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ΤΜΗΜΑ ΟΙΚΟΝΟΜΙΚΗΣ ΕΠΙΣΤΗΜΗΣ

RISK ANALYSIS OF CREDIT DEFAULT SWAPS WITH AN APPLICATION TO GREEK GOVERNMENT BONDS

ΒΑΣΙΛΙΚΗ ΖΕΡΦΟΥ

**Διατριβή υποβληθείσα προς μερική εκπλήρωση
των απαραίτητων προϋποθέσεων
για την απόκτηση του
Μεταπτυχιακού Διπλώματος Ειδίκευσης**

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1. Introduction

Over the years, financial and market participants have recognised the need for managing credit risk in their underlying transactions. Therefore, attempts were made through several insurance mechanisms and financial guarantees so as to isolate, disperse, and reduce credit risk. Credit risk is defined as the potential that a borrower will fail to meet its contractual obligations. Credit exposure is a source of risk that is included in almost every financial transaction and credit derivatives presented an innovative method to protect against this risk. Credit derivatives were introduced to the market in the early 1990's and since then they have experienced an exponential growth.

Credit default swap (C.D.S.) is the most commonly traded credit derivative product and it represents over thirty percent of the credit derivatives market. These financial instruments transfer credit risk of an underlying asset between two or more parties. In other words, they are simply an insurance-like contract that covers losses on a broad range of securities in case of a credit event. At first glance, protection against a credit event is the primary purpose of these financial instruments. In practice, they are also used for speculation and in order to benefit from arbitrage opportunities. For instance, risk speculators who want exposure to specific classes of assets but don't actually own them, now have a means by which to speculate on them, that is to say, making actually bets. This fact can be proved really frightening. It is like you insure your house in case of a catastrophic event and someone else will be paid its value if actually your house is burned. It is unavoidable not to consider the losses or the payoffs at the relevant case of a government bankruptcy. On the other hand, if this kind of insurance for loans, bonds and mortgages disappears or becomes more expensive, creditors will become more cautious, resulting all this in a domino effect that could affect everyone.

The recently liquidity and credit crisis (2007-2008) and the subsequent European debt crisis has raised many questions and concerns over the advantages and disadvantages of these instruments. Not only were these products unregulated but there were also no standard contracts and no transparency. According to Deutsche Bank managing director Athanassios Diplas "the industry pushed through 10 years worth of changes in just a few months". However, it is true to say that credit derivatives have essentially changed the shape of liquidity and the dynamics of the financial system.

1.1 Structure of the study

The study is structured as follows: In chapter 2 we analyze financial risks and in particular, credit risk. We discuss the critical role of credit rating agencies with regard to the recent financial crisis.

Chapter 3 gives a general overview of credit derivatives, their background, their types and their applications. Moreover, we give a brief analysis of the financial crisis of 2007.

Chapter 4 gives us an in-depth analysis of credit default swaps, their types and we discuss their role in the Greek debt crisis.

Finally, in chapter 5 we present credit risk models in the literature and we analyze the reduced-form model of Hull and White (2000). We build a model, based on this approach in the Mat lab programming language and we create a theoretical framework in order to acquire estimates for the risk-neutral default probabilities and the recovery rate on Greek bonds. We discuss the results and the possible errors during this application.

2 Credit risk

2.1 Financial Risks

Risk is an integral feature of our everyday life. In fact, risk affects people's life in a variety of ways, for example, in business, in daily life, and most times is almost impossible to be eliminated. There is risk wherever there is uncertainty about future events. In finance, risk is the probability of loss, which is associated with any type of financial investment or security. Thus, it is obvious why firms and other corporations place too much importance in financial risk management.

In general, there are four types of financial risks:

- Market risk
- Credit risk
- Liquidity risk
- Operational risk

Market risk is the risk that the value of an investment will decline owing to economic changes or other factors, such as interest rates and exchange rates that impact the market. Market risk is also referred to as systematic risk and it is this risk that can be diversified and mitigated. The related market risks are:

- Equity risk is the risk that stock prices or stock market dynamics will change.
- Interest rate risk is the risk that interest rates will change causing the possible depreciation of the value of a security, especially a bond's value.
- Currency risk is the risk that foreign exchange rates will change, so that related investments will be affected.
- Commodity risk is the risk that commodity prices will change.

