

Article

The Role of Redenomination Risk in the Price Evolution of Italian Banks' CDS Spreads

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Abstract: The recent financial crisis offered an interesting opportunity to analyze the markets' behavior in a high-volatility framework. In this paper, we analyzed the price discovery process of the Italian banks' Credit Default Swap (CDS) spreads through the Merton model, extended with the inclusion of a redenomination risk proxy, as to say, the risk that Italy could leave the eurozone. This paper contributes to the literature by integrating the classic Merton model with a political-sensitive market variable able to explain the greatest variance in the Italian banks' CDS spreads during the most relevant and commonly recognized periods of socio-political and financial distress. Results show that the redenomination risk is progressively becoming the main driver of the process during crises, in particular for the sovereign debt crisis and in 2018.

Keywords: CDS spreads; redenomination risk; quanto CDS; Granger-causality

JEL Classification: G01; G12; G14; G20

1. Introduction

The recent financial crisis offers an interesting opportunity to analyze the markets' behavior in a high-volatility framework. In particular, the second wave of the crisis, identified as the sovereign debt crisis (2010–2012), driven by the effects of the recession on public finances and of its expected worsening, due to the actual and possible support to the distressed financial sector on public budgets, induced the re-assessment of financial operators portfolios, both for the new values of sovereign bonds risk and for its consequences on banks' shares values and riskiness. This turmoil affected in some way all financial markets, but banks' shares, bonds and CDS spreads were directly involved, due to the banks' exposures to sovereign bonds. These effects, on the one side, determined a significant risk of a vicious circle between banks' and public finances distress (Galliani and Zedda 2015), and, on the other side, showed a significant impact on banks' ratings and share values (Lahmann 2012), suggesting that politics can actually affect the banking system risk evaluation by market investors.

In this framework, one of the most successful points of populist parties' campaigns is the idea that the banking system is the main driver of the economic disaster and that ordinary citizens pay for crimes committed by banks, which are conscious of the pro-establishment governmental support in case of difficulties, thus prone to moral hazard. In technical terms, the explicit message of these political parties is the idea that the banking system risk induces (Granger-causes) the sovereign risk and not vice versa.

The Italian case, from an empirical point of view, offers an interesting opportunity to study these dynamics, so to verify if there is a feedback loop in terms of risk, or if the relationship can be more correctly described as unidirectional, and, in the latter case, which risk drives the other one.

The case of Italy is particularly suited for this analysis as it suffers both weak GDP growth and a high public debt, so it is subject to volatility and speculation during periods of financial stress. On top of this, from March 2018, Italy has experienced a government coalition so-defined anti-establishment or populist (Politi and Ghiglione 2018), explicitly oriented to deficit growth and against the EU Commission austerity, so that the markets considered the possibility of a path of severe financial and economic instability, leading to the “Italexit” and eventually to the end of the euro. As a consequence, the Italian economy resulted in being highly sensitive to macro events, which overwhelmed the role of economic fundamentals. This paper contributes to the literature by integrating the classic Merton (1974) model with a political-sensitive market variable able to explain the greatest variance in the Italian banks’ CDS spreads during the most relevant and commonly recognized periods of socio-political and financial distress

For analyzing the dynamics which characterized the bank credit risk within the considered time span, we firstly analyzed the lead–lag structure between the banking and sovereign CDS series, then assessed the determinants of bank CDS spreads by means of an extension of the classic Merton (1974) model, including a redenomination risk variable, during the most volatile phases of this decade.

Results show that the inclusion of the redenomination risk variable enhances the explanatory power of the classic Merton (1974) model.

The structure of the paper is the following. Section 2 reports the literature review, Section 3 describes the models and data, Section 4 reports the results of the analysis and Section 5 reports the economic discussion and conclusions.

2. Literature Review

In a recent literature, four main streams analyzed the relationship among sovereign bonds and banks’ values.

The first stream is aimed at analyzing the determinants of sovereign and corporate CDS spreads. Collin-Dufresne et al. (2002) used the structural approach for identifying the theoretical determinants of CDS spreads of corporate bonds, finding that its explicative power is poor. Zhang et al. (2005) analyzed the determinants of CDS spreads relative to CDS written on US entities (sovereign entities excluded) and denominated in US dollars, on monthly values for a panel of 307 issuers from January 2001 to December 2003, specifically focusing on volatility effects at the firm level and jump-to-default risks. They used a regression model, including performance indicators (Return on Equity, ROE, and dividend payout ratio), structure indicators (leverage) and macro variables (slope of the risk-free rate, etc.), showing that 54% of the credit spread is explained by volatility and jump-to-default risk.

The second stream is aimed at analyzing the determinants of banks’ CDS spreads and their linkages with sovereign risk. A reference paper is Acharya et al. (2011), which described a two-way feedback effect between sovereign risk and banking risk, where bank bailouts by governments produce a negative effect on the sovereign’s public finances that, in turn, reduces the implicit value that the government guarantees for bank debt. This process generates a strong co-movement between the CDS spreads of sovereign countries and financial companies. Avino and Cotter (2014) also investigated the interconnectedness of bank and sovereign CDS markets in the period preceding the financial crisis that started in mid-2007. They proved that, especially during crisis periods, sovereign CDS spreads incorporate more timely information on the default probability of European banks than their corresponding bank CDS spreads.

The third stream is aimed at investigating the explanatory power of the Merton (1974) model determinants in the price discovery process of the CDS premia. Among the others, Guazzarotti (2004) verified that the Merton model’s main determinants explain less than 20% of the CDS values variation, while the residual 70% is unexplained by the default risk factors. Ericsson et al. (2009) investigated

the relationship between the theoretical determinants of default risk as defined in Merton (1974) and current market premia on corporate CDSs, employing both a cross-section regression model and a panel model, finding that the theoretical determinants explain around 60% of the CDS spreads. Di Cesare and Guazzarotti (2005) did a similar exercise, analyzing, through the Merton model, the CDS spreads determinants of a sample of non-financial European firms, with five-year CDS, from 2001 to 2004. They show that the default risk factors included in the model explain around 40% of spreads variations.

A subsequent paper by the same authors (Di Cesare and Guazzarotti 2010), on a sample of 167 non-financial US firms, both for the pre-crisis period and for the subsequent years, proved that the financial leverage variation modifies the credit risk pricing in the CDS market.

The fourth literature stream is focused on the banks' CDS premia price discovery process.

Studying banking CDS spreads, Panetta et al. (2009) verified a negative relationship between CDS spreads and the amount of state interventions for rescuing banks. Considering that the capital injections on the total assets (or total loans) ratio is a proxy of the financial leverage variation, they explain that the negative correlation (0.7 at 10% of significance) means that the banks' CDS spreads decrease as the capital injection goes up, as to say, when the financial leverage goes down.

