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Has the Relationship Between Market and Model CDS Price Changed during the EMU Debt Crisis?

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Abstract:

Basic purpose of a credit default swap (CDS) is to protect its buyer against a default of a reference entity. During the ongoing EMU debt crisis this purpose was questioned when Greek default was postponed continuously and actions of European public authorities gave rise to speculations that Greece could effectively default without CDS protection payment being triggered. In this article we examine whether this development in Greek case influenced CDS price of EMU member states in general, i.e. whether investors' trust in this instrument decreased. Our presumption is that if there are no uncertainties about the CDS contract conditions, market price of a CDS should be closely related to its modelled risk-neutral fair price. In the first part of the article we use adopted reduced form CDS valuation model to obtain model CDS price which is compared to market CDS price in the second part of the article using two methods: heteroskedasticity- and autocorrelation-robust estimates and Johansen cointegration test. The main finding

of this article is that the relationship between market and model CDS price mostly weakened during the crisis. More interestingly, using the first method it weakened in case of all riskier countries such as Portugal, Italy, Ireland, Spain and Belgium and this trend is not confirmed in case of safer countries such as Finland, France, Netherlands and Austria. In both methods we take into account a role of counterparty and liquidity risk and conclude that whereas counterparty risk role increased during the crisis, liquidity risk does not seem to play an important role in CDS market price determination.

Keywords:

credit default swap, CDS valuation, reduced form model, debt crisis, robust estimator, Johansen cointegration test

JEL: C22, G01, G12

1. Introduction: CDS Contract and Its Development

Credit default swap (CDS) is a derivative contract where one counterparty (CDS buyer) agrees to pay regular payments (CDS spread or CDS premium) to another counterparty (CDS seller) either until maturity of the contract or until a credit event of a reference entity, whichever is sooner. On the other hand, CDS seller agrees to compensate a loss incurred by the buyer in case of a credit event before CDS maturity. Credit event is defined as at least one of the following: bankruptcy, failure to make a principal or interest payment, obligation acceleration, obligation default, repudiation/moratorium (for sovereign borrowers) and restructuring. All these events are referred to as default. The compensation usually corresponds to the difference between nominal amount of some underlying asset issued by the reference entity and its recovery amount. That implies that for the buyer CDS represents a form of insurance against default of the underlying asset and the seller acts as an insurer.

In this paper we analyse if and how recent development in Europe influenced sovereign EMU CDSs market prices. Using standard probabilistic CDS pricing model by Hull and White (2000) we compare how actual CDS market price deviates from the model price and if there was any apparent change in this relationship between 2009 and 2013. Our main hypothesis is that this relationship relaxed at the end of 2011 when first uncertainties about Greek debt restructuring and CDS settlement trigger appeared, i.e. CDS market price is not driven by the model price (price calculated by weighting future cash-flows by their probability) to the extent it used to be. To be more specific, we expect that continuing postponement of Greek default by EU and IMF bailout plans and an effort to avoid CDS trigger negatively influenced willingness of investors to protect their bond exposures to other European sovereign bonds using CDSs. This would result in lower CDS market price than the model price – after Greek experience investors are willing to pay less for the protection because they aren't so sure of it.

We are aware of the fact that there are more factors that influence CDS price and that have changed during the observation period. To deal with it we account for the most serious ones in our models - changing liquidity and counterparty risk.

Analysis in this paper is motivated by recent development of CDS contract. Therefore historical context of the research is summarized in Section 2. In Section 3 we present an overview of current literature that deals with CDS valuation and CDS behaviour during European sovereign debt crisis. Then, in Section 4 we discuss the data used for the calculation. In Section 5 we shortly present adopted CDS pricing model and CDS valuation results which are necessary for their use in Section 6. Section 6 introduces two methods that we applied to analyse model and market CDS price: heteroskedasticity- and autocorrelation-robust OLS estimation and Johansen cointegration test. At the end of each subsection of Section 6 we compare and discuss results of the methods.

2. Historical Context

Despite its rather short existence - it was invented in 1990's - CDS went through a chequered history. Its issuance experienced rapid growth after year 2000 when the documentation used for agreeing CDS contract was standardized by International Swaps and Derivatives Association (ISDA). Nominal outstanding amount of single name CDS gradually grew from \$5.1 trillion in 2004 and peaked at \$32.4 trillion in 2007 (BIS (2013)). Initially, CDS was mainly used by banks to hedge their exposures but it soon attracted speculators and hedge funds have become the main investor type (Barrett and Ewan (2006)). CDS attractiveness lied among others in the fact that it offered high leverage – investors were exposed to a reference entity with no need for initial investment.

Subsequent world financial crisis brought CDS to public attention and it was subject to criticism. Its main points were lack of transparency, regulation and standardization¹. Critics argued that there was no central counterparty which would have an overview about all trades and which would ensure their settlement. Regulators had no data on CDS transactions because they were concluded OTC and demanded more transparency, especially after a default of two important CDS traders – Lehman Brothers and AIG. Also, CDSs were criticized for being a source of serious systemic risk causing unforeseen interconnection of financial markets' participants and so called "domino effect" when one entity defaults.

As a reaction to these calls CDS contracts were internationally standardized during 2009 and U.S. and Europe launched their central clearing houses to settle CDS trades. These efforts were supported on a consecutive G-20 meeting (Financial Stability Board (2010)). At the same time offsetting CDS transactions were enabled to be cancelled which contributed to ongoing contraction of CDS market (Bloomberg (2010)). In 2008 outstanding notional of single-name CDSs was \$25.7 trillion, in 2010 it was \$18.1 trillion and in 2012 \$14.3 trillion (BIS (2013)).

European sovereign debt crisis brought another important question which is in detail studied in this paper - CDS elemental function was questioned. While Greece was gradually heading towards default the definition of credit event which triggers CDS early settlement caused doubts (Reuters (2011) or Bloomberg (2012a)). Greek difficulties were to be solved among others by partial restructuring of its bonds. This restructuring basically consisted in lengthening their maturity and lowering their coupon. Main Greek bond holders were addressed with terms of the restructuring and they were asked to agree on its voluntary basis. If this restructuring was voluntary and not binding for all bond holders, it would not trigger CDS settlement according to ISDA EMEA Determinations Committee² which is responsible for the decision on credit event occurrence (ISDA (2012a)). As a result, Greek bond investors that agreed on the restructuring and that bought protection against Greek bonds in their possession via CDS would not be compensated for their losses, they would continue paying for the protection and holding CDS which maturity would no longer match maturity of new Greek bonds.

In February 2012 Greece inserted collective action clauses (CAC) in existing bonds' terms. The retroactive insertion of CAC itself was perceived as a default by some market participants. For example Standard & Poor's downgraded these bonds to SD – selective default arguing that "issuer's unilateral change of the original terms and conditions of an obligation may be viewed as a de facto restructuring and thus a default by S&P's published definition" (Standard & Poor's (2012)). By contrast on March 1 ISDA EMEA Determinations Committee released a statement that credit event on Greek bonds hasn't occurred yet (ISDA (2012b)).

After negotiations with investors' representatives Greece finally reached that on March 9, 2012 85.8% of Greek debt holders accepted voluntarily the restructuring scheme and exchange of their bonds³. This restructuring participation rate enabled Greece activate CACs which forced also the remaining investors to participate in the restructuring. As a reaction to the CACs activation ISDA EMEA Determination Committee announced restructuring credit event arguing that the right of all bond

¹ See for example Reuters (2008a; 2008b), The Economist (2008) or Cox (2008).

² ISDA EMEA Determinations Committee consists of ten voting dealers, five voting non-dealers, two consultative dealers and one consultative non-dealer. Dealers are selected annually based on the volumes of their CDS trades and other criteria such as their participation in CDS auctions. Non-dealers are selected randomly from CDS buyers based on some volume criteria and they also change on an annual basis.

³ Participation rate among investors was 95.7% and investors tendered 85.8% of Greek-law governed sovereign bonds (Bloomberg 2012b).

holders to receive payments has been reduced. This finally resulted in CDS early settlement trigger (ISDA (2012c)).

3. Literature Overview

To be able to compare model and market price of a CDS we need a CDS valuation model to determine fair model price. Basically, there are two types of credit risk models: structural models and reduced form models.

Structural models are based on Merton (1974) model which uses Black and Scholes (1973) option pricing theory to price default risk of a bond. Company default occurs, if its assets fall below certain level. The model evaluates credit spread of a risky bond using assets' growth, assets' volatility and leverage. It was then used and further developed by for example Black and Cox (1976) who relaxed some assumptions, Longstaff and Schwartz (1995) who incorporated default and interest rate risk or Das (1995) who applied the model to credit derivatives. Parameters of these models are hard to estimate partly because of the fact that assets' market value or their volatility is hard to observe and quantify.