Credit or default risk is associated with the probability that a borrower, most frequently a bond borrower, will fail to meet his obligations, in other words he will default.

Liquidity risk arises from the difficulty of a financial asset or an investment to be sold instantly.

Operational risk refers to the probability of loss occurring from a company's business disfunction, by which we mean the ineffective way that people and system operate within the company.

2.2 Credit Risk

Credit risk has to do with changes in the credit quality for a counterparty in a contract. Whatever contract or agreement consists of a debt obligation involves credit risk. Credit risk can be divided into three types:

- Default risk
- Credit spread risk
- Downgrade risk

Default risk is the risk that a borrower will not repay the entire undischarged debt, that is to say default risk illustrates the uncertainty the issuer will fail to meet his obligations with respect to timely payment of interest and repayment of the amount borrowed.

Credit spread risk reflects the possibility of financial losses due to changes in the level of credit spreads. Credit spreads represent the credit risk premiums sought by investors for a given credit quality. Credit spreads change over time for several reasons, for example changes in the credit ratings of issuers, varying market conditions and other macroeconomic forces.

Downgrade risk arises from the deterioration of the financial condition of an issuer by a credit rating agency. In a way, downgrade risk seems familiar to credit spread risk. However, they differ in that the former is combined with a formal credit review by a credit agency, while the latter reflects the financial market's reaction to possible declines in credit quality.

2.3 Credit Risk Management

If there were no capital market imperfections, the issue of managing and measuring any kind of risk, and credit risk in particular, would not exist. The key role in managing credit risk is identifying and rating credit exposure. In order to analyze the creditworthiness of the borrower, credit analysts should first evaluate the factors that affect the business risk of a borrower; either the borrower is a financial corporation, more usually a bank, or a government.

As for financial institutions, these factors can be classified in four categories:

- The character of management, which involves ethical reputation and qualifications of company's establishment.
- The capacity of the borrower which reflects his quality and ability to satisfy debt obligation.
- The collateral available to supply an additional support in case of bankruptcy or default procedures.
- The restrictions and the terms imposed to the borrower by the lending contract.

On the other hand, there are two main factors combined with the valuation of sovereign debt:

- Economic risk, which refers to the ability of the government to satisfy its obligations on time. Both quantitative and qualitative models are used for empirical studies on this scope.
- Political risk, which attributes the willingness of the country to repay its debt.

The increasing use of credit derivatives, among other mechanisms, implement credit risk management solutions which help the organizations to achieve several benefits, such as:

- Protection from the organization's lending assets, so as the company can improve its collection rates and be able to better fulfil its duties.
- Costumer profitability, since harsh credit measures and low or conservative credit limits barely attract clients.
- Internal coordination within the company's departments which involves better communication between departments and as a result possible reduction of operating costs.

Obviously, credit risk management is often associated with banks and it is essential for managing credit risk not only at their own portfolios of investment but in individual transactions as well. Banks identify and manage credit risk by using several mechanisms, such as loans, credit derivatives and securitisation programs. Thus, it is essential for them to ensure efficiency of their internal controls and to establish certain regulation, so as to achieve the best functioning of all parts of credit administration. In other words, banks should take advantage of all necessary, available information, follow the appropriate monitor controls, and utilize internal rating systems and analytical techniques, in order to ensure the effectiveness and quality of credit management. Additionally, considering the relationship of credit risk with other types of risk, it seems that credit risk management ensures that capital flows in the appropriate investors, so as we can maintain a healthy economy and a constant capital growth.

2.4 Importance and Creditability of Credit Rating Agencies

A credit rating agency is a nationally recognized statistical rating organization which evaluates the issuer's creditworthiness by estimating his capacity to pay its debt obligations. Standard & Poor's (S&P), Moody's Investor's and Fitch Ratings are the most highly recognizable agencies. Lower ratings suggest that an issue is riskier than another one with higher ratings and as a consequence its price is lower. A downgrade from the rating agencies could be proved a real disaster for banks or other financial institutions who bought protection against credit exposure as, to a great extent, risk ratings influence bank's decisions to buy or sell credit facilities. Identification and evaluation of credit exposure is an important first step for managing effectively credit risk.