Chiaramonte and Casu (2010) analyzed the determinants of CDS spreads, verifying if these can be considered a good proxy of bank default risk. They split their analysis time span into three sub-periods, the pre-crisis (January 2005 to end June 2007), the main crisis (July 2007 to March 2009) and the lower crisis (April 2009 to June 2011), and only considered the typical banking balance-sheet ratios. They found that also the pre-crisis period—but mainly the crisis—mainly reflects the risk measured by balance sheet ratios, while Tier1 ratio and financial leverage are non-significant in all three sub-periods, and liquidity indicators are only significant during the crisis.

Samaniego-Medina et al. (2016) empirically analyzed banks' CDS spreads determinants for a panel of 45 European banks for 2004–2010, using both market values and balance sheet ratios. They found that the market variables had a higher explicative power during the crisis (2008–2010) than during the pre-crisis period (2004–2007).

This paper is mainly related to the last two literature streams, and contributes to them by integrating the classic Merton model with a political-sensitive market variable that explains the significant variance in the Italian banks' CDS spreads during different periods of socio-political and financial distress.

3. Model and Data Description

The main aim of this paper is to evaluate how a redenomination risk variable impacts on the explanatory power of the classic Merton (1974) model, and to investigate the determinants of the Italian banks' credit risk during the most volatile phases of this decade: the financial crisis (August 2007–October 2009)¹; the sovereign debt crisis (October 2009–July 2012)²; and the anti-establishment government/pre-Italy's budget update (March 2018–September 2018)³.

The analysis is performed on the Italian banks' credit risk estimation (Italian banks proxy), proxied by the weighted average of the values of the five years senior (modified-modified restructuring) CDS contracts of the most capitalized Italian banks⁴. Specifically, it includes the Intesa San Paolo and

¹ On 9 August 2007, BNP Paribas announced that it was ceasing activity in three hedge funds specialized in US mortgage debt. On 15 September 2008, Lehman Brothers declared bankruptcy (Kingsley 2012).

² On 18 October 2009, the Greek prime minister, George Papandreou admitted that the budget deficit would have been doubled with respect to the previous Government's estimate and would have hit 12% of the GDP. On 26 July 2012, the ECB president Mario Draghi tried to convince international investors that the eurozone's economy was not as bad as it seemed, and he announced a program to buy the bonds of its distressed countries, known as *Outright Monetary Transactions* (Cesaratto 2016).

³ On 4 March 2018, the so-called populist parties were elected (Matteucci 2018). Before 27 September 2018, the Italian Government presented the *NaDef* (Ministero dell'Economia e delle Finanze 2018).

⁴ The Italian banking system includes more than 700 banks. Intesa San Paolo and Unicredit are the largest Italian banks in terms of market capitalization and total assets (Sirletti and Salzano 2018).

Unicredit 5y CDS contracts, weighted by the respective market capitalization, for the time interval Q2 2007–Q3 2018, with daily values coming from Bloomberg (2859 observations)⁵. In this framework, the 5y CDS contracts for both series show the higher liquidity, as it can be observed by the bid–offer spreads. The descriptive statistics of the dataset are shown in Table 1. The overtime movements of the series are shown in Figure 1.

Table 1. Descriptive statistics—April 2007 to September 2018 (2859 Obs.).

Variable (Basis Points—0.01%)	Mean	SD	Min	Max	Median
Sovereign Italian 5y CDS	134.58	91.48	4.04	472.86	114.90
Italian banks proxy 5y CDS	163.86	120.26	6.70	653.68	128.27

Source: authors’ calculations based on Bloomberg data.

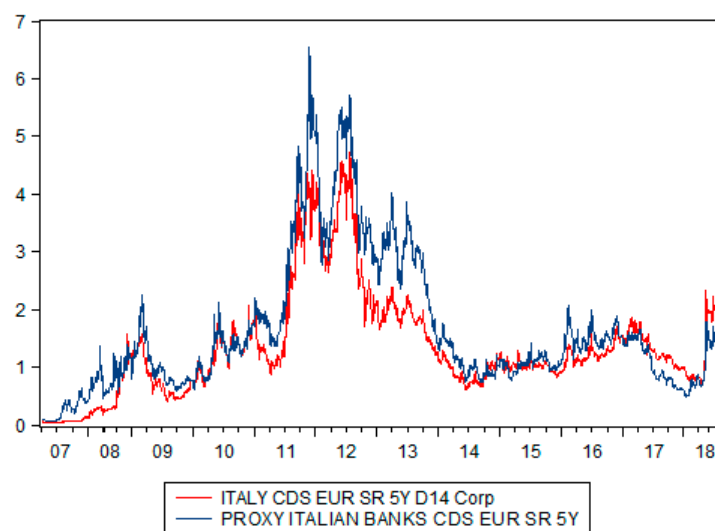


Figure 1. Sovereign Italian 5y CDS spreads and Italian banks proxy 5y CDS contracts series: period Q2 2007–Q3 2018. Source: authors’ calculations in Eviews 10 based on Bloomberg data.

About the modeling, the starting point is the classic Merton model⁶ which can be represented as follows:

$$ITBS_t = \beta_0 + \beta_1 r_{ft} + \beta_2 \sigma_t + \beta_3 L_t \tag{1}$$

where

- $t = 1, 2, \dots, T$ is the time horizon;
- $ITBS_t$ is the Italian banks’ 5y CDS spread proxy at time t ;
- r_{ft} is the risk-free rate at time t ;
- σ_t is the volatility of the assets at time t ;
- L_t is the leverage ratio at time t .

For testing the influence of a possible Italexit, we expanded the model for including a proxy of the sovereign debt redenomination risk, as to say, the risk that the considered sovereign debt could be

⁵ In Bloomberg, the CDS spreads series are available only for three Italian banking groups, namely Unicredit, Intesa San Paolo and Monte dei Paschi di Siena. In our view, Monte dei Paschi di Siena should not be included due to specific idiosyncratic issues that have also caused the acquisition of a stake close to 70% by the Italian State, approved by the EU Antitrust Commission in 2017 (Romano 2017). Unicredit and Intesa San Paolo represented in 2018 around 45% of the Italian banking system in terms of total assets (own calculation based on data provided by Banca d’Italia (2018a)).

⁶ The Merton model sets the firm’s default probability as determined by the firm’s leverage, equity volatility and risk-free interest rate (Merton 1974).

redenominated into new local currencies (which does not automatically imply the break-up of the euro area). The extended model can be represented as follows:

$$ITBS_t = \beta_0 + \beta_1 rf_t + \beta_2 \sigma_t + \beta_3 L_t + \beta_4 RR_t \quad (2)$$

where RR_t is the debt redenomination risk measure at time t , proxied by the quanto CDS spread as in De Santis (2019).

