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Correlation between Maltese and euro area sovereign bond yields

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WP/03/2017

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Abstract

This paper investigates correlation in Malta government stock (MGS) yields and assesses correlation between these yields and those of Malta's major euro area partners. Correlation coefficients are found to be high, indicating the existence of a long-run relationship in the setting of MGS yields with short-term deviations. The analysis also includes an MGARCH-DCC(1,1) system based on spreads over the German ten-year bond, which are modelled for eleven euro area countries. Dynamic conditional correlations (DCCs) confirm that Maltese ten-year bond yields tend to be broadly insulated from event specific volatility in other countries' yields. Simple 'benchmark' regressions are estimated over the period 2007 – 2016, allowing the comparison of actual ten-year bond yields with composite equation outputs. The benchmarked yields based on euro area bonds track consistently actual MGS yields, while from mid-2015 onwards, MGS yields follow closely a benchmark derived on the basis of underlying economic fundamentals.

JEL classification: E43, E44, E63

Keywords: correlation, sovereign bond yields, MGARCH-DCC, Malta.

Note

The author of this study had no access to the official methodology used by the Central Bank of Malta (CBM) in its market making role, and relied solely on observations available in the public domain. Moreover, the econometric modelling detailed in this paper is carried out for investigative purposes, and does not purport to be the official method with which the Bank carries out its market making activity.

Table of Contents

Abstract.....	ii
Note	iii
Introduction	1
Literature review.....	2
Data.....	7
Measuring rolling correlations.....	9
Measuring dynamic conditional correlations	10
Econometric modelling of MGS yields	13
International bond yield basket approach.....	13
'Economic fundamentals' MGS yields approach	15
Comparing actual MGS yields with benchmarked yields.....	17
Conclusions	19
References	20
Appendix 1: MGARCH-DCCs.....	21
Methodology.....	21
Pairwise DCC plots	22
Appendix 2: 'Economic fundamentals' sensitivity analysis.....	27

Introduction

Yields on long-term sovereign bonds are a fundamental metric in financial markets, as they act as benchmarks in the pricing of long-term financial assets as well as in financial decision making. A decrease in long-term sovereign bond yields may, for example, impinge on the profitability of capital investment projects. On the other hand, if benchmark long-term yields stay low for a prolonged period, it could possibly lead to excessive leverage and the overvaluation of other long-term assets, such as equity prices or houses. A change in the relationship between long-term bond yields in Malta and its euro area partners is important for monetary policy analysis, macro-prudential policymaking, financial stability concerns and public debt management.

The aim of this study is two-fold. The first is to assess Malta government stock (MGS) yields' correlation with those of other euro area countries. Simple, rolling and dynamic conditional correlations between Maltese and euro area sovereign bond yields are computed. This analysis shows that MGS yields are broadly insulated from shocks reflecting both euro area and events specific to other countries, such as bailout requests, political instability or speculation. Secondly, simple linear regressions are estimated over the available sample to examine the link between domestic and selected euro area bond yields. This part of the study is supplemented by a moving estimation window, to examine the link between MGS yields and euro area rates over time. Actual Maltese government bond yields over time are compared with multiple composite benchmarks modelled on the basis of comparable composite yields in the four largest euro area economies as well as on the basis of underlying Maltese economic fundamentals. The methods used here are different from the methodology used to set yields at the Central Bank of Malta (CBM), and are purely intended for econometric analysis, rather than exact replication of official yields. MGS yield developments are stable, and are hardly ever subject to sharp swings over a short period of time. While some volatility linked with specific international events does exist, swings are markedly less sharp. Additionally, factors linked with the limited size of the MGS market – such as yield basket, liquidity premia and composition effects – may be playing a role. In general, MGS yields appear to be highly correlated with core euro area yields, even if they do not exhibit sharp volatilities. As expected, in Italy, Spain and France, domestic fundamentals – along with the core euro area reference government bond interest rate – drive sovereign bond yields. In Malta, fundamentals do not appear to play a major role in determining yields.

The remainder of the paper is structured as follows. In Section 2 the literature review is presented, and in Section 3 the data and correlations are discussed in detail. In Section 4, the methodology and results are discussed, while Section 5 concludes.

Literature review

The relationships between different European economies have been analysed frequently over the past decades. These studies have expanded on the relationship and inter-linkages among various European financial markets to investigate the nature of European economic integration. Studies on the role of the monetary union, and empirical evaluations of further integration - such as the capital markets union – have also increased. Many of these studies tend to focus on stock exchange markets, rather than bond market relationships.

However, a number of authors have examined sovereign bond market developments over recent years. Most have focused on bond markets of larger economies, such as that of the United States (US), Japan, and Germany. Literature focusing on the European sovereign bond market is not as rich, or it tends to concentrate on contagion effects arising from stressed euro area countries.

Swanson (2008) notes how between the introduction of the Maastricht Treaty and the birth of the common currency, euro area bond yields converged significantly. This is attributed to the anticipation of monetary union, and the credibility of the European Central Bank (ECB). From 1999 until mid-2008, ten-year bond yields across euro area countries converged further.² Once the 2008 financial crisis began, and then developed into a European sovereign debt crisis, this narrative of yield convergence morphed into the measurement of contagion effects between peripheral euro area sovereign bond yields, or the impact of unconventional monetary policies on the determination of sovereign yields.

The literature suggests that sovereign bond yields are determined by various factors, such as risk aversion (time-factor), and liquidity (country specific factor). Other important economic factors linked with underlying economic fundamentals include debt-to-GDP ratios, public deficits, GDP growth, unemployment rates, inflation rates, and short-term interest rates.

Some studies have found evidence that a country's fiscal position and ability to honour its commitments may determine sovereign bond yields. Bayoumi et al. (1995) find evidence of the impact of debt level on bond spreads for the US, with similar literature for the euro area with the same conclusions, such as Faini (2006), and Hallerberg and Wolff (2006). Other factors behind the movements in the sovereign bond yields include fears of financial contagion and international risk

² Most studies tend to focus on ten-year bond yields as important market indicators. They affect investment decisions, signal market confidence and offer easier comparisons across countries. In that sense, they are considered a good, benchmark indicator for long-term interest rates. In the local MGS market, the 10-year point tends to be the point of maximum liquidity.

aversion levels. Manganelli and Wolswijk (2009), identified several dynamics affecting sovereign bond yields in the euro area, such as market liquidity, risk appetite and cyclical conditions. Attinasi et al. (2011) control for the effect of such factors on euro area sovereign bond spreads with respect to German sovereign bonds, while Missio and Watzka (2011) explore the impact of contagion from Greece to other euro area countries.

Notably, Alexopoulou et al. (2009) found that fundamentals matter for markets' assessment of a country's creditworthiness. Countries' levels of external debt, fiscal and current account balances, foreign exchange and inflation rates, their degree of trade openness as well as short-term interest rate spreads play an important role in new EU countries' access to long-term finance.³

Unfortunately, the vast majority of studies focus on the impacts on large economies in the euro area. Lack of data and trade volumes play a role in applying these methodologies to small financial markets. Studies on increased integration of smaller financial markets within the euro area, as is the case with Malta, tend to be particularly uncommon. These have either focused on economic convergence (Micallef, 2017), or on the integration of the Malta stock exchange (MSE) market with international stock markets (Ellul, 2015).

Malta's small market size has limited the development of financial markets. In a speech in 1997, the then CBM governor, Mr. E. Ellul described Malta as "a small, open economy with relatively underdeveloped financial markets."⁴ Despite the latter becoming more complex over the years, relative thinness and weak liquidity remains a feature of Maltese financial markets. This may also contribute to a high demand for domestic cash balances (Grech, 2014). As noted by Grech, notwithstanding significant declines in Malta's savings rate, households have accumulated considerable financial wealth over time. On a per capita basis, the average Maltese household holds twice the financial assets of the average euro area household.⁵ For a number of years, the majority of these savings ended up either as cash or bank deposits due to strict capital controls and the relative unavailability of financial assets. In turn, such a financial environment may make MGSs appear as an attractive diversification of otherwise idle balances.

³ The study was based on a dynamic panel error correction model that accounts for both common long-run determinants and cross-country heterogeneities in sovereign bond spreads for Bulgaria, the Czech Republic, Latvia, Lithuania, Hungary, Poland, Romania and Slovakia.

⁴ Ellul E., (1997), "Exchange Rate Policy in Malta," CBM Quarterly Review, Central Bank of Malta, December 1997.

⁵ An estimate of household wealth based on the results of a survey carried out in 2010 can be found in Caruana, K. & Pace, C., "Household Finance and Consumption Survey in Malta: main results of 2010 exercise", Central Bank of Malta, 2013.

Farrugia and Grech (2013) note how in the years 1995 to 2012, except for a brief period in the mid-2000s, the general government debt-to-GDP ratio in Malta was on an upward trend. By the end of 2012 it stood around 70.0%. The vast majority of general government debt is held as debt securities, namely bonds, and denominated in national currency. Data on the structure of this debt indicate that around 60.0% is held by financial corporations and 27.0% by households and non-profit making institutions serving households.⁶

In all, general government debt stood at just over €5.7 billion euro at end-2016. While the total outstanding debt of the Maltese government is comparable with the volume of a single debt issuance by a larger country, its efficient management by one of Malta's small private sector financial market players is undoubtedly a daunting prospect.