Regardless of the key role of rating agencies[1] in international markets, there exist significant doubts about the effectiveness of risk rating processes and controls. In contract with flourishing economic times, the recent global financial crisis and the subsequent fall of the value of credit securities proved, among others, the weakness and the flaws of credit rating procedures. By the time the credit bubble exploded, there were too many of these products, including credit default swaps and collateralized debt obligations (CDOs), that were top rated at the assessments of credit rating agencies. Eventually, they turned up so-called "toxic waste". Rating agencies were accused of taking fees from financial institutions and giving generous ratings while evaluating the quality of risky products in order to serve specific purposes.

At the same time, as far as credit ratings of sovereign debts are concerned, the rating agencies tend to act in a more conservative way. On account of that reason, one could wonder "Greece got downgraded because it is likely to default or it is likely to default because it got downgraded"? In fact, Greek bonds were traded as being in the "junk bond" category quite a while before the rating agencies classify them as such. Actually, now the top three agencies have at least 37 nations-states on their downgrade list. Sharp judgments on a country's debt make a bad situation even worst, spreading panic and being a really bad influence over all markets.

On 27 April 2010, the credit quality of Greek debt deteriorated to the level of "junk" status by Standard & Poor's. The interest and the attention of the eurozone countries are being focused right now on Greek economy. During the 2000's. everything seemed to functioning quite well for the Greek economy. However, this fact didn't prevent the country from following a deficit financing. In the beginning of 2010, it was discovered that the Greek governments had paid Goldman Sachs a great amount in fees in order to make agreements which helped the country to hide its debts and the actual deficit. Actually, Greece was not the only country to follow such procedures and "control" the statistics of its finance. Moreover, it is true to say that Greece represents only the 2% of the eurozone economy. So, it is clear that the problem is focused actually on the fact that a possible default by a eurozone country will affect the market mood, causing investors to lose confidence in other eurozone countries.

All things considered, further measures should be taken and greater regulation should be established in order to ensure the appropriate rating, especially of sovereign debt. It is highly debated either it is the over-reliance of financial institutions and other market participants on these ratings or the conflicts of interest of these agencies, that cause harmful effects on the functioning of financial markets. In the light of this evidence, it is an immediate prospect to restore confidence across markets and instil a sense of morality and responsibility regarding the rating agencies.

[1] For an overview in credit rating methodologies and ratings see discussion paper "Credit Rating Agencies and their potential impact on developing countries" (2008).

Table 1: Bond Ratings Codes

Source: Moody's Investor's Service and Standard and Poor's

The following table provides a brief definition of rating symbols of each of the two major rating agencies.

Rating	S&P	Moody s
Highest quality	AAA	Aaa
High quality	AA	Aa
Upper medium quality	A	A
Medium grade	BBB	Baa
Somewhat speculative	BB	Ba
Low grade, speculative	B	B
Low grade, default possible	CCC	Caa
Low grade, partial recovery possible	CC	Ca
Default expected	C	C

3 Credit Derivatives and Credit Derivatives Market

3.1 Credit Derivatives

Credit derivatives were introduced in the market in the beginning of 1990's and since then, they remain a rapidly growing sector. There is no surprise that these financial instruments have transformed the shape of the market as, they transfer credit risk in the most efficient and simple way. Credit derivatives are simply a mean of protecting against default risk, but to expose the truth, their use of speculation over the last years and the recent credit crunch have generated a great deal of heated debate. Although all participants in the credit derivatives market are entitled to benefit from these innovative products, many are still unaware of the range and variety of dangers tugged at them.

The term credit derivative refers to a broad range of securities. According to Schoenbucher (2003):

(a) A credit derivative is a derivative security that is primarily used transfer, hedge or manage credit risk

(b)A credit derivative is a derivative security whose payoff is materially affected by credit risk.

Credit derivatives are contingent claims whose payoffs are materially affected by credit events. Therefore, their payoffs are linked to the performance of an underline credit product, such as bonds, loans, mortgages and credit cards. Credit derivatives themselves, can be used as an underline asset for other credit derivatives. Underlying credit products are contracts between two parties, the borrowers and the lenders. Following that, credit derivatives are also contracts between two parties, the credit protection buyers and the credit protection sellers. International Swap & Derivatives Association (ISDA) standardized the terminology in credit derivatives transactions in 1999.