The same model can also be expressed in elasticities terms, through a log–log transformation. This transformation is useful both from a technical point of view, as it solves the non-stationarity problem⁷ and allows dealing with non-negative variables, and, from the economic evaluation point of view, allows for a straightforward interpretation of the parameters estimates, as the percent change of the dependent variable is directly explained by a percent change of the independent variable.

After the log–log transformation, the model to be estimated can be represented by the following Equation (3):

$$\log(ITBS_t/ITBS_{t-1}) = \beta_0 + \beta_1 \log(rf_t/rf_{t-1}) + \beta_2 \log(\sigma_t/\sigma_{t-1}) + \beta_3 \log(L_t/L_{t-1}) + \beta_4 \log(RR_t/RR_{t-1}) + \varepsilon_t \quad (3)$$

where ε_t is the error term.

For testing the model, we followed De Santis (2019), which proposed to use the difference between the quanto CDS for Italy and Germany, which is the benchmark for the euro area sovereign debt market, as a proxy of the redenomination risk associated with the break-up of the euro area.

In operational terms, the quanto CDS spread is computed as the difference between the CDS spreads on bonds denominated in US dollar, and the CDS spreads on equivalent bonds denominated in euros.

Formally, the *quanto CDS spread* at time t , QCS_t , is computed as follows:

$$QCS_t = (ITEUCDS_t - ITUSDCDS_t) - (DEEUCDS_t - DEUSDCDS_t) \quad (4)$$

where

- $ITUSDCDS_t$ is the sovereign Italian 5y CDS spread in US dollars;
- $ITEUCDS_t$ is the sovereign Italian 5y CDS spread in euros;
- $DEEUCDS_t$ is the sovereign German 5y CDS spread in US dollars;
- $DEUSDCDS_t$ is the sovereign German 5y CDS spread in euros.

In this way, the quanto CDS measures the compensation demanded by market participants for the risk that a euro denominated asset could be redenominated into a different currency. US dollar is the best currency benchmark in order to calculate the quanto CDS spread for three main reasons: it is the classical safe haven asset during high-volatility periods; the most important commodities (i.e., oil, gold, etc.) are exchanged in USD; USA is the more suitable comparison for the euro area from a socio-political perspective. The computed quanto CDS spreads series are reported in Figure 2.

⁷ See e.g., Berlinger et al. (2015).

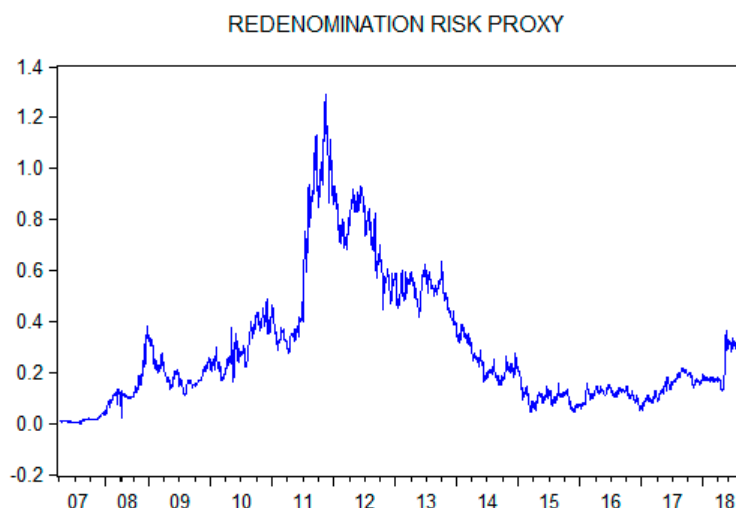


Figure 2. Quanto CDS spreads series: period Q2 2007–Q3 2018. Source: authors' calculations based on Bloomberg data.

For the estimation of the extended model, the risk-free rate is proxied by the daily 5y euro swap rate⁸, the volatility⁹ is proxied by the daily price volatility and the financial leverage is proxied by the daily debt to equity ratio¹⁰, with the data coming from Bloomberg. For a more in-depth analysis of the subjacent economic process, we focused our attention on the most significant phases of the Italian sovereign bonds market evolution, as to say, the financial crisis (2007–2009), the sovereign debt crisis (2009–2012), and the pro-deficit government (March 2018–September 2018)¹¹. The descriptive statistics of the dataset, both for the whole sample and for the most significant considered episodes, are shown in Table 2.

About the expected results, the risk-free rate is expected to be negatively correlated with the CDS spreads, as a higher risk-free rate is symptomatic of better macroeconomic conditions. At the micro-level, a higher interest rate has a positive impact on the net interest income, improving banks' profitability, which, in turn, should reduce the probability of default. The stock volatility is expected to be positively correlated with the CDS spread, as higher volatility means more uncertainty, a smaller distance to default and a higher probability of default.

⁸ Traders approximate risk-free interest rates with Libor/Swap rates when they evaluate derivatives. Some researchers have shown that the same seems to apply to the credit market (Hull et al. 2004).

⁹ As shown by Byström; (2006), equity and asset volatility are related by a positive linear expression. For simplicity, based on the efficient market hypothesis (EMH), we quantified the equity volatility, assuming that share prices reflect all information available in the market. As in Galil et al. (2013), we expect that higher stock volatility determines a higher probability of default and higher CDS spreads.

¹⁰ Daily market cap adjusted.

¹¹ As crises are characterized by higher variance, when considering the whole period, we do have heteroskedasticity. This is another reason why we just considered crises times and estimated it separately, as in this latter case, the estimations do not suffer from heteroskedasticity.

Table 2. Descriptive statistics of data—extended model (EM).

Variable	Mean	SD	Min	Max	Median
Financial crisis (Aug 2007–Oct 2009)—492 Obs.					
Δ5y Euro Swap Rate (%)	3.68	0.79	2.63	5.19	3.92
ΔDaily Volatility Stock (%)	2.82	1.26	1.30	4.40	3.05
E/D (%) ¹²	36.50	7.53	18.14	45.03	39.41
ΔQuanto CDS Spread (0.01%)	13.64	8.50	−0.22	38.05	13.47
Sovereign debt crisis (Oct 2009–Jul 2012)—723 Obs.					
Δ5y Euro Swap Rate (%)	2.20	0.52	1.01	3.23	2.15
ΔDaily Volatility Stock (%)	3.42	0.66	2.54	4.40	3.49
E/D (%)	31.98	9.21	17.47	42.55	38.63
ΔQuanto CDS Spread (0.01%)	52.41	29.70	16.15	129.25	38.80
Anti-establishment Government (Mar 2018–Sep 2018)—96 Obs.					
Δ5y Euro Swap Rate (%)	0.36	0.06	0.22	0.47	0.37
ΔDaily Volatility Stock (%)	1.75	0.95	1.59	1.95	1.69
E/D (%)	33.57	0.95	32.39	34.54	33.51
ΔQuanto CDS Spread (0.01%)	23.74	7.83	12.83	36.62	20.19
Q2 2007–Q3 2018—2859 Obs.					
Δ5y Euro Swap Rate (%)	1.61	1.43	−0.18	5.19	1.12
ΔDaily Volatility Stock (%)	2.89	0.91	1.29	4.40	2.77
E/D (%)	33.74	6.59	17.47	45.03	35.13
ΔQuanto CDS Spread (0.01%)	29.28	25.10	−0.22	129.25	19.55

Source: authors' calculations based on Bloomberg data.

