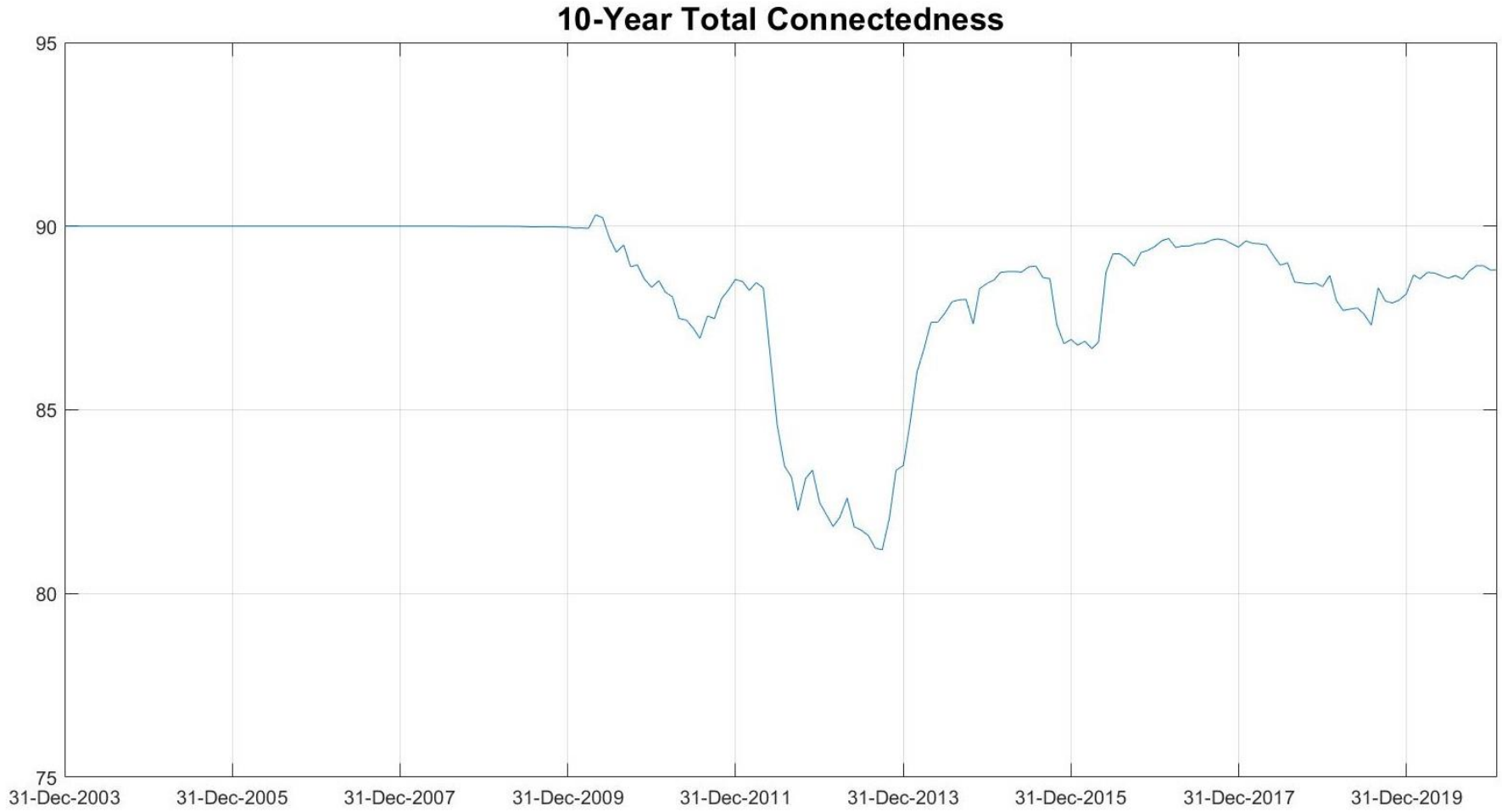
In the post-crisis period, all the nations are more clustered than in the previous case. We can also see that Italy and Portugal follow very similar trends in this phase, particularly a descending trend until June 2019 and an increasing one from there. Spain loosely follows these two, starting its increasing phase way earlier however, in April 2018. Germany presents a descending trend in the entirety of the post-crisis period, while the rest of the sample is consistently stable.