The key terms of credit derivatives come as follows:

- Reference entity: In credit derivatives transactions, the protection seller pays the buyer in case of default of the reference entity. The reference entity is not party to the contract. For example, a bank may need to buy protection from an insurance company, or simply from another bank so as to hedge it's risk against a possible default of a company to whom has lend a great amount. This company is the reference entity.

- Reference assets: This term is often refers to a set of assets issued by the reference entity. Reference assets are used for the determination of the credit event and the recovery rate[2].

- Credit event: A credit event for a firm is its default and it is usually defined with respect to the reference entity and the reference assets. Possible credit events include[3]:

  - bankruptcy (for non-sovereign entities),
  - failure to pay,
  - repudiation/moratorium (for sovereign entities),
  - restructuring,
  - obligation acceleration ,
  - obligation default

- Default payment or contingent payment: The payments which have to be paid from the protection seller in case a default event has happened.

- Notional amount: The notional amount is the nominal or face amount that is used to compute the periodic payments made on the contract.

- Premium payment: Premium payments are the payments which are usually made periodically from the protection buyer to the seller.

[2] Recovery rate's value depends on many factors (such as the bond's seniority, economic environment etc), so it is not always easy to be predicted and modelled in a credit risk framework. There is usually an offset, which means we use an exogenous value.

[3] The 1999 ISDA Credit Derivatives Definitions include these six types of credit events.

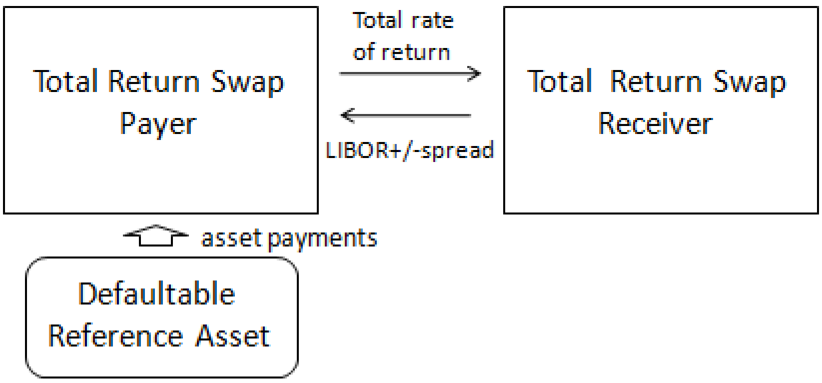
3.2 Credit derivatives types

In general, we can classify credit derivatives in three primary types:

1. Total return instruments: The most popular within this class are total return swaps. This is a swap transaction in which counterparties agree to exchange the actual cash flows that arise from two different investments. Usually, one of them is a defaultable investment, for example a bond, and the other one a default-free investment with returns referenced to a certain reference rate, such as LIBOR[4] (London Interbank Offered Rate). The protection buyer will receive LIBOR plus a spread and pays to the protection seller all he earns from the reference assets, namely the bond. This transaction allows the transfer of the total risk of the underlying assets without actually transferring the ownership of the assets. Obviously, it is true to say that the market risk is not eliminated, since these products are instruments written on both credit and market risk.

Figure 1: Total Return Swap Contract

This figure illustrates a Total Return Swap Contract.



2. Credit spread instruments: These products are instruments whose payoffs are dependent on the behaviour of credit spreads. Credit Spread Options and Forwards are common examples of this class. These transactions allow investors to take positions on changes of the relative spread between two credit instruments or on the future movement in a credit spread relative to a risk free benchmark, such as LIBOR, or a government bond. The option style may be European or American or Asian.