The leverage ratio is generally expected to be positively correlated with the CDS spread. In Merton's approach, higher leverage indicates a shorter distance to the default barrier and a higher probability of default (Galil et al. 2013). The debt to equity (DE) ratio is a leverage ratio that shows how much a company's financing comes from debt or equity. A higher DE ratio means that more of a company's financing is from debt versus issuing shares of equity. A relatively high DE ratio is commonplace in the banking industry: banks carry higher debt amounts because of the amount of fixed assets that banks own as a result of their branch network (Maverick 2018).

Assuming that the bank is fully respecting Basel principles and central bank capital requirements, the standard measure of the leverage ratio, defined as debt to equity ratio, could be expected to be negatively correlated with the CDS spread. During a period of economic expansion, savers are more willing to spend money and make investments in durable goods. At the same time, it is reasonable to expect that the bank's management increases the investment weight in riskier assets (high expected yield, but high risk-weighted asset coefficient) and buyback operations. Moreover, market operators are more willing to increase their exposure in bank shares (high-beta), due to a higher trust in the financial system and future economic perspectives. Hence, assuming that market participants move faster and with a decisively larger exposure than retail savers, this would imply that the ratio's denominator grows faster than the numerator in a stable and non-volatile way, which, in turn, should reduce the leverage ratio. On the contrary, during adverse economic conditions or negative economic outlook, it is reasonable to expect an increase in the leverage ratio and a positive correlation with the CDS spread due to a faster and volatile contraction of the denominator than the numerator of the ratio. In absolute terms, the numerator and the denominator of the leverage ratio tend to move together and in the same direction during different stages of the business cycle (procyclicality), but with a different

¹² The E/D ratio is the inverse of the classical leverage ratio (Debt/Equity). This measure gives us a better idea of the evolution of the equity portion on total debts during the whole decade under investigation. The variation in the leverage ratio elasticities, indeed, is relatively small and could be confusing for the reader's sensitivity.

pace of growth. What could make the difference in the explanation of the leverage ratio impact on the CDS premium, therefore, is the business cycle outlook. As long as savers and investors are confident about the future economic perspectives and trust in the financial system, assuming no capitalization problems by banks, it is reasonable to expect a higher positive and stable variation in the denominator than the numerator of the ratio. In the case of a negative economic outlook or, even worse, during stages of generalized panic about the capacity of the banking system to ensure stability, then it is possible to observe volatile variations in the leverage ratio and a positive relationship with the CDS premium (due to higher credit risk).

4. Results

4.1. Financial Crisis

The augmented Dickey–Fuller test (see the Appendix A Table A1) shows that series are stationary, and the evaluations on the correlation between the regressors (in Appendix A Table A5) do not suggest multicollinearity problems.

Table 3 shows the estimated coefficients for the August 2007–October 2009 period (financial crisis).

Table 3. OLS estimates: period August 2007–October 2009 (492 Obs.).

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_0	−0.000309	0.003002	−0.102779	0.9182
$\Delta(\text{Risk-free Rate})$	−0.814622 ***	0.221771	−3.673263	0.0003
$\Delta(\text{Volatility})$	0.131785	0.820409	0.160633	0.8724
$\Delta(\text{Leverage})$	0.017579	0.050774	0.346210	0.7293
$\Delta(\text{Reden. Risk})$	0.080068 ***	0.024640	3.249537	0.0012
R^2			0.10	
Adj. R^2			0.09	
Prob(F-statistic)			0.00	

Note: *** signals parameter significance at 1%. Source: authors’ calculations in Eviews 10 based on Bloomberg data.

The obtained R^2 of just 10% signals that the model is not able to explain a significant part of the change in the Italian banks’ CDS spreads, in particular when considering that the redenomination proxy variable adds around 6% in terms of explanatory power to the classic Merton Model over the selected period (see the Appendix A Table A2). The risk-free rate and the redenomination risk proxy percentage change sensitivities result to be statistically significant at a 1% threshold.

The relationship between the risk-free variable and the CDS spread is negative as expected, reporting a coefficient of about −0.82. This means that an increase/decrease of 100 basis points of the regressor corresponded to a decrease/increase of approximately 82 basis points of the CDS spread.

The relationship between the redenomination risk variable and the CDS spread is positive, as expected, and reporting a coefficient of about 0.08, which means that an increase of 100 basis points in the quanto CDS spread induced an average increase of around 8 basis point in the CDS spread.

The leverage and daily stock volatility variables result to be not statistically significant. The F-test still confirms the regressors’ appropriateness in the analysis, which is significant with a 95% confidence interval.

4.2. Sovereign Debt Crisis

The augmented Dickey–Fuller test shows that series are stationary, and the evaluations on the correlation between the regressors do not suggest multicollinearity problems (see the Appendix A Tables A1 and A6 for more details).

Table 4 shows the estimated coefficients for the October 2009–July 2012 period (sovereign debt crisis).

Table 4. OLS estimates: period October 2009–July 2012 (723 Obs.).

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_0	0.001337	0.001216	1.099076	0.2721
$\Delta(\text{Risk-free Rate})$	−0.340677 ***	0.066582	−5.116620	0.0000
$\Delta(\text{Volatility})$	0.401680	0.278591	1.441824	0.1498
$\Delta(\text{Leverage})$	0.002897	0.009493	0.305228	0.7603
$\Delta(\text{Reden. Risk})$	0.491289 ***	0.029953	16.40215	0.0000
R^2			0.40	
Adj. R^2			0.40	
Prob(F-statistic)			0.00	

Note: *** signals parameter significance at 1%. Source: Authors' calculations in Eviews 10 based on Bloomberg data.

In this period, the estimated determination coefficient R^2 goes up to 40%, significantly increasing from the previous period estimation. A significant part of this increase can be attributed to the inclusion of the redenomination risk proxy, which added a benefit of around 32% in terms of the explanatory power of the model over the selected period (see the Appendix A Table A3).