Reduced form or intensity-based model defines default using hazard rate or default probability function. The model was introduced by Jarrow and Turnbull (1995) or Duffie (1999). In this article we use its version presented by Hull and White (2000) who apply the theory to CDSs. CDS is priced based on default probability function which is extracted from bond yields. Parity of the model was tested by Longstaff et al. (2003), Longstaff et al. (2005) or Blanco et al. (2005) on selected liquid companies in corporate and financial sector or by Houweling and Vorst (2005) who recommend to use swap or repo rates as a risk-free rate rather than government bond yields. Drawback of this model is that bond spreads which are used to determine CDS spread contain other factors such as liquidity and tax effects which shouldn't influence CDS spread (Chen et al. (2007)). Nevertheless, Longstaff et al. (2005) divided corporate bond spread to default and non-default component and discovered that the default component represents at least majority of corporate bond spreads even for the highest investment-grade firms. Another weakness is that some researches documented that it is bond price which follows CDS spread in the price discovery process not vice versa (Coudert and Gex (2010) or Delatte (2012)). On the other hand, O'Kane (2012) found that this causality differed for different European sovereigns during 2009-2011 and in case of some sovereigns he discovered Granger causality in both directions.

In this paper we examine Eurozone CDSs in recent European debt crisis. Similar data are examined e.g. by already mentioned O'Kane (2012) who uses Granger causality test to compare CDS and bond prices or Calice et al. (2011) who show credit and liquidity interactions and discover that liquidity of CDS market influences substantially bond credit spreads. Annaert et al. (2013) study recent Euro area bank CDSs and point out that determinants of their price such as default risk, liquidity, business cycle or risk aversion vary strongly in time. Another view is presented by Hull et al. (2004) who carried an analysis showing that credit spreads provide helpful information in estimating the probability of negative credit rating changes and that credit rating downgrades carry no new information for a CDS market. Other authors that deal with CDS value determinants during the financial crisis are Badaoui et al. (2013) or Beirne and Fratzscher (2013).

In this article we take over existing CDS pricing model but models used to compare market and model CDS hasn't been applied to similar data by any other author to our knowledge. Also, hypothesis about loosening of the relationship between market and model CDS hasn't been tested yet.

4. Data

Time series data used for the purposes of this article are summarized in Table 1. They were downloaded from Bloomberg. Data range is from 1.1.2006 until 31.1.2013. We are analysing all Eurozone members as of the beginning of the observation period. All calculations are based on mid-market values.

Table 1: Summary of Downloadable Data

instrument	data type	issuer	currency	Bloomberg ticker (5Y maturity)	maturity
government bond	generic bid and ask yield	Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain	EUR	GTATS5Y, GTBEF5Y, GTFIM5Y, GTFRF5Y, GTDEM5Y, GTGRD5Y, GTIEP5Y, GTITL5Y, GTNL5Y, GTPTE5Y, GTESP5Y Govt	3M, 6M, 1Y, 2Y, 3Y, 4Y, 5Y, 6Y, 7Y, 8Y, 9Y, 10Y
credit default swap	bid and ask spread	USA	USD	AUST CDS USD SR, BELG CDS USD SR 5Y, FINL CDS USD SR 5Y, FRTR CDS USD SR 5Y, GERMAN CDS USD SR 5Y, GREECE CDS USD SR 5Y, IRELAND CDS USD SR 5Y, ITALY CDS USD SR 5Y, NETHER CDS USD SR 5Y, PORTUG CDS USD SR 5Y, SPAIN CDS USD SR 5Y Corp	5Y, 10Y
cross-currency swap	bid and ask swap rate		EUR/USD	ZCTO CDS USD SR 5Y Corp	5Y, 10Y
credit default swap	mid spread	various European banks	EUR	e.g. BNP CDS EUR SR 5Y, RBOS CDS EUR SR 5Y, HSBC BK CDS EUR SR 5Y, DB CDS EUR SR 5Y, ING BK CDS EUR SR 5Y, LLOY CDS EUR SR 5Y, SOCGEN CDS EUR SR 5Y	5Y

Government bond yields enable us to price CDSs in Section 5 and are used for the analysis of market credit default swaps in Section 6. Resulting model CDSs have a different denomination than market CDSs. Therefore market CDSs are adjusted by a EUR/USD cross-currency swap value⁴.

In the regression analysis in Section 6 we account for market liquidity risk and counterparty risk of a CDS. As a measure of market liquidity risk we use the bid-ask spread of the government bond yield from the respective issuer with the respective maturity. As a measure of CDS counterparty risk we use average five year CDS spreads of ten largest European banks according to their assets (Banks around the World (2013)). The list of the banks is updated for each calendar year.

5. CDS Valuation

To be able see how market CDS price has been reacting to model CDS price we first have to evaluate model CDS price. To do so we use basic no-arbitrage CDS valuation model presented by Hull and White (2000). In Hull and White (2001) this model is enhanced by including a risk of CDS writer in the CDS

⁴ The cross-currency swap may be used to compare yields of the same floating rate bonds with different denomination. Buying a bond in one currency should be equivalent to buying a similar bond in the other currency together with a cross-currency swap between the two currencies. Although the liquidity profile is different in case of credit default swaps, we find this adjustment of market CDS denominated in USD as the most suitable solution to account for different currency denomination.

price. Being aware of the fact that counterparty risk might play an important role in CDS pricing, we account for counterparty risk in consecutive analysis.

The model is briefly presented in the first part of this section and results of the valuation are summarized in the second part.

5.1. CDS Valuation Model

Extraction of default intensity $q(t)$ from bond prices

If we assume that the only reason why the present value of a defaultable bond differs from the present value of a default-free bond with the same cash-flows is the possibility of default, we can estimate the risk-neutral probability of default from bond prices. Model presented in this article works on this presumption.

We consider plain-vanilla CDS with 1 unit of currency nominal amount. Suppose that for each CDS reference entity (in this case Eurozone member state) there are N bonds issued by the reference entity (called issuer further in this section). Also suppose that the maturity of j -th bond is t_j and $t_1 < t_2 < t_3 < \dots < t_N$. Assume that time t is a continuous variable expressed in years and $t \geq 0$. Define $q(t)\Delta t$ as a probability of default of the issuer between times t and $t + \Delta t$ as seen at time 0, i.e. $q(t)$ stands for the default probability density.

As a first step the model extracts $q(t)\Delta t$. Assume that $q(t)$ is constant and equal to q_i for $t_{i-1} < t < t_i$. This simplified assumption is limiting to some extent; the probability of default takes as many values as the number of bonds from which it is extracted. Also assume that default events, risk-free interest rates and recovery rates are mutually independent. In our calculations all bonds from one issuer have the same seniority and therefore they should have the same recovery rate at a given time. Additionally, we add an assumption that recovery rate is independent of time.

Then, if an issuer defaults at time $t < t_j$, then holders of j -th bond receive the claim amount $C_j(t)$ times the recovery rate R . As discussed by the authors of this model, a reasonable assumption is that claim amount corresponds to the nominal amount of the bond plus accrued interest. It follows that present value of loss incurred by the j -th bond holder at time t_i denoted as α_{ij} is

$$\alpha_{ij} = v(t)[F_j(t) - RC_j(t)]. \quad (1)$$

$v(t)$ is a risk-free discount factor, i.e. present value of 1 unit of currency received at time t with certainty. $F_j(t)$ is a forward market price of j -th bond for a forward contract maturing at time t including accrued interest.

Let's denote present value of j -th bond B_j and present value of j -bond as if it was a risk-free bond (i.e. future cashflows of the bond are discounted by a risk-free rate) G_j . Then the difference between these two prices should correspond to the sum of possible losses multiplied by their probabilities:

$$G_j - B_j = \sum_{i=1}^j q_i \beta_{ij}, \quad (2)$$

where $\beta_{ij} = \int_{t_{i-1}}^{t_i} v(t)[F_j(t) - RC_j(t)]dt$. From equation (2) we can deductively calculate q 's:

$$q_j = \frac{G_j - B_j - \sum_{i=1}^{j-1} q_i \beta_{ij}}{\beta_{jj}} \quad (3)$$

CDS spread determination

Having estimated the risk-neutral probabilities of default the next step is to calculate the expected present value of CDS cash-flows.

Firstly, we will evaluate the expected value of CDS premium payments. If there is no default then yearly premium payments w , made by CDS buyer, continue until maturity of the swap T . The probability of no default over the whole swap life is π .

$$\pi = 1 - \int_0^T q(t)dt \quad (4)$$

On the other hand, if there is a default at time $t < T$, there is an early settlement and CDS buyer pays regular premium payments and the last premium payment before the default is reduced to an accrual part from the preceding premium payment. As a result the expected present value of CDS premium payments is

$$w \int_0^T q(t)[u(t) + e(t)]dt + w\pi u(T), \quad (5)$$

where $u(t)$ and $e(t)$ denote the discount factors: $u(t)$ is a present value of payments at the rate of 1 unit of currency per year on payment dates between time 0 and t and $e(t)$ is a present value of an accrual payment at time t which accrued between t^* and t where t^* is the payment date immediately preceding time t . The first part of equation (5) corresponds to the expected present value of CDS premium payments in case there is a default during the life of the swap and the second part corresponds to the expected present value of premium payments in case of no default over the whole life of the swap.