3. Credit event instruments: These are contracts, in which one party make payments in case of the occurrence of a specified credit event. Credit default

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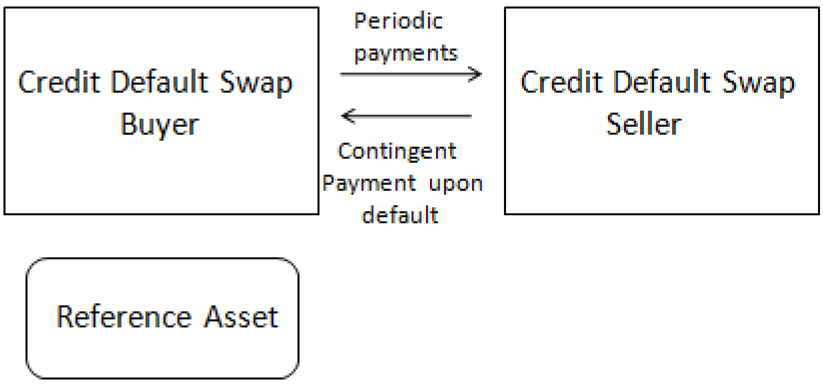
[4] LIBOR represents the rate banks in England charge one another on overnight loans or loans up to five years. It is often used by banks to quote floating rate loan interest rates. Typically, the benchmark LIBOR used on loans is the three-month rate.

swaps, credit default options, credit default swaptions and indemnity agreements are classic examples of this category. The most popular form of this class and the most widely used credit derivative product is Credit Default Swap (CDS). A credit default swap pays a pre-agreed amount of money on a trigger event of the reference entity, which means the buyer make periodic payments to the seller and in return, he receives an offset payoff if the reference entity defaults or experiences a similar credit event. Figure 2 illustrates the figure of a CDS contract.

Figure 2: Credit Default Swap Contract

This figure illustrates the structure of a Credit Default Swap Contract



4. Other credit derivatives:

-Credit linked notes: A credit linked-note is a fixed or floating rate-note which is paying the investor a fixed or floating coupon based on the chosen reference asset. If there is no credit event of the reference entity all the coupons and principals will be paid appropriately, otherwise the investor will receive a recovery rate, or any other pre-agreed payment. They involve credit spread linked notes and credit default linked notes and they are economically equivalent to credit default swaps.

-Collateralized debt obligations (CDOs): CDOs are a kind of structured asset-backed securities. They are also referred to as “tranches” and are designed to slice the credit risk of a portfolio of reference assets. They involve a portfolio of cash assets, such as bonds, loans and asset-backed securities, or they are synthesized through more basic credit derivatives (collateralized synthetic obligation), such as credit default swaps and credit linked notes. Sometimes investors use Hybrid CDOs which is an intermediate instrument between the two cases. The portfolio of assets is transferred into a special created company, called the special purpose vehicle (SPV), which is issuing the notes. Each tranche carries different ratings, which represent the possible default losses in the portfolio that will be paid by the issuer when the CDO is liquidated. Due to the complexity and the large size of reference pools, CDOs’ valuation is much more complicated than other ordinary securities.

Figure 3: Credit Linked-Note

This figure illustrates the structure of a Credit Linked-Note contract.

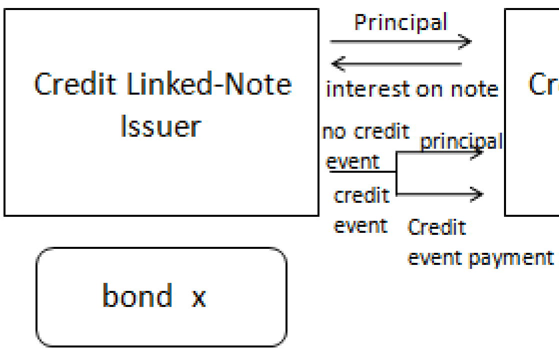
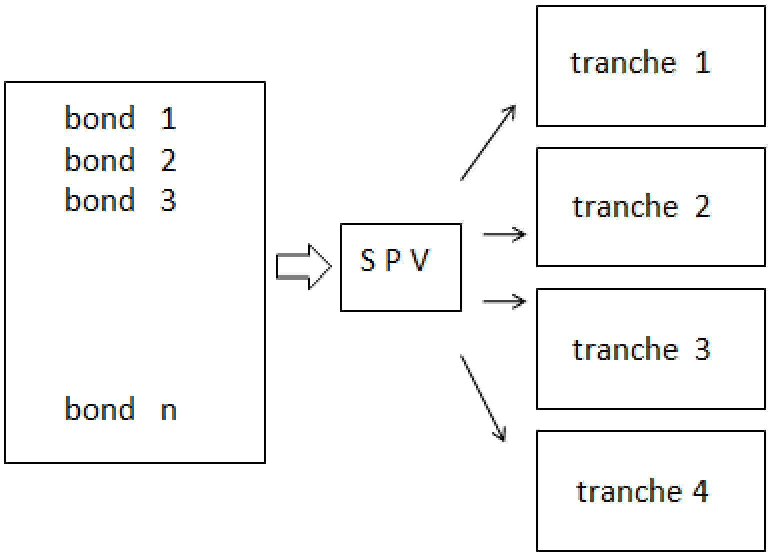