In fact, there are no private market-makers or primary dealers willing to act as a market-maker for Maltese government securities.⁷ The CBM has acted as a market-maker for these securities since its foundation in 1968. Over its history, the Bank contributed significantly to the development of domestic money and capital markets, and enhances the liquidity of the government bond market. The market for MGSs is intrinsically linked with the characteristics of the Maltese economy. Factors such as the composition of the investor base, the relative small size of the market – particularly when compared with foreign public debt markets – may affect important bond market metrics such as liquidity premia. Prudent market players ought not assume these factors, and in turn the metrics they underpin, will remain unchanged forever.

As an example, in an October 2016 release,⁸ Standard and Poor's (S&P) raised its long-term sovereign credit ratings on Malta to "A-" from "BBB+". The upgrade reflected what S&P termed as "Malta's improved credit metrics." Malta's current credit rating is comparable with that of Latvia and Lithuania, and is in line with other 'new' EU member states, like Slovenia and Slovakia (see Table 1).

These credit metrics are typical economic fundamentals used to assess a country's relative economic strength. Malta's outlook was also seen to be stable, reflecting the view that "the upside potential of Malta's economic and fiscal performance is counterbalanced by downside risks related to Brexit, external flows, and the structure of the financial sector." Some of these concerns may not be considered to be downside risks, but rather structural legacies of the local economy or public-sector

⁶ NSO 090/2017: Structure of General Government Debt: 2016, May 2017.

⁷ A "market maker" is an entity or firm which stands ready to buy or sell a particular instrument, or class of instruments, on a continuous and regular basis, at publicly quoted prices.

⁸ Standard and Poor's, (October 2016), "Malta Long-Term Ratings Raised To 'A-' On Strong Economic Growth; Outlook Stable."

obligations. The country's short-term foreign and local currency sovereign credit rating remained stable at "A-2". Moreover, Malta's rating is also close to a number of larger euro area countries.

A salient difference linked with the limited size of the MGS market are trading turnover figures. For most euro area countries, post-2014, the average daily trading volume always exceeds the €0.5 billion threshold. Larger countries, such as Germany and France, have average daily turnovers in excess of €8.0 billion.⁹ In Malta's case, the yearly trading volume does not exceed €1.0 billion (see Table 2). Factors such as Malta's limited market size and low trading turnovers and the existence of a single market maker indicate that a number of market metrics, such as liquidity premia, may be at play on Malta's sovereign bond yields.

Ultimately, the CBM's role is solely limited to secondary market dealing - with absolutely no involvement in the primary market. In that respect, the Bank's quoted indicative yield on the secondary market is a major indicator for the rest of the Maltese financial system. Understanding its drivers, and whether its pricing is consistent with Malta's euro area peers is therefore imperative.

⁹ For further analysis, see *AFME – Finance for Europe, 2016Q4 Government Bond data report*.

**Table 1: Sovereign ratings and country transfer and convertibility assessments
as at end-2016 for euro area sovereign bonds – S&P**

	Foreign currency ratings (LT/outlook/ST)	Local currency ratings (LT/outlook/ST)	T&C assessment
Austria	AA+/Stable/A-1+	AA+/Stable/A-1+	AAA*
Belgium	AA/Stable/A-1+	AA/Stable/A-1+	AAA*
Cyprus	BB/Positive/B	BB/Positive/B	AAA*
Estonia	AA-/Stable/A-1+	AA-/Stable/A-1+	AAA*
Finland	AA+/Stable/A-1+	AA+/Stable/A-1+	AAA*
France	AA/Stable/A-1+	AA/Stable/A-1+	AAA*
Germany	AAA/Stable/A-1+	AAA/Stable/A-1+	AAA*
Greece	B-/Stable/B	B-/Stable/B	AAA*
Ireland	A+/Stable/A-1	A+/Stable/A-1	AAA*
Italy	BBB-/Stable/A-3	BBB-/Stable/A-3	AAA*
Latvia	A-/Stable/A-2	A-/Stable/A-2	AAA*
Lithuania	A-/Stable/A-2	A-/Stable/A-2	AAA*
Luxembourg	AAA/Stable/A-1+	AAA/Stable/A-1+	AAA*
Malta	A-/Stable/A-2	A-/Stable/A-2	AAA*
Netherlands	AAA/Stable/A-1+	AAA/Stable/A-1+	AAA*
Portugal	BB+/Stable/B	BB+/Stable/B	AAA*
Slovakia	A+/Stable/A-1	A+/Stable/A-1	AAA*
Slovenia	A/Positive/A-1	A/Positive/A-1	AAA*
Spain	BBB+/Stable/A-2	BBB+/Stable/A-2	AAA*

Source: S&P

Table 2: On-exchange turnover of MGSs in millions of euro - MSE

On-exchange turnover	
2012	534.1
2013	621.9
2014	751.9
2015	637.5
2016	480.9
2017¹⁰	190.0

Source: MSE

¹⁰ As at June 20, 2017.

Data

A series of ten-year MGS yields was collated from daily historic data, from January 2003 to December 2016.¹¹ As seen in Figure 1, the first four years of daily observations change on a weekly basis, with the series beginning to show meaningful daily variations from July 2007 onwards. As this study investigates correlation, the analysis was limited from July 2007 to December 2016.

This historic ten-year MGS yield has a mean of 3.5%, with a maximum of 5.5% in July 2008 and a minimum of 0.5% in October 2016, (see Table 3). Ten-year MGS yields appear to be on a historic downward trend, with relatively stable day-to-day changes. Volatility is limited, with few sharp changes in yields occurring over short periods of time.

Table 3: Summary statistics

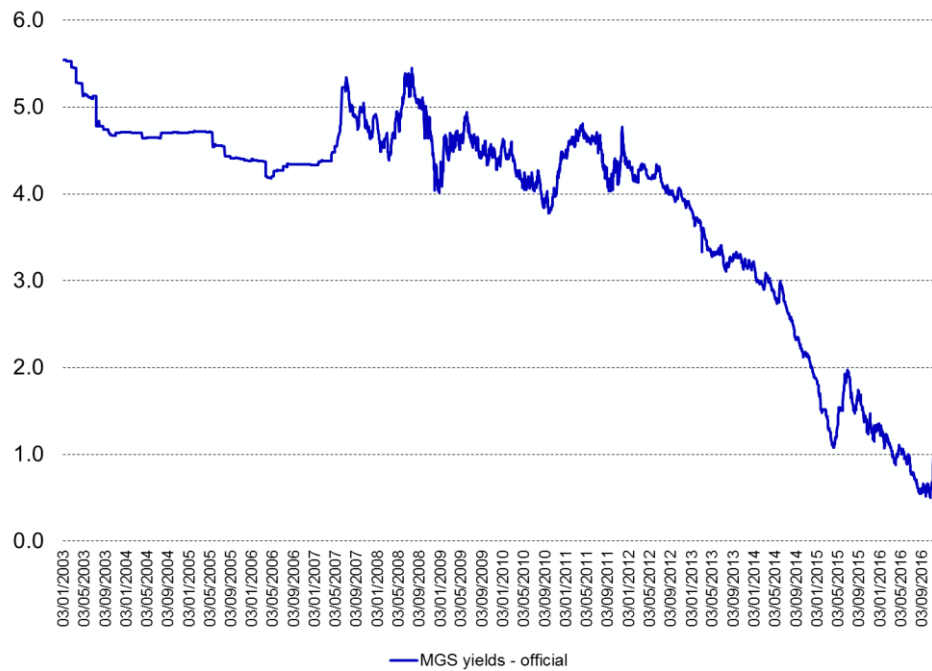
Mean	3.46
Median	4.07
Maximum	5.45
Minimum	0.50
Std. Dev.	1.37
Skewness	-0.77
Kurtosis	2.22
Jarque-Bera	311.79
Probability	0.0000
Sum	8597.00
Sum Sq. Dev.	4663.30
Observations	2479

Daily comparable composite yields for eleven other euro area countries were obtained from the ECB statistical data warehouse. These are Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal and Spain. The countries were chosen on the basis of data availability, euro area membership, the existence of established economic ties and similar economic makeup.

¹¹ Data was made available by the Government Securities Research Office at the Central Bank of Malta.

MGS 10-YEAR YIELDS

(percentages per annum)

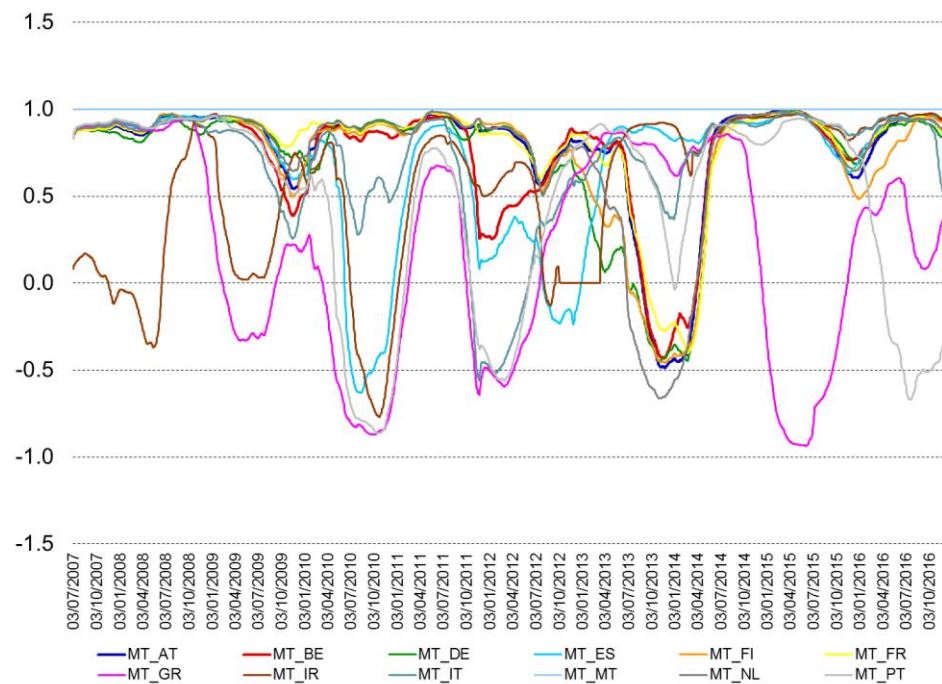


Sources: Central Bank of Malta.