Secondly, we will evaluate expected present value of the payment from CDS issuer to CDS buyer, i.e. the settlement amount in case of default. It corresponds to the nominal value of the reference bond minus its value just after the default, which is - based on the assumption about the claim amount – nominal value plus accrued interest expressed as a percent of nominal value $A(t)$, both multiplied by the recovery rate R : $1 - [1 + A(t)]R$. The expected present value of the CDS payoff is then

$$\int_0^T [1 - R - A(t)R]q(t)v(t)dt \quad (6)$$

The fair value of a CDS premium payment w is the value of w which makes the net present value of CDS cash-flows equal to zero, i.e. a value which makes expressions (5) and (6) equal:

$$s = \frac{\int_0^T [1 - R - A(t)R]q(t)v(t)dt}{\int_0^T q(t)[u(t) + e(t)]dt + \pi u(T)} \quad (7)$$

Value of s in equation (7) then shows yearly CDS premium payment expressed as a percentage of CDS nominal amount.

5.2. CDS Valuation Results

Model Inputs

We calculated model CDS price for a 5-year and 10-year maturity for each of the Eurozone countries listed in Section 4. Before presenting the results we will summarize model inputs.

For each country we extracted the probability of default in equation (3) using $j = 12$ benchmark bond mid-market yields with the following maturities: 3 months, 6 months and yearly maturities from 1 to 10 years.

As a proxy for a risk-free rate we used benchmark German government bond yields from which we calculated zero coupon yields. Houweling and Vorst (2005) perform a comparative analysis of a fit of model CDS spread to market spread using three types of discount rates: interest rate swaps, repo rates and government curve showing that government curve yields the poorest results. On the other hand Longstaff et al. (2005) who extract default component from bond yields again using all three types of the curves yield robust results in all three cases. However, purpose of this article is not to fit the market CDS data best but contrarily to analyse the difference between model and market price. The reason why we prefer German bond curve over the swap curve is that low risk government bonds often traded below swaps during our observation period⁵ and that would lead to negative default probabilities. The reasons for this trend is a different nature of swap and bond instrument. The main point is that there is no initial investment in an interest rate swap compared to the bond, i.e. bonds and swaps are naturally used for different purposes. Although swap curve is widely used as a benchmark in practice, in this case of evaluating government CDS spreads the different liquidity profile of these two instruments wouldn't provide reasonable results. Therefore we prefer to benchmark government yields on the yields of the same instrument which is considered the least risky – German government bond. As Germany is used as a benchmark, German CDS is not modelled and Germany is not included in our analysis.

The recovery rate value is set to 53% for all states based on historical experience. It is an average sovereign issuer-weighted recovery rate from 1983 to 2010 according to an annual report of sovereign bond issuers' default issued by Moody's (2011). Hull and White (2000) point out that recovery rate value should be set to its expected value in risk-neutral world which – if there is no systemic risk – corresponds to its value in the real world. They also test the sensitivity of the CDS valuation model to recovery rate value and show that that it is generally rather small. However in our case of more turbulent times with high probabilities of default the importance of this value gains strength.

As a result of using generic bond yield-to-maturity data which are not assigned a coupon, we expect each day that the bond trades at par and coupon rate corresponds to the yield. Maximum value of cumulative default probability used in equation (4) was set to 1. Although it is possible that after one default the country may default again, second default would not have any impact on CDS price because CDS would be settled right after the first default.

To evaluate definite integral value in equations (5) and (6) we used Simpson's rule.

Model CDS Values

Figure 1 shows the relationship between model CDS and bond spreads. For low bond spreads it is visible that generally the relation is more or less linear with cases of both higher and lower model CDS spreads than bond spreads (see for example the case of Finland). In more turbulent times in riskier countries the variability increases and in crisis times of very high bond spreads model CDS spreads tend to be higher than bond spreads. This trend is most visible in case of Ireland where recovery rate value plays an important role because of relatively high probabilities of default.

On the other hand the abovementioned trend is lowered by the cap of 1 on cumulative probability of default. Bond curve may point to more than one default in following years whereas CDS is settled and

⁵ For example 10-year German government bond yield has been lower than 10-year EUR interest rate swap over the whole observation period.

stops existing right after the first default. As a result, if bond market implies that the first default will for sure take place in less than k years, then equation (7) implies that model CDS spread would be the same for all CDS maturities higher than or equal to k years⁶. Expected CDS cash-flow would be the same no matter the maturity and CDS spread would not grow with the bond spread.

Regarding the Greek case, we performed the valuation only until 9.3.2012 when ISDA announced that Greek credit event was triggered and currently existing CDSs will be settled⁷. Still the model is not able to give reasonable results in extreme financial distress such as pre-default period when market liquidity is extremely low and market data are not reliable. Although Greece is included in the following analysis the results are less reliable than the results of other non-distressed countries.

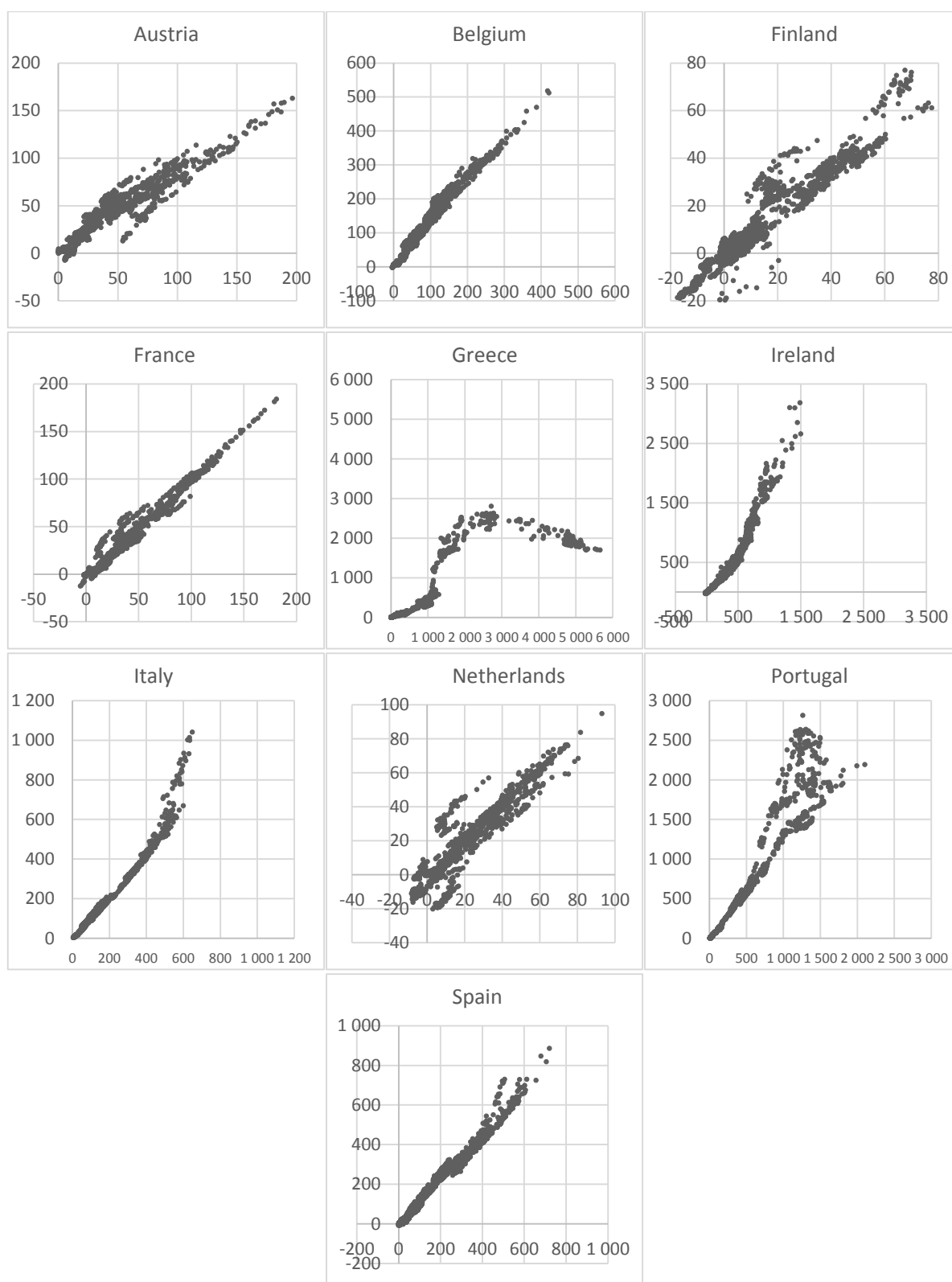
The development of model CDS spreads is depicted in Figure 2. Their value first peaks during the world financial crisis at the beginning of 2009 (this peak is however much less visible in case of riskier countries because of extreme spread growth in the future) and a second peak is visible at the end of 2011 as a result of escalating Eurozone debt crisis.

