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THE EFFICIENCY OF SOVEREIGN DEBT MARKETS IN THE EMU: TRUTH OR MISTRUTH?

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Abstract

Ever since the last financial crisis, the efficiency of financial markets has been widely challenged. On the basis of sovereign debt markets in the European Monetary Union (EMU), we tried to contrast some reservations about the market efficiency existing in the literature with findings coming from our empirical analysis of weak-form efficiency.

To do so, we first outlined the crux of the efficient market hypothesis. Secondly, we show the main reservations in relation to this concept. Then, after a brief review of outcomes from contributions in this area, we conducted a three-stage empirical procedure that Worthington and Higgs (2006) as well as Borges (2009) had employed to stock markets analysis. Then, the results were evaluated and conclusions were drawn.

To sum up, we did confirm the weak-form efficiency on examined sovereign debt markets from the EMU. That suggests that a random process plays a key role in shaping bond yields. Finally, neither theoretical nor practical reservations deflate the weak-form efficiency in the public debt markets of the EMU.

EFEKTYWNOŚĆ RYNKÓW DŁUGU PUBLICZNEGO W EMU: PRAWDA CZY FAŁSZ?

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Abstrakt

Od ostatniego krysysu efektywność rynków finansowych jest szeroko podważana. W artykule postarano się zweryfikować, czy zastrzeżenia co do efektywności rynków finansowych pojawiające się w literaturze przedmiotu potwierdza empiryczna analiza słabej efektywności rynków długu publicznego w krajach EMU. W pierwszej części tekstu przedstawiono istotę hipotezy rynków efektywnych oraz główne zarzuty kierowane wobec tej koncepcji. Następnie, po krótkiej analizie dotychczasowych wyników badań empirycznych, przeprowadzono trójstopniową procedurę badawczą tożsamą z badaniami Worthingtona i Higgsa (2006), a także Borgesa (2009), prowadzonymi wcześniej dla rynków akcji. Na koniec przedyskutowano rezultaty i zaproponowano wnioski.

Potwierdzono występowanie efektywności informacyjnej w formie słabej na wszystkich rozważanych rynkach obligacji skarbowych. Wynika z tego, że proces błądzenia losowego odgrywa główną rolę w kształtowaniu się rentowności obligacji długoterminowych. Ani zatem zastrzeżenia teoretyczne, ani praktyczne co do nieefektywności finansowej w segmencie obligacji publicznych nie znajdują uzasadnienia w przypadku badanych gospodarek ze strefy euro.

Introduction

Questioning the financial markets' efficiency intensified after 2008. Most likely, such a tendency resulted from the fact that the roots of the last crisis were mostly financial. Although there are some well-grounded reservations as to the efficiency of financial markets in the literature, we decided to re-evaluate them empirically on the basis of data from sovereign debt markets.

In order to scrutinize public debt market efficiency, this paper is organized as follows. In the first part, the theory of efficient markets is presented. We also cover theoretical and practical reservations against the debt market efficiency. The second part is empirical in nature. First, a brief review of previous findings is presented. Next, our empirical procedure is conducted on the basis of Worthington and Higgs (2006) and Borges (2009) methodology, which has been applied to stock markets before. Finally, our findings are interpreted as well as conclusions being drawn.

Finally, the analysis points to very strong evidence that the EMU public debt market exhibits weak-form efficiency. As a consequence, the random process, showing the reaction of creditors, plays a key role in shaping sovereign bond yields.

The crux of an efficient market

The efficient market hypothesis (EMH) belongs to the main neoclassical theories describing financial markets. It depicts the situation where prices are accommodating themselves promptly to new information from inside and outside the economy (Fama, 1970, p. 384, 385) without ignoring any piece of information and without systematic errors (Beechey *et al.*, 2000, p. 2). The financial market is efficient in an informational sense when it provides all market participants with news that may be quickly discounted into the return of a financial instrument (Sharpe *et al*, 1998, p. 92-97). The concept of informational efficiency was linked to the stock market at the beginning, however, it has also been applied to other sectors of financial markets e.g. to the bond markets in the 1970s. (Katz, 1974; Shiller, 1979). According to EMH, whatever happens is discounted into the bond yields by market players. Based on that assumption, future bond yields are an effect of previous values as well as unexpected news (random factor) that is described as a current market reaction to new information. To put it simply, the debt market's participants expect a higher risk premium incorporated into the yields of national bonds when news about the economic, financial and political situation becomes precarious. Many commercial agencies unfailingly analyze the macroeconomic situation taking on board the wide range of well-known socio-political and economic factors as well as news from public and private institutions, which are responsible for promoting and conducting informative policy about their own decisions and actions. Standard and Poor's evaluates the stance of the national debtor through the prism of political risk, income and economic structures, economic growth and prospects, fiscal and monetary flexibility, external liquidity, public and private sector external debt, and potential debt (Kodres, 2010, p. 99). Other studies point to citizens' revenues, economic growth, inflation, budgetary balance, current account balance, economic development and credit history as indicants determining the current as well as the future credibility of a national debtor (Afonso & Strauch, 2007, p. 262-264).

The given information (about fundamental economic factors as well as authortity behaviour) is gathered not only by individual and institutional investors, but also by national and international analytics, and supervisors who finally provide creditors with expertise about a national debtors' solvency (debt sustainability). As long as lender's expectations converge on good outcomes, bond costs can remain stable (Deburn *et al.*, 2019, p. 22). According to Wyplosz (2011, p. 25), the market players' reaction function depends on the debt sustainability that is achieved as long as the authorities react adequately to the shocks. Such an approach treats the political agents' behavior as a cause for financial market reaction due to the potential risk transfer from the political sphere to finance (Waszkiewicz, 2017, p. 127). Thus, market players are obliged to take into consideration not only a country's economic capability, but also a country's (national authorities) willingness to service its debt (Waszkiewicz, 2015, p. 261). Finally, when any kind of uncertainty grows investors may react and expect a higher yield and lower prices for public bonds (Mishkin, 2002, p. 157-162). The role of a debtor is to meet a creditors' requirements, if he still needs loans from the financial market. When the debtor cannot pay a greater risk premium he will limit budgetary spending or collect money another way, without placing bonds. This means the financial markets (market players together) impose discipline on the debtor.

Informational efficiency is classified into three categories, the first one is the weak efficiency, where bond yields (price) solely reflect all the information contained in the history of past yields (prices), decomposing them into previous value and random effect. The next category is semi-strong efficiency. Besides the information considered above, bond yields should discount all current information from the public sphere such as the budgetary deficit, public debt, inflation, etc. The final category is strong efficiency, this happens when bond yields incorporate both previous groups of news as well as actual information coming from the public and private spheres such as commercial data (Zunino *et al*., 2012, p. 4343, 4344).

Typical reservations about financial market efficiency

Contemporary criticism of debt market efficiency has developed on the basis of arguments form behavioral economists as well as a critique of European Union institutions. Theorists concentrate on psychological and sociological aspects of investing, and market anomalies (seasonal, fundamental as well as hyperactivity, and market resilience) as reasons for inefficient markets. Individual investors are treated as irrational because they tend to deviate from rationality into misjudgment. Typical deviations present regret and cognitive dissonance, anchoring, mental compartmentalization, overconfidence, over (under) reaction, gambling behavior and speculation, etc. (Shiller, 1998). Behaviorists pay attention to limited access to reliable knowledge and informational asymmetry, because some groups of creditors are not capable of keeping up with all the new information or they do not have indispensable experience in investing. Some academics (Sims, 2003) address the problem of rational inattention that is connected with the fact that people suffer from a limited capability of information processing, and they are predisposed to notice information according to their interests and needs.

The practical aspect is associated with international governance in the EMU. Firstly, the configuration of primary dealers made public debt markets overbanked[1] with high liquidity (Dunne *et al*., 2006, p. 31). That created market distortions through overbidding at auctions, because auction prices were normally higher than post-auction valuation on secondary markets. Finally, high prices in comparison to low coupons give preferences to national debtors. Secondly, the European Central Bank (ECB) created short-term interest rates (3M – three months) at a low level due to repurchase agreement (repo) transactions (Buiter & Sibert, 2005, p. 1-42). Because of the low rate of haircuts, all public issuers could be treated on similar terms regardless of their macroeconomic performance. This gave an anchor for long-term bond yields (Allen, 2007, p. 36-53). Moreover, the introduction of non-standard monetary measures has helped to restore national debtors' confidence since 2010. Such a solution predominantly gave

[1] Variety of banks from inside and outside Europe.

relief for highly indebted member countries and offered them time for structural reforms. De Grauwe and Ji (2015, p. 2-5) noticed that implementation of Outright Monetary Transactions (OTM) in 2012 caused the ECB to become a lender of last resort, which could stabilize (and protect) the entire system. This way the ECB could quell the power of financial market participants (threat of real evaluation), and avoid sovereign debtor bankruptcies (Coeure, 2012).

Finally, the practical aspect seems to be prevailing since the non-financial creditors play a minor role in public debt markets[2]. Instead, OTM, and next quantitative easing (QE) could hamper the common response of investors (bond yields evaluation). This way, the politically-related actions of the ECB might have stiffened the rules of efficient markets.

A short review of previous research

The research on the efficiency of public debt markets is not as popular as the analysis of stock markets. Katz (1974) was a pioneer in that field because he pointed at adjustment processes into bond yields, however, he concentrated on bond yield sensitivity towards rating classification. Shiller (1979) addressed the problem of short-term volatility and the structure of long-term bond yields. Nonetheless, our approach fits in with the strand that was initiated by Afonzo and Teixeria (1998). By employing daily observations and non-linearity tests (namely the BDS test and the Hinich bispectrum), they tested the weak-form efficiency of government bonds in the EMU. Finally, the authors found some countries to be efficient while others were not, therefore, challenging the belief that the daily rates of return can be viewed as independent random variables.

In recent years, after a crisis, more economists were interested in examining the efficiency of the public bond markets. Fakhry and Richter (2015) studied the impact of the recent crisis in the US and on German public bonds. They confirmed that both markets were also too volatile (over/under reaction) to be weak-form efficient. In the next study, Fakhry and Richter (2016) enriched the previous procedure (Fakhry & Richter, 2015) with an asymmetric effect. They concluded that debt markets were efficient in spite of the volatile time during the last crisis.

Testing semi-strong efficiency on debt markets, Zunino *et al.* (2012) tested the sovereign market efficiency of thirty bond indices in both developed and emerging economies, using a complexity-entropy causality plane. He found a link between the entropy measure, economic growth, and market size. Finally, according to the work of Zunino *et al.* (2012), developed markets tend to be more efficient

[2] The share of sovereign debt held by non-financial residents in 2014: Germany (6.4%); France (2%); Italy (10.2%); Portugal (7.2%); Czech Republic (5.8%); Hungary (11.1%); Poland (3.5%); Spain (2.4%) (Structure, 2015).

than emerging markets. In turn, Ahdieh (2004) and Cross (2006) scrutinized sovereign bond contracts. Network effects and information costs made bonds contractse boilerplate (inefficiently static), such a specificity makes it difficult to examine the debt market reaction. On the other hand, applying time-varying detrended fluctuation analysis, Farreira (2018) noticed that Eurozone countries were mostly affected by the last crisis, that is why the dependence is more evident, but only during the term of a large variation in bond yields.

To sum up, there is a scarcity of research dedicated to the efficiency of the European sovereign bond market in the literature. Rare works provide mixed results depending on applying empirical methodology.

Empirical examination

Taking into consideration the fact that market efficiency is more often scrutinized in the context of equity markets than public debt markets, we have applied developed and tested econometric techniques that are commonly used when analyzing the behavior of stock prices. Similarly to Worthington and Higgs[3] (2006) and Borges[4] (2009), we focused on examining the weak-form market efficiency, because those assumptions seem to be the most possible to fulfill. Thus, only previous values of one variable were tested. Market players know the value of past bonds yields (official data), there are no other factors that need to be found or bought. That allowed us to posit that potential inefficiency would not be dependent on the lack of information on bond yields. In this way, we excluded typical reservations about efficient markets. What is important from the econometric perspective, is the concept of avoiding seeking yield sensitivity to various factors (often unknown to a wide audience or is commercial information), which is contrary to semi-strong and strong market efficiency. Moreover, the applied methodology has been used just to examine weak-form efficiency before.

Data description

Yield time series (daily data) are available on www.stooq.pl. We took into consideration only daily closing yields. Because applied variables (yields of 10 year government bonds) were traded on secondary markets, they include a factor of investor prizing. Our analysis concerned data from January 2007 to December 2018. We considered only 10 Euro members[5] out of 13 that had

[3] Examination of Asian emerging and developed stock markets.

[4] Examination of Portugal stock market.

[5] Belgium (BEL), Germany (GER), Greece (GRE), Spain (ESP), France (FRA), Italy (ITA), Netherlands (NDL), Austria (AUS), Portugal (PRT), Finland (FIN).

participated during the entire period. In the case of Slovenia, Luxemburg, and Ireland we couldn't obtain reliable data encompassing the whole time-range. Unlike Worthington and Higgs (2005) and Borges (2009), we applied daily bond yields, not daily stock prices. For this reason, we did not compute data as the logarithmic difference between two consecutive prices in a series (Borges, 2009), because part of our time-series presents values below zero, especially since 2016. Table 1 presents descriptive statistics of utilized time-series. Contrary to reference works, the mean shows the daily average of bond yields, not the day-to-day return. What is more, the greater volatility of bond yields was observed in GRE and PRT; whereas the lowest was observed in NDL and FRA.

Table 1

Descriptive statistics: bond yields 2007-2018 (daily data)

Economy / Results	AUS	BEL	ESP	FIN	FRA	GER	GRE	ITA	NLD	PRT
Mean	2.29	2.57	3.49	2.15	2.33	1.92	9.77	3.55	1.97	4.80
Median	2.10	2.75	4.01	1.92	2.30	1.67	7.84	4.00	1.85	4.17
Std. Dev.	1.48	1.53	1.60	1.44	1.37	1.42	6.71	1.43	1.36	2.85
Variance	2.18	2.34	2.55	2.07	1.88	2.00	45.05	2.06	1.85	8.11
Kurtosis	-1.48	-1.57	-1.23	-1.38	-1.40	-1.24	4.05	-1.00	-1.22	1.72
Skewness	0.10	-0.17	-0.06	0.22	0.04	0.33	2.04	-0.01	0.31	1.42
No. of Obs.	3,071	3,494	3,073	3,066	3,073	3,066	2,810	2,835	2,835	3,340

Source: own calculations on the basis of original data.

Method

Both Worthington and Higgs (2005) and Borges (2009) employed a three-stage procedure to test random walk in daily returns. Firstly they applied parametric serial correlation and a nonparametric run test. Secondly, the Augmented Dickey--Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test as well as the Phillips-Peron unit root test were also applied. Finally, they used multiple variance test statistics as a decisive measure, because the unit root test does not track departures from a random walk (Liu & He, 1991).

In our verification, we considered a random walk process with a drift:

$$Yd_t = Yd_{t\text{-}1} + \beta + \varepsilon_t \tag{1}$$

$$_{\Delta}Yd_t = \beta + \varepsilon_t \tag{2}$$

where:

Yd_t – bond yields at time t,

β – drift parameter (trend),

ε_t – random process (white noise),

Δ – increment, change of variable.

Under the random walk hypothesis, the market is weak-form efficient if the current yield contains all available information. That is why there is no chance to beat the market only on the basis of previous yields. Future yields can be driven by unexpected information or actions, which are incorporated into the future bond yields, and depicted as a random process (ε_t). Besides the random process, there can be a drift in the time-series that signals the trend (Equation 2).

In the first stage, we checked parametric serial autocorrelation in order to test increment independence and non-parametric run tests to verify their serial dependence. Secondly, taking into consideration the fact that even if yields are serially uncorrelated with independent increments, the series must be identically distributed to conform to the random walk model. For this reason, unit root tests were employed. That allowed us to determine whether time-series (original and detrended data) have any kind of trend and if they are stationary or not.

Whether unit root exists or not, there is still a chance to predict future yield movement (volatility) because the market may present the most restrictive notion of a random walk. In such a market, bond yields are serially uncorrelated and conform to a random walk hypothesis with independent and identically distributed increments. Therefore, in the third stage, we used the Chow and Denning (1993) statistic that examines maximum absolute value from a set of multiple variance ratio statistics as well as the Lo and MacKinlay (1988) variance test ratio.

Results

In the beginning, we checked the parametric serial correlation in time-series on the basis of the Ljung-Box test. The lack of autocorrelation (in the case of one series) is tantamount to the fact that future bond yields are not dependent on the previous ones. We built basic Var models for each economy where current bond yields are dependent on the previous ones. On this basis, we checked serial correlation for the following intervals (lags): two days, one week (five days), two weeks (10 days) and one month (20 days). The autocorrelation test assumes that:

H_0: time-series are independently distributed (no serial correlation)

H_1: time-series are dependently distributed (serial correlation)

Firstly, observing correlograms, we noticed that autocorrelation in the original data is close to 1 and slowly drops, this is a sign of random walk. Secondly, H_0 was rejected for all economies regardless of the number of lags (Tab. 2). Finally, past values are crucial to predict future bond yields. That suggests weak-form inefficiency.

Table 2

Autocorrelation test (Qstatistics)

Market \ Lag	2	5	10	20
AUS	0.50	1.45	0.36	0.46
BEL	0.00	1.83	0.26	1.21
ESP	1.82	1.49	0.10	0.61
FIN	1.20	0.70	0.41	0.83
FRA	1.11	0.92	0.58	0.46
GER	1.90	0.88	0.13	0.93
GRE	3.32	2.26	0.77	0.69
ITA	3.88	1.66	0.68	0.14
NDL	0.90	0.95	0.47	1.04
PRT	1.27	1.03	1.54	0.44

Note: all statistics present insignificance level.
Source: own calculations.

The next step is in regards to a non-parametric run test (Tab. 3) that assumes:

H_0: data distribution is random H_1: data distribution is not random

According to Table 2, H_0 was rejected for all considered markets. The number of observations under/above the mean value is reflected by the sign of skewness. Finally, run tests show a lack of random walk into the time-series (Tab. 3). Like the test above, the run test is in favor of weak-form inefficiency.

Next, we concentrated on testing time-series stationarity, a fundamental method in tracking random walk. According to this concept, two options were assumed. If yields are shaped by a random walk process, their changes cannot be foreseen on the basis of previous observations. Alternatively, bond yields may be stationary and they tend to return to mean values. This time future bond yields can be foreseen and the market is predisposed to be inefficient. The examination comes down to checking the stationarity of the time-series on the basis of three types of tests – parametric: Augmented Dickey-Fuller test (ADF), Kwiatkowski-Phillips-Schmidt-Shin test (KPSS), and non-parametric: Phillips-Peron test (PP).

Table 3

Runs test

Economy \ Results	Runs test					
	Obs.>*M*	Obs.≤*M*	No. of observations	No. of runs	Z_{value}	p_{value}
AUS	1,439	1,632	3,071	14	-54.95	0.00***
BEL	1,830	1,664	3,494	18	58.54	0.00***
ESP	1,846	122	3,073	2	-55.40	0.00***
FIN	1,387	1,679	3,066	22	-54.61	0.00***
FRA	1,504	1,569	3,073	20	-54.75	0.00***
GER	1,298	1,768	3,066	38	-54.01	0.00***
GRE	956	1,854	2,810	29	-51.84	0.00***
ITA	1,614	1,221	2,835	12	-52.83	0.00***
NDL	1,318	1,517	2,835	19	-52.57	0.00***
PRT	1,035	2,305	3,340	25	-56.83	0.00***

Note: *M* means the mean. Significance level: *** 1%.
Source: own calculations.

The ADF and PP test assumes that:

H_0: unit root	H_1: no unit root
(time-series distribution is random)	(time-series distribution is not random)

In order to check the level of variable integration, we conducted the ADF test, which allowed us to hold or reject H_0. We employed the Akaike criterion and 28-29 lags dependent on the length of the particular times-series.

ADF and P-P tests confirmed the lack of stationary input data. Moreover, our verification suggested that the series are mostly trend (incremental) stationary. To verify the preceding results, we applied the KPSS test, where:

H_0: no unit root	H_1: unit root
(time-series distribution is not random)	(time-series distribution is random)

Taking on board the dynamic characteristics of the financial time-series developed by Nelson and Plosser (1982)[6], we examined the structural breaks. After 2008 the dynamic of political and economic events could have had an impact on the unit roots test's sensitivity, especially the engagement of ECB into OMT and QE. Verification was done on the basis of an ADF test with one structural break. According to Zivot and Anders (2002), we assumed an unknown time

[6] Endogenous shocks might have permanent effects on the long-run level of variables. This time ADF tests may be biased towards the non-rejection of H_0.

of endogenous shock. The results are presented in the Table 4. Finally, except for Belgium, structural breaks had no impact on the trends of the examined time-series in the long perspective. This problem deserves a discrete examination in the future since all other unit root tests have suggested the same findings (Tab. 4). Namely, original time-series were nonstationary, whereas detrended data turned out to be stationary. Such results confirmed the typical non-stationary characteristic of financial time-series. Results of the unit root test proved time-series follow the random walk model (markets are weak-form efficient).

Table 4

Unit roots test (test statistic)

Test / Economy	ADF test		P-P test		KPSS test		ADF test with structural break	
	YLD	D(YLD)	YLD	D(YLD)	YLD	D(YLD)	YLD	D(YLD)
AUS	0.89	50.94***	0.78	59.77***	6.78***	0.06	3.64	51.4***
BEL	0.47	49.77***	0.26	49.05***	6.92***	0.16	5.10***	50.09***
ESP	0.83	31.27***	0.78	47.63***	4.59***	0.15	3.78	32.04***
FIN	0.97	53.21***	0.96	53.18***	6.73***	0.06	3.23	53,61***
FRA	0.92	53.05***	0.91	53.01***	6.74***	0.05	3.26	13.27***
GER	1.09	53.72***	1.05	53.81***	6.65***	0.05	3.36	40.30***
GRE	1.93	31.55***	1.87	48.14***	1.03***	0.12	2.37	20.01***
ITA	1.41	38.44***	1.33	47.89***	4.32***	0.09	3.36	11.72***
NDL	1.33	51.09***	1.32	51.07	6.27***	0.07	3.18	51.54***
PRT	0.76	19.63***	1.07	49.04***	2.11***	0.19	2.83	18.59***

Note: significance level: *** 1%; ** 5%; * 10%. Test statistics denotes critical value for ADF, P-P tests (absolute values); p_{value} denotes asymptotic value (only results with the lowest P_{value}). Critical values in ADF and P-P tests: *** 3.43; ** 2.86; * 2.56. Critical values in ADF with break point: *** 4.93; ** 0.44; * 4.19. Critical values in KPSS test: *** 0.74; ** 0.46; * 0.35.
Source: own calculations.

Taking into consideration that in fact the results from the correlation test and run tests are not consistent with results from unit root tests, we applied Chow and Denning's (1993) multiple variance tests. We assumed two hypotheses:

H_0: time-series follow random walk

H_1: time-series do not follow a random walk

According to Chow and Denning (1993), the final decision about the null hypothesis is obtained from the maximum value of the individual V_r statistic (Charles & Darné, 2009). If test values are bigger than the critical value of the Studentized Maximum Modulus distribution (2.49) and the p_{value} is significant

(<0.05), we can reject H_0. Taking the results of multiple variance test ratios into account, we found that the maximum value of the series is mostly obtained for the 2 day-interval.

In the Table 4 presents only the maximum absolute value of $Z_{(q)}$ – a test statistic for a homoscedastic random walk, and $Z^*_{(q)}$ – a test statistic for a conditional heteroscedastic random walk. Z statistics characterize q and Variance ratio (V_r) with the lowest p_{value}. We avoided presenting individual specifications because they do not change the general conclusions apart from cases that require further checking.

With regard to homoscedastic increments $Z_{(q)}$, all tests rejected H_0 (Tab. 5). Therefore, we were compelled to make a decision on the grounds of conditional heteroscedasticity $Z^*_{(q)}$. H_0 was held in the case of AUS, BEL, FRA, GER, NDL, and FIN. Thus, the achieved results gave evidence that sovereign debt markets are efficient in those economies.

Table 5

Multiple Variance Test for 2007-2018

Economy \ Results	Maximum values		
	VR_q	$Z_{(q)}$	$Z^*_{(q)}$
AUS	1.08 $_{(2)}$	4.65***	1.30
BEL	0.90 $_{(2)}$	2.61**	0.69
ESP	1.07 $_{(2)}$	4.03***	2.62**
FIN	0.39 $_{(20)}$	6.72***	1.33
FRA	1.05 $_{(2)}$	3.04***	0.96
GER	0.86 $_{(5)}$	11.45***	2.17
GRE	1.23 $_{(2)}$	7.26 ***	3.73***
ITA	1.06 $_{(2)}$	3.38***	2.33*
NDL	0.65 $_{(5)}$	8.31***	1.56
PRT	1.14 $_{(2)}$	8.24***	3.37***

Note: $Z_{(q)}$ – test statistic for homoscedastic random walk, $Z^*_{(q)}$ – test statistic for heteroscedastic random walk. Significance level: *** 1%; ** 5%, * 10%.
Source: own calculations.

In reference to ESP, PRT, ITA, and GRE we gained mixed results on all stages of our procedure. Taking unclear results into consideration as well as the fact that Lo and MacKinlay (1988) argued that the individual variance ratio test is more powerful than the Augmented Dickey-Fuller unit root test, we decided to check the individual variance ratio for those four markets. We examined individual intervals for ESP, PRT, ITA, and GRE for four distant intervals (2, 5, 10, 20). Finally, it is noticeable (Tab. 6) that at higher intervals H_0 is not rejected. Additionally, conditional heteroskedasticity is confirmed by

Table 6

Individual Variance Test for 2007–2018 (heteroscedastic factor)

Economy \ q		2	5	10	20
ESP	VR_q	1.07	1.02	0.94	0.91
	$Z^*_{(q)}$	2.62***	0.72	0.50	0.46
GRE	VR_q	1.14	1.13	1.08	0.98
	$Z^*_{(q)}$	3.73***	1.65*	0.69	0.06
ITA	VR_q	1.06	0.99	0.97	1.01
	$Z^*_{(q)}$	2.33*	0.06	0.23	0.13
PRT	VR_q	1.14	1.17	1.12	1.12
	$Z^*_{(q)}$	3.37***	1.84*	0.86	0.67

Significance level: *** 1%; ** 5%, * 10%.
Source: own calculations.

autocorrelation in the original data (Tab. 2). Thus, public debt markets in ESP, PRT, ITA, and GRE are efficient, especially at higher rows.

To sum up, all scrutinized debt markets turned out to be weak-form efficient on the basis of the applied restrictive procedure from stock markets. Empirical findings from parametric and non-parametric unit root tests were confirmed by a multiple variance test or an individual variance test.

Discussion: empirical findings against EMH criticism

Analysis of random walk into the behavior of bond yields comes down to determining whether yields are created by random processes or not. If the following yields are generated by unexpected news or actions that are unknown for market players, it is impossible to predict future yields. According to Equation 1, future bond yields are dependent on the previous yields as well as drift, and random processes. Our empirical analysis has proven that the drift (β) is incrementally stationary, not deterministic. For this reason, the trend does not play an important role here. Thus, bond yields might have followed previous yields provided that a random factor (ε_t) does not exist in the time-series. Our three-stage empirical verification has provided conclusions that sovereign bond yields are generated by a conditional random walk.

With regard to the above-mentioned reservations, the literature willingly credits irrationality to individual investors based on sociological and psychological aspects, but their tendency to deviate from rationality into misjudgment results from operating in highly uncertain investing conditions that Fakhry and Ritcher (2015) called bounded rationality. Certainly, governing practice connected with preventing bond yields' erosion could have increased the uncertainty in the economic and financial milieu.

To sum up, on the one hand, the randomness in bond yields means that an individual investor cannot predict future bond yields (prices) regardless of access to reliable information. On the other hand, due to a random transition, bond yields are not rigid but are susceptible to changes. The randomness of bond yields is crucial from the point of view of investors and decision-makers. Debt market participants, in response to irresponsible internal economic policy (or growing uncertainty) in the debtor's economy, can complicate its situation in international debt markets.

Conclusions

The theory of efficient financial markets is fundamental to financial economics. However, this notion is often criticized on the grounds of behavioral economics and European institutions' governance. Regardless of the number of objections to market efficiency, our empirical findings provide strong evidence that scrutinized public bond markets present conditional weak-form efficiency. According to existing theory, the sudden change into bond yields is an effect of new, adverse information that has been revealed. Randomness into bond yields proves that investors react to unexpected or adverse news and put creditors under pressure. Thus, neither individual investors' weaknesses, nor politically-related anchors for long-term credit costs eliminate the weak-form efficiency in public debt markets in the EMU.

Because of the applied empirical procedure, typical to stock markets, our approach to the problem may be novel. Apart from its novelty, our work provokes some implications for both market players and academics. Firstly, financial markets can impose discipline on public debtors due to the shifts in bond yields (prices). Secondly, our research is an introductory piece that needs to be developed. As only one factor (past bond yieds) has been taken into account, there is room for verifying our findings on the basis of a semi-strong form of efficiency.

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