Figure 4: Collateralized Debt Obligation

This figure illustrates the structure of a CDO.



. Hybrid credit derivatives[5] are those which combine credit risk with other market risks, such as interest rate or currency risk. Clean and perfect asset swaps are some common structures of this kind of securities.

[5] See the "Lehman Brothers Guide to Exotic Credit Derivatives".

- Asset Swaps, constant maturity products, basket products, fixed recovery products and forward products are some other credit securities also tailored to investor's needs and designed to transfer and reduce credit risk, offering at the same time great flexibility.

3.3 Credit Derivatives Market - Background, Applications and the financial crisis of 2007

3.3.1 Background

Although the credit derivatives market was created over the past decade, it has experienced so far accelerated growth. The total notional amount of credit derivatives was 180 billion USD in 1997 and the market grew more than tenfold to 2.0 trillion USD by the end of 2002. In April 2007, the total notional amount on outstanding credit derivatives was 35.1 trillion USD. Thus, it is needless to say that there exists a wide and ever-expanding range of credit derivatives products. However, ISDA reported that credit derivatives decreased to 26.3 trillion at the end of June 2010. The largest share of the market is taken up by credit default swaps (approximately the 35%), while the second largest group are portfolio-related credit derivatives, such as collateralised loan obligations (CLOs) and collateralised synthetic obligations (CSOs). Credit default swap is also the dominant player in credit derivatives emerging markets, representing 85% of outstanding notional according to Deutsche Bank.

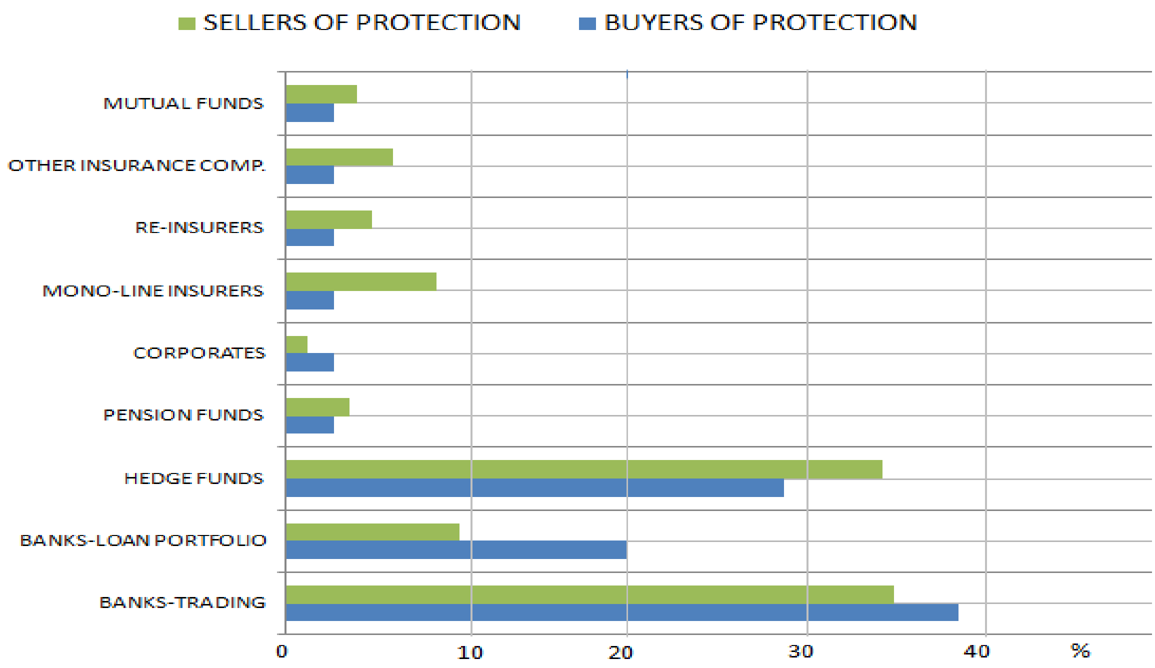
Derivatives markets attract three main types of participants: hedgers, speculators and arbitrageurs. Hedgers try to reduce and manage the risk in terms of their underlines assets by using derivatives products. Speculators speculate on potential gains or losses, by taking advantage on future movements in such products. Finally, arbitrageurs attempt to profit from price indifferences in different markets. The main market participants for credit derivatives are banks (47%), insurances and reinsurances hold the 23% of the market, while hedge funds are entering the market in increasing numbers. Pension funds and other asset managers also join the market.