⁶ For example in case of Ireland implied value of probability of no default during the whole swap life (π) in June 2011 is 0 already for a 3-year swap maturity.

⁷ On March 19, 2012 Greek CDS auction took place with final settlement price of 21.5% (complete results of the auction can be reached at <http://creditfixings.com/CreditEventAuctions/results.jsp?ticker=GREECE>).

Figure 1: Model CDS compared to government bond spread

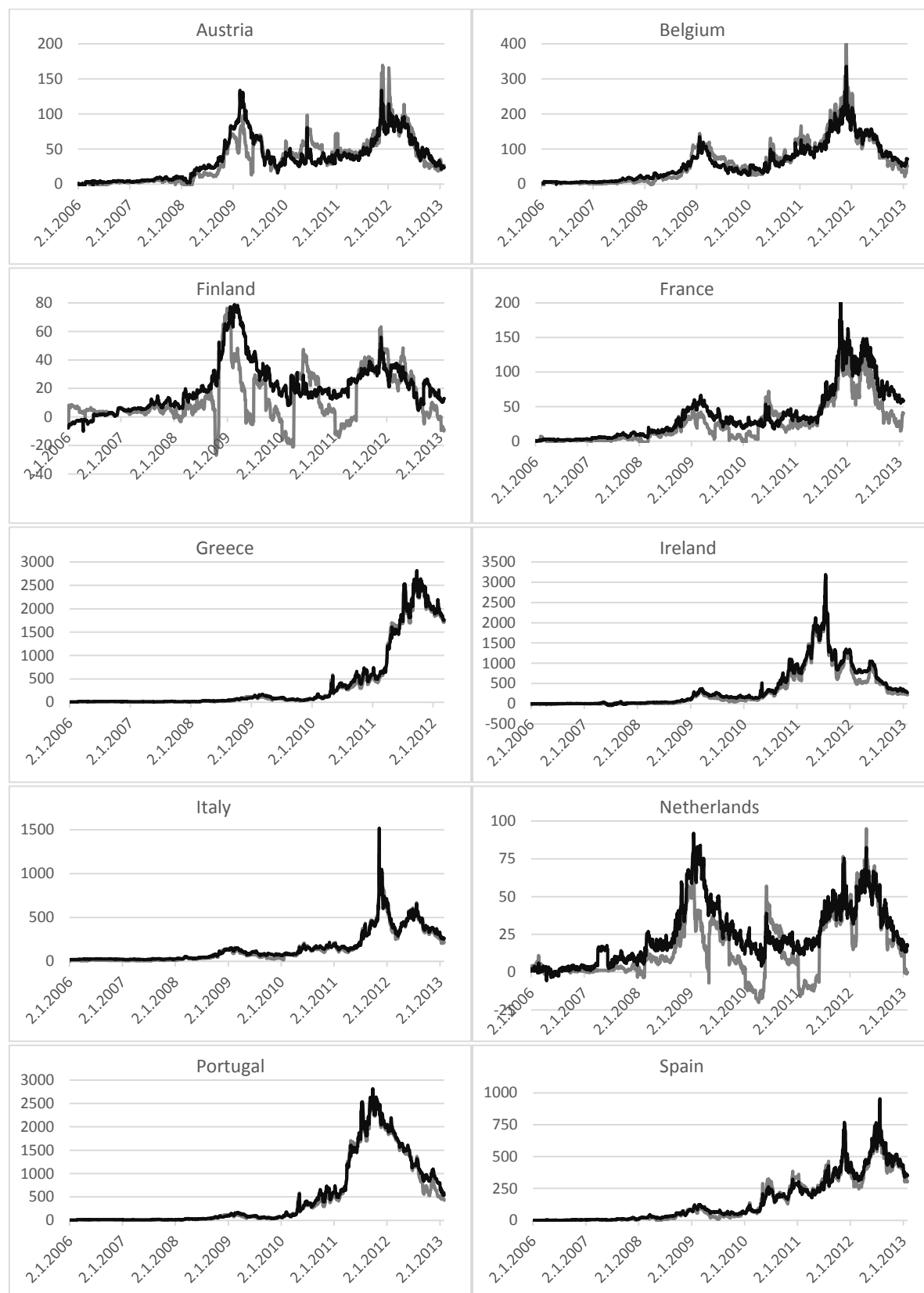
(x-axis: 5-year government bond spread over German Bund; y-axis: model 5-year CDS; both in basis points from January 2006 until January 2013)



Source: Bloomberg, author's calculations

Figure 2: Results of CDS Valuation

(grey line: model 5-year CDS; black line: model 10-year CDS; both in basis points)



Source: author's calculations

6. Relation between Model and Market CDS during the EMU Crisis

At the end of Section 1 we introduced the aim of this paper. Based on recent development on European financial markets we would like to investigate whether investors changed their attitude to credit default swaps. Our hypothesis is that based on Greek experience and attempts to avoid CDS early settlement investors' trust that CDS will for sure protect them against sovereign default lowered. As a result we expect that the relationship between model CDS and market CDS price changed after first doubts about CDS early settlement appeared. To be more concrete we expect that the link weakened and CDS investors are willing to pay less for the protection via CDS than before.

Being aware of the fact that there are other factors that may have recently influenced this relationship we will include in the modelling the two most apparent – CDS counterparty default risk and liquidity risk. Firstly, pricing model introduced in Subsection 5.1 doesn't take into account counterparty risk. In case CDS seller defaults, CDS buyer will lose his protection against the reference entity. Usually, CDS issuers are highly rated banks but after the world financial crisis the awareness of their possibility to default pervaded. Secondly, liquidity premium requested by investors in turbulent times of low liquidity increases.

Subsection 6.1 will summarize the data and their properties. Based on that we will run multiple time series regression analyses in Subsection 6.2 aimed at the discovery of the relationship between model and market CDS price. Another method applied in Subsection 6.3 is the Johansen test which discovers cointegrating relationship between two time series. We will see if the results of the test differ before and during the European debt crisis.

6.1. Data Properties

In this subsection we are interested in examining the period of the EMU debt crisis. Therefore we analyse data range from December 2009 until January 2013. As a starting point of the crisis we take December 2009 because at the end of October 2009 Greece admitted having the highest debt in modern history revising its budget deficit forecast from 3.7% to 12.5% of GDP (European Commission (2010)). Moreover we distinguish two sub-periods: until September 2011 and from October 2011. At that time we spotted first articles speculating about CDS trigger in case of voluntary debt exchange⁸.

We are analysing daily time series data of the following variables: market CDS price as dependent variable (5-year and 10-year maturity) and model CDS price (5-year and 10-year maturity), bid-ask bond yield spread (5-year and 10-year maturity, to account for liquidity risk) and average CDS spread of top European banks (5-year maturity, to account for counterparty risk) as independent variables. The case of ten Eurozone countries listed in Table 1 without Germany is studied.

Stationarity of all variables was tested using augmented Dickey-Fuller unit root test (Wooldridge (2009), Chapter 11) and it is reported in the Appendix. As the data is mostly non-stationary and highly persistent and there are visible trends we used first differences of all variables instead of their absolute levels. As such the null hypothesis of the test that the data are non-stationary was rejected on 95% significance level in all cases⁹.