In terms of total connectedness, we can point out how much more stable it was in the post-crisis period compared to the 2-year case.

4.1.3 10-year yields

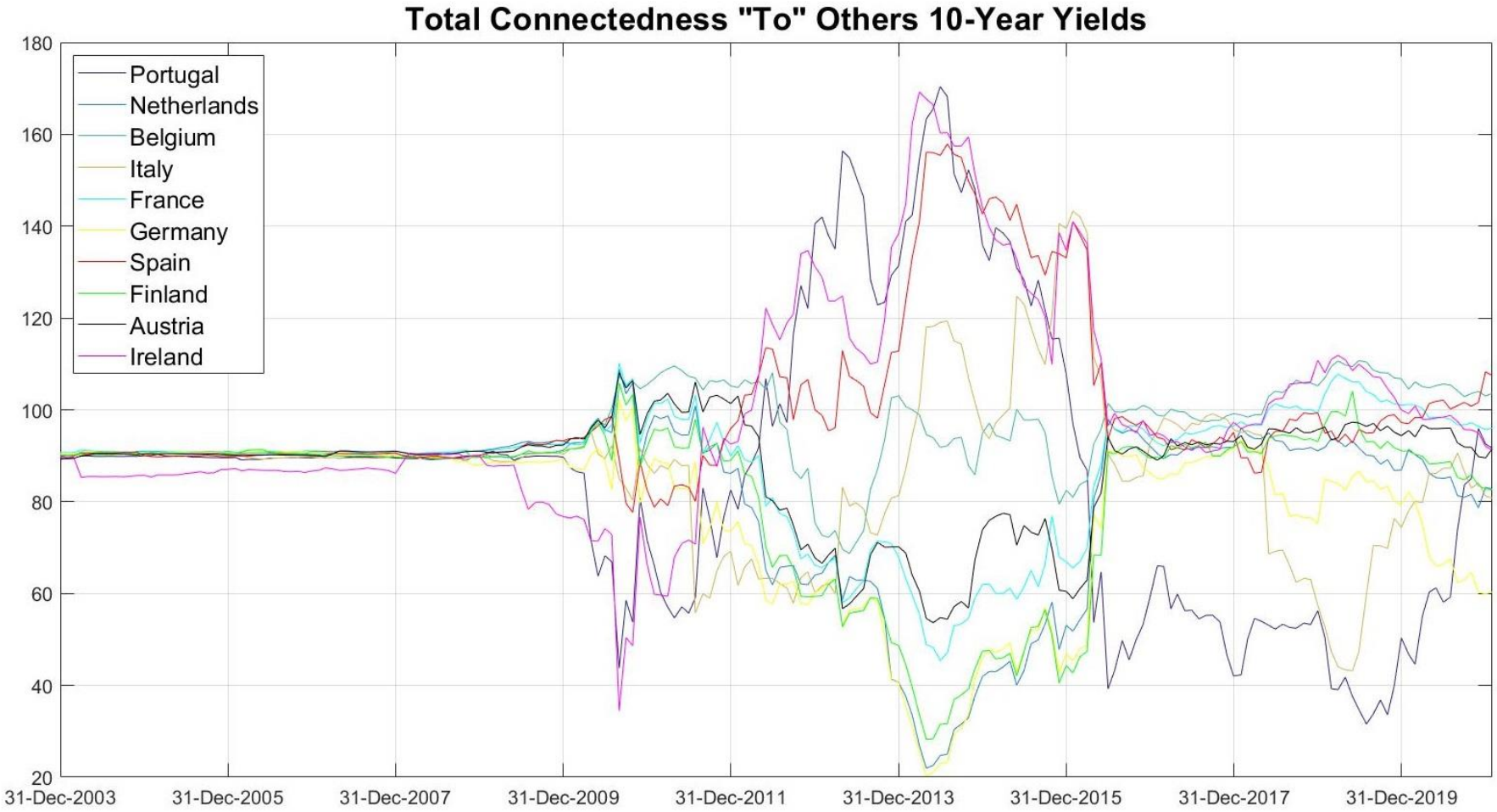
Lastly, we are going to discuss the 10-year yields. The approach will be similar to the 5-year one, meaning that we will point out the peculiarities that this maturity shows compared to the previous two. Below are the total connectedness graph and the total connectedness “to” others graph.

Graph 8. 10-year total dynamic connectedness.



Source: Own production.

Graph 9. 10-year total dynamic connectedness “to” others for each individual country.



Source: Own production.

We start off by pointing out how the connectedness for individual countries is the least volatile than for any other maturity. Continuing with the reference used previously, Portugal range just between 170 and 30 percent, as opposed to 250-20 percent for the 5-year case and 320-20 percent for the 2-year case.

The pre-crisis period is very stable, similarly to the previous two cases. We notice that Ireland has a similar behavior to the two years maturity, presenting lower connectedness compared to the rest of the sample, even thou this time it is way less significant.

The crisis period appears rather peculiar for the 10-year yields. There is a considerably long period of time, between mid-2009 to mid-2012, in which the connectedness begin to diverge, being way less clustered than during the pre-crisis period. In this time, that includes the subprime crisis and the beginning of the sovereign debt crisis, the trends related to connectedness that we consider peculiar to the sovereign debt crisis period are literally flipped. Core countries present higher connectedness and peripheric countries lower ones. In terms of total connectedness we can see that there was a drop here that bounced back up briefly at the end of 2012 when connectedness trends for the individual nations were reversing (increase for peripheric nations and decrease for core nations) a to then drop again towards the end of 2015. This last drop was due to the fact that the rolling windows related to 2015 encompass the whole period of the sovereign bond crisis. Previously, talking about the sovereign debt crisis in the 2-year case, we stated that the impact of core countries on total connectedness was greater than the one of peripheric countries, therefore, since core nations have lower connectedness “to” others during the sovereign debt crisis, total connectedness decreases. The observations that we just made, however (related to the lower connectedness of peripheric countries at the beginning of the crisis in the 10-year case), suggest that, generally, connectedness tends to drop during crisis and such drop is led by whoever has the lowest connectedness at that time, whether it be peripheric or core nations.

Another significant feature of the 10-year yields is that both core and peripheric countries are not as clustered as they were for shorter maturities. Particularly we notice how Italy is rather detached from the rest of the peripheric countries, with its

connectedness picking up only towards the end of 2013. The other peripheric countries (Spain, Portugal, Ireland) are rather clustered, even if not as much as they were for the shorter maturities. Also Belgium has a particular behavior here, acting as a bridge between the two groups of countries. Similarly to the 5-year case, Germany, Finland and the Netherlands are very clustered together and present the lowest values of connectedness. At the beginning of 2013 Austria and France diverge from the cluster of core countries showing higher values than the rest of the core nations. In general some of these are not really surprising since they were already hinted in the analysis by segments that we did earlier.

Also in this case, in the post-crisis period connectedness for individual nations tend to converge, with some notable exceptions. In particular connectedness of Portugal and Italy diverged from the rest of the sample when the two countries experienced an increase in yields, in 2016 and 2018 respectively. We saw how in this case of Portugal this event caused a spike in connectedness in the 2-year case and, conversely, a drop in the 5-year case. The ten years scenario follows the latter. Similarly the Italian political crisis of 2018 caused a spike in connectedness in the 2-year case and was pretty much inconsequential in the 5-year one. The 10-year case caused, instead, a drop. Noticeably both countries are converging with the rest of the sample towards the end of the time period considered. Germany is the only country that, as time goes by, diverges more and more from the rest of the sample.

This overall stability is reflected in the total connectedness graph that shows high and stable values in the post-crisis period.

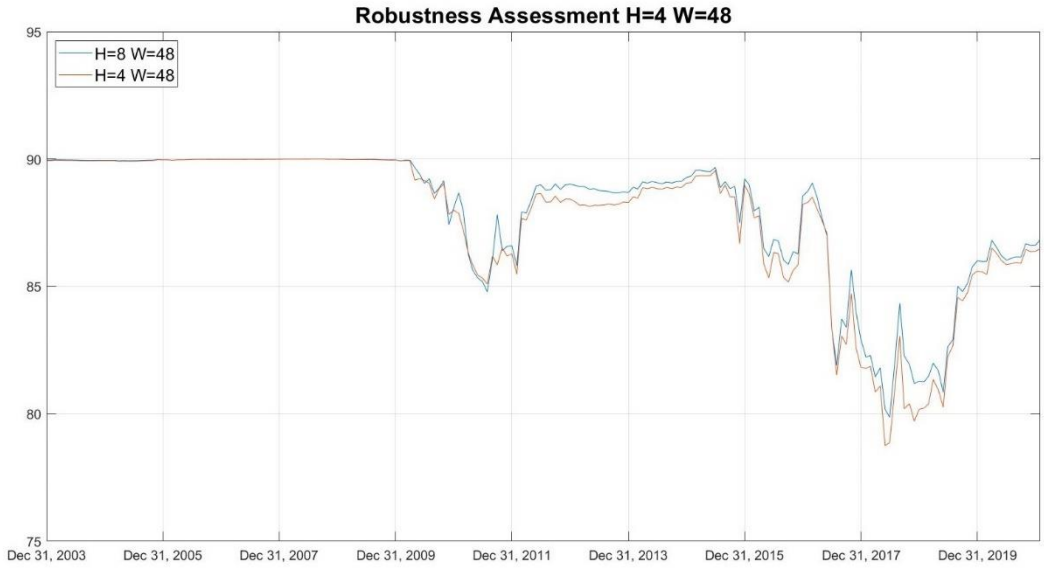
4.2 Robustness assessment

This section aims at addressing the robustness of the dynamic part of our analysis. What we are going to do here is present the same analysis done before for smaller and greater values of the time horizon H and the window length w. We will point out the differences and similarities in total connectedness for the different values of the parameters specified above and show the consistency of our results.

We will perform this robustness check only for the 2-year yields since the two longer maturities presents analogous results and the discussion about them would be very similar to this one and therefore redundant.

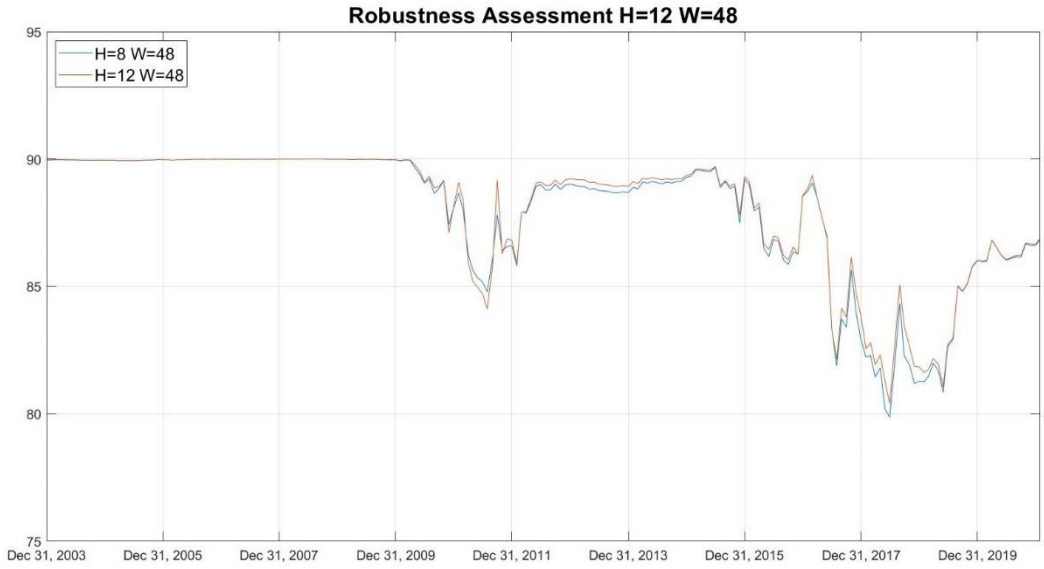
The values chosen for H are 4 and 12, while the ones chosen for the window width are 36 and 60, corresponding to 3 and 5 years, as opposed to 4 years.

Graph 10. Comparison between time horizons 4 and 8



Source: Own production.

Graph 11. Comparison between time horizons 12 and 8



Source: Own production.

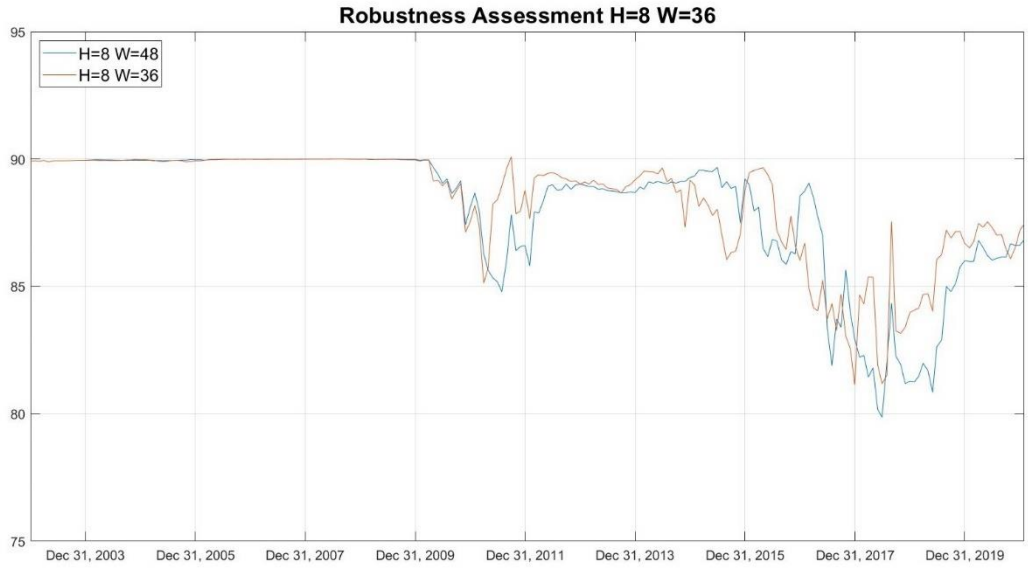
Graph 10 and Graph 11 present a comparison between total connectedness computed for H equal to 4 and 12, respectively, and 8, with a window width equal to 48. We can notice how there are not any glaring differences in terms of trends (the two curves move almost simultaneously in both graphs), so much so that in Graph 11 the two connectedness curves coincide from early 2018 onwards. In both graphs the two curves coincide in the pre-crisis period, suggesting that in periods of stability the choice of the time horizon H is completely meaningless.

Differences appear in regard to positioning. In particular in Graph 10 the curve with H equal to 4 is constantly lower than, or at best equal to, the curve with H equal to 8 and the opposite is true for Graph 11. We can explain this phenomenon by recalling the role of H and the way it influences the computation of connectedness in our analysis. H determines the lag up to which you keep adding together the components of the d values that appear in the connectedness table. As H increases so do the connectedness values between any two countries and, as a consequence, the total connectedness (this holds both for total connectedness and total connectedness “from” and “to” others for each individual nation). Conceptually H represents the time instant up to which you take

into account shocks that arise at t0 from one entity and influence another. Usually the magnitude of said shocks decreases with time, tending to 0 for H → ∞.

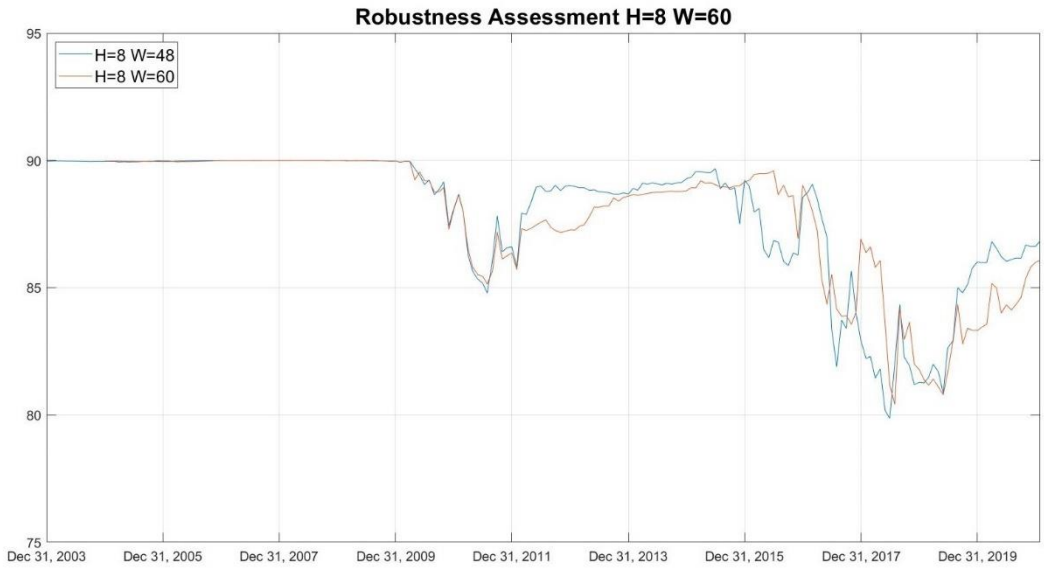
From an economic perspective this behavior can be explained similarly to how we explained the differences between total connectedness in the 2 and 10 years static cases. We observed that connectedness tends to stabilize for longer maturities (with connectedness between any two countries tending to 10 percent and total connectedness tending to 90 percent). Here we can see that longer time horizons H tend to push up connectedness, getting it closer to 90 percent, especially during periods of financial instability, and that shorter time horizons push it down. Noticeably the divide between the two curves in Graph 10 is greater than the divide between the curves in Graph 11. This suggests that the choice of H becomes marginally less relevant as H increases. Overall picking one value of H over another seems quite inconsequential, as long as we keep in mind the "normalization" effect that takes place for greater values of H.

Graph 12. Comparison between window width 36 and 48



Source: Own production.

Graph 13. Comparison between window width 60 and 48



Source: Own production.

Graphs 12 and 13 present a comparison between different window widths, in particular Graph 12 compares 48 and 36 window widths and Graph 13 compares 48 and 60 window widths, all of them use a time horizon H equal to 8.

The first thing to point out is that in both graphs the two curves coincide up to 2010, meaning until the subprime crisis. In Graph 13 this concurrence holds until early 2012. Focusing specifically on the comparison with the longer window width in Graph 13, we can see that the impact of the sovereign debt crisis had a longer lasting effect. The curve associated with the greater value w, in fact, converged with the other one only in early 2014. This is not surprising since a wider window width translates in more lagged and diluted connectedness. Moving on to the second part of the graph we can see a drop in total connectedness depicted by both curves that was caused, as we explained earlier, by the financial instability of Portugal and Italy. The fluctuations caused by Italy (corresponding to the peak and the following drop in total connectedness of late 2018 and early 2019, respectively) and Portugal (the peak in early 2017) were recorded similarly by both curves. The drop in total connectedness that took place between the spikes in Italian (mid-2018) and Portuguese (late 2015) yields was characterized by some fluctuations caused by these two aforementioned countries repositioning themselves

within the sample as big net providers of connectedness (Italy) or recipients of connectedness (Portugal). Such movements were for the most part inconsequential and had been over-represented by the red curve (greater w) in the graph. The steady increase in connectedness that took place from early 2018 onward was less accentuated for the curve with a greater value w.

In general Graph 13 shows that choosing a wider window width would have led to smoother and more lagged results. Given that a certain amount of lag is unavoidable in this analysis, trying to minimize said lag, without obfuscating the interpretation of the most relevant trends, is desirable and a wider window width seems to not be helpful in this regard. Despite this, Graph 13 shows that the trends that we focused on in the thesis are present for greater values of w as well.

Moving on to Graph 12 we can see that the two curves have a similar behavior in recording connectedness during the sovereign debt crisis. Some differences arise in the second part of the graph where the curve associated with a lower w is more volatile than the other one. This volatility is not really representative of much economically since, as we saw, the only major shocks of the post-crisis period were the periods of political instability that led to spikes in Portuguese and Italian yields. These crises didn't have any serious systemic consequences therefore many of the fluctuations in total connectedness in this period are just countries readjusting their position within the sample towards other countries and as such are not particularly interesting from an economic perspective. The three years window width does a poor job at suppressing these trends and the advantages produced by having a reduced lag are not enough, in our evaluation at least, to make up for it.

Conclusions

We applied the generalized variance decomposition method to the yields of ten countries for different maturities in the attempt to identify trends that could be used by policy makers to better intervein in the financial market in order to stabilize yields and returns.

What we found is that connectedness is way more volatile for shorter maturities, similarly to how yields are more volatile for shorter maturities. This suggests that an intervention on these maturities might lead to a greater policy impact. On the other hand, we have seen how in the 10-year case connectedness tends to naturally stabilize. This became particularly evident when we compared the 10-year full-length sample with the full-samples for shorter maturities and again when we compared connectedness relative to the 10-year sovereign debt crisis period with connectedness relative to the same period in the 2-year case. In both these instances the connectedness displayed in the 10-year case was more similar to a situation of perfect equilibrium, with every country equally influencing the others.

We have also pointed out how total connectedness for each individual country tend to balance themselves, for every maturity. Every time we have discussed connectedness during the sovereign debt crisis, independently of the context, we have seen a push of peripheric countries to increase total connectedness and a simultaneous push of core countries to decrease it.

In this regard we have come to the conclusion that connectedness is a useful tool for analyzing systemic crisis, like the sovereign debt crisis. The most impressive results come from this period, while in the pre-crisis period connectedness showed to be for the most part an uninformative tool of analysis. Similar observations can be made for the post-crisis period, where connectedness was relatively stable, even thou to a lesser degree than in the pre-crisis period. Of particular interest is the marginal reactivity of connectedness in response of shocks in yields that took place in this period (particularly in regard to the peaks of the Portuguese and Italian yields). This shows that connectedness is probably not the best tool to record crises that concerns only individual actors in the absence of a systemic turmoil.

One important piece of evidence that we collected is that connectedness between nations have deeply changed in the post-crisis period, as showed by the fact that connectedness in this period is not as stable as in the pre-crisis period despite yields being relatively clustered and despite the absence of systemic crisis. This shows that the European financial landscape is more fragmented than what it used to be as a consequence of the sovereign debt crisis.

Lastly, we would like to suggest a few direction in which this study can be expanded to. It would be interesting to further investigate the apparent fragmentation of the post-crisis period. Specifically, factors that may cause this phenomenon are the propensity of core countries to limit their exposure towards peripheric countries after the sovereign debt crisis and the impact of the Quantitative Easing, that became particularly relevant from 2015 onward. An attempt to tie these phenomena to connectedness would surely be compelling. On the data side of things what could also be done is use denser data (maybe weekly or even daily observations) in order to have a more hermetic and a less lagged analysis, which would be especially relevant in the dynamic analysis.

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