Trading, in credit derivatives markets, takes place over-the counter after direct negotiations between buyers and sellers. This means that the dealers do not physically meet, but the trades are done over the phone and telephone conversations are usually taped. A key advantage of this market is that dealers are free to negotiate any kind of agreement. It is true to say that the over-the counter market is much larger than the exchanged-traded market.

Chart A: Credit Derivatives Markets Players

Source: BBA 2006 Credit Derivatives Survey

This chart shows the players (sellers of protection and buyers of protection) in Credit Derivatives Market.



3.3.1 Applications

Credit derivatives market provides a number of economic benefits and a wide range of applications:

– In Credit Risk Management.

Investors can use credit derivatives to manage credit exposure in a more efficient and simple way, based on their own credit profile. These instruments provide a great flexibility (they are traded in the OTC market) and a more efficient allocation and pricing of credit risk. In addition, they are less expensive than actually using cash instruments and investors are able to direct hedging of default risk without the requirement of upfront buying the assets.

Furthermore, credit derivatives facilitate bank's portfolio management and manage regulatory capital. Financial institutions, such as banks and insurance companies, are imposed to minimum capital requirements by governments and regulators[6], so as the market can be protected against shocks. By using such

[6] The Basel Accords refer to the recommendation on banking laws and regulations. According to Basel I, banks are required to hold capital equal to 8% of their risky-weighted assets. With Basel II,

instruments, banks can hold debt, without being necessary for them to increase the amount of capital they must hold.

– In hedging of Credit Risk on Portfolio level.

Traditionally, investors used to manage their credit portfolios' performance without being able to take easily and quickly short views. The strategies they were using do not separate the management of credit risk from the asset to which that risk is related to. For instance, taking short positions on a bond, by using a pure derivatives portfolio, is cheaper and more efficient than actually first borrowing the bond in the Repo market and then selling it.

– In trading and market making.

Credit derivatives products can be used from market participants, for arbitrage opportunities across different market sectors as well as across different countries, in case of price inefficiencies between the cash market and the derivative market prices. As a result, they increase the market liquidity and improve its function, by keeping prices more accurate than they otherwise would be.

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banks can use credit derivatives in order to manage their portfolios'' risks. Basel III is currently under construction.

3.3.2 The financial crisis

We are now about three years of the financial crisis that started in 2007. Thousands of people lost their homes and many others their jobs. But how and why did these products contributed to the deterioration of financial markets and the recent credit crisis? Subprime mortgages are structured financial products which resulted in the credit crunch, by giving the opportunity to many people borrow loans and own their own home, an opportunity that otherwise wouldn't have. These innovative products were designed synthetically, so was the risk inherent in them. An increase in subprime mortgages, first noted in February 2007 triggered the inception of the liquidity crisis. Ratings downgrades of securities followed this start, home sales declined and by August 2007, many hedge funds had suffered significant losses. Lehman Brothers, IKB and other institutions, active in the credit derivatives market declared bankruptcy (near failures of Bear Sterns, Meryll Lynch and AIG). The central bank of the USA, the Federal Reserve, along with other central banks around the world made efforts to support the market liquidity and functioning. The most effective methods to confronting the crisis and alleviate the liquidity crunch were to create a variety of lending opportunities, undertake open-market operations[7] and reduce the target for the Federal fund rate and the discount rates.