Figure 3 illustrates the relationship between daily model and market CDS change for a 10-year maturity. In addition, it distinguishes the two sub-periods. Slope of added regression lines is positive in nearly all cases (except for Greece in second sub-period) pointing to a positive relationship between

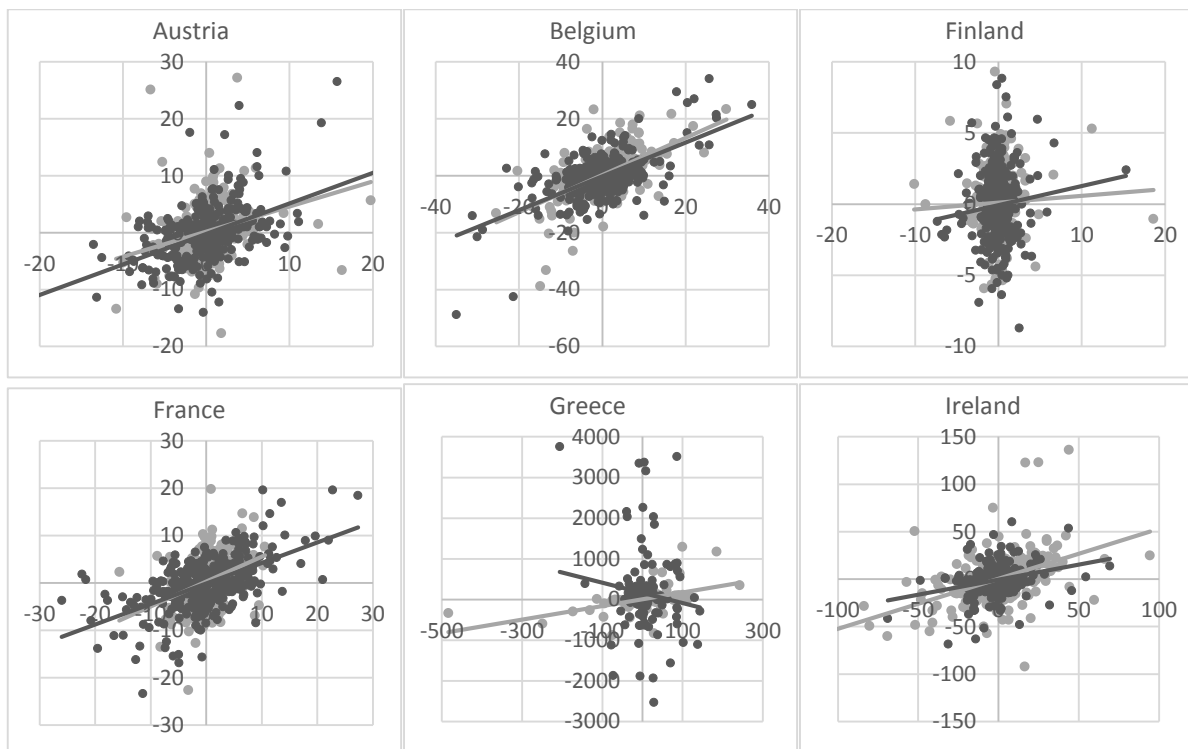
⁸ For example Reuters (2011) or NY Times Dealbook (2011)

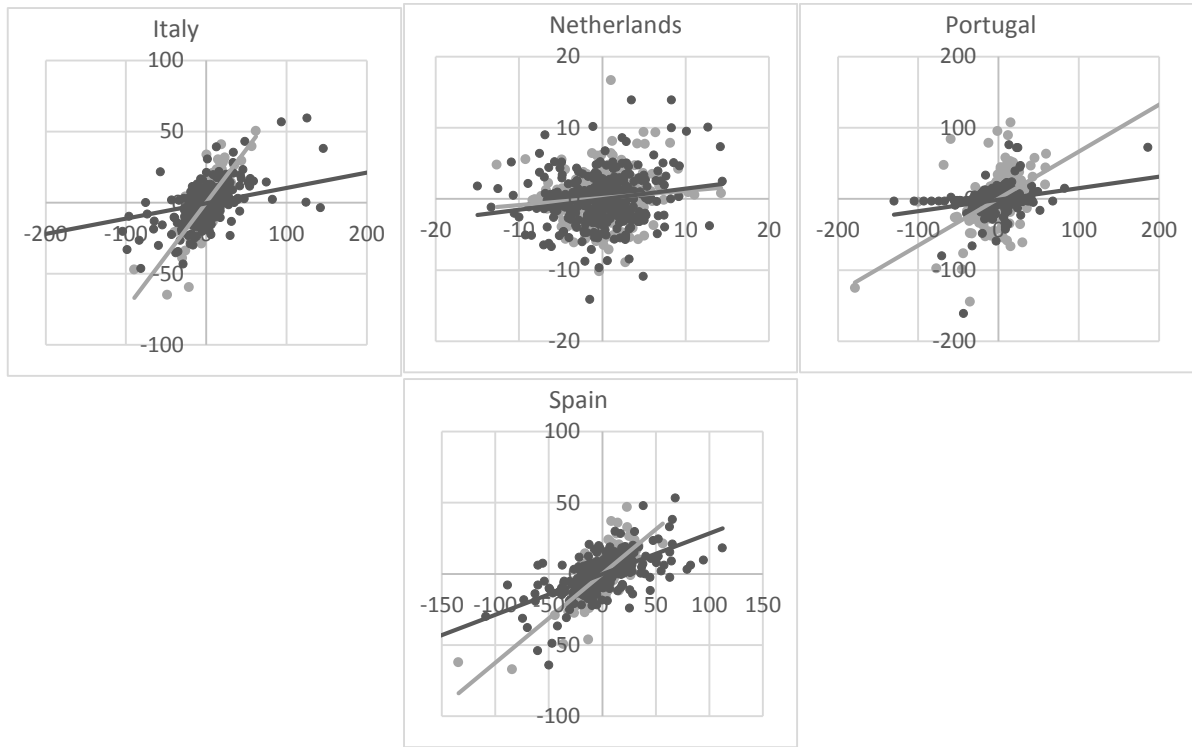
⁹ These results are not reported in this article because of their large scale and no variety in the result – i.e. it is just simply summarized.

model and market CDS spreads. Moreover the slope of dark grey regression line is lower than the slope of light grey regression line in most cases, i.e. in case of Belgium, France, Greece, Ireland, Italy, Portugal and Spain. This preliminary and simplified first look at the data goes in favour of the hypothesis that market CDS spread reacts less to model CDS spread in the second sub-period. Contrary to that, the opposite holds in case of countries that are considered less risky, i.e. Austria, Finland and Netherlands.

Figure 3: Daily Changes of 10-year Model and Market CDS Prices from December 2009 until January 2013

(x-axis: model CDS spread change; y-axis: market CDS spread change; light grey points represent sub-period until September 2011, dark grey points represent sub-period from October 2011; linear regression line is added in case of both sub-periods)





Source: Bloomberg, author's calculations

6.2. Heteroskedasticity- and Autocorrelation-Robust OLS

To obtain the relationship between the variables we will estimate following regressions for each country C listed in Table 1 (without Germany).

$$\begin{aligned} \Delta marketCDS_5Y_{t_i,C} &= \alpha_{1,C} \Delta modelCDS_5Y_{t_i,C} + \alpha_{2,C} \Delta liq_5Y_{t_i,C} \\ &+ \alpha_{3,C} \Delta cpty_5Y_{t_i,C} + \varepsilon_{t_i,C} \end{aligned} \quad (8)$$

and

$$\begin{aligned} \Delta marketCDS_10Y_{t_i,C} &= \beta_{1,C} \Delta modelCDS_10Y_{t_i,C} + \beta_{2,C} \Delta liq_10Y_{t_i,C} \\ &+ \beta_{3,C} \Delta cpty_10Y_{t_i,C} + \eta_{t_i,C}, \end{aligned} \quad (9)$$

where $\Delta marketCDS_{t_i,C}$ denotes daily change of mid-market CDS spread, $\Delta modelCDS_{t_i,C}$ denotes daily change of model CDS calculated in Section 5, $\Delta liq_{t_i,C}$ stands for daily change in bid-ask sovereign bond yield spread and $\Delta cpty_{t_i,C}$ daily change in CDS of top European banks. $_5Y$ ending of the variables in equation (8) denotes 5-year maturity and $_10Y$ ending in equation (9) denotes 10-year maturity of the variables. Equations (8) and (9) are estimated three times for different periods ($i = 3$) discussed at the beginning of Subsection 6.1: $t_1 = 1, 2, \dots, 828$ (whole period); $t_2 = 1, 2, \dots, 479$ (1st sub-period); $t_3 = 480, 481, \dots, 828$ (2nd sub-period)¹⁰.

First, the model was estimated using simple OLS method. Then, a postestimation analysis was performed. We tested the presence of heteroskedasticity using Breusch-Pagan test (Wooldridge (2009), Chapter 12). Also a serial correlation of the residuals was tested using Cumby-Huizinga test

¹⁰ I.e. there are 479 observations in the first sub-period, 349 observations in the second sub-period. In case of Greece there are 115 in the second sub-period. If some observations were missing, linear interpolation of the adjacent data was used.

(Cumby and Huizinga (1992)). The null hypothesis of the test is that residuals are moving average process of order q and q is 0 by default. The alternative is that serial correlation is present in given range of lags. Also the test verifies a hypotheses of a presence of serial correlation in each specific lag. In our case the main advantage of this test is that it allows for heteroskedasticity in the residuals whereas other autocorrelation tests such as Breusch-Godfrey test, Ljung-Box test or Box-Pierce test assume homoskedasticity.

Then the model was reestimated taking into account specific data properties to reach valid test statistics of the estimates. First, in case of homoskedastic data with no serial correlation simple OLS estimation of equations (8) and (9) was used. Second, if the errors are homoskedastic but serially correlated, Prais-Winsten estimation (Prais and Winsten (1954)) was used. Third, in case of heteroskedastic data with no serial correlation in its errors and other Gauss-Markov assumptions fulfilled, heteroskedasticity-robust OLS estimation was applied (White (1980)). And fourth, method derived by Newey and West (1987) was applied to data with both heteroskedasticity of unknown form and autocorrelation of arbitrary order in the error term. The value of the autocorrelation lag was set according to the result of Cumby-Huizinga test.

Results

Results are summarized in Table 2. OLS postestimation of the residuals is included in first six rows. We chose to test the presence of serial correlation in OLS residuals up to 20 lags. The number of lags is high enough to detect serial correlation of more complicated structure. It was confirmed in eight cases. This result does not point to a misspecification of the general model because in 32 cases the null hypothesis of no serial correlation could not be rejected. Also the serial correlation is not strong - if 95% confidence level was used instead of 90%, it would be confirmed in 4 out of 40 cases. Homoskedasticity of the residuals was rejected in all cases except for Portugal and Spain using 90% significance. These data properties were taken into account using robust estimates of Equations (8) and (9).

Results of these estimates are displayed in second part of Table 2.

Generally, in nearly all cases model CDS is significant as well as counterparty risk. On the contrary, liquidity risk doesn't seem to play an important role in market CDS determination. Counterparty risk coefficient increased between the sub-periods in nearly all cases except for Portugal and Ireland 5-year maturity. The role of the counterparty risk in CDS market price thus increased.

Important outcome for the purpose of this article which was already indicated by Figure 3 is that model CDS coefficient decreased between the two sub-periods in case of nearly¹¹ all countries except for the least risky ones – Austria, Finland, France and Netherlands. It supports our hypothesis that the dependence of market CDS on model CDS weakened during the EMU debt crisis and market CDS price is determined by other factors than probability-neutral model price.

Overall there is not a large difference between 5-year and 10-year maturity as far as the significance and inter-period development of the parameters is concerned.

Predictive power of the model is higher in the second sub-period in case of less risky countries – Austria, Finland, France, Netherlands and Belgium. Overall, R-squared of the model is not high. However, our aim is not to find a best fit model to predict future development but to discover whether one variable is significant in determining the other variable. R-squared is low in case of Greece, Finland

¹¹ In case of Greece 5-year maturity the coefficient increased between the sub-periods. On the other hand the predictive power of the regression in the second sub-period is very low - 8%.

and Netherlands. This refers to the fact that Greece went through a distressed time and it is hard to fit a model explaining last years' development. In case of Finland and Netherlands it is a result of choosing Germany as a benchmark for CDS valuation. Government bond spreads of these countries are low and fluctuate around similar levels. Consequently, resulting CDS model value is less stable depending on the choice of the benchmark than in case of countries with higher spreads and the regression model is less precise.

Table 2: Heteroskedasticity- and Autocorrelation-Robust Estimates

		AT	BE	FI	FR	GR	IR	IT	NE	PT	SP
Serial correlation		yes*	no	no	no	no	no	no	no	no	yes*
χ^2 value	1st subp	29.41	11.15	19.96	24.87	21.54	24.82	13.21	23.07	25.88	28.45
Serial correlation		no	no	no	no	no	no	yes**	no	no	no
χ^2 value	2nd subp	11.93	26.08	22.37	27.25	19.89	19.58	31.65	12.56	24.84	24.06
Heteroskedasticity		yes***	yes***	yes***	yes***	yes***	yes***	yes***	yes**	no	no
χ^2 value		93.17	113.07	32.35	69.40	173.79	137.98	50.38	9.44	5.40	1.34
Model	1st subp	N-W (6)	HR OLS	HR OLS	HR OLS	HR OLS	HR OLS	HR OLS	HR OLS	OLS	P-W
(lags)	2nd subp	HR OLS	HR OLS	HR OLS	HR OLS	HR OLS	HR OLS	N-W (14)	HR OLS	OLS	OLS
1st sub-period (12.2009 - 9.2011)	modelCDS	0.15	0.41***	0.02	0.14	1.25***	0.45***	0.52***	0.01	0.48***	0.43***
		(0.11)	(0.06)	(0.02)	(0.09)	(0.48)	(0.06)	(0.03)	(0.03)	(0.03)	(0.03)
	liq_5Y	0.54*	-0.9	1.05***	-0.11	2.32*	-0.09	-0.21	0.05	-0.2**	0.34
		(0.32)	(0.57)	(0.34)	(1.27)	(1.18)	(0.15)	(0.26)	(0.18)	(0.08)	(0.26)
	cpty_5Y	0.28***	0.39***	0.02	0.32***	1.9	1***	0.74***	0.1***	1.72***	0.61***
		(0.07)	(0.1)	(0.04)	(0.07)	(1.77)	(0.19)	(0.09)	(0.03)	(0.13)	(0.08)
	R-squared	24%	42%	13%	25%	27%	57%	72%	19%	64%	53%
2nd sub-period (10.2011 - 1.2013)	modelCDS	0.3***	0.38***	0.21***	0.34***	1.39**	0.26***	0.13***	0.25***	0.37***	0.29***
		(0.05)	(0.04)	(0.06)	(0.04)	(0.58)	(0.05)	(0.03)	(0.06)	(0.03)	(0.02)
	liq_5Y	-0.12	0.28	-0.06	-0.1	1.4	-0.06	0.48	0.35	-0.13	-0.06
		(0.12)	(0.25)	(0.2)	(0.29)	(1.12)	(0.06)	(0.37)	(0.34)	(0.08)	(0.2)
	cpty_5Y	0.33***	0.53***	0.06***	0.38***	11.8	0.89***	1.16***	0.17***	0.98***	0.8***
		(0.04)	(0.06)	(0.02)	(0.04)	(7.9)	(0.12)	(0.15)	(0.03)	(0.15)	(0.08)
	R-squared	50%	51%	22%	60%	8%	43%	62%	34%	45%	67%

		AT	BE	FI	FR	GR	IR	IT	NE	PT	SP
Serial correlation		no	no	no	yes**	no	no	no	yes**	no	yes*
χ^2 value	1st subp	14.85	19.7	26.64	34.48	18.41	23	20.81	36.59	16.1	28.54
Serial correlation		no	no	yes*	no	no	no	no	no	no	yes**
χ^2 value	2nd subp	19.23	19.39	28.87	22.57	18.58	21.33	27.21	18.13	25.52	31.42
Heteroskedasticity		yes***	yes***	yes***	yes***	yes***	yes***	yes**	yes**	yes***	yes***
χ^2 value		69.20	84.24	14.11	47.78	71.11	68.23	8.94	8.14	16.41	38.22
Model	1st subp	HR OLS	HR OLS	HR OLS	N-W (15)	HR OLS	HR OLS	HR OLS	N-W (17)	HR OLS	N-W (15)
(lags)	2nd subp	HR OLS	HR OLS	N-W (11)	HR OLS	HR OLS	HR OLS	HR OLS	HR OLS	HR OLS	N-W (14)
1st sub-period (12.2009 - 9.2011)	modelCDS	0.33*	0.48***	0.03	0.26***	1.6***	0.45***	0.55***	0.003	0.47***	0.5***
		(0.17)	(0.07)	(0.06)	(0.08)	(0.49)	(0.09)	(0.04)	(0.04)	(0.1)	(0.03)
	liq_10Y	0.27	-1.04	0.02	1.45	2.26*	0.29	0.75	0.38	0.35	-0.25
		(0.59)	(0.79)	(0.33)	(1.84)	(1.26)	(0.37)	(0.88)	(0.49)	(0.46)	(0.59)
	cpty_10Y	0.15***	0.34***	0.02	0.26***	-1.76	0.52*	0.73***	0.11***	1.4***	0.57***
		(0.05)	(0.09)	(0.02)	(0.09)	(2.75)	(0.29)	(0.09)	(0.04)	(0.29)	(0.08)
	R-squared	12%	42%	11%	21%	28%	22%	70%	13%	38%	59%
2nd sub-period (10.2011 - 1.2013)	modelCDS	0.33***	0.38***	0.09	0.27***	-2.95	0.11	0.06***	0.009	0.14**	0.18***
		(0.08)	(0.06)	(0.06)	(0.04)	(2.89)	(0.07)	(0.01)	(0.05)	(0.06)	(0.03)
	liq_10Y	0.04	0.43	0.57	0.52	3.45	-0.07	-0.04	0.15	-0.14	-0.2
		(0.35)	(0.41)	(0.56)	(0.5)	(2.49)	(0.08)	(0.48)	(0.77)	(0.1)	(0.44)
	cpty_10Y	0.34***	0.45***	0.08***	0.35***	12.3	0.78***	1.04***	0.2***	0.48**	0.75***
		(0.05)	(0.06)	(0.03)	(0.04)	(13.94)	(0.12)	(0.08)	(0.03)	(0.23)	(0.12)
	R-squared	38%	51%	17%	50%	3%	23%	51%	16%	12%	53%

Source: author's calculations

Note: In the first four rows the results of tests for serial correlation and heteroskedasticity are shown. Next row then displays method used for the estimation: OLS denotes standard OLS method, P-W denotes Price-Winsten estimation, HR OLS heteroskedasticity-robust OLS estimation and N-W OLS with Newey-West standard errors with number of lags of the serial correlation of residuals in brackets. Significance of the estimates is distinguished

by stars (***) means the estimate is significant at 99% significance level, ** at 95% significance level and * at 90% significance level) and their standard errors are displayed in brackets below.

6.3. Johansen Cointegration Test

Financial time series are often not covariance stationary. Instead, they are often first-difference stationary. First-difference stationary processes are known as processes integrated of order 1, i.e. $I(1)$ processes. Generally, a process whose d -th difference is $I(0)$ is integrated of order d , $I(d)$. Covariance stationary processes are $I(0)$. (Wooldridge (2009), Chapter 11)

Regressing $I(1)$ time series on another $I(1)$ time series may lead to spurious regression with misleading results (Phillips (1986)). If for example both these time series are trending, simple OLS regression may show dependence even if there is not any. One possible solution is to regress their first differences. A different situation is, if the two time series both being $I(1)$ processes are cointegrated, i.e. if a linear combination of them is $I(0)$. Then using first differences limits the scope of questions we are able to answer and it is reasonable to include absolute values of these variables in the regression using error correction models.

As discussed in Subsection 6.1 non-stationarity is present in our data. More concretely, the data is first order stationary. Johansen cointegration test (Johansen (1991), (1995)) will enable us to discover, if there is a cointegrating relationship between model and market CDS and if this relationship has changed between the first and the second sub-period.

Results

We tested pairwise cointegration between the following variables: market CDS and model CDS (modelCDS), market CDS and liquidity risk (liq), market CDS and average CDS spread of top European banks (cpty) for both maturities 5 and 10 years. Appropriate number of lags was chosen according to the results of multiple information criteria¹². Results are summarized in Table 3. Before running the Johansen test stationarity of all variables in both sub-periods was tested using augmented Dickey-Fuller unit root test. Results of the test are provided in Appendix. Cointegration test makes sense only if we are studying cointegration between two non-stationary variables. Thus in case the Dickey-Fuller test rejected the stationarity of a variable within an examined period cointegration test was not performed (labelled *n.a.* in Table 3). Confirmed cointegration is tinged with a light grey colour in Table 3, cases with no cointegrating relationship are not coloured.

¹² Akaike information criterion, Hannan-Quinn information criterion, Schwarz Bayesian information criterion, final prediction error and sequential likelihood ratio for all the full vector autoregressions of order less than or equal to the highest lag order. The lowest lag selected by at least two criteria was chosen.

Table 3: Johansen Cointegration Test Results

Variable		(p - r)	AT	BE	FI	FR	GR	IR	IT	NE	PT	SP
model CDS_5 Y	1st sub-	2	n.a.	20.060	4.756	10.174	15.960	8.496	17.990	15.543	7.909	19.383
	period	1		2.277	1.042	3.176	3.992	2.857	2.148	1.556	2.556	5.029
	2nd sub-	2	19.279	8.765	10.108	17.837	13.744	8.666	11.164	12.293	19.493	12.386
	period	1	1.420	1.634	2.035	1.610	5.352	3.542	3.366	2.519	1.194	3.034
liq_5Y	1st sub-	2	14.022	11.679	20.105	21.056	31.840	13.620	n.a.	n.a.	16.844	16.239
	period	1	0.946	2.966	1.039	2.562	1.831	2.234			3.208	3.603
	2nd sub-	2	7.749	25.216	12.610	12.909	27.847	16.069	n.a.	n.a.	14.015	n.a.
	period	1	1.601	1.594	3.140	1.317	2.246	2.872			1.549	
cpt_5 Y	1st sub-	2	10.438	7.271	10.687	15.367	23.120	6.687	22.335	14.522	9.321	10.612
	period	1	2.441	3.028	2.110	4.183	4.086	2.274	3.198	5.267	2.649	3.077
	2nd sub-	2	9.080	8.524	12.445	10.475	14.093	14.762	16.447	10.563	9.775	7.417
	period	1	1.468	1.367	5.060	2.731	2.813	3.324	2.926	4.033	1.814	2.679
model CDS_1 0Y	1st sub-	2	n.a.	14.276	22.296	23.675	22.370	23.984	20.681	17.137	18.502	18.754
	period	1		2.954	1.866	2.330	5.317	2.291	2.138	1.405	4.808	3.721
	2nd sub-	2	21.246	11.002	8.834	17.833	14.087	15.089	14.082	19.332	10.288	14.183
	period	1	1.193	1.812	2.741	2.757	5.531	2.256	2.714	1.758	2.370	4.859
liq_10Y	1st sub-	2	n.a.	12.244	n.a.	19.881	21.883	8.245	n.a.	n.a.	13.612	n.a.
	period	1		3.276		3.130	2.832	2.132			2.247	
	2nd sub-	2	12.063	12.371	11.368	n.a.	24.078	n.a.	17.197	n.a.	15.023	n.a.
	period	1	1.501	1.503	2.418		0.793		3.403		1.237	
cpt_1 0Y	1st sub-	2	13.309	6.979	12.213	12.151	24.600	9.382	21.000	14.175	9.017	9.501
	period	1	2.527	3.241	3.640	4.089	2.592	2.861	3.165	6.175	2.998	3.336
	2nd sub-	2	8.309	10.000	9.922	12.292	17.588	13.106	19.217	10.334	7.317	10.229
	period	1	1.765	1.799	4.240	3.318	2.701	1.319	3.098	3.886	1.772	3.125

Source: author's calculations

Note: Cointegration of market CDS (5-year resp. 10-year) with the variable in the first column was tested in the two sub-periods. In each case two values of the trace statistic are reported. p denotes number of variables (i.e. 2), r denotes number of cointegrating equations under the null hypothesis. I.e. the first value is the value of the test statistic testing null hypothesis of no cointegrating equations and below is the test statistic value testing the case of one or less cointegrating equations. The test depends on a trend specification in the data. In our case we specified that there is no single linear trend in the levels of the data and we allowed the cointegrating equations to be stationary around a constant mean (i.e not trend stationary). The test was done on a 90% significance level. Values are compared with critical values reported in Enders (1995): 17.957 for $(p-r) = 2$ and 7.563 for $(p-r) = 1$. Presence of cointegration is distinguished by a light grey colour. Cases of stationary variable in which the test wasn't performed are labelled n.a.

From Table 3 it is visible that in most cases a result of no cointegration was reached which points to a fact that the co-movement of the variables must be rather strong so that cointegration was present. However there is an interesting finding in case of market CDS and model CDS with 10-year maturity. In nearly all cases (Finland, France, Greece, Ireland, Italy, Portugal and Spain) these variables cointegrated in the first sub-period and the cointegration disappeared in the second sub-period. Even in case of Belgium the value of test statistic decreases between the two sub-periods. And we can't make any conclusion about Austria because 10-year model CDS turned out to be stationary. Cointegration of 10-year market CDS with other 10-year variables didn't prove to be present in most cases (except for a specific case of Greece) meaning that liquidity risk and counterparty risk didn't play an important role in market CDS price determination in neither sub-period.

In case of a 5-year maturity our findings are even less uniform. Overall the variables cointegrated more in the first sub-period than in the second one. On the other hand it is visible that the relationship between market CDS and model CDS is lower than in case of a 10-year maturity. In case of Belgium, Italy and Spain the same trend of disappearance of cointegration as in the 10-year case is shown. Contrary to that the opposite trend is apparent in case of Portugal which is quite controversial to our previous findings.

7. Summary

Throughout this article a relationship between probability-neutral market price of a credit default swap contract and its model value was examined. We focused on the EMU countries and a period of European sovereign crisis starting with sudden Greek budget deficit reassessment. An initial purpose of a CDS was to protect its buyer against a default of a reference entity. During the ongoing Greek crisis speculations emerged that theoretically Greece could effectively default without CDS protection payment being triggered. These speculations were supported by actions and declarations of European authorities. In this article we analysed whether this development had an effect on market CDS prices in general. Based on the events surrounding Greek CDS early termination we expect that investors' trust in CDS decreased and they will be willing to pay less for the protection.

In the first part of the article we calculated a fair price of a CDS using basic reduced form model which extracts default probability function from bond prices with different maturities. Generally, the relationship between bond spread and model CDS spread is narrower, if spreads are low and the difference becomes wider for higher values of spreads. In crisis times of high bond spreads model CDS spread tends to be higher than bond spread and in distressed times the model fails to provide a reasonable outcome.

Our presumption was that if there are no uncertainties about the CDS contract, market price of a CDS should be closely related to its modelled fair price. Based on that, in the second part of this paper we used two methods to discover the nature of the relationship of these two variables: heteroskedasticity- and autocorrelation-robust OLS estimates (Prais-Winsten estimation, heteroskedasticity robust OLS and OLS with Newey-West standard errors) and Johansen cointegration test. Being aware of the fact that there are other factors that may cause market CDS price differ from its model value we took into consideration two of them the most apparent: counterparty risk and liquidity risk. As a measure of counterparty risk we used average rating of top 10 European banks and as a measure of liquidity risk the bid-ask spread of a government bond yield was used.

The main finding is that we can't reject our hypothesis of weakened connection between market and model CDS price after the appearance of first doubts about CDS protection payment trigger. More interestingly, using the first method this hypothesis was confirmed in case of all countries with riskier credit profile such as Italy, Spain, Portugal, Ireland, Belgium and Greece. And on the other hand, the trend of lower dependence of market CDS on model CDS was not perceptible in case of the least risky countries in our sample, i.e. Finland, France, Austria and Netherlands. Based on this finding and in compliance with our line of reasoning it seems that investors' trust in CDS did not decrease generally but that it decreased only in case of riskier countries and it is preserved in case of less risky ones. This contributes to a common fact that after the EU debt crisis investors better distinguish between individual member states. On the contrary, this result is quite surprising because we expected that the attitude of the EU, IMF and local governments to country's insolvency and a treatment of CDS early settlement would be similar no matter which EMU member state is defaulting and therefore we expected a uniform result.

One should also bear in mind that there might be other factors which lead us to these findings because recent years brought more changes. For example to prevent speculation naked CDSs were banned in the European Union at the end of 2012. This step should decrease the volatility of both CDS and bond market and it could have an impact on CDS prices. Still, we believe that the Greek default and increased threat of other European countries' default supported by the speculations about bond and CDS investors' losses were the main driver of the EMU CDS market prices during the observation period.

Although the outcome of the second method is not so definite, it shows similar results – weakened dependency was confirmed in case of Italy, Spain, Portugal, Ireland, Greece, France and also Finland - but only for a 10-year maturity of the variables. For a 5-year maturity mostly no cointegration was proved between the model and market CDS price. Generally, Johansen cointegration test returned less uniform and therefore less informative results.

As far as other variables are concerned, liquidity risk mostly didn't prove to be important in market CDS price determination by neither of the two methods. Counterparty risk role in CDS market price increased in most cases (17 out of 20) using the first method. On the other hand, using the second method no cointegration with market CDS was reached.

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Appendix 1

Augmented Dickey-Fuller Unit Root Test Results

Variable		AT	BE	FI	FR	GR	IR	IT	NE	PT	SP
marketC DS_5Y	whole	-1.43	-1.76	-2.14	-1.87	2.38	-1.47	-1.86	-2.00	-1.58	-2.27
	period	(0.57)	(0.40)	(0.23)	(0.35)	(1.00)	(0.55)	(0.35)	(0.29)	(0.49)	(0.18)
	1st sub-	0.20	-1.00	-0.31	-0.28	3.15	-1.27	-0.06	0.40	-0.08	-1.82
	period	(0.97)	(0.75)	(0.92)	(0.93)	(1.00)	(0.64)	(0.95)	(0.98)	(0.95)	(0.37)
modelCD S_5Y	2nd sub-	-0.87	-0.63	-2.17	-1.34	1.51	-0.24	-1.48	-1.53	-0.51	-1.53
	period	(0.80)	(0.86)	(0.22)	(0.61)	(1.00)	(0.93)	(0.54)	(0.52)	(0.89)	(0.52)
	whole	-2.77	-2.24	-1.90	-2.36	1.58	-1.81	-1.83	-2.04	-1.65	-2.64
	period	(0.06)	(0.19)	(0.33)	(0.15)	(1.00)	(0.38)	(0.36)	(0.27)	(0.46)	(0.09)
liq_5Y	1st sub-	-3.38	-1.32	-1.46	-1.88	-0.13	-1.51	-0.05	-1.69	-0.60	-2.06
	period	(0.01)	(0.62)	(0.55)	(0.34)	(0.95)	(0.53)	(0.95)	(0.44)	(0.87)	(0.27)
	2nd sub-	-1.53	-1.21	-0.89	-1.78	-1.65	-0.42	-1.87	-1.41	-0.74	-2.04
	period	(0.52)	(0.67)	(0.79)	(0.39)	(0.46)	(0.91)	(0.34)	(0.58)	(0.84)	(0.27)
marketC DS_10Y	whole	-3.34	-2.46	-2.42	-2.12	2.17	-2.27	-3.34	-3.74	-2.07	-3.36
	period	(0.01)	(0.13)	(0.14)	(0.24)	(1.00)	(0.18)	(0.01)	(0.00)	(0.26)	(0.01)
	1st sub-	-2.52	-1.68	-2.60	-1.70	0.46	-1.29	-3.21	-5.08	-0.87	-2.53
	period	(0.11)	(0.44)	(0.09)	(0.43)	(0.98)	(0.63)	(0.02)	(0.00)	(0.80)	(0.11)
modelCD S_10Y	2nd sub-	-2.45	-2.02	-2.01	-1.52	-0.27	-2.07	-2.88	-2.20	-1.53	-4.47
	period	(0.13)	(0.28)	(0.28)	(0.52)	(0.93)	(0.26)	(0.05)	(0.21)	(0.52)	(0.00)
	whole	-1.71	-1.91	-1.72	-1.84	2.18	-1.74	-1.87	-1.70	-1.81	-2.30
	period	(0.43)	(0.33)	(0.42)	(0.36)	(1.00)	(0.41)	(0.35)	(0.43)	(0.38)	(0.17)
liq_10Y	1st sub-	0.02	-0.96	-0.70	-0.31	0.75	-1.49	-0.04	0.64	-0.92	-1.67
	period	(0.96)	(0.77)	(0.99)	(0.92)	(0.99)	(0.54)	(0.96)	(0.99)	(0.78)	(0.45)
	2nd sub-	-1.01	-0.98	-1.96	-1.48	2.46	-0.40	-1.83	-1.56	-0.45	-2.03
	period	(0.75)	(0.76)	(0.31)	(0.54)	(1.00)	(0.91)	(0.37)	(0.51)	(0.90)	(0.27)
cpty	whole	-2.46	-2.22	-2.97	-1.87	1.07	-1.68	-2.56	-2.35	-1.75	-1.99
	period	(0.13)	(0.20)	(0.04)	(0.35)	(1.00)	(0.44)	(0.10)	(0.16)	(0.41)	(0.29)
	1st sub-	-3.87	-1.36	-2.71	-1.42	0.02	-1.37	0.10	-2.11	-0.59	-1.34
	period	(0.00)	(0.60)	(0.07)	(0.57)	(0.96)	(0.60)	(0.97)	(0.24)	(0.87)	(0.61)
	2nd sub-	-1.30	-1.39	-1.61	-1.89	-1.69	-0.04	-2.71	-1.71	-0.88	-2.30
	period	(0.63)	(0.59)	(0.48)	(0.34)	(0.44)	(0.95)	(0.07)	(0.43)	(0.79)	(0.17)
	whole	-2.69	-2.39	-4.17	-4.23	1.16	-2.38	-3.18	-3.23	-1.72	-3.72
	period	(0.08)	(0.14)	(0.00)	(0.00)	(1.00)	(0.15)	(0.02)	(0.02)	(0.42)	(0.00)
	1st sub-	-2.92	-2.58	-3.62	-2.54	-0.52	-1.04	-473.00	-3.26	-1.04	-3.75
	period	(0.04)	(0.10)	(0.01)	(0.11)	(0.89)	(0.74)	(0.00)	(0.02)	(0.74)	(0.00)
	2nd sub-	-1.70	-1.74	-2.53	-4.17	-1.20	-4.02	-2.30	-2.91	-1.36	-3.88
	period	(0.43)	(0.41)	(0.11)	(0.00)	(0.67)	(0.00)	(0.17)	(0.04)	(0.60)	(0.00)
	whole	-1.81									
	period	(0.38)									
	1st sub-	0.21									
	period	(0.97)									
	2nd sub-	-1.11									
	period	(0.71)									

Source: author's calculations

Note: Stationarity of each variable was tested over the whole period and in the 1st and in the 2nd sub-period for each country. In each case two values are reported. On the top there is a value of the test statistic and in the brackets below there is its p-value. Time series stationary on a 95% significance level is then reported on a grey background for a better visibility. Appropriate number of lags of each variable was chosen according to AR model results.

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