The risk-free rate and the redenomination risk proxy resulted to be statistically significant at a 1% threshold, respectively reporting a coefficient of −0.34 and 0.49, which confirms, as expected, that the market perception of a redenomination risk had a significant role during this period of financial instability.

As in the previous period, the leverage value and daily stock volatility variables showed no statistical significance.

The F-test still confirms the model significance at a 95% confidence interval.

4.3. Pro Deficit Government

Even in this case, the augmented Dickey–Fuller test shows that series are stationary, and the evaluations on the correlation between the regressors do not suggest multicollinearity problems (see the Appendix A for more details Tables A1 and A7).

Table 5 shows the estimated coefficients for the March 2018–September 2018 period (pro-deficit government).

Table 5. OLS estimates: period March 2018–September 2018 (96 Obs.).

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_0	0.002929	0.004784	0.612316	0.5419
$\Delta(\text{Risk-free Rate})$	−0.288470 ***	0.084666	−3.407152	0.0010
$\Delta(\text{Volatility})$	0.115309	0.322290	0.357779	0.7213
$\Delta(\text{Leverage})$	−0.286173 **	0.118990	−2.405022	0.0182
$\Delta(\text{Reden. Risk})$	0.635197 ***	0.107532	5.907030	0.0000
R^2			0.65	
Adj. R^2			0.64	
Prob(F-statistic)			0.00	

Note: *** signals parameter significance at 1%, ** is for significance at 5%. Source: authors' calculations in Eviews 10 based on Bloomberg data.

The R^2 obtained in this estimation reaches 65%, showing that, during the pro-deficit government period, the model explanatory power is even higher than it was for the sovereign debt crisis. Here also, a significant part of this explanatory power can be attributed to the redenomination risk proxy (around 36%).

Regarding the estimated coefficients, the risk-free rate and the redenomination risk proxy are statistically significant at a 1% threshold. The risk-free rate reported a coefficient of about -0.29 , reversing the sign of the previous periods' estimation, while the redenomination risk coefficient raised to 0.64 , which is even higher than it was during the sovereign debt crisis period when the Italian economy was close to a potential default.

Within this period, the leverage variable becomes statistically significant, even if just at a 5% threshold, reporting a coefficient of about -0.29 , nearly the same value obtained for the risk-free rate during the same period. This result can be explained by reminding that Italy in 2017 reported some positive GDP growth (differently from the two periods of economic contraction analyzed previously) and that its value can be due to the numerator and denominator's different adjustment speeds of the ratio. The daily stock volatility variable results to be not statistically significant.

4.4. Granger-Causality Tests

The Granger-causality tests allow further analysis of the results obtained for the pro-deficit government period between the daily banks' stock price percentage variation and the daily redenomination risk growth rate.

The results, reported in Table 6, suggest the existence of a feedback relationship between the two variables over the considered time span. The correspondent impulse response functions, reported in Figures 3 and 4, allow a more specific evaluation of the daily banks' stock price percentage change and the redenomination risk growth rate impulse responses following a unit shock of the other variable. Results show that the impulse coming from one variable has a negative response on the other variable, resulting in a progressive smoothed rebounding from negative to positive as in a typical negative AR1 autocorrelated process.

Table 6. Granger-causality test: period March 2018–September 2018.

Null Hypothesis	Obs	F-Statistic	Prob.
% Δ daily banks' stock price does not Granger-cause redenomination risk growth rate	96	2.51428	0.1162
redenomination risk growth rate does not Granger-cause % Δ daily banks' stock price		0.43497	0.5112

Source: authors' calculations in Eviews 10 based on Bloomberg data.

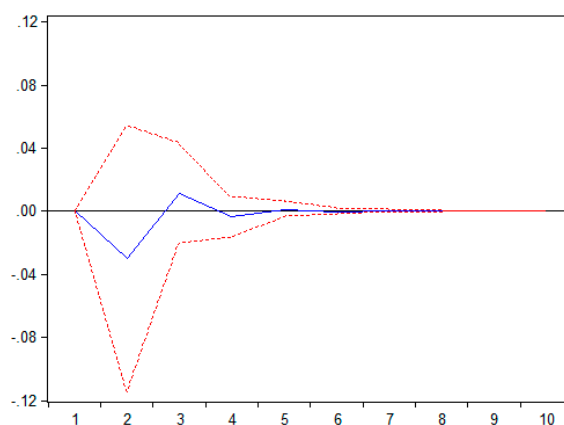


Figure 3. Daily banks' stock price percentage change impulse response to a unit shock of the redenomination risk growth rate. Source: authors' calculations in Eviews 10 based on Bloomberg data.

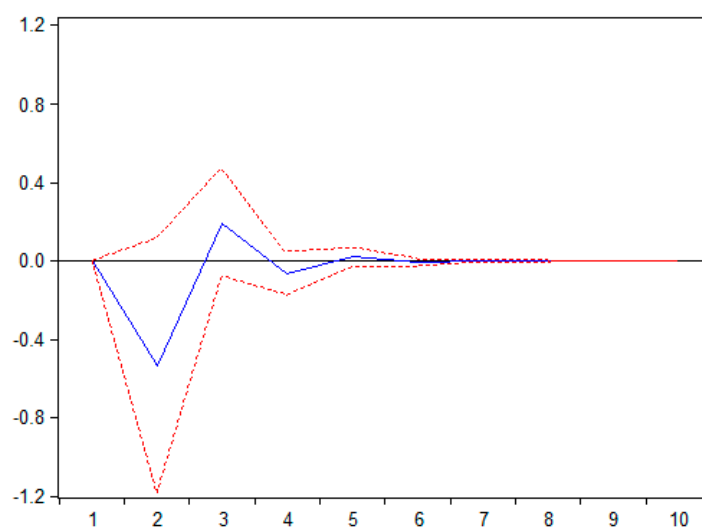


Figure 4. Redenomination risk growth rate impulse response to a unit shock of daily banks' stock price percentage change. Source: authors' calculations in Eviews 10 based on Bloomberg data.

Even if two graphs show a similar shape, the values scale highlights that the response to the redenomination risk growth rate has a higher impact on the process.

5. Economic Discussion and Conclusions

From an economic point of view, the estimations reported above show how the redenomination risk impacted on the Italian banks' CDS spreads.

The economic evolution reported above explains why the political variable plays a fundamental role in this period. In quantitative terms, the redenomination risk component progressively gained the role of main driver of the sensitivity of the Italian banks' CDS spreads, in so pricing the risk of an "Italexit" event already in the sovereign debt crisis, but more during the anti-establishment government period.