These innovative structured products can fit the needs of different investors groups, that otherwise wouldn't be allowed to hold such risky assets. The demand for higher–yielding pools which did not require the ownership of assets increased rapidly. In fact, these securities reduce credit risk and allocate it to different parts. Moreover, they provide regulatory capital relief. Many banks needed securitization to free up their cash and make more loans. However, according to the empirical work of Keys, Mukhergee, Seru, and Vig (2008) increased securitization led to a decline in credit quality. Furthermore, most investors weren't able to determine the risk combined with these products. Hence, by the time we saw the first signals in the market, many investors' survival had become highly depended on the quality of these products. The need for extra cash got very high, credit for firms and governments tightened and liquidity vanished. The statistical methods that the credit rating agencies used gave a false image of the quality of these securities, since they provided the investors with optimistic forecasts. Secondly, the agencies received higher fees for structured products so they were motivated to give more favourable ratings which did not also illustrate the reality. The credit rating agencies have also played a central and controversial role to the current European bond market crisis.

Regardless of the global and financial consequences, one may say that the recent crisis[8] produced changes in financial rules, or at least revealed the need

[7] By undertaking open-market operations, we mean the buying or selling of previously issued U.S. securities. In practice, when the government buys more securities, banks are injected with more money than they can use for lending and as a consequence, interest rates decrease.

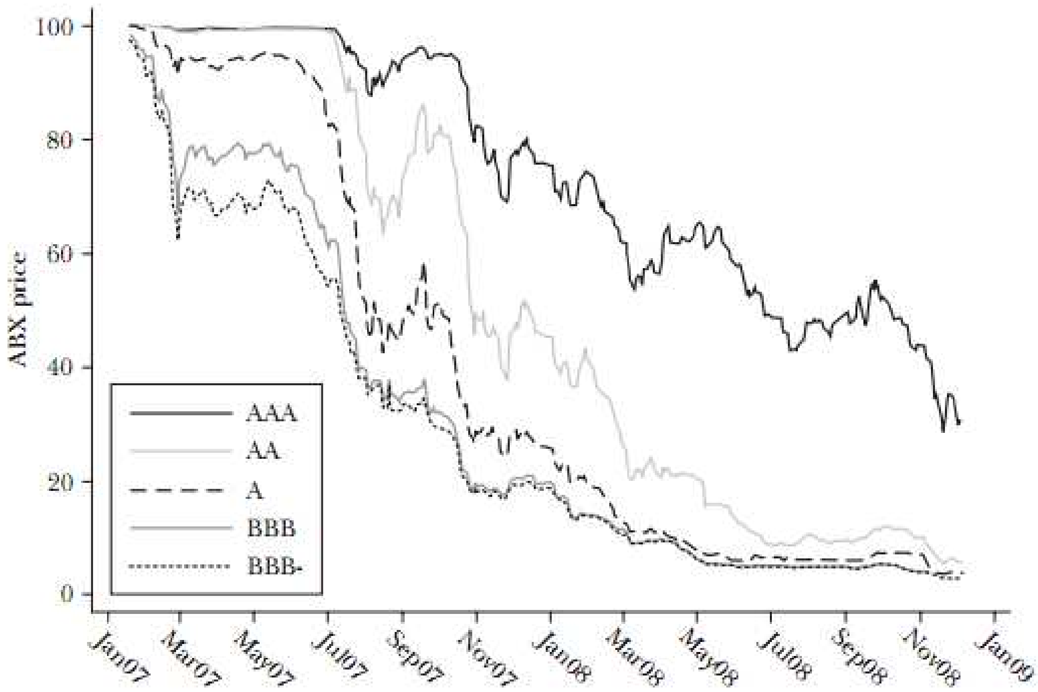
[8] For an in depth analysis of the credit crisis see Brunnermeier (2008), Gorton (2008).

for further research and progress in this sector. The market crash led all participants re-evaluate the validity of the models used to value such products and conceded the intermediate need for enhance the existing regulatory framework and eliminate the documentation inconsistencies.

Figure 5: Decline in Mortgage Credit Default Swap ABX Indices

Source: LehmanLive

(the ABX 7-1 series initiated in January 1, