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Evaluating the Impact of Quantitative Easing and Tightening Events on Portuguese Sovereign Bond Yields: A New Methodology for the Redenomination Premium

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Abstract

This paper evaluates the effects of Quantitative Easing and Quantitative Tightening programs on the Portuguese Sovereign Bond Yields and its channels from 2020 to 2023, using an events-study methodology. Credit Default Swaps with different clauses and currencies are used to obtain Quanto Credit Default Swaps and the ISDA Basis, which are then used to estimate the channels that compose the yield. For the 5-year maturity, QE affected the yield through the Default and Redenomination channels particularly in the announcements of the creation of PEPP and the first additional package of PEPP, with an abnormal effect of -29 and -18 basis points, respectively. QT affected the yield mainly through the Euro Swap Rate and the Segmentation channels, with the abnormal effects corresponding to 36 and 32 basis points for the first and second announcements of 2022, respectively.

Keywords: Quantitative Easing; Quantitative Tightening; Monetary Policy Transmission; Sovereign Bond Market; Credit Default Swap

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1. Introduction – QE and QT from 2010 until 2020

The introduction of Unconventional Monetary Policy tools arose in the Euro Area during the height of the financial crisis. The ECB introduced programs with the objective of lowering yields and reducing their volatility, with the additional presumption that it would create additional economic benefits. Later, these programs were continued to lower the real interest rate, in a period where the nominal interest rate was presumed to be at its lower bound, to stimulate the economy and push inflation closer to the 2% target.

The ECB programs included direct purchases of government debt (the Securities Markets Program (SMP), which lasted from May 2010 until September 2012) and conditional commitments to purchase government debt (the Outright Monetary Transactions (OMT), announced in September 2012 which did not result in any net purchases of bonds).

One of the consequences of these programs was the reduction of the yields on sovereign bonds. As shown in Krishnamurthy, Nagel and Vissing-Jorgensen (2018), the SMP reduced the yields on Portuguese sovereign bonds for the 2-, 5- and 10-year maturities and the OMT reduced the yields on the 5- and 10-year maturities. The channels that fueled the reductions in the yields were, however, different for the two programs due to the differences in the objectives.

The SMP's goal was to reduced market dysfunctionality, in a period of increased volatility, with the purchases of bonds focusing solely on bonds for Portugal, Greece and Ireland, and, from August 2011, for Spain and Italy. Therefore, the channel that contributed the most to the reduction of the yields was the Segmentation Premium. The OMT consisted of giving the ECB the power to purchase government bonds of any country in the euro area, as long as they agreed to undertake a set of fiscal adjustments. Although no purchases were ever made under this program, giving the

ECB the power to buy bonds from countries under the condition they balanced their budgets gave the market the impression that there was a lower chance for default and redenomination scenarios, which resulted in decreased Redenomination and Default Premia simply by managing market expectations. Over the two programs, the Default and Segmentation Premia were the most impactful while the redenomination premium played a smaller role.

In 2014, the Asset Purchase Program (APP) was created, with the objective of lowering interest rates while stimulating the economy and pushing inflation closer to 2%. Between October 2014 and July 2022, the ECB purchased securities under the APP, including Public Sector Debt Securities (PSPP), Corporate Bonds, Asset-Backed Securities and Covered Bonds. The PSPP was the most important part of the program, corresponding to around 80% of the holdings in euros throughout the duration of the program (ECB 2024). The purchases of bonds under the APP (PSPP) needed to be euro-denominated, have a remaining maturity of between 1 and 30 years, and the purchase allocations were made in accordance with the share of capital each Central Bank had in the ECB. Under the APP, net purchases of public sector bonds lasted from March 2015 to December 2018, switching to reinvestment of the principal payments from maturing securities from January 2019 to October 2019, at which point the net purchases restarted until June 2022. In July 2022 the ECB ended net purchases, reinvesting the principals from maturing securities until February 2023. From March 2023 the reinvestments became partial and were discontinued in July 2023.

In March 2020, to counter the risks to the monetary policy transmission mechanisms posed by the Covid-19 pandemic, the Pandemic Emergency Purchases Program (PEPP) was created. The program had very similar conditions to the APP (with the most important difference being that the minimum remaining maturity eligible was decreased to 28 days). The program started in March 2020 and net purchases lasted until March 2022, at which point the principals from maturing securities were reinvested until mid-2024. Partial reinvestment of the principals began at this time, and the PEPP reinvestments were discontinued at the end of 2024.

For both the APP and PEPP, the ECB ended the net purchase of bonds in 2022 and started to reinvest the principals of maturing securities, reducing the percentage of the principal that was reinvested over time until it reached 0%. This meant that the ECB was, for the first time, reducing the size of its balance sheet, commonly known as Quantitative Tightening. Due to the novelty of this type of operation, little is known about its effects on government bond yields.

The only example of such measures, before the current QT measures applied, was when the USA applied QT after the balance sheet expansion enacted during the 2008 financial crisis. The most important take from this example is that QT is not simply QE in reverse.

For QE events, there was a large signaling component, as shown in Krishnamurthy and Vissing-Jorgensen (2011), which indicated to the markets that the real interest rate was decreasing. However, during QT the signaling channel was largely absent, since the FED wanted to avoid a repetition of the "taper tantrum"[1], by separating expectations of future interest rate increases from QT, as explained in Smith and Valcarcel (2022). In addition, this asymmetry was also caused by the different periods in which they were introduced, as QE was introduced during the financial crisis where Default and Segmentation Premia were increasing, and QT was introduced during a period of higher stability.

Smith and Valcarcel (2022) found that in the USA QE events from 2008 to 2013 cumulatively decreased the yields of the 10-year Treasury Bond by 149 basis points, and QT events from 2013 to 2017 increased the yields of the 10-year Treasury Bond by 28 basis points. The paper also found

[1]The "Taper Tantrum" occurred when in 2013, the FED announced that it would reduce net bond purchases. This resulted in increased yields as investors sold bonds expecting increases of the real interest rate.

that only “taper” events (slowing purchases down) had significant effects in increasing yields, while unwind past purchases did not have a significant effect.

In this thesis, the effects of 4 QE and 4 QT events on the Portuguese Sovereign Bond Yields were measured to see if the effects are asymmetrical as they were for the USA. Additionally, the impact of these events on the 4 channels that together compose the yields were also calculated, the Default Premium, Redenomination Premium, Segmentation Premium and the Euro Swap Rate, with special attention to the differences between the effects of QE and QT for each of the channels.

Section 2 explains the effects of QE and QT, the APP and PEPP, and how the dates from those programs were selected to be used to determine the abnormal returns. Section 3 explains the methodology behind the channels and the decomposition of the yield and section 4 shows the methodology used to calculate the abnormal returns. Section 5 presents the results and explains them.

2. APP and PEPP – Programs and Relevant Event Dates

The two programs that will be evaluated are the Asset Purchase Program and the Pandemic Emergency Purchase Program. The thesis focuses on the impact of ECB announcements related to these programs on the Portuguese Sovereign Bond Yield.

QE started due to lower than expected monetary stimulus from the low interest rates (which were perceived to be at their lower bound), and additionally seen as a way to increase inflation to keep it around the 2% target. These set of measures, called unconventional monetary policy, had the objective of increasing the prices of bonds in the secondary market, allowing governments and other public-sector entities to finance themselves at lower rates, therefore increasing their spending.

On the other hand, QT consists of large decreases of net purchases, which results in a slower paced growth of the balance sheet, or end of net purchases with or without a degree of reinvestment of the principal payments from maturing securities, resulting in a decrease of the bond portfolio accordingly to the percentage of reinvestment. QT announcements in the EU do not include the active sale of bonds, although that has been done in other jurisdictions.

To measure the effect of the APP and PEPP on the Portuguese Sovereign Bond Yields, the dates of official ECB announcements of net purchases, end of net purchases and extensions of reinvestment periods are used. However, it is possible that certain events were anticipated by the markets. So, for those events, it is not possible to measure abnormal effects at the date of the announcement since the market already incorporated that information into the prices. To account for this, if there is information on the first 3 pages of the Financial Times about the announcement, before the event occurs, then that date will be used as the event date instead, as done in Urbschat and Watzka (2019).

The period considered begins on March 10th, 2020, two days before the announcement of an increase of the APP by 120 billion euros, until December 14th, 2023, the day the ECB announced the details of the end of PEPP. During this period, 4 QE dates (March 10th, 2020; March 18th, 2020; June 4th, 2020; and December 10th, 2020) and 4 QT dates (June 9th, 2022; December 15th, 2022; May 4th, 2023; December 14th, 2023) are considered.

For the first QE date, on March 12th, 2020, a 120 billion euro increase in net purchases over the year 2020 was announced under the APP program. Despite this, there was news in the FT about this event on March 10th, so this date will be used. The second date is March 18th, 2020, which marks the announcement of PEPP with a net purchases package of 750 billion euros, with purchases supposed to take place in 2020. The third and fourth QE dates are reinforcements of the PEPP package (600 billion for June 4th and 500 billion for December 10th), increases of the net purchase period (until June 2021 for the 3rd event and March 2022 for the 4th event) and increases in the reinvestment period of maturating bonds principal payment (Until the end of 2022 for the 3rd event and 4th events). In addition, it was also announced on both occasions that the APP was continuing and maintaining net purchases of 20 billion euros per month.

The first QT date is June 9th, 2022, when the ECB announced the end of net purchases under the APP, with principal reinvestments continuing, and that the key interest rates would increase 25 basis points in July (the interest rates increased by 50 basis points in that July meeting).

On the second date, December 15th, it announced that the full reinvestment of the principal of the APP would end in February 2023 and be replaced by partial reinvestments, corresponding to a monthly decrease of around 15 billion euros in securities held until the second quarter of 2023. The key interest rates would increase by 50 basis points. These first two events can be classified as tapering events, since there is an announced decrease in the level of net purchases.

On May 4th, 2023, the third date, the ECB announced the end all APP reinvestments as of July 2023, meaning that the portfolio of sovereign bonds would decrease at a faster pace as the bonds matured, and that the key interest rates would increase by 25 basis points. Lastly, on December 14th, 2023, the ECB announced more details regarding a previous extension of the reinvestment period of PEPP. On December 16th, 2021, the ECB announced that the principal reinvestments were being expanded from the end of 2022 to the end of 2024. And on December 14th, 2023, they announced that full reinvestments of the principal would only occur in the first half of 2024, and on the second half of 2024 only partial reinvestment would be made corresponding to a portfolio decrease of around 7,5 billion euros per month. After 2024 all reinvestments will end. These last two events, despite signaling to the markets the end of net purchases, are not taper events since they did not result in significant changes in policy and only confirmed the dates for previously defined policy changes. They are classified as wind-down events instead.

3. Methodology for Channel Decomposition

The yield of a bond, the return that an investor gets on its investment, is inversely proportional to the price of a bond. So, when the price of a bond goes up, its yield decreases. The return that an investor demands from a bond depends on the risk-free interest rate, the expected loss given default, the expected loss given a redenomination event, and a compensation required due to market dysfunctionality.

Considering the yield on a euro-denominated government bond issued by a country c with maturity T, its decomposition is the following[2]:

$$y_T^c = \frac{1}{T}\int_0^T E\,[i_t]dt + Term\ Premium_T + Default\ Risk\ Premium_T^c + Redenomination\ Risk\ Premium_T^c + Segmentation\ Premium_T^c \quad (1)$$

The first term, $\frac{1}{T}\int_0^T E\,[i_t]dt$, is the signalling component, which is, how the markets anticipate the future path of nominal interest rates. ECB announcements can change market perceptions about the future interest rates, as QE announcements can be taken as a signal that in the future real interest rates will decrease, and QT announcements can be taken as a signal of the opposite. As explained in Smith and Valcarcel (2022) for QT, the signaling effect is only verified on tapering events. This is because the signaling channel exists due to the role of expectations, and therefore it is more pronounced in significant changes in policy. As wind-down events are simply letting the current bonds in the portfolio mature, there is not a fast change in policy and so the markets do not expect

[2] In the formulas, the yield of a sovereign bond will be represented as y, the Default Premium will be represented as DP, the Redenomination Premium as RP, the Segmentation Premium as SP, and the Euro Swap Rate as ES.

the path of future interest rates to change. On the other hand, taper events result in fast changes in monetary policy and revisions about the future path of interest rates occur. For the case of the USA, this means an increase in the 8 Quarter ahead Eurodollar futures, which does not occur for wind-down events in the results presented in Smith and Valcarcel (2022).

The second term is the Term Premium (or Duration Risk Premium). Duration is the sensitivity of a security price to changes of interest rates levels and is calculated based on a fixed-income security's maturity and the interest rate it is subjected to. Let's imagine 2 zero-coupon bonds with principals equal to 100 million euros: Bond A has a maturity of 5 years and Bond B has a maturity of 10 years. If interest rates increase by 1 basis point, then the price of Bond A decreases by 50 thousand euros, but the price of Bond B decreases by 100 thousand euros. As higher maturity bonds have higher duration, then investors will require additional compensation to account for the added level of risk they are holding. However, central banks can absorb some duration risk that is held by investors, by purchasing longer maturity bonds. According to Vayanos and Vila (2021), when preferred-habitat investors, characterized by their preference for certain maturities irrespective of their price, increase their holdings over certain maturities they are also reducing the amount of duration risk on the hand of arbitrageurs, investors that only care about bond prices, who increase their holdings over these bonds. When the increase in holdings occurs over long-term maturities, the term premium is suppressed as the duration risk of long-term maturities is reduced, and the yield of longer-term maturities becomes more similar, or even smaller, than the yields of shorter-term maturities. So, QE is expected to reduce the term premium, while QT is expected to increase the term premium.

Both channels will be measured in sum, by the Euro Swap Rate (ESTER Overnight Indexed Swaps), extracted from Bloomberg. This rate functions as a proxy for the risk-free rate, as explained in Hull (2012, 164-165).

The next channel is the Default Premium, which is the additional compensation required by investors due to the expected losses for default. Considering a two-period model, the Default Premium is defined by the probability that a country defaults on their debt (D), and the percentage of what investors are entitled to that they will not receive (recovery rate - r). K is a time discount variable.

$$DP_t^c = N_t^{€,c} * E[D_{t+1}^c * (1 - r_{t+1}^c)] * k \qquad (2)$$

QE events are expected to decrease the Default Premium, since increased purchases of debt by the ECB will allow governments to get funding at lower rates, making it less likely they will default on their debts. It also gives confidence to the markets that the ECB may function as a lifeline for governments that are on the verge of defaulting, keeping them from doing so.

QT events, on the other hand, are expected to do the opposite. Since the ECB lowers the "support" for governments funding, they may become more likely to default. However, markets may still recognize that the ECB will end QT and restart QE if the financial situation of any particular government becomes too dire.

The next channel is the Redenomination Premium, which is the additional compensation required by investors due to the expected losses in a Redenomination event. In a Redenomination event, Portugal would leave the Euro for a new national currency which would devalue in relation to the Euro or against a new benchmark currency.

As with Default Risk, the additional compensation that investors require for Redenomination is equal to the expected losses the event would cause:

$$RP_t^c = N_t^{€,c} * E\left[R_{t+1}^c * \left(-x_{t+1}^{c/EUR}\right)\right] * k \qquad (3)$$

So, the Redenomination Premium is defined by the probability of a Redenomination event times the expected devaluation of the currency comparatively to the benchmark currency.

However, unlike Default Premium, it is possible for Redenomination Premium to be negative, if investors expect the new currency to gain value comparatively to the benchmark currency. In that case, a Credit Default Swap would not trigger payments, but it would mitigate the expected losses caused by Default.

Since a Redenomination event becomes more likely as the risk of a default event increases, QE and QT are expected to affect Redenomination Risk in the same direction that it affects Default Risk.

The last channel that composes the yield is the Segmentation Premium. This value differs from 0 whenever investors differ on their valuation of the bond, or whenever they face constraints that impede them from purchasing or selling the bond at will. For example, if the market is facing liquidity constraints and the price of a bond on the secondary market is below its “correct price”, investors may not be able to purchase as many bonds as they would like. Then the bond remains underpriced, leading to high yields and a positive segmentation component. On the other hand, if investors consider that the bond is overpriced, they will want to hold a short position on the bonds. But there can be market restrictions that do not allow them to take such a position, which will mean the bond remains overpriced, leading to low yields and a negative segmentation component.

QE will therefore increase the liquidity present in the market, reducing the Segmentation component. QT will increase the Segmentation component, by reducing market liquidity.

3.1. Identification of the channels

The Default, Redenomination and Segmentation components are not directly observable. The Euro Swap is observable and is extracted directly from Bloomberg for each specific maturity used.

To calculate the three channels, the Credit Default Swaps (CDS) of Portugal and Germany will be utilized for maturities of 6 months, 2-, 5-, 7-, and 10-years. The analysis will include CDS's both in euros and dollars and consider different clauses. For Portugal, the CDS's from the 2014 ISDA convention are used, and for Germany the CDS's defined by both the 2003 and 2014 ISDA conventions are used. All the CDS data was extracted from Refinitiv.

The main differences between the CDS14 and CDS03[3], consist in how they incorporate Redenomination Risk. CDS03 defines that losses from Redenomination Events are not included for countries that are in the G7 or have a AAA credit rating. So, if Germany dropped the Euro and replaced it with a devalued "German Mark" that would not trigger CDS03 payments, but, if Portugal replaced the Euro with a devalued "Escudo" that would trigger CDS03 payments. CDS14 incorporates Redenomination Risk for all countries, so if Germany and/or Portugal suffered a Redenomination event, that would trigger CDS14 payments for both countries.

That means that for G7 or AAA rated countries, the difference between CDS14 and CDS03 is the Redenomination Premium component, an approach called the ISDA Basis. But for countries not part of this group, it is harder to calculate it.

[3] From this point CDS's from the 2014 and 2003 conventions will be written as CDS14 and CDS03, respectively.

In this thesis, a new method to calculate the Redenomination Premium will be used, specifically useful for non-G7/non-AAA Euro Area countries, which involves calculating the Intra-Euro Area Redenomination Premium[4] in addition to using the Redenomination Premium from Germany:

$$RP_{Pt} = IEARP + RP_{Gr} \tag{4}$$

The Intra-Euro Area Redenomination Premium, which shows the expected devaluation of the Portuguese currency versus the German currency, is equal to the difference between the Quanto CDS for Portugal and the Quanto CDS for Germany. The Quanto CDS, the difference between the CDS spreads in Euros and Dollars, captures the premium required by investors due to the expected devaluation of the national currency against the US dollar.

As explained in De Santis (2018), in the perspective of an American investor, a CDS's premium leg is defined as equal to the expected losses covered by the CDS, which in the case of CDS14 includes losses from default and currency devaluation:

$$N_t^{€} E\left[CDS_t^{€} * X_t{}^{c/USD} * (1 - D_{t+1})\right] = N_t^{€} E\left[X_{t+1}{}^{c/USD} * D_{t+1}\right] \tag{5}$$

$$N_t^{\$} E\left[CDS_t^{\$} * (1 - D_{t+1})\right] = N_t^{\$} E[D_{t+1}] \tag{6}$$

Formulas 5 and 6 define the components of the CDS's in Euros and Dollars, assuming a two-period model and a recovery rate of 0%. The expected losses for an investor, written on the right side of the formula, are equal to the expected probability of default (represented as a D) for the CDS in US dollars. For the CDS in Euros, the expected losses are equal to the probability of default times the expected National Currency/USD exchange rate in case of default (represented as $X_t{}^{c/USD}$).

The premium leg, the left side of the equation, represents the payments the investor is expected to make, which should be equal to the value of the expected losses. The expected value of the

[4] The Intra-Euro Area Redenomination Premium will be written as IEARP.

payments is equal to the payments (as the CDS spread) times the probability that a default event does not occur, for the CDS in US Dollars. For Euro CDS, the expected payments are equal to the expected payments for Dollar CDS times the exchange rate National Currency/USD at the period of payment.

Isolating the CDS spreads in equations 5 and 6, the final formulas are obtained. The value of x is calculated by diving the expected exchange rate at period t+1 by the exchange rate at period t, obtaining the expected depreciation of the euro or the new national currency against the US Dollar:

$$CDS_t^{€} = \frac{E\left[D_{t+1} * \left(1 + x_{t+1}^{c/USD}\right)\right]}{E[(1 - D_{t+1})]} \tag{7}$$

$$CDS_t^{\$} = \frac{E[D_{t+1}]}{E[(1 - D_{t+1})]} \tag{8}$$

These values for the CDS's are not denominated in any currency, since the notionals from both legs annul themselves, being denominated in basis points. Therefore, the only difference in the values for the CDS in Euros and Dollars corresponds to the additional premium required by investors holding euro denominated assets due to the expected appreciation of the US Dollar against the euro or a new national currency.

The difference between the Dollar and Euro CDS's will be represented as following:

$$QuantoCDS_t^{c} = CDS_t^{\$} E\left[-x_{t+1}^{c/USD}\right] + \frac{COV\left[-x_{t+1}^{c/USD}, D_{t+1}\right]}{E[(1 - D_{t+1})]} \qquad (9)^{5}$$

The Default Premium is eliminated because it is the same across both CDS's. The first component is the expected depreciation of the euro or new national currency against the US Dollar, weighted by the CDS Premium in Dollars, and the second premium is a currency risk premium, which

[5] The full formula calculation is in the annexes, as formula (A1).

becomes larger as the risk of default increases. As shown, the Quanto CDS isolates the premium required by investors based on the expected depreciation of the euro or new national currency against the US Dollar.

This depreciation premium has two overarching components: The premium required due to the depreciation of the new national currency against the euro (Euro RP); and the premium required due to the depreciation of the Euro against the Dollar (Exchange Risk Euro/Dollar):

$$QuantoCDS_t^c = Euro\ RP_t^c + Exchange\ Risk\ Euro/Dollar_t^c \tag{10}$$

The Intra-Euro Area Redenomination Premium is the difference between two Euro Area countries Quanto CDS's, specifically Portugal and Germany for this thesis. This difference eliminates the euro exchange risk component, because it is the same for both countries, and maintains the redenomination premia of the domestic currency with respect to the euro:

$$IEARP = Euro\ RP_t^{Pt} - Euro\ RP_t^{Gr} \tag{11}$$

If the Euro is considered irreversible, then the Euro Redenomination Premium will be 0 for both countries and so will the Intra-Euro Area Redenomination Premium. If, however, the Portuguese Quanto CDS is higher than the German Quanto CDS, then Portugal is expected to have higher Redenomination losses compared to Germany's expected Redenomination losses.

On this first step, the IEARP defines the premium required by investors due to Portugal having higher Redenomination losses than Germany, and it specifies how higher than Germany's the Redenomination Premium of Portugal is.

To determine exactly the value of the Portuguese Redenomination Premium, Germany's Redenomination Premium must be added to the IEARP. The value for Germany's Redenomination Premium is found by calculating the ISDA Basis.

The CDS14 is triggered for both Redenomination and Default Events which cause losses, so its spread is composed of the sum between the Default and Redenomination Premia:

$$CDS14_t^{Pt,€} = DP_t^{Pt} + RP_t^{Pt} \tag{12}$$

The Redenomination Premium was previously calculated, so the Default Premium is the difference between CDS14 and the Redenomination Premium.

The last channel is calculated as the residual value of the yield. The Segmentation Premium is equal to the bond yield minus all the previously defined channels: Euro Swap Rate, Redenomination Premium, and Default Premium.

The channel decomposition for the 5-year maturity is the following, for the 2020 to 2023 period:

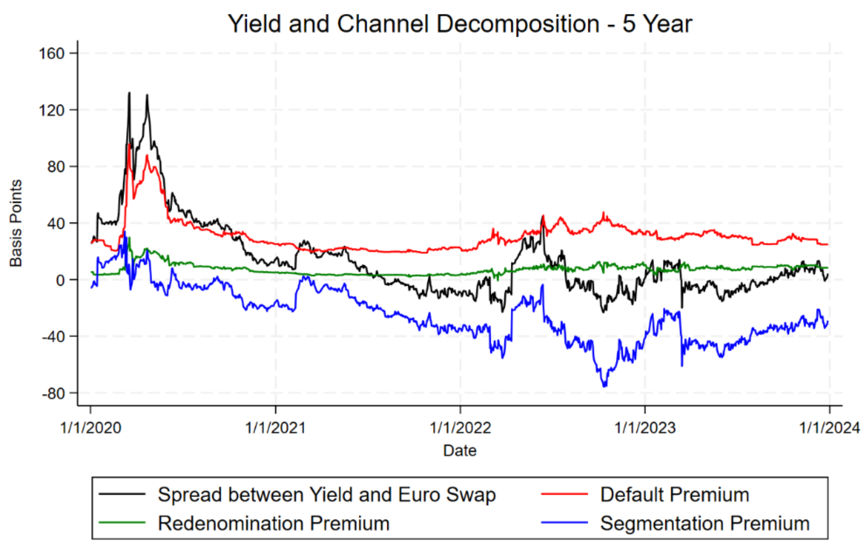

Figure 1 - Spread between Yield and Euro Swap and Channel Decomposition for the 5-year maturity[6]

[6] The decomposition for the other maturities and the values for the Euro Swap and Yield are in figures A1 to A6 in the annexes.

3.2. Limitations

There are some limitations and biases in the channel estimations that are important to consider:

Germany's ISDA Basis: To calculate Germany's Redenomination Premium the ISDA Basis is used. This method assumes only the Redenomination Premium exists between CDS14 and CDS03, but in reality, there are three components, the Redenomination Premium, a Liquidity Component and the APD Premium (the Asset Package Delivery). The liquidity component exists since the CDS03 contracts are less liquid than the CDS14 contracts, so, the CDS03 will include a Liquidity premium component higher than the CDS14 has, resulting in a net negative Liquidity Premium. The APD relates to the fact that the CDS14 allows investors to receive payments if the defaulted debt is converted into new devalued debt. Under the CDS03 if a country forced investors to exchange their bonds with lower value bonds to avoid default, investors could not receive CDS payments on those losses. Under CDS14, those losses for investors trigger CDS payments, so there are higher losses covered under this CDS clause so it will have a higher spread. The presence of an APD premium can be confirmed by looking at the difference between CDS14 and CDS03 for Portugal and Spain, since if there was no APD (and Liquidity Premium) the difference would be zero (Figure A7). Since they are not, then there are additional components that cause the CDS14 to be higher. The APD is positive, since it only exists on CDS14, and the Liquidity Premium is negative, so the APD must be larger than the Liquidity Premium.

The existence of a positive premium would result in an upwardly biased value for Germany's Redenomination Premium, which in turn, would lead to a downwardly biased Portuguese Redenomination Premium and an upwardly biased Portuguese Default Premium.

On average, for Portugal and Spain around 30% of the value of CDS14 corresponds to the net premium between APD and LP in the 2020-2023 period, with relatively low variation over time

(Figure A7). Calculating the APD premium as the ISDA Basis minus the value for Redenomination Premium calculated using the methodology of the thesis, the value will be on average around 18% of CDS14 for France. Because the APD correlates highly with the Default Premium, the APD decreases as the Default Premium decreases, so likely, the APD premium for Germany is lower than the APD premium for France, which is lower than the APD premium for Portugal and Spain. Therefore, this net premium will be assumed to be stable over the analyzed period, which would not have any impact on the results, since the analysis will be performed in first differences, therefore eliminating any fixed effects. The German Redenomination Premium will therefore be biased upwards, although the bias will be very low. If the APD minus Liquidity Premium varies between 0% to 20% of CDS14 for Germany, then for the 5-year maturity, the first differences of the Redenomination Premium will be at most biased by 0.7 basis points (Figure A8).

Intra-Euro Redenomination Premium: In the calculations for this premium 4 different financial products are used: CDS14 in both euros and dollars for Portugal and Germany. These CDS contracts in different currencies will not have the same liquidity, so there will be a liquidity premium present. However, this specific methodology minimizes any potential biases that may arise, since the CDS's in dollars for Portugal are subtracted by CDS's in dollars for Germany, eliminating the liquidity premium present in both dollar CDS's and the same for the Euro CDS's. But as with the ISDA basis, even if there is a bias, it will likely be stable over time, meaning that in the analysis phase it will be eliminated.

4. Methodology for Abnormal Returns

4.1. Abnormal effects of QE and QT

To determine the abnormal effects of each event on the yield of Portuguese Bonds and its channels, the following models were constructed for each of the 4 channels:

$$Predicted\ \Delta DP^{c}_{T,t} = \alpha \Delta DP^{c}_{T,t-1} + \beta QA \tag{13}$$

$$Abnormal\ Return\ DP^{c}_{T,t} = Actual\ \Delta DP^{c}_{T,t} - Predicted\ \Delta DP^{c}_{T,t} \tag{14}$$

The coefficients α and β of formula (13) are determined by OLS using a 60-day estimation period, up to 5 days before the event, in which the predicted value for the channel is obtained. QA is a dummy variable which is equal to 1 whenever there is either a QE or QT announcement on a day in the 60-day estimation period. The abnormal returns for any day are obtained by subtracting from the actual value of the channel by its predicted value. The abnormal returns of the event are the sum of the abnormal returns of the day of the event and the following day, to account for late-day announcements on the day of the event (Figure A9).

The daily change of the yield of Portuguese Bonds is equal to the sum of the daily change of all its channels. If there is an abnormal component in each of the channels, then the sum of all the abnormal components will be equal to the abnormal component of the yield:

$$\Delta y^{c}_{T} + AR^{y,c}{}_{T,t} = \left(\Delta ES_{t} + AR^{ES,c}{}_{T,t}\right) + \left(\Delta DP^{c}_{T} + AR^{DP,c}{}_{T,t}\right)$$
$$+\left(\Delta RP^{c}_{T} + AR^{RP,c}{}_{T,t}\right) + \left(\Delta SP^{c}_{T} + AR^{SP,c}{}_{T,t}\right) \tag{15}$$

The sum of the normal component of the channels is equal to the normal component of the yield as well. So, the value for the yield and for the channels is composed of both a normal component and an abnormal component, which results from the ECB announcements that could either reduce or increase the value of the channels against what was expected based on the trend. Therefore, the abnormal effects of each announcement on the yield of the Portuguese Sovereign Bond will be:

$$AR^{y,c}{}_{T,t} = AR^{ES,c}{}_{T,t} + AR^{DP,c}{}_{T,t} + AR^{RP,c}{}_{T,t} + AR^{SP}{}_{T,t} \quad (16)$$

4.2. Comparison of Methodology with the literature

To ensure the thesis methodology produces accurate results, it is used for a period already analyzed using a different methodology. The analysis is performed in 2010 and 2011 in comparison with Krishnamurthy, Nagel and Vissing-Jorgensen (2018) for the SMP and OMT, which are the more similar programs to APP and PEPP.[7]

The results for the yield (Table A1) and the channels (Tables A2 and A3) are similar between both analyses, showing that despite the difference in methodologies the results show the same conclusion. There are two important caveats to consider: First, because these dates are before 2014, it is not possible to separate the Default and Redenomination Premia using the methodology of the thesis, so the comparison is performed with the channels combined. Second, the paper does not provide information regarding the effects on the channels for each maturity, only the average across the maturities analyzed. Therefore, for the comparison with the paper, the 5-year maturity is used as it likely has the most similar results with the average.

The effects for the Euro Swap and the Segmentation are similar both on aggregate and for individual dates. The Default + Redenomination channels effects are lower using the thesis methodology, possibly due to the paper estimating the channels separately. Despite that, these results follow the trend of the results presented in the paper.

[7] The decomposition of the channels for 2010 and 2011 is in figure A10.

5. Results and Discussion

The values for the 2-day abnormal effect of the events on the yields and its channels are best seen as reactions to the possible effects of a given ECB program or action, and not as the full effect. Therefore, the results are driven by the markets' perceptions about the likely effect of the programs.

The presentation of the results and the analysis will focus on the 5-year maturity, with the results for the remaining maturities being presented in the annexes. The conclusions for the other maturities are similar to the conclusions for the 5-year maturity.

The effects QE and QT have on the bond yields are influenced differently by the channels and not all events affect the yield similarly. For QE, the Euro Swap Rate and the Segmentation channel do not have an aggregate significant effect on the yield, although they produce significant effects for certain dates, and the Default and Redenomination channels are responsible for decreasing the bond yield, having significant effects for all dates except the last. For QT, all channels except the Redenomination channels significantly increase the bond yield on aggregate. However, the effects are very different across dates, especially between taper and wind-down events:

Table 1 - Results per date for the 5 Year Maturity in Basis Points[8]

Policy	Date	Yield	Euro Swap	Default	Redenomination	Segmentation
QE-APP	10/03/2020	-6	**7*** **	**6** **	**7*** **	**-25*** **
QE-PEPP	18/03/2020	**-29*** **	3	**-31*** **	**-11*** **	**9*** **
QE-PEPP	04/06/2020	**-18*** **	**-9*** **	**-7** **	**-12*** **	**9** **
QE-PEPP	10/12/2020	-2	-1	0	0	-1
	QE – Sum	**-54*** **	0	**-32*** **	**-16*** **	**-7* **
QT-APP	09/06/2022	**36*** **	**20*** **	**4*** **	1	**12*** **
QT-APP	15/12/2022	**32*** **	**21*** **	1	**3** **	**7** **
QT-APP	04/05/2023	1	-3	2	-1	4
QT-PEPP	14/12/2023	**-22*** **	**-17** **	-1	0	-4
	QT - Sum	**47*** **	**21*** **	**5*** **	1	**19*** **

[8] The ***, ** and * denote the value is significant at a 1%, 5% and 10% levels, respectively.
All the values in all the tables are in basis points and rounded to the first unit.

5.1. Effects on the Euro Swap Rate

For QE, the first APP date produces positive significant effects which indicates that the market anticipated a stronger action by the ECB, and so it adjusted the expectations regarding the path of interest rates and the value of the duration risk. On the other hand, for the second PEPP event the opposite occurred, since the ECB actions exceeded market expectations, so they adjusted their expectations resulting in a drop in the value for the Euro Swap.

On aggregate, the Euro Swap Rate did not have a significant effect on the yield, so the announcements did not work in decreasing interest rates. This is expected, as the effects of QE on the market perceptions regarding the future path of the interest rates have decreased over time. In Krishnamurthy and Vissing-Jorgensen (2011) there are significant effects for the decrease in the real interest rates for both QE1 and QE2 caused by increases in inflation expectations and decreases in the nominal interest rate, but in Krishnamurthy, Nagel and Vissing-Jorgensen (2018) the effects on the real interest rate are smaller and not significant for some maturities.

For QT, the first 2 dates produced significant positive effects on the Euro Swap Rate, and the last two dates produced negative effects on the Euro Swap Rate, with the last date being significant. This occurred because the first two events are taper events, in which the ECB decreased the level of purchases, so the markets adjusted their expectations regarding the future path of interest rates. The expected increases of the key interest rates likely did not have significant effects on increasing the Euro Swap channel. As seen in Table A11, the abnormal returns of the key interest rates, on dates where no QT announcement was made, show that at neither event the effects were significant. This likely occurs because the markets anticipate key interest rate increases based on economic conditions, before official ECB announcements. So, increases in the key interest rates do not produce abnormal effects at the date of the event, as that information was already incorporated in the channel premium. The last event was a wind-down event, so the effects were expected to be lower, but not negative. This likely occurred because the market was anticipating a stronger QT stance, with a more aggressive end to reinvestments. Since that was not the case, the expectations had to be adjusted.

5.2. Effects on the Default Premium

For QE, the effects on the Default Premium are mostly significant for the event which creates the PEPP. As with the Euro Swap Rate there are significant positive effects for the first event, which likely shows that the market was expecting stronger action by the ECB and adjusted its expectations upwardly.

QT only significantly impacted the premium for the first date and for the other dates the effects are not statistically significant. These results were also expected, since QE gives the markets more security that a country will pay back its debt. QT does not have the opposite effect, at least to the same degree since markets expect the ECB to be flexible in applying QT if a country's financial situation becomes too dire.

5.3. Effects on the Redenomination Premium

QE reduces the yields through the Redenomination Channel mainly through the second and third dates. The first date, as with the previous two channels, can be explained by the same reasoning. These results are to be expected since QE gives the markets more security that a country will pay back its debt, ensuring they are also more likely to retain the Euro. For QT, the effects are not significantly different from 0, since the markets likely expect the ECB to be flexible in applying QT for any country that is at risk of leaving the Euro.

5.4. Effects on the Segmentation Premium

For QE, the effects are negative for the first date, and positive for the second and third dates. The first QE event was important for increasing market liquidity during an unstable period, and so despite the package announced not corresponding to the amount expected to the market, resulting in increases for all other channels, it allowed for a drop in the Segmentation component. For QT, the effects are most pronounced on the first two dates. Because these dates are taper events, the market expects these events to have a more significant impact on market liquidity resulting in a larger increase in the yields. The increase of the key interest rates could have some effect on the Segmentation channel, but as shown in Table A11, these effects seem very small. On aggregate, the results fall in line with what was expected.

5.5. Effects on the Portuguese Sovereign Bond Yield

For QE, the only two significant events are the announcement of PEPP and the first additional package. The announcement of PEPP affected the yield mainly through the Default and Redenomination channels and the first additional package affected the yield mainly through the Euro Swap, Default and Redenomination channels. The last date is not significant, which can indicate that the market already anticipated the second additional package before the announcement date. For QT, the two taper events are significant, mainly affected by the Euro Swap Rate. The last QT event is also significant but negatively impacted mainly through the Euro Swap Rate. The last APP date is not significant, but unlike QE, this does not indicate the market already anticipated the announcement. As this date was a wind-down event, the expected result is that there is no significant effect on the yield, as there is not a significant shift in policy.

6. Conclusion

The main contribution of this thesis is the framework to decompose the bond yield into the channels which allows for the calculation of the Redenomination Premium for non-G7/AAA rated Euro Area countries.

This thesis shows that QE announcements in 2020 had an aggregate effect in reducing the yields through the Default and Redenomination Premia, as shown in the literature for previous periods. The Euro Swap Rate does not impact the yield, unlike the literature, due to the exceptionally low interest rate that existed in the markets. The results for QT during the 2022 to 2023 period show that the yield increases through the Euro Swap Rate and to a lower extent, the Segmentation component. These effects occur during taper events, as it is presented in the literature.

This methodology could be useful to replicate this study to other Euro Area countries, to understand if the channels behave equally across the Euro Area or if it is an isolated phenomenon for Portugal. It could also be useful for other programs, such as the Transmission Protection Instrument, announced in July 2022. Additionally, it could also be interesting to analyze if the effects of announcements are persistent over time, or if they are simply temporary. The Euro Swap Rate was not separated into a signaling component and duration risk premium, because based on previous literature, it did not seem useful due to the low values of the abnormal effects on the Euro Swap Rate. However, this separation may prove useful in better describing the behavior of the channel for QT, for which there are larger effects.

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Data

Portuguese Sovereign Bond Yields – Bloomberg

Germany Sovereign Bond Yields - Bloomberg

ESTER Overnight Indexed Swap - Bloomberg

Credit Default Swaps (CDS14, CDS03, CDS in Euros, CDS in Dollars) – Refinitiv

Appendix

Table A1 - Comparison between the results from *Krishnamurthy, Nagel and Vissing-Jorgensen (2018)* and the Thesis – 2-day Abnormal effects on the Portuguese Sovereign Bond Yield[9]

Yield	Date	5Y – Krishnamurthy, Nagel, Vissing-Jorgensen	5Y - Thesis
SMP	10/03/2010	**-268***	**-197***
	07/08/2011	**-188***	**-152***
	SMP Sum	**-456***	**-349***
OMT	16/07/2012	-3	-8
	02/08/2012	-42	**-50***
	06/09/2012	**-107***	**-80***
	OMT Sum	**-152***	**-138***

Table A2 - Results with Thesis Methodology for the Dates in *Krishnamurthy, Nagel and Vissing-Jorgensen (2018)* for 5-year maturity – 2-day Abnormal Effects

Program	Date	Euro Swap	Default + Redenomination	Segmentation	Yield
SMP	10/03/2010	9	**-140***	**-66***	**-197***
SMP	07/08/2011	**-21***	-31	**-101***	**-152***
	SMP Sum	**-12***	**-170***	**-167***	**-349***
OMT	16/07/2012	0	-52	44	-8
OMT	02/08/2012	**7***	30	**-87***	**-50***
OMT	06/09/2012	6	-40	-46	**-80***
	OMT Sum	**13***	**-62***	**-89***	**-138***

[9] The tables A1, A2 and A3 only look at 5% significance, as that is the only information presented in Krishnamurthy, Nagel and Vissing-Jorgensen (2018).

Table A3 - Results with Methodology from *Krishnamurthy, Nagel and Vissing-Jorgensen (2018)* – Average for 6-month, 2-, 5-, 10-year maturities – 2-day Abnormal Effects

Program	Date	Euro Swap - 5Y only	Default + Redenomination	Segmentation
SMP	10/03/2010	5	**-198***	**-79***
SMP	07/08/2011	**-15***	**-48***	**-88***
	SMP Sum	-10	**-246***	**-167***
OMT	16/07/2012	4	-32	25
OMT	02/08/2012	6	-24	-67
OMT	06/09/2012	6	**-89***	-9
	OMT Sum	16	**-144***	-51

Table A4 – 2-day Abnormal QE effects on the channels and yield per maturity in basis points

Maturity/ Channel	Yield	ES	DEF	RED	SEG
6M	-1	**-2***	**-12*****	**-7*****	**19*****
2Y	**-41*****	-1	**-18*****	**-13*****	**-10*****
5Y	**-54*****	0	**-32*****	**-16*****	**-7***
7Y	**-62*****	2	**-30*****	**-17*****	**-17*****
10Y	**-64*****	3	**-27*****	**-19*****	**-22*****
Average except 6M	-55	1	-27	-16	-14

Table A5 – 2-day Abnormal QT effects on the channels and yield per maturity in basis points

Maturity/ Channel	Yield	ES	DEF	RED	SEG
6M	**92***	**6***	-1	**4*****	**84*****
2Y	**32*****	**26*****	**2***	**3*****	3
5Y	**47*****	**21*****	**5*****	1	**19*****
7Y	**47*****	**20*****	**8*****	1	**19*****
10Y	**44*****	**19*****	**8*****	**2***	**14*****
Average except 6M	42	22	6	2	14

Table A6 – 2-day Abnormal QE and QT effects on the Euro Swap Rate

Policy	Date	6-Month	2-year	5-year	7-year	10-year
QE-APP	10/03/2020	1	**3****	**7*****	**8*****	**9*****
QE-PEPP	18/03/2020	-2	1	3	**5***	**6***
QE-PEPP	04/06/2020	-2	**-4*****	**-9*****	**-9*****	**-8*****
QE-PEPP	10/12/2020	0	0	-1	-2	-3
	QE – Sum	**-2***	-1	0	2	3
QT-APP	09/06/2022	3	**24*****	**20*****	**17****	**13***
QT-APP	15/12/2022	**9*****	**25*****	**21*****	**20*****	**18*****
QT-APP	04/05/2023	-6	-9	-3	0	3
QT-PEPP	14/12/2023	0	**-13***	**-17****	**-17****	**-15****
	QT - Sum	**6***	**26*****	**21*****	**20*****	**19*****

Table A7 - 2-day Abnormal QE and QT effects on the Default Premium

Policy	Date	6-Month	2-year	5-year	7-year	10-year
QE-APP	10/03/2020	2	3	**6****	**6****	**7***
QE-PEPP	18/03/2020	**-12*****	**-19*****	**-31*****	**-31*****	**-30*****
QE-PEPP	04/06/2020	-1	-2	**-7****	-5	-3
QE-PEPP	10/12/2020	0	0	0	0	0
	QE – Sum	**-12*****	**-18*****	**-32*****	**-30*****	**-27*****
QT-APP	09/06/2022	1	**3****	**4*****	**4*****	**4****
QT-APP	15/12/2022	-1	-1	1	2	2
QT-APP	04/05/2023	0	0	2	**3***	2
QT-PEPP	14/12/2023	0	0	-1	-1	-1
	QT - Sum	1	**2***	**5*****	**8*****	**8*****

Table A8 - 2-day Abnormal QE and QT effects on the Redenomination Premium

Policy	Date	6-Month	2-year	5-year	7-year	10-year
QE-APP	10/03/2020	**2*** **	**3*** **	**7*** **	**7*** **	**7*** **
QE-PEPP	18/03/2020	**-6*** **	**-8*** **	**-11*** **	**-11*** **	**-12*** **
QE-PEPP	04/06/2020	**-3*** **	**-9*** **	**-12*** **	**-13*** **	**-14*** **
QE-PEPP	10/12/2020	0	0	0	0	0
	QE – Sum	**-7*** **	**-13*** **	**-16*** **	**-17*** **	**-19*** **
QT-APP	09/06/2022	0	0	1	1	**3* **
QT-APP	15/12/2022	**3*** **	**3*** **	**3** **	2	2
QT-APP	04/05/2023	0	0	-1	**-2* **	-1
QT-PEPP	14/12/2023	0	0	0	0	0
	QT - Sum	**4*** **	**3*** **	1	1	**2* **

Table A9 - 2-day Abnormal QE and QT effects on the Segmentation Premium

Policy	Date	6-Month	2-year	5-year	7-year	10-year
QE-APP	10/03/2020	-3	**-9*** **	**-25*** **	**-28*** **	**-28*** **
QE-PEPP	18/03/2020	**33*** **	1	**9*** **	**7* **	5
QE-PEPP	04/06/2020	**-8*** **	-1	**9** **	5	0
QE-PEPP	10/12/2020	-3	-1	-1	-1	1
	QE – Sum	**19*** **	**-10*** **	-7*	**-17*** **	**-22*** **
QT-APP	09/06/2022	-1	6	**12*** **	**11*** **	**10*** **
QT-APP	15/12/2022	-3	-5	**7** **	**7** **	**6** **
QT-APP	04/05/2023	**79*** **	5	4	1	1
QT-PEPP	14/12/2023	9	-4	-4	-1	-4
	QT - Sum	**84*** **	3	**19*** **	**19*** **	**14*** **

Table A10 - 2-day Abnormal QE and QT effects on the Portuguese Sovereign Bond Yield

Policy	Date	6-Month	2-year	5-year	7-year	10-year
QE-APP	10/03/2020	2	0	-6	-7	-6
QE-PEPP	18/03/2020	**14*** **	**-24*** **	**-29*** **	**-30*** **	**-31*** **
QE-PEPP	04/06/2020	**-14*** **	**-16*** **	**-18*** **	**-22*** **	**-25*** **
QE-PEPP	10/12/2020	-2	-1	-2	-3	-2
	QE – Sum	-1	**-41*** **	**-54*** **	**-62*** **	**-64*** **
QT-APP	09/06/2022	2	**32*** **	**36*** **	**33*** **	**30*** **
QT-APP	15/12/2022	9	**22*** **	**32*** **	**31*** **	**28*** **
QT-APP	04/05/2023	73	-4	1	2	6
QT-PEPP	14/12/2023	8	**-18*** **	**-22*** **	**-19*** **	**-20*** **
	QT - Sum	**92***	**32*** **	**47*** **	**47*** **	**44*** **

Table A11 – 2-day abnormal effect of key ECB interest rate increases

Non-expected Increase	Date	Euro Swap	Segmentation
25 b.p.	20/07/2022	-2	**6***
75 b.p.	27/10/2022	4	-2