In fact, during the sovereign debt crisis, the higher sovereign CDS premia had not suffered from a high redenomination risk component, as market operators were expecting the ECB to intervene, which happened on 26 July 2012, when the ECB announced its plan to buy bonds from the euro area's distressed countries, known as outright monetary transactions. As pointed out by Nelson (2017), this intervention obtained the expected effects, as traders immediately reacted to it, bringing down bond yields across the eurozone.

In the following years, characterized by the quantitative easing (QE) program launched in March 2015 by the ECB, the increased amount of outstanding liquidity injected in financial markets lowered the market volatility. This price stability went on for three years and was broken in March 2018, when Italy experienced an (anti-establishment or populist) pro-deficit government coalition. Populist parties' rhetoric has been frankly against the technocratic European Union since their origins, completely in line with the political idea that in June 2016 caused the famous "Brexit". So, after the Brexit event, the market participants' read-across of what happened in the UK with what could potentially happen in other European governments led by populist parties became almost automatic. The market values reacted by a significant volatility spike, immediately reflected in its sovereign CDS spreads.

As reported by Reed (2018), the high volatility Italian banks had suffered in 2018 was mainly due to political uncertainty, rather than to business outlook. Further, it is exactly in this period that the redenomination risk variable showed the highest coefficient and significance in our estimations.

The political turmoil went evident since Italy's two populist parties had a significant result in the parliament elections. From April to September (the first six months after the elections), foreign net sales of Italian bank securities were of about EUR 13 billion (USD 14.8 billion), while sovereign bond

sales reached EUR 58 billion (Sirletti and Salzano 2018). In this framework, the repeatedly declared intention to leave the euro area by both political parties, during and after the electoral campaign, added further uncertainty about the future of the Italian economy and powered the sell-off of the Italian government bonds over the year (Ainger 2018). As banks typically hold large shares of domestic sovereign bonds¹³, the widening of the BTP-Bund spread had a significant negative impact on their balance sheets, entailing negative effects in terms of CET1 ratio.

This was due not only to the general pro-deficit attitude declared by the same government coalition, but also as the critique on the excessive costs paid for sustaining the national banking system resulted in being one of the most successful arguments proposed by the anti-establishment parties during the electoral campaign. In other words, the underlying message is that the government's riskiness (as perceived by the market) is a pure consequence of the excessive risks taken by the banking sector, which induced economic instability, and weakened public finances, which, in turn, determined higher BTP-Bund spreads and expected costs for rescuing distressed banks.

These political factors became so strong in influencing the market behavior, as at the same time the euro area was suffering the influence of populist parties, reducing the attitude of member states' governments to dialogue and coordination. In such a socio-political framework, economic fundamentals become secondary and raise the entire system vulnerability to financial speculation. From an operative perspective, the evolution of the quanto CDS spreads could be a significant leading indicator on the price discovery process of the banks' CDS spreads for European countries led by euro-skeptical governments.

In this paper, we analyzed the drivers of Italian bank credit risk during the most volatile phases of this decade, namely the financial crisis (August 2007–October 2009), the sovereign debt crisis (October 2009–July 2012) and the anti-establishment government/pre-Italy's budget update (March 2018–September 2018) period.

Results show that the inclusion of the redenomination risk variable enhances the explanatory power of the classic Merton (1974) model, already during the sovereign debt crisis, but even more during the anti-establishment government period, showing how the market reacts to specific political interventions, reducing the banks economic fundamentals to a secondary role in a context of economic uncertainty and lack of political coordination.

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¹³ According to Banca d'Italia, Italian banks held in their portfolios around EUR 380 billion of sovereign Italian bonds in October 2018. See Banca d'Italia (2018b).

Appendix A

Appendix A.1 Unit Root Tests¹⁴

Table A1. Augmented Dickey–Fuller test.

Augmented Dickey-Fuller Test		
	Residuals	
Period	t-Statistic	Prob. *
Financial crisis (492 Obs.)	−19.24291	0.0000
Sovereign debt crisis (723 Obs.)	−21.51060	0.0000
Pro deficit Government (96 Obs.)	−9.863148	0.0000

* MacKinnon (1996) one-sided p-values. Source: author’s own calculations in Eviews 10.

Appendix A.2 Basic Model (Inspired by the Classic Merton (1974) Model)

- Financial crisis

Table A2. OLS estimates: period August 2007–October 2009 (492 Obs.).

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_0	6.44×10^{-6}	0.003116	0.002066	0.9984
$\Delta(\text{Risk-free Rate})$	−0.861810 ***	0.267762	−3.218569	0.0014
$\Delta(\text{Volatility})$	0.407496	0.960730	0.424152	0.6716
$\Delta(\text{Leverage})$	0.043429	0.068708	0.632086	0.5276
R ²			0.05	
Adj. R ²			0.04	
Prob(F-statistic)			0.00	

Note: *** signals parameter significance at 1%. Source: author’s own calculations in Eviews 10.

- Sovereign debt crisis

Table A3. OLS estimates: period October 2009–July 2012 (723 Obs.).

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_0	0.002165	0.001519	1.425300	0.1545
$\Delta(\text{Risk-free Rate})$	−0.552276 ***	0.085677	−6.446025	0.0000
$\Delta(\text{Volatility})$	0.109614	0.733384	0.149464	0.8812
$\Delta(\text{Leverage})$	−0.006041	0.013461	−0.448774	0.6537
R ²			0.08	
Adj. R ²			0.08	
Prob(F-statistic)			0.00	

Note: *** signals parameter significance at 1%. Source: author’s own calculations in Eviews 10.

- Pro Deficit Government

¹⁴ We follow the approach suggested by Brooks (2002). Time horizons selected to realize the whole analysis are not discretionary but justified by important exogenous historical events, as reported by the Italian stock exchange supervision institution, the Consob.

Table A4. OLS estimates: period March 2018–September 2018 (96 Obs.).

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_0	0.007310	0.006905	1.058616	0.2925
$\Delta(\text{Risk-free Rate})$	−0.465662 **	0.235470	−1.977590	0.0510
$\Delta(\text{Volatility})$	0.480214	0.818202	0.586914	0.5587
$\Delta(\text{Leverage})$	−0.375821	0.648974	−0.579100	0.5639
R^2			0.29	
Adj. R^2			0.27	
Prob(F-statistic)			0.00	

Note: ** signals parameter significance at 5%. Source: author's own calculations in Eviews 10.

Appendix A.3 Correlation Matrix

Table A5. Correlation matrix: period August 2007–October 2009 (492 Obs.).

Variable	$\Delta(\text{Risk-Free Rate})$	$\Delta(\text{Volatility})$	$\Delta(\text{Leverage})$	$\Delta(\text{Reden. Risk})$
$\Delta(\text{Risk-free Rate})$	1	0.16308	0.14920	−0.00185
$\Delta(\text{Volatility})$	0.16308	1	0.18848	0.14343
$\Delta(\text{Leverage})$	0.14920	0.18848	1	0.12399
$\Delta(\text{Reden. Risk})$	−0.00185	0.14343	0.12399	1

Source: author's own calculations in Eviews 10.

Table A6. Correlation matrix: period October 2009–July 2012 (723 Obs.).

Variable	$\Delta(\text{Risk-Free Rate})$	$\Delta(\text{Volatility})$	$\Delta(\text{Leverage})$	$\Delta(\text{Reden. Risk})$
$\Delta(\text{Risk-free Rate})$	1	0.03003	0.01426	−0.18996
$\Delta(\text{Volatility})$	0.03003	1	0.11177	−0.06803
$\Delta(\text{Leverage})$	0.01426	0.11177	1	−0.03480
$\Delta(\text{Reden. Risk})$	−0.18996	−0.06803	−0.03480	1

Source: author's own calculations in Eviews 10.

Table A7. Correlation matrix: period March 2018–September 2018 (96 Obs.).

Variable	$\Delta(\text{Risk-Free Rate})$	$\Delta(\text{Volatility})$	$\Delta(\text{Leverage})$	$\Delta(\text{Reden. Risk})$
$\Delta(\text{Risk-free Rate})$	1	−0.09275	−0.00188	−0.32308
$\Delta(\text{Volatility})$	−0.09275	1	−0.01285	0.11611
$\Delta(\text{Leverage})$	−0.00188	−0.01285	1	−0.01423
$\Delta(\text{Reden. Risk})$	−0.32308	0.11611	−0.01423	1

Source: author's own calculations in Eviews 10.

Appendix A.4 Basic and Extended Model for the Whole Period (August 2007–September 2018)

- Basic Model

Table A8. Basic Model OLS estimates: period August 2007–September 2018 (2751 Obs. after adjustments).

Variable	Coefficient	Std. Error	t-Statistic	Prob.
B_0	0.000577	0.000875	0.659485	0.5096
$\Delta(\text{Risk-free Rate})$	−0.007744	0.006293	1.230467	0.2186
$\Delta(\text{Volatility})$	0.415109	0.323954	1.281382	0.2002
$\Delta(\text{Leverage})$	0.004257	0.019649	0.216628	0.8285
R^2		0.004		
Adj. R^2		0.003		
Prob(F-statistic)		3.87		

Source: author's own calculations in Eviews 10.

- Extended Model

Table A9. Extended model OLS estimates: period August 2007–September 2018 (2751 Obs. after adjustments).

Variable	Coefficient	Std. Error	t-Statistic	Prob.
β_0	0.000304	0.000828	0.367692	0.7131
$\Delta(\text{Risk-free Rate})$	−0.007493	0.006182	−1.212124	0.2256
$\Delta(\text{Volatility})$	0.266848	0.288883	0.923725	0.3557
$\Delta(\text{Leverage})$	−0.011348	0.013020	−0.871559	0.3835
$\Delta(\text{Reden. Risk})$	0.150402 ***	0.035404	4.248143	0.0000
R^2		0.11		
Adj. R^2		0.11		
Prob(F-statistic)		84.47		

Note: *** signals parameter significance at 1%. Source: author's own calculations in Eviews 10.

References

- Acharya, Viral V., Itamar Drechsler, and Philipp Schnabl. 2011. *A Pyrrhic Victory? Bank Bailouts and Sovereign Credit Risk*. NBER Working Paper. Cambridge: National Bureau of Economic Research, Available online: <https://www.nber.org/papers/w17136.pdf> (accessed on 9 July 2020).
- Ainger, John. 2018. Another Euro Crisis? Here's What Markets Are Saying about Italy. Available online: <https://www.bloomberg.com/news/articles/2018-09-28/another-euro-crisis-here-s-what-markets-are-saying-about-italy> (accessed on 28 September 2018).
- Avino, Davide, and John Cotter. 2014. Sovereign and Bank CDS Spreads: Two Sides of the Same Coin? *Journal of International Financial Markets, Institutions and Money* 32: 72–85. Available online: <https://www.sciencedirect.com/science/article/abs/pii/S104244311400064X> (accessed on 9 July 2020). [CrossRef]
- Banca d'Italia. 2018a. Banche e Moneta: Serie Nazionali–Ottobre 2018. Available online: https://www.bancaditalia.it/pubblicazioni/moneta-banche/2018-moneta/statistiche_BAM_20181211.pdf (accessed on 11 December 2018).
- Banca d'Italia. 2018b. Rapporto Sulla Stabilità Finanziaria. Available online: http://www.bancaditalia.it/pubblicazioni/rapporto-stabilita/2018-2/RSF_2_2018.pdf (accessed on 23 November 2018).
- Berlinger, Edina, Illés Ferenc, Badics Milan, Banai Adam, Daróczi Gergely, Dömötör Barbara, Gabler Gergely, Havran Daniel, Juhász Peter, Margitai Istvan, and et al. 2015. *Mastering R for Quantitative Finance*. Birmingham: Packt Publishing.
- Brooks, Chris. 2002. *Introductory Econometrics for Finance*. Cambridge: Cambridge University Press.
- Byström, Hans. 2006. Merton Unraveled. *The Journal of Alternative Investments* 8: 39–47. Available online: <https://jai.pm-research.com/content/8/4/39.short> (accessed on 9 July 2020).

- Cesaratto, Sergio. 2016. *Sei Lezioni di Economia*. Reggio Emilia: Imprimatur.
- Chiaromonte, Laura, and Barbara Casu. 2010. Are CDS Spread a Good Proxy of Bank Risk? Evidence from the Financial Crisis. *SSRN Electronic Journal*. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1666793 (accessed on 9 July 2020). [CrossRef]
- Collin-Dufresne, Pierre, Robert Goldstein, and J. Spencer Martin. 2002. The Determinants of Credit Spread Changes. *The Journal of Finance* 56: 2177–207. Available online: <https://onlinelibrary.wiley.com/doi/abs/10.1111/0022-1082.00402> (accessed on 9 July 2020). [CrossRef]
- De Santis, Roberto. 2019. Redenomination Risk. *Journal of Money, Credit and Banking* 51: 2173–206. Available online: <https://onlinelibrary.wiley.com/doi/abs/10.1111/jmcb.12582> (accessed on 9 July 2020). [CrossRef]
- Di Cesare, Antonio, and Giovanni Guazzarotti. 2005. An Analysis of the Determinants of Credit Default Swap Spread Using Merton's Model. Banca d'Italia. Available online: https://www.researchgate.net/publication/228638411_An_analysis_of_the_determinants_of_credit_default_swap_spreads_using_Merton%27s_model (accessed on 9 July 2020).
- Di Cesare, Antonio, and Giovanni Guazzarotti. 2010. An Analysis of the Determinants of Credit Default Swap Spread Changes before and during the Subprime Financial Turmoil. *SSRN Electronic Journal*. Available online: http://www.bancaditalia.it/pubblicazioni/temi-discussione/2010/2010-0749/en_tema_749.pdf (accessed on 9 July 2020). [CrossRef]
- Ericsson, Jan, Kris Jacobs, and Rodolfo Oviedo. 2009. The Determinants of Credit Default Swap Premia. *The Journal of Financial and Quantitative Analysis* 44: 109–32. Available online: <https://www.cambridge.org/core/journals/journal-of-financial-and-quantitative-analysis/article/determinants-of-credit-default-swap-premia/C90E99F64F47A41170EACD7F7A4929EE> (accessed on 9 July 2020). [CrossRef]
- Galil, Koresh, Offer Shapir, Dan Amiram, and Uri Ben-zion. 2013. The Determinants of CDS Spreads. *SSRN Electronic Journal*. Available online: <https://www.sciencedirect.com/science/article/abs/pii/S0378426613004676?via%3Dihub> (accessed on 9 July 2020). [CrossRef]
- Galliani, Clara, and Stefano Zedda. 2015. Will the Bail-in break the vicious circle of banks and their sovereign? *Computational Economics* 45: 597–614. Available online: <https://link.springer.com/article/10.1007/s10614-014-9436-9> (accessed on 9 July 2020). [CrossRef]
- Guazzarotti, Giovanni. 2004. The Determinants of Changes in Credit Spread of European Corporate Bonds, Mimeo, Banca d'Italia, Economic Research Department. Available online: http://www.greta.it/credit/credit2005/Friday/Poster/05_DiCesare_Guazzarotti.pdf (accessed on 9 July 2020).
- Hull, John, Mirela Predescu, and Alan White. 2004. The relationship between credit default swap spreads, bond yields, and credit rating announcements. *Journal of Banking & Finance* 28: 2789–811. Available online: <https://www.sciencedirect.com/science/article/abs/pii/S0378426604001098?via%3Dihub> (accessed on 9 July 2020).
- Kingsley, Patrick. 2012. Financial Crisis: Timeline. *The Guardian*. Available online: <https://www.theguardian.com/business/2012/aug/07/credit-crunch-boom-bust-timeline> (accessed on 18 December 2018).
- Lahmann, Wolfgang. 2012. Contagion Effects between Sovereign and Bank Credit Spreads—A Global Analysis of Interdependencies between Sovereign and Bank CDS Spreads. *SSRN Electronic Journal*. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1994866 (accessed on 9 July 2020). [CrossRef]
- MacKinnon, J. G. 1996. Numerical distribution functions for unit root and cointegration tests. *Journal of Applied Econometrics* 11: 601–18. [CrossRef]
- Matteucci, Piera. 2018. Elezioni Politiche: Vincono M5s E Lega. Crollo Del Partito Democratico. Centrodestra Prima Coalizione. Il Carroccio Sorpassa Forza Italia. Available online: https://www.repubblica.it/speciali/politica/elezioni2018/2018/03/04/news/risultati_elezioni_politiche_pd_centrodestra_m5s_fi_lega-190424815/ (accessed on 18 December 2018).
- Maverick, Jack. 2018. What Debt-to-Equity Ratio Is Common for a Bank? Available online: <https://www.investopedia.com/ask/answers/052515/what-debt-equity-ratio-common-bank.asp> (accessed on 20 December 2018).
- Merton, Robert C. 1974. On the pricing of corporate debt: the risk structure of interest rates. *Journal of Finance* 29: 449–70. Available online: <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1540-6261.1974.tb03058.x> (accessed on 9 July 2020).

- Ministero dell'Economia e delle Finanze. 2018. Nota Di Aggiornamento Del Documento Di Economia E Finanza 2018. Available online: http://www.mef.gov.it/inevidenza/documenti/NADEF_2018.pdf (accessed on 18 December 2018).
- Nelson, Eshe. 2017. Five Years ago Today, Mario Draghi Saved the Euro. Available online: <https://qz.com/1038954/whatever-it-takes-five-years-ago-today-mario-draghi-saved-the-euro-with-a-momentous-speech/> (accessed on 26 July 2017).
- Panetta, Fabio, Faeh Thomas, Giuseppe Grande, Corrinne Ho, Michael King, Aviram Levy, Federico Signoretti, Marco Taboga, and Andrea Zaghini. 2009. *An Assessment of Financial Sector Rescue Programmes*. BIS Papers No. 48. New Delhi: BIS, Available online: <https://www.bis.org/publ/bppdf/bispap48.pdf> (accessed on 9 July 2020).
- Politi, James, and Davide Ghiglione. 2018. Italy Anti-Establishment Parties Make Big Gains in Election | Financial Times. Available online: <https://www.ft.com/content/e6a89252-1ffa-11e8-a895-1ba1f72c2c11> (accessed on 5 March 2018).
- Reed, Jonathan R. 2018. Major Global Markets Are Already in a Bear Market or Getting Close, Stoking Fears of Slowing Growth. Available online: <https://www.cnbc.com/2018/12/17/major-global-markets-already-in-bear-market-stoking-growth-fears.html> (accessed on 18 December 2018).
- Romano, Beda. 2017. La Ue Approva Il Salvataggio Di Mps. Lo Stato Avrà Il 70%. Rimborsi Sui Bond Fino A 1,5 Miliardi. Available online: <https://www.ilsole24ore.com/art/la-ue-approva-salvataggio-mps-stato-avra-70percento-rimborsi-bond-fino-15-miliardi-AETrvUrB> (accessed on 4 July 2020).
- Samaniego-Medina, Reyes, Antonio Trujillo-Ponce, Purificación Parrado-Martínez, and Filippo di Pietro. 2016. Determinants of bank CDS spreads in Europe. *Journal of Economics and Business* 86: 1–15. Available online: <https://www.sciencedirect.com/science/article/abs/pii/S014861951630011X?via%3Dihub> (accessed on 9 July 2020). [CrossRef]
- Sirletti, Sonia, and Giovanni Salzano. 2018. Italy Banks Get Some Relief as EU Budget Deal Lifts Shares. Available online: <https://www.bloomberg.com/news/articles/2018-12-19/italy-banks-gain-breathing-room-as-budget-accord-with-eu-nears> (accessed on 9 July 2020).
- Zhang, Benjamin, Hao Zhou, and Haibin Zhu. 2005. *Explaining Credit Default Swap Spreads with the Equity Volatility and Jump Risks of Individual Firms*. Working Paper No. 181. New Delhi: BIS, Available online: <https://www.bis.org/publ/work181.pdf> (accessed on 9 July 2020).



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