Figure 1: MGS 10-year yields

ROLLING CORRELATIONS

(260-day window correlations)



Sources: Author's calculations.

Figure 2: Rolling correlations for MT 10-year yields

Measuring rolling correlations

Rolling correlations were calculated over a 260-day window, to assess correlation between Maltese 10-year sovereign bond yields and comparable bonds in eleven other countries.¹² This calculation returns the statistical correlation between two arrays of data over a moving window. A constant value of +1 implies a perfect linear relationship, while a value of -1 indicates an inverse linear relationship. A value of 0 implies that there is no linear correlation between the two variables.

As seen in Figure 2, for the period from March 2007 to January 2017, these moving correlations exhibit strong fluctuations and event specific volatilities. These reflect both country-specific shocks, as well as shocks which affect a group of countries. For example, the rolling correlation between Maltese government bond yields and those of Germany fell to -0.4 in late February 2014. An element which might be causing some of this particular volatility in the rolling regressions between the MGS yields and those for the comparable German instrument is the demand for German bonds as a safe haven asset in times of heightened financial stress.

To control for such effects, simple correlations were computed for spreads over the German ten-year bond benchmark (see Table 4).

Table 4: Simple correlations

	AT	BE	ES	FI	FR	GR	IR	IT	MT	NL	PT
AT	1.00										
BE	0.89	1.00									
ES	0.69	0.83	1.00								
FI	0.88	0.73	0.52	1.00							
FR	0.85	0.91	0.89	0.70	1.00						
GR	0.70	0.84	0.87	0.48	0.87	1.00					
IR	0.70	0.85	0.86	0.54	0.76	0.78	1.00				
IT	0.76	0.88	0.97	0.58	0.95	0.91	0.82	1.00			
MT	0.68	0.78	0.85	0.49	0.78	0.75	0.82	0.84	1.00		
NL	0.89	0.76	0.65	0.91	0.78	0.54	0.59	0.69	0.62	1.00	
PT	0.73	0.90	0.91	0.54	0.90	0.94	0.87	0.94	0.80	0.61	1.00

However, it is obvious from these simple rolling correlations that the relationship between Maltese and euro area yields is not constant in nature. There is no 'fixed pattern' which translates movements on sovereign bond markets in the euro area to Maltese yields. However, it is apparent that these correlations can be quite high. These were further investigated using more advanced methods.

¹² This window corresponds with a simple assumption for trading days in a year, based on five trading days a week for 52 weeks.

Measuring dynamic conditional correlations

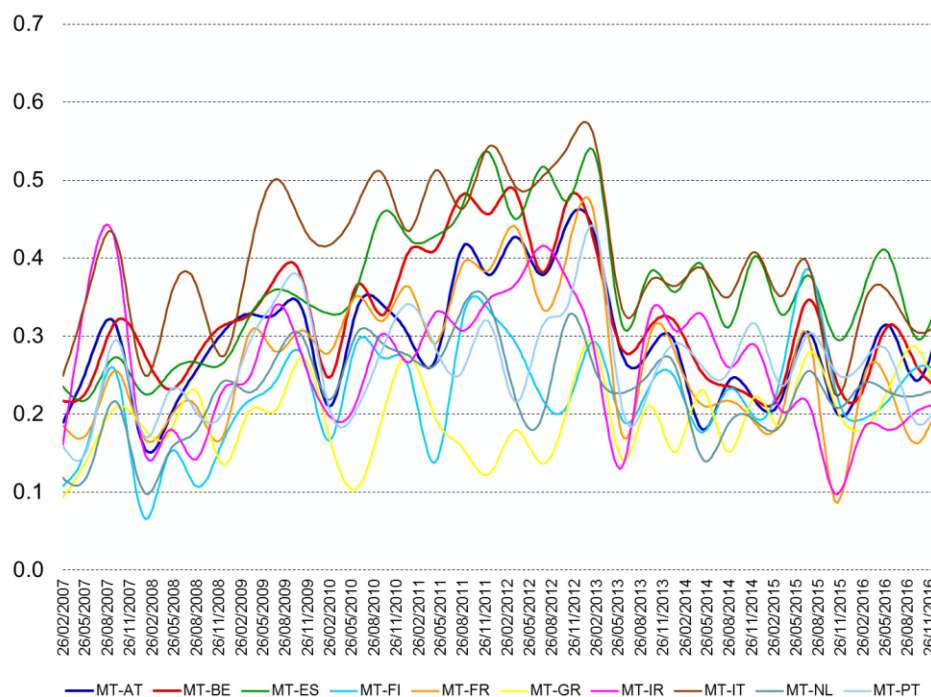
In order to understand the nature of MGS yields correlations with those of other euro area sovereign bond yields, more complex dynamic conditional correlations (DCCs) were computed.¹³ A multivariate generalised autoregressive conditional heteroskedasticity (MGARCH) system was modelled for MGS yields and those of ten other euro area countries. In order to exclude possible safe-haven movements, the yields in this part of the study were specified in terms of spreads over German sovereign bonds.

Dynamic correlations between different sovereign bond yields will explain whether yields move together, allowing the analysis of interdependencies. Thus, for example, an exogenous shock will drive correlated sovereign bond yields together. On the other hand, if a country's sovereign bond yields have low correlation with those of another, it implies that yield movements are more explained by country-specific, or internal, events rather than events in other countries. Additionally, literature on cross-country contagion indicates that temporary decreases or increases in correlations following a shock in one country imply contagion effects between countries, while 'level shifts' in correlations imply interdependence.

This technique is preferable to the more traditional methods of correlations in that it does not give equal weights to past observations, as in rolling-windows approaches. This model incorporates time-varying volatilities from the estimated GARCH processes. Past realisations of market volatilities and correlations will affect the estimated conditional correlations, giving more weight to recent observations and less to more distant ones.

¹³ For a discussion on the methodology used to compute these DCCs, refer to Appendix 1.

Median spline of dynamic conditional correlations



Sources: Author's calculations.

Figure 3: Median spline of pairwise DCCs for spreads over the 10-year German bond, for MGS yields against ten other countries

A number of stylised facts can be drawn from these DCCs.¹⁴ Firstly, as expected, MGS yields are correlated with those of the euro area. Average pairwise-DCCs ranging from a maximum of 0.40 with Italy to a minimum of 0.20 with Greece may not seem to be very high¹⁵ – however these betray significant pairwise volatility, with peaks in the raw DCCs as high as almost 0.70 in certain cases.

Another observation comes from the apparent breaks in the DCCs, as shown in their median spline (see Figure 3). This further refinement to raw DCCs renders their presentation and analysis more tractable. The median spline calculates cross medians and then uses these values as ‘knots’ around which to fit a cubic spline. The resulting spline is graphed as line plots. This smoothed representation in Figure 3 shows that median conditional correlations are positive and definitely vary over time. While correlations have been rather stable post-2013, they display marked volatility beforehand.

The breaks occur in periods of heightened volatility or financial stress on international sovereign bond markets. For example, the break evident in late June 2013 can be traced to a worldwide bond market

¹⁴ Plots of raw pairwise DCCs are presented in Appendix 1.

¹⁵ Ellul (2015) investigating stock market integration in Malta, shows how average DCCs for the Malta stock exchange (MSE) index with five other major stock exchanges stood at nil. In comparison, the correlation on sovereign bonds is stronger.

rout occurring in those weeks. This followed comments by the Federal Reserve signalling the tapering of its quantitative easing program. MGS yields appear to be relatively insulated from these sudden breaks on international bond markets.

Even sudden increases in the raw pairwise correlations,¹⁶ such as the ones occurring in late June 2016 have to be looked at with caution. In the wake of the results from the British EU membership referendum, sovereign yields across the euro area fell markedly, however a look at the MGS yields reveals that the change here was minimal. This increase in DCCs occurred over a relatively short period of time. At face value, this indicates isolated contagion effects from one-off events which hit the whole class of euro area sovereign bonds, rather than country specific movements. Due to this commonality, this phenomenon is not as sharp when looking at median splines.

The pairwise DCCs indicate that MGS yields tend to be broadly insulated from most shocks which affected the spreads of other countries. Historic shocks in a number of stressed euro area countries feature as shifts to negative pairwise correlations with Maltese MGS yields. Thus, MGS yields were unaffected by bailout news or related events emanating from Greece, Spain, Ireland and Portugal. In terms of DCCs, the three countries with the highest average pairwise DCCs with Malta are Italy, Spain and Belgium (see Table 5).

Table 5: Average DCCs

	MT
AT	0.29
BE	0.32
ES	0.36
FI	0.23
FR	0.27
GR	0.20
IR	0.26
IT	0.40
MT	1.00
NL	0.23
PT	0.27

¹⁶ See Appendix 1 for the raw DCC plots obtained from this methodology.

Econometric modelling of MGS yields

This section deals with the modelling of yields on ten-year MGSs in Malta, following two broad assumptions. A priori, one can assume that there are two extremes used to set MGS yields. On the one hand, yields can be purely the result of underlying economic fundamentals in the Maltese economy. On the other, yields may be some function of a basket of international sovereign bond yields. The aim of this section is not to uncover the actual methodology used to arrive at indicative MGS prices, but to put forward “fitted” MGS yields based on the two methods discussed above, and compare the resulting yield with the actual yields as found in the local financial market. This will allow a broad discussion on the implications of the actual MGS yields, when compared with the theoretical benchmark yields. Moreover, the econometric modelling detailed in this paper is carried out for investigative purposes, and does not purport to be the official method with which the CBM carries out its market making activity.¹⁷

International bond yield basket approach

Restricted fixed coefficients benchmarked MGS yields

MGS yields can be seen to follow some function of international bond yields. Their high correlation with a number of euro area countries, as discussed in the previous section, indicates this to be a plausible hypothesis. This approach first regresses the MGS yields on the previous trading day’s values for the four largest euro area countries, namely Germany, France, Spain and Italy, along with a constant, (see Table 6).

This assumption is carried out for modelling simplicity, and does not imply that this is the manner with which the CBM analyses, or sets bond prices. Another simplifying assumption relates to the coefficients on the euro area sovereign bonds which, in this simple OLS regression, are restricted to sum to unity. Yields are regressed in levels, and equation residuals are stationary.¹⁸

¹⁷ The author of this study had no access to the official methodology used by the Central Bank of Malta (CBM) in its market making role, and relied solely on observations available in the public domain.

¹⁸ A subsidiary equation specified in daily changes returned significant coefficients for changes in MGS yields on Spanish, Italian and French bond yields. The aim of the equation presented above is not to assess the stationarity conditions of the series, but to check the hypothesis that MGS yields can be summarised as some linear combination the previous trading day’s euro area yields.

Table 6: Restricted coefficients model, full sample

Dependent Variable: MT_10YR

Method: Least Squares (Gauss-Newton / Marquardt steps)

Sample: 3/01/2007 12/19/2016

Included observations: 2558

$$MT_10YR = C(1) + C(2)*DE_10YR(-1) + C(3)*FR_10YR(-1) + C(4) \\ *ES_10YR(-1) + (1-C(2)-C(3)-C(4))*IT_10YR(-1)$$

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.5366	0.0084	63.8290	0.0000
C(2)	0.1474	0.0353	4.1727	0.0000
C(3)	0.5119	0.0458	11.1574	0.0000
C(4)	0.2982	0.0126	23.5826	0.0000
R-squared	0.9712	Mean dependent var		3.5173
Adjusted R-squared	0.9711	S.D. dependent var		1.3581
S.E. of regression	0.2305	Akaike info criterion		-0.0947
Sum squared resid	135.80	F-statistic		28714.26
Log likelihood	125.1906	Prob(F statistic)		0.0000

Indirectly, coefficients C(2) to C(4) imply that, on average, Italian sovereign bond yields $[1-C(2)-C(3)-C(4)]$ have a rather low weight in this simple decomposition of MGS yields. This is counterintuitive given the high correlation with Italian yields found in the simple, rolling and dynamic conditional correlations. However, this result is due to the fact that while the coefficients are being restricted to sum to unity, they are not being restricted to remain positive.¹⁹ Thus, coefficients may take on negative values.

This choice stems from the observation of negative rolling correlations and dynamic conditional correlations between MGS yields and other euro area yields. Forcing coefficients to be always positive leads to highly implausible results, and it negates observations where yields on a euro area country move in one direction, and MGS yields move in the opposite one.

¹⁹ Such a further restriction would be feasible if the coefficients were to be expressed in both logarithmic form and logarithmic fractions.

Restricted rolling coefficients benchmarked MGS yields

Implicitly the simplification discussed above may lead to prolonged periods where the fitted benchmark yield diverges from the actual yield. If, as shown in the previous section, MGS yields are relatively insulated from shocks to particular economies, and these economies feature in our imaginary basket then the divergence can be easily explained in that manner. In order to check this hypothesis, the same equation was estimated using a rolling time window, with a size of 90 days and a step of 60 days in the estimation period. Any divergence between the rolling coefficients benchmark and the fixed coefficients benchmark would be due to volatility in the period which pushes the estimated rolling coefficients away from their average value in the fixed coefficients model.

Another limitation in this approach is linked with the nature of MGS issues. The limited size of this market means that when there are no outstanding long-term debt securities with a residual maturity of close to ten-years, yields with different maturities are computed as *de facto* ten-year yields. This means that, on occasions, the MGS ten-year yield reported in the official series may not be fully harmonised with its European peers. This is an extension of the concerns relating to issue sizes and liquidity premia on MGSs discussed above.

'Economic fundamentals' MGS yields approach

The other possible methodology for setting MGS yields is to model economic fundamentals along with a reference yield. Following the literature, equations include multiple important economic variables such as inflation rates, GDP growth and unemployment, along with the euro area 'reference' ten-year government bond, that is, the German ten-year bond (DE 10YR). The daily yields data and the quarterly GDP figures were converted to monthly frequency. Dummy variables for 2011 and 2012, are also included. Use of public finance variables and balance of payments statistics was considered for this analysis, but had to be excluded due to data availability.

This methodology is based on a similar study analysing yield compression in central European countries (IMF, 2003). In that study, local currency bond yields were regressed on domestic fundamentals – namely inflation and lagged retail sales – as well as on a constant, and German bond yields. For this study's purposes, GDP growth was used instead of retail sales in the IMF study, due to data availability.

No strong relationship was found between MGS yields, inflation and GDP growth in Malta (see Table 7). This confirms the tenuous link between MGS yields and local economic fundamentals. The unemployment rate appears to be significant. However, this may result from drops in unemployment registered over recent years coinciding with a low interest rate environment, rather than a true causal

relationship. In order to arrive to a meaningful benchmarked MGS yield, similar equations were estimated for France, Italy and Spain. The coefficients for inflation, GDP growth and unemployment were then averaged (see Table 8). A benchmarked MGS yield on the basis of these calibrated parameters was then computed. No constant parameter was included, as this was either insignificant in this specification or very close to zero in other versions.²⁰ A sensitivity analysis on different specifications of a benchmark based on macroeconomic fundamentals may be found in Appendix 2.

Table 7: MGS yields and economic fundamentals

Dependent Variable: MT_10YR
Method: Least Squares
Sample (adjusted): 2003M01 2016M12
Included observations: 168 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.2273	0.3108	-0.7313	0.4656
@PCY(MT_OHICP)	0.0395	0.0244	1.6196	0.1073
@PCY(MT_GDP)	-0.0111	0.0123	-0.9074	0.3655
MT_U	0.3068	0.0529	5.7976	0.0000
DE_10YR	0.7183	0.0353	20.292	0.0000
@YEAR=2011	0.7669	0.1106	6.9311	0.0000
@YEAR=2012	1.1856	0.1233	9.6094	0.0000
R-squared	0.9246	Mean dependent var		3.8442
Adjusted R-squared	0.9218	S.D. dependent var		1.2685
S.E. of regression	0.3547	Akaike info criterion		0.8056
Sum squared resid	20.255	F-statistic		329.17
Log likelihood	-60.678	Prob (F-statistic)		0.0000

Table 8: Parameters for Spain, France and Italy, and the calibrated parameters for Malta, based on average values

	ES	FR	IT	Average
Inflation	0.22	0.04	0.28	0.18
GDP Growth	-0.06	-0.04	-0.13	-0.08
Unemployment	0.13	0.04	0.18	0.12
DE 10YR	0.85	0.93	0.70	0.83
Dummy 2011	0.79	0.41	1.57	0.92
Dummy 2012	1.71	0.54	1.45	1.24

²⁰ Data from 2003 onwards is included in the estimations, to avoid the unnecessary loss of degrees of freedom. As data was converted to monthly frequency, the argument requiring meaningful variation in the daily series was no longer relevant.

Comparing actual MGS yields with benchmarked yields

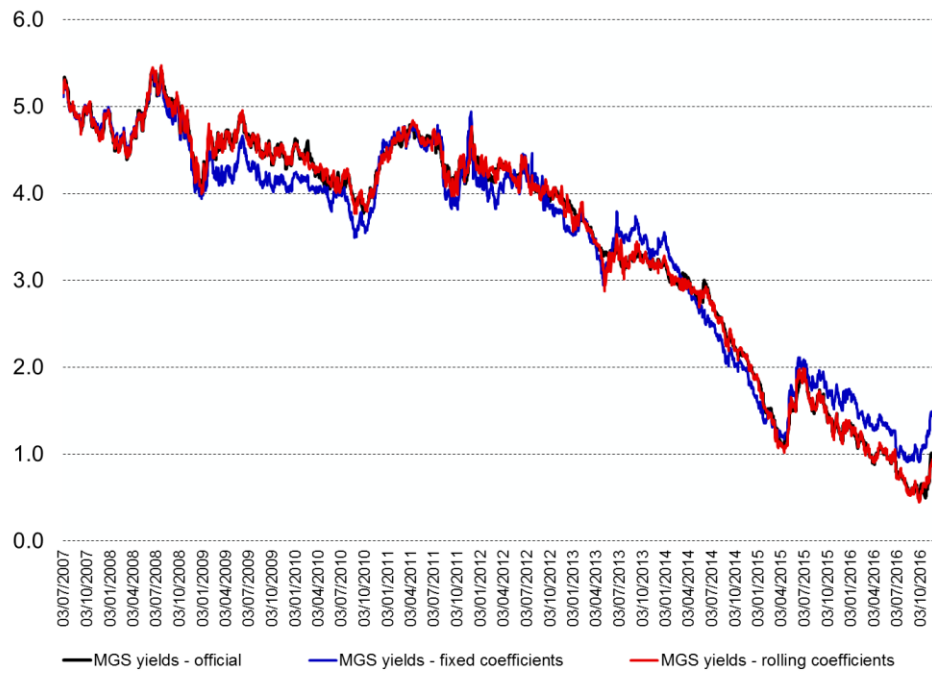
As seen in Figure 4 below, as expected, the rolling coefficient series – which re-estimates the coefficient more frequently – tracks closely the official MGS yield series. The two are almost indistinguishable at first glance. The fixed coefficients benchmark, which estimates the coefficients over the whole sample, does track the official series – although there are instances where the discrepancy is wider. These can be explained either by volatilities affecting yields in the basket during specific periods, such as 2009 and 2010, or MGS composition effects – as may be the case from mid-2015 onwards.

On the basis of this simple regression, it appears that the official MGS yield can be explained reasonably well with some basket of euro area yields. It is apparent, therefore, that there is no long-run deviation from euro area yields, and that short-run deviations are very rare and sporadic in nature.

An interesting result appears from the secondary method of benchmarking MGS yields, namely the analysis based on economic fundamentals. As seen in Figure 5 below, the benchmark MGS yield based on economic fundamentals is more volatile than official MGS yields, due to the volatility present in Maltese macroeconomic datasets. It is apparent, however, that yields have been higher, and MGS prices lower, than what true underlying economic conditions would have indicated during the global financial crisis of 2008 and again during the period of economic recovery in the following years.

Specific market metrics, such as liquidity premia concerns highlighted above, may be at work in the determination of MGS yields. A striking result of this simple method is that from mid-2015 onwards, official MGS yields are more in line with what would be expected from economic conditions in Malta.

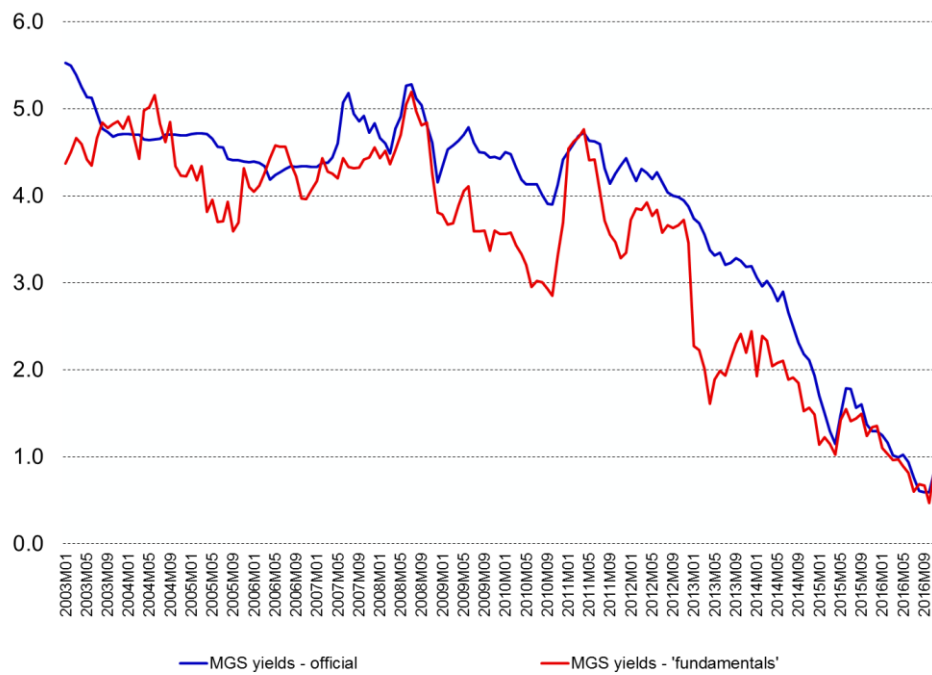
MGS 10-YEAR YIELDS, ACTUAL AND BENCHMARKED
(percentages per annum)



Sources: Central Bank of Malta, author's calculations.

Figure 4: MGS yields, actual and benchmarked on euro area yields

MGS 10-YEAR YIELDS, ACTUAL AND BENCHMARKED
(percentages per annum)



Sources: Central Bank of Malta, author's calculations.

Figure 5: MGS yields, actual and benchmarked on economic fundamentals

Conclusions

MGS yields appear to move in line and are strongly correlated with euro area yields. However, they are not as volatile as euro area sovereign bond yields. Rolling correlations and dynamic conditional correlations show how MGS yields are relatively insulated from external shocks. Yield pricing in periods of significant volatility on euro area bonds appears to ensure the isolation of shocks peculiar to specific euro area countries.

Moreover, not only do yields track consistently developments in euro area countries, but the analysis based on economic variables indicates that from mid-2015 onwards, official MGS yields follow closely the benchmark derived from underlying economic fundamentals. Further research in this area, to assess the merits of simple forecasting techniques may be warranted.

Finally, while the pricing appears to be consistent with euro area yields over the long-run, if the Maltese economy keeps growing substantially above its euro area partners, economic fundamentals would imply that a differential should begin to feature in these yields against its euro area partners.

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Appendix 1: MGARCH-DCCs

Methodology

This methodology behind dynamic conditional correlations is preferable to the more traditional studies in that it does not give equal weights to past observations, as in moving-windows models. This model incorporates time-varying volatilities from the estimated GARCH processes. Past realisations of volatilities and correlations will affect the estimated conditional correlations, giving more weight to recent observations and less to more distant ones. Dynamic conditional correlations are estimated in three stages. The first step requires a demeaning process, usually via autoregressive-moving average models, in order to calculate residual returns. In the second step, these returns are modelled as autoregressive conditional heteroskedasticity or, if required, GARCH processes.

These residuals follow the standard MGARCH-DCC representation, see Engle (2000). Letting $\mathbf{r}_t = [r_{1,t}, \dots, r_{k,t}]'$ be the vector of demeaned variables in the DCC model:

$$\mathbf{r}_t | \Phi_{t-1} \sim N(\mathbf{0}, \mathbf{D}_t \mathbf{R}_t \mathbf{D}_t) \quad (1)$$

$$h_{i,t} = \varpi_i + \alpha_i r_{i,t-1}^2 + \beta_i h_{i,t-1} \quad (2)$$

for $i = 1, \dots, k$.

$$\boldsymbol{\varepsilon}_t = \mathbf{D}_t^{-1} \mathbf{r}_t \quad (3)$$

$$\mathbf{R}_t = \text{diag}(\mathbf{Q}_t)^{-1/2} (\mathbf{Q}_t) \text{diag}(\mathbf{Q}_t)^{-1/2} \quad (4)$$

$$\mathbf{Q}_t = (1 - a - b) \bar{\mathbf{Q}} + \alpha (\boldsymbol{\varepsilon}_{t-1}) (\boldsymbol{\varepsilon}_{t-1})' + \beta \mathbf{Q}_{t-1} \quad (5)$$

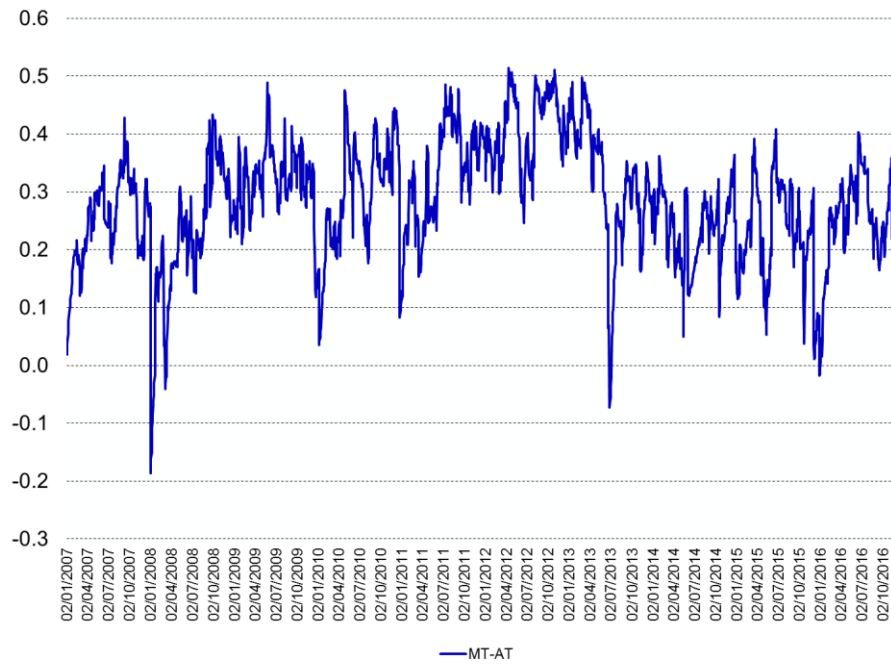
Where \mathbf{R}_t in (1) is a $k \times k$ matrix of time-varying correlations and \mathbf{D}_t is a diagonal matrix of standard deviations, $\sqrt{h_{i,t}}$, which derives from univariate GARCH models (or other GARCH variants) as in (2). The variables are then standardised by the respective standard deviations by dividing them, see (3). This standardisation enables the specification of the correlation estimator, see (4) and (5). In (5), $\bar{\mathbf{Q}}$ is the unconditional covariance matrix of the standardised variables, $\bar{\mathbf{Q}} = E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t')$. The DCC parameters are then estimated via maximum likelihood methods.²¹ After modelling the GARCH parameters as in (2), these are then used in the final stage to estimate the DCC parameters in (5). Additionally, the methodology allows testing of constant correlations between bond yields over time.

²¹ Quasi-maximum likelihood (QML) methods are applied if the variables are not normal.

Pairwise DCC plots

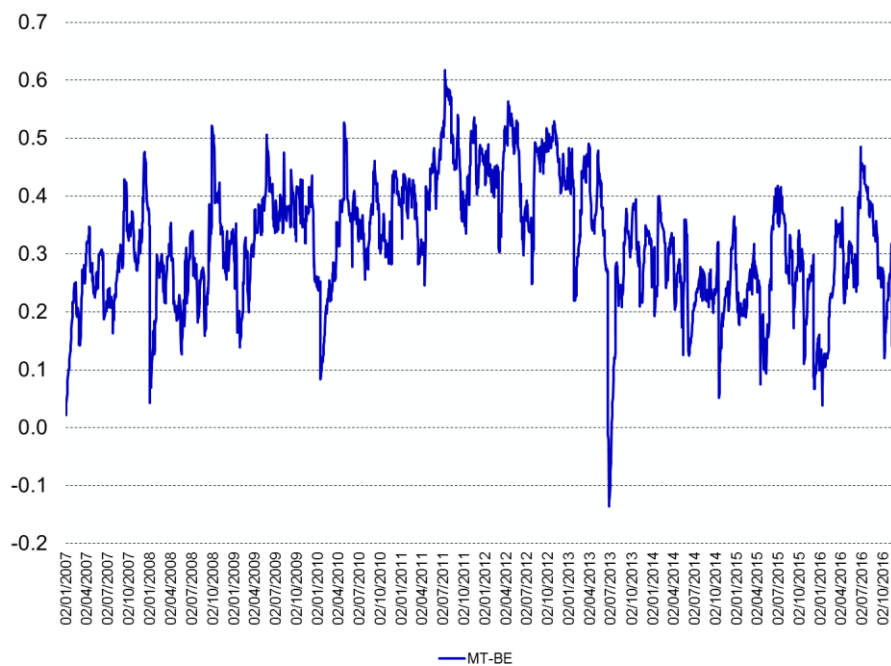
This section presents the raw DCCs from the MGARCH-DCC(1,1) process. The series presented in Figure 3 above, is a further filtering of these pairwise correlations, which is a calculation based on their median points.

MT - AT



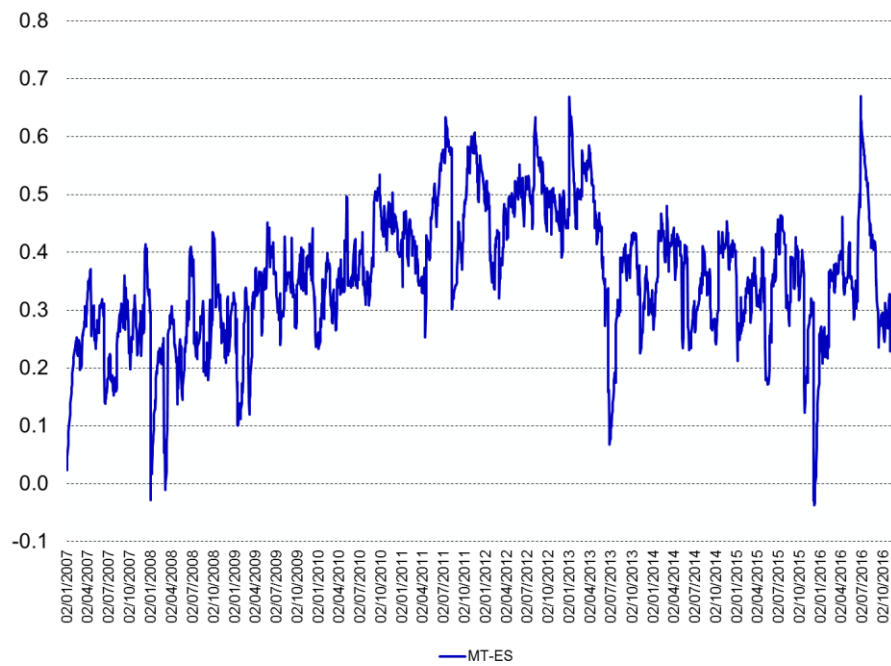
Sources: Author's calculations.

MT - BE



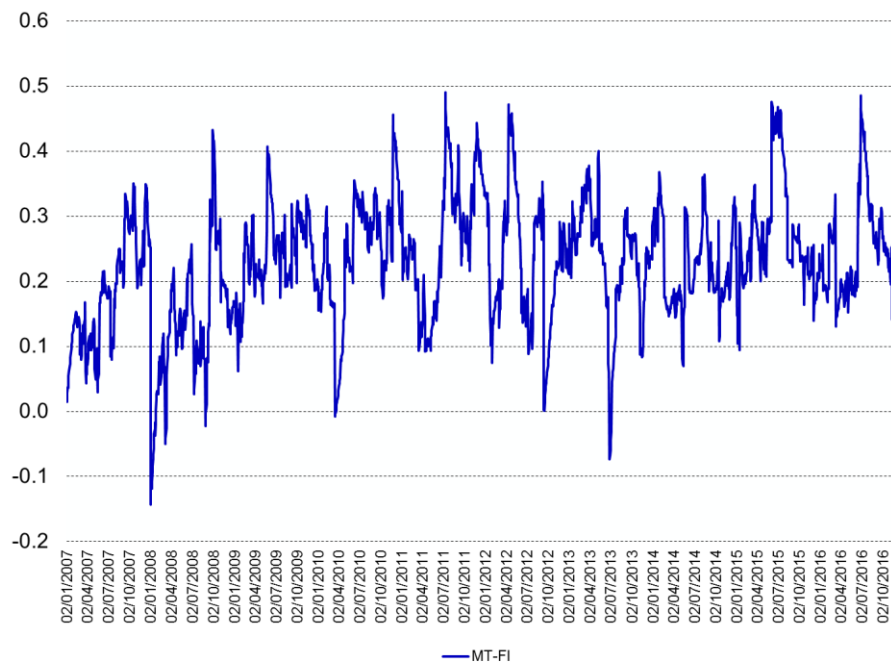
Sources: Author's calculations.

MT - ES



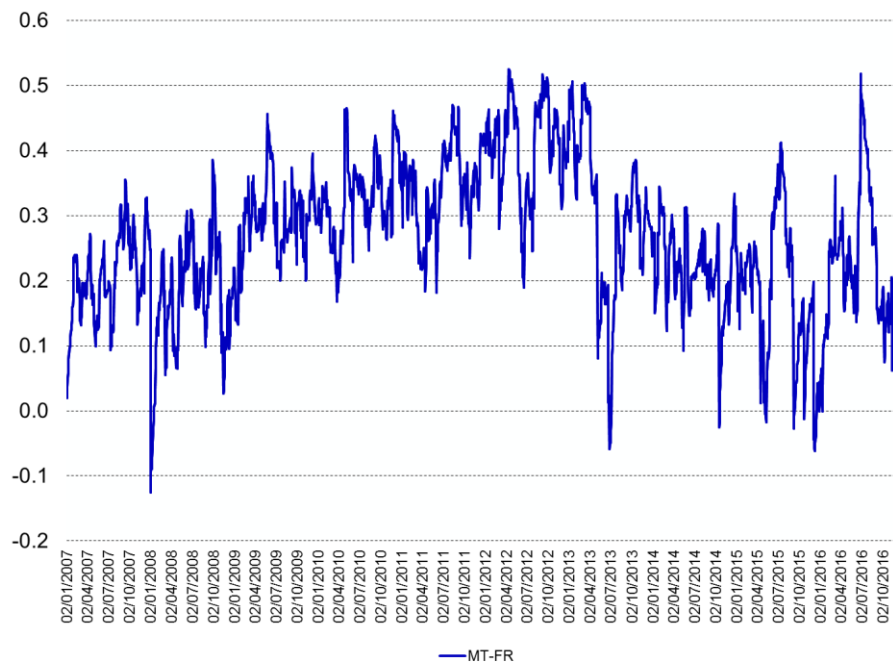
Sources: Author's calculations.

MT - FI



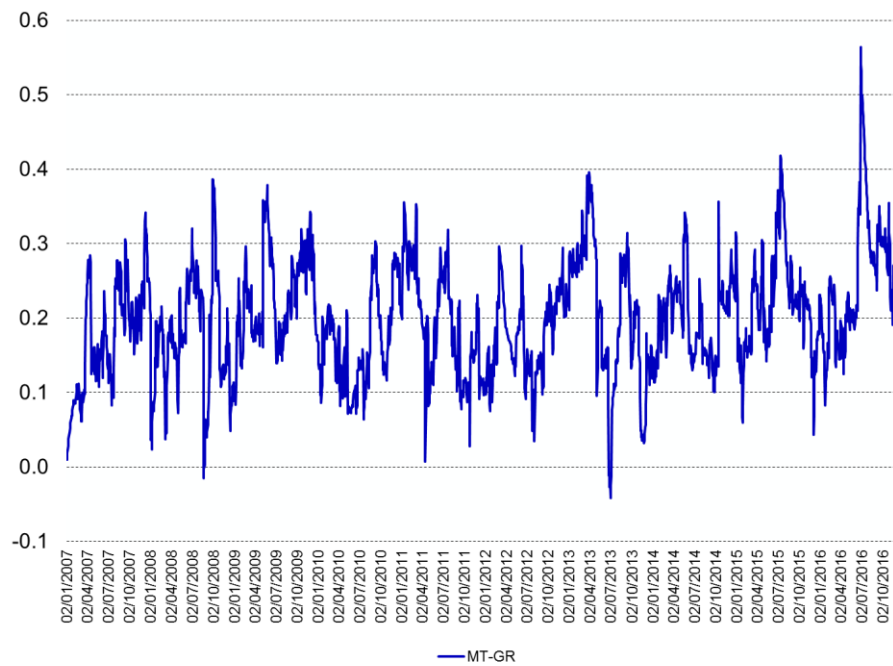
Sources: Author's calculations.

MT - FR



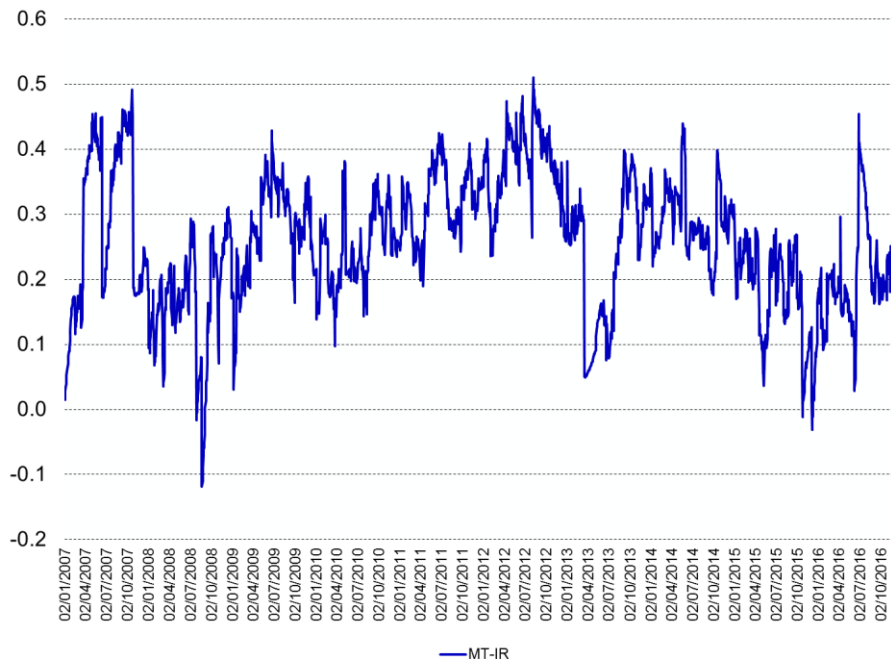
Sources: Author's calculations.

MT - GR



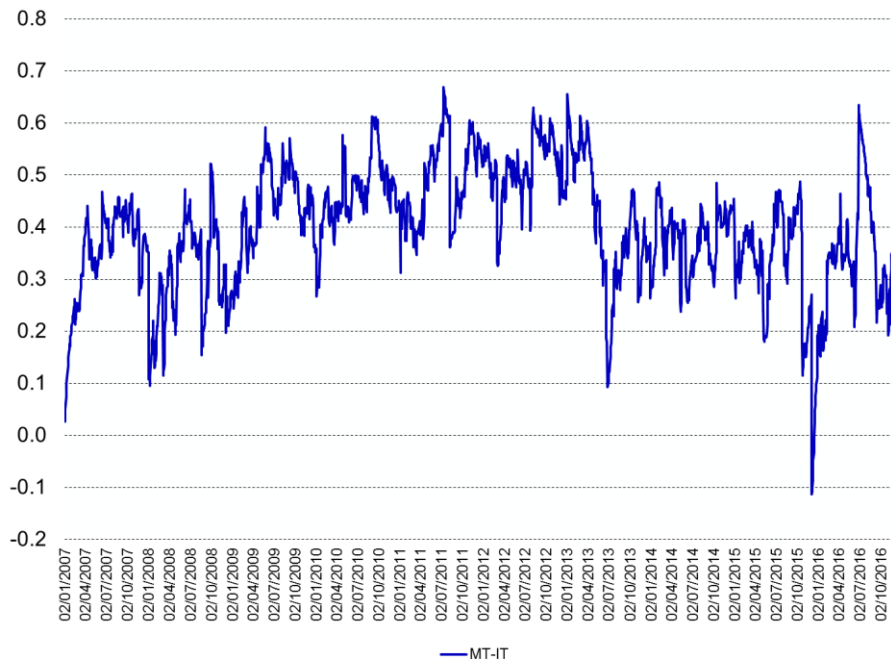
Sources: Author's calculations.

MT - IR



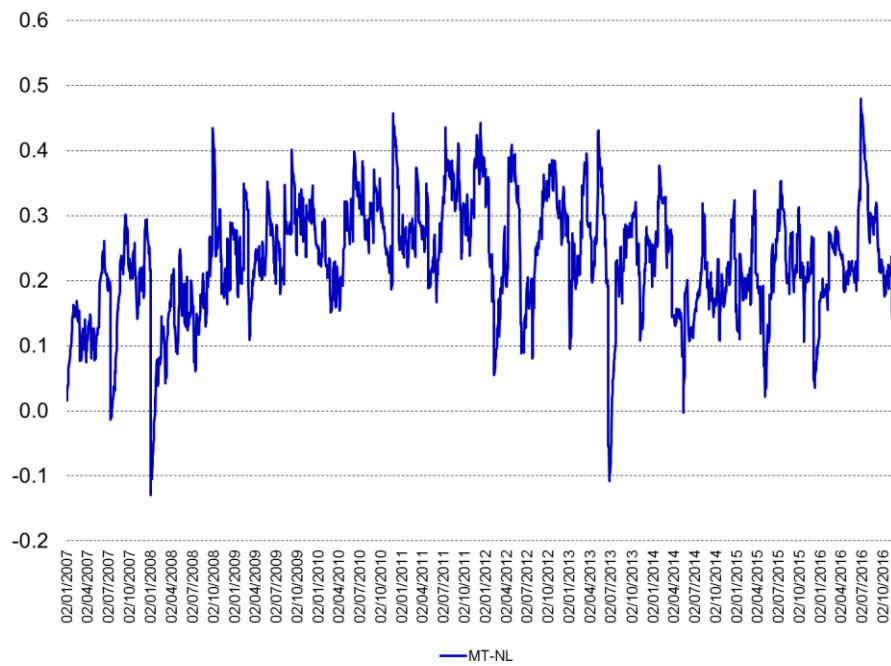
Sources: Author's calculations.

MT - IT



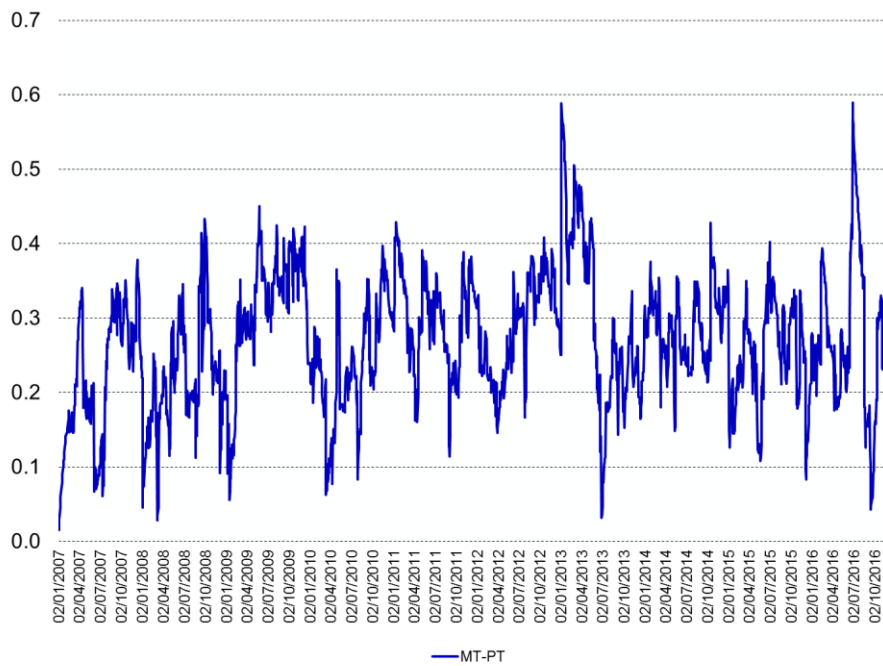
Sources: Author's calculations.

MT - NL



Sources: Author's calculations.

MT - PT



Sources: Author's calculations.

Appendix 2: 'Economic fundamentals' sensitivity analysis

Upon a close inspection of the parameters obtained from the equations,²² one notices some disparities in the coefficients estimated for the different countries. This might lead the questioning of the stability of this analysis based on the choice of averaging these parameters. In order to ensure no bias in this analysis, the benchmark based on economic fundamentals was computed on the basis of the individual countries' parameters. This choice would tend to make the MGS 10-Year yield behave according to the debt rating and market expectations for the country being modelled such that, one would expect the MGS-yield based on French parameters to be the lowest, the Italian and Spanish benchmarks would be expected to be highly volatile in 2011 and 2012 and then move in lockstep thereafter. These prior assumptions appear to be confirmed by the data (see Figure 6).

The yield compression noticed post mid-2015 onwards remains, with each benchmark returning dynamics which are very similar to actual MGS yields. The differences in the levels may be linked with market specific factors, such as liquidity premia and the existence of a single market maker which are not being accurately captured in this simple framework.

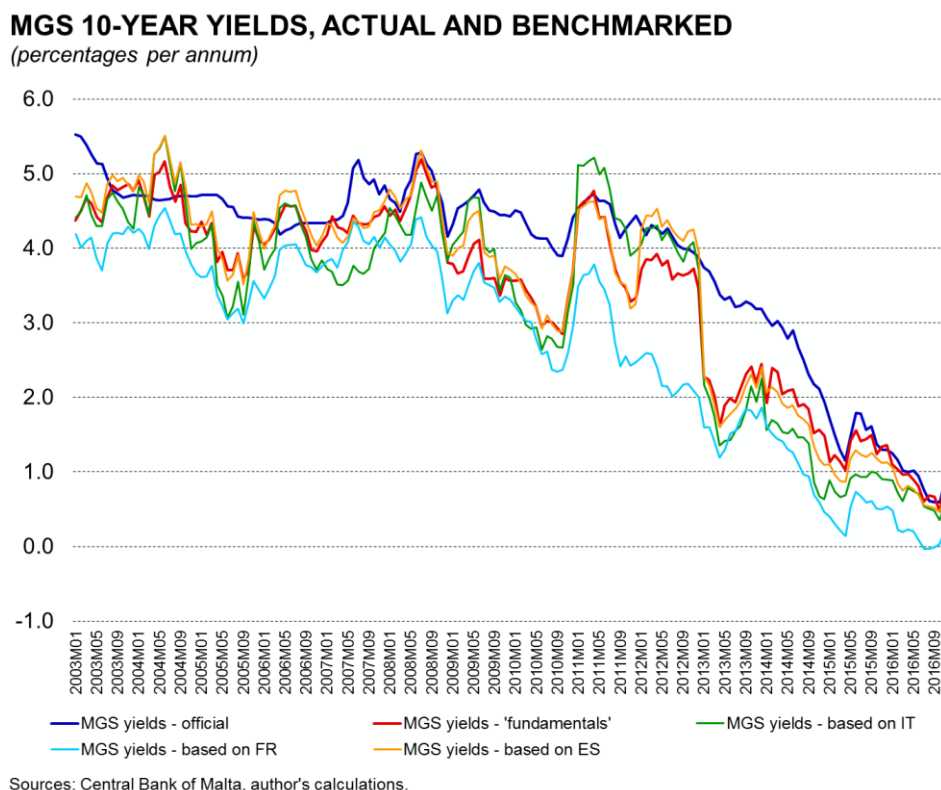


Figure 6: MGS 10-Year yields, actual and benchmarked upon average and specific country parameters

²² Refer to Table 8.

Of course, the choice of the countries itself – here dictated by the ‘Big euro area four, less Germany’ assumption – may be affecting the results. A further sensitivity analysis, comparing the results with a group of economic peers, might lead to more reasonable results. This was based on five countries with sovereign debt ratings close to MGSs (see Table 1, in main text). These are Ireland, Latvia, Lithuania, Slovakia and Slovenia (see Table 9). The variables for this part of the analysis follow closely those used in IMF (2003), and are inflation, retail trade, unemployment²³ and the German 10-year yields.

The main drawback of this group of peers is that a number of these countries experienced remarkable volatilities in the European sovereign debt crisis. To bypass the problem relating to the exact timing of the crisis in each country, annual dummy variables are included in each country equation, but are excluded in the construction of the Maltese benchmark yield, which includes parameters for 2011 and 2012 based on Maltese data.²⁴ The conclusions from this analysis may not be directly translatable to Malta, given the Maltese economy was relatively unscathed from the crisis and did not feature the large imbalances seen in other countries. Different market characteristics linked with market features such as liquidity premia, are not being modelled in this analysis. This may lead to significant differences in the estimation of constants, which are not being estimated in this simple framework.²⁵

Table 9: Parameters for Ireland, Lithuania, Latvia, Slovakia and Slovenia, and the calibrated parameters for Malta, based on average values

	IR	LT	LV	SK	SL	Average
Inflation	0.16	0.10	0.12	0.15	0.55	0.22
Unemployment	0.27	0.18	0.48	-	0.42	0.34
Retail trade	-0.02	-0.05	-0.10	-0.10	-0.90	-0.23
DE 10YR	0.99	0.93	1.01	0.79	0.65	0.87

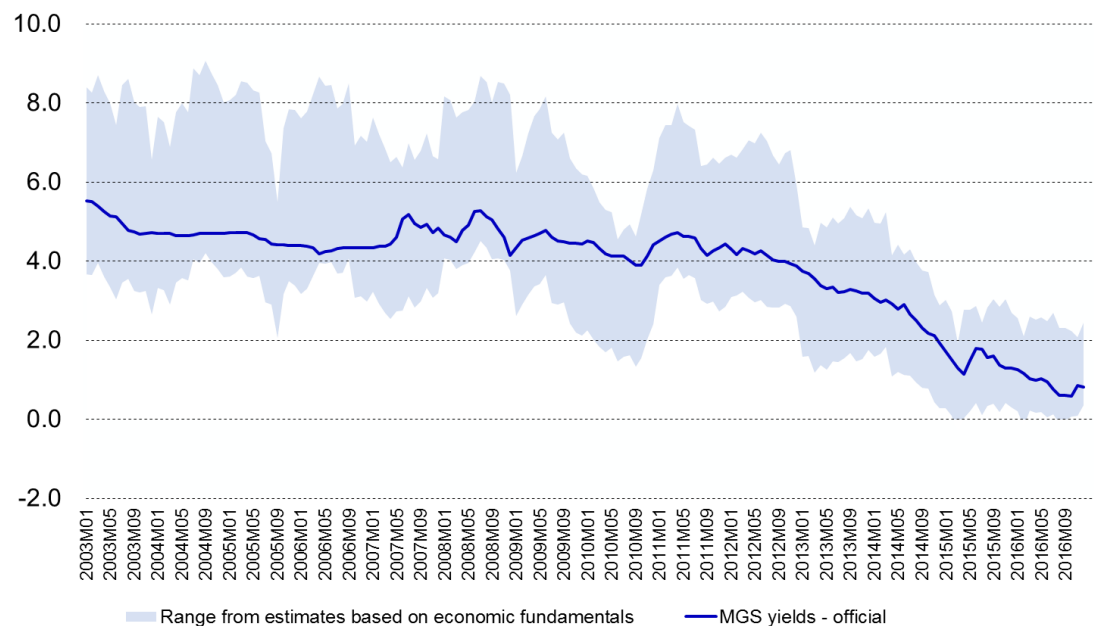
²³ The unemployment variable for Slovakia was omitted, as a break in series yielded results which were not in line with economic theory.

²⁴ Being 0.78 and 1.24, respectively.

²⁵ The inclusion of macroeconomic variables in an equation with official MGS yields renders the constant insignificant and very close to nil.

MGS 10-YEAR YIELDS, ACTUAL AND BENCHMARKED

(percentages per annum)



Sources: Author's calculations.

Figure 7: MGS 10-Year yields, actual and range of benchmarked estimates from IR, LT, LV, SK and SL.

It is apparent that the official MGS yield series is more stable than the ones resulting from this simple computation. The official series does not return the volatilities inherent in the one based on the series constructed upon economic fundamentals. As the chosen group of countries were Malta's peers in the October 2016 S&P ratings, temporal comparison may not be exact. The economic fundamentals underpinning the ratings – and thus the ratings themselves - were not constant across the time horizon.

In any case, prior to 2012, the official MGS yield series rests towards the bottom end of the range estimates. The series does seem to stand very close to the mid-point of the estimated range following 2013, and to ease further after June 2015. The analysis carried out above appears to be robust to various combinations of estimated parameters.