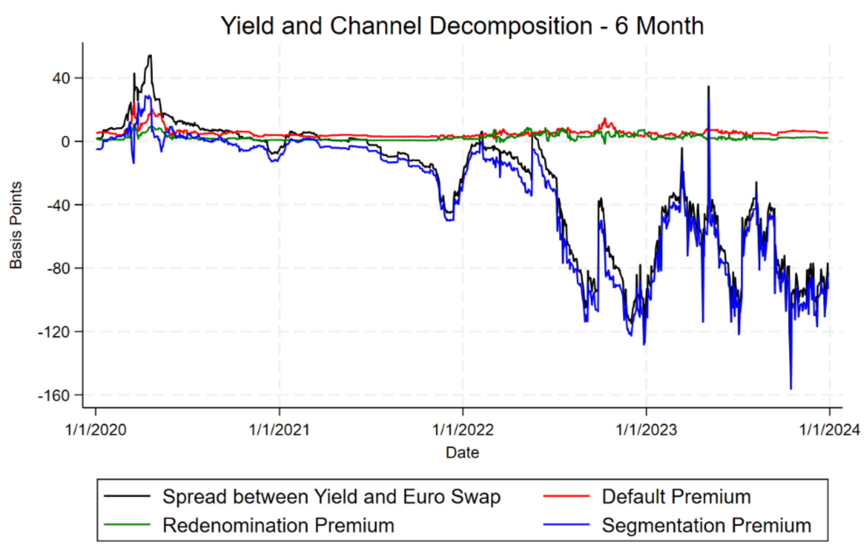

Figure A1 - Spread between Yield and Euro Swap and Channel Decomposition for the 6-month maturity

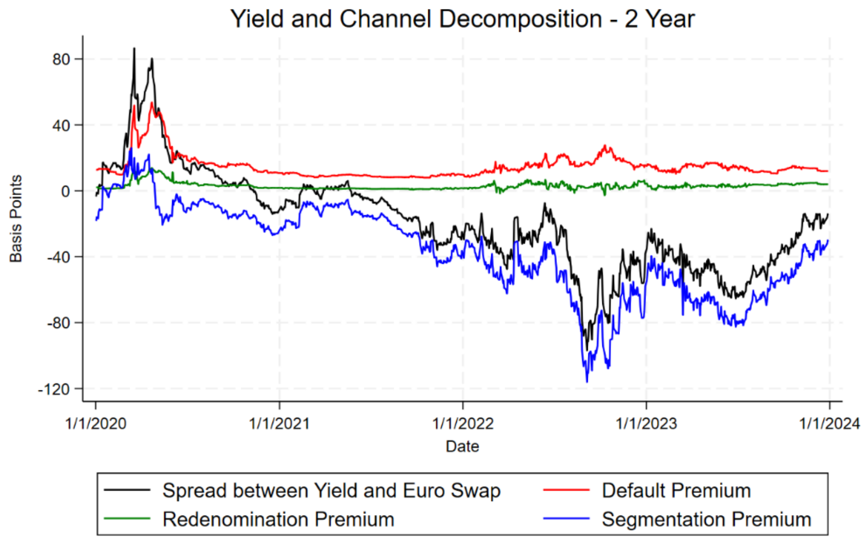

Figure A2 - Spread between Yield and Euro Swap and Channel Decomposition for the 2-year maturity

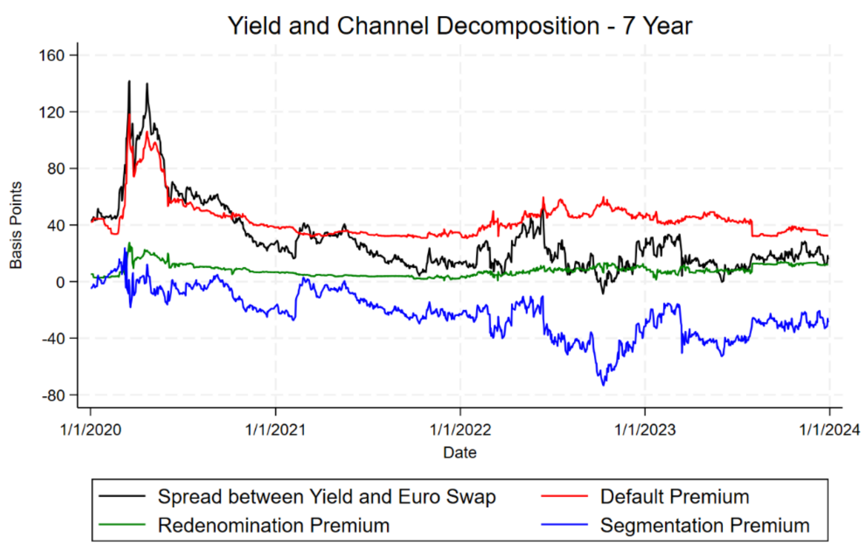

Figure A3 - Spread between Yield and Euro Swap and Channel Decomposition for the 7-year maturity

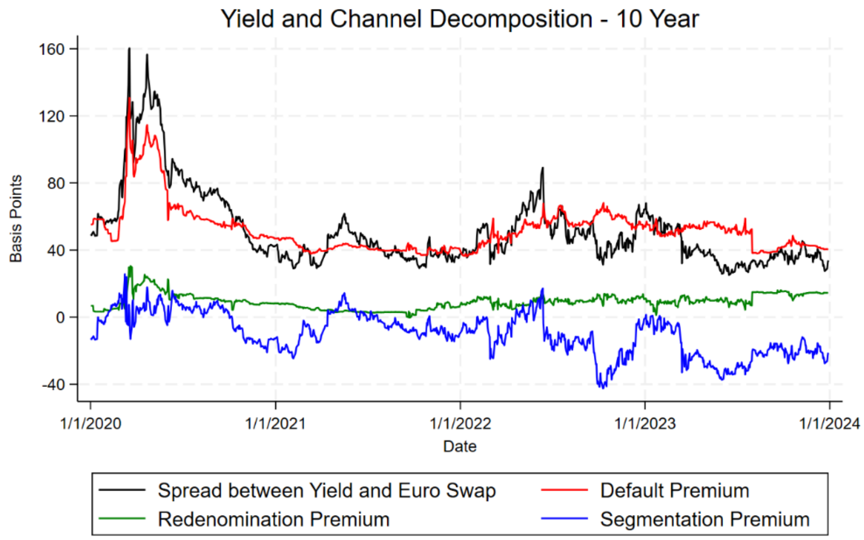

Figure A4 - Spread between Yield and Euro Swap and Channel Decomposition for the 10-year maturity

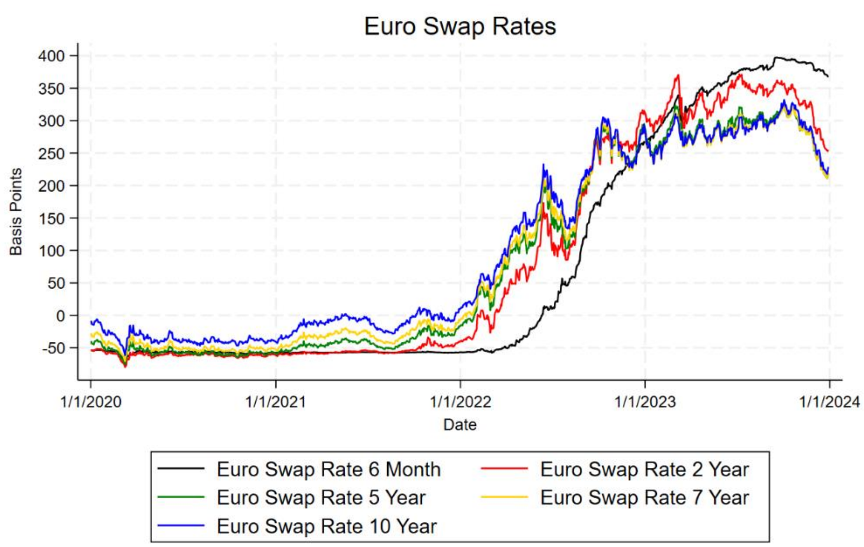

Figure A5 - Euro Swap Rate for all maturities analyzed

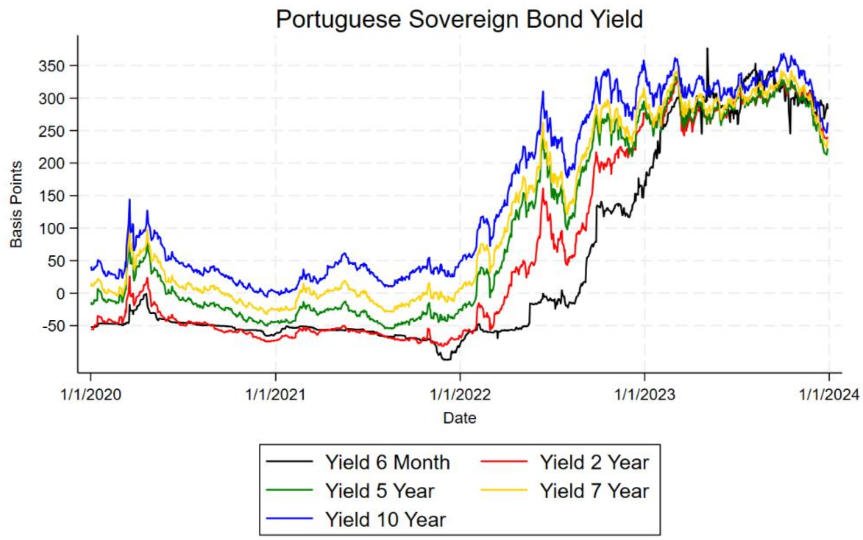

Figure A6 - Portuguese Sovereign Bond Yield for all maturities analyzed

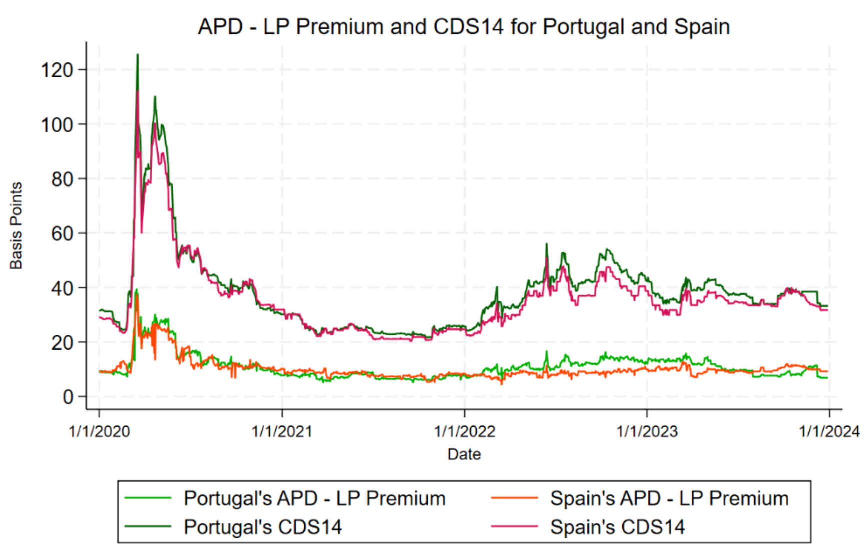

Figure A7 - Comparison between the Asset Package Delivery Premium minus the Liquidity Premium and the CDS14 for both Portugal and Spain

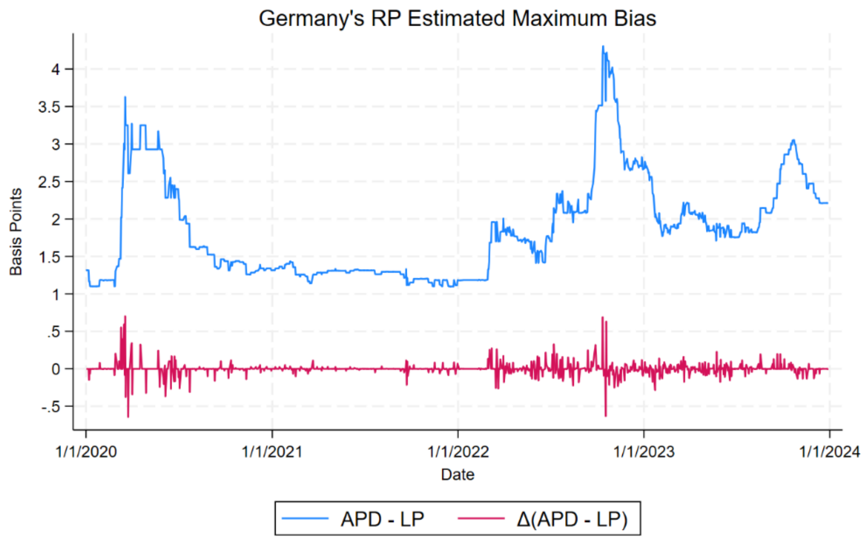

Figure A8 - Estimated maximum bias for Germany's Redenomination Premium due to the APD - LP

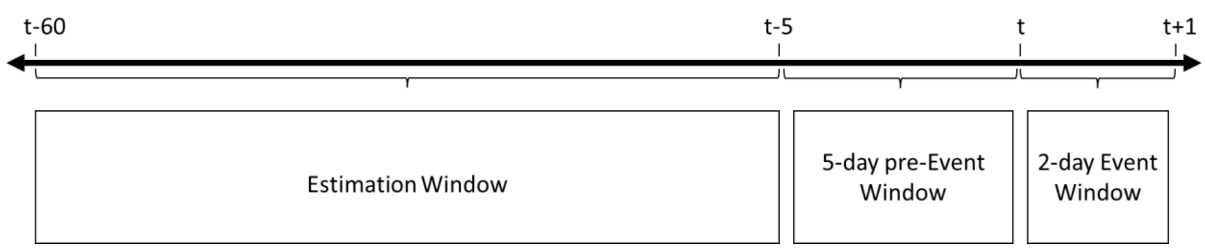

Figure A9 - Forecast Windows Chart

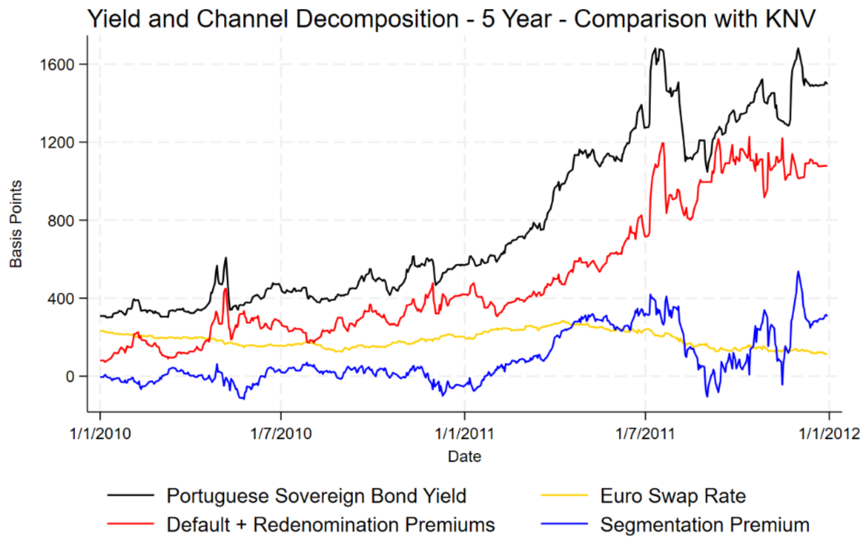

Figure A10 - Decomposition of the Yield for 2010 and 2011 - Used for the comparison with *Krishnamurthy, Nagel and Vissing-Jorgensen (2018)*

$$QuantoCDS_t^c = CDS_t^{\$} - CDS_t^{€} = \frac{E[D_{t+1}]}{E[(1-D_{t+1})]} - \frac{E\left[D_{t+1} * (1+x_{t+1}^{c/USD})\right]}{E[(1-D_{t+1})]}$$

$$= \frac{E[D_{t+1}]}{E[(1-D_{t+1})]} - \frac{E[D_{t+1}]}{E[(1-D_{t+1})]} - \frac{E\left[D_{t+1} * x_{t+1}^{c/USD}\right]}{E[(1-D_{t+1})]} \Leftrightarrow$$

$$\Leftrightarrow QuantoCDS_t^c = E\left[\frac{D_{t+1}}{(1-D_t)}\right] - E\left[\frac{D_{t+1}}{(1-D_t)}\right] + CDS_t^{\$} E\left[-x_{t+1}^{c/USD}\right] + \frac{COV\left[-x_{t+1}^{c/USD}, D_{t+1}\right]}{E[(1-D_{t+1})]}$$

$$\Leftrightarrow QuantoCDS_t^c = CDS_t^{\$} E\left[-x_{t+1}^{c/USD}\right] + \frac{COV\left[-x_{t+1}^{c/USD}, D_{t+1}\right]}{E[(1-D_{t+1})]} \qquad \text{(A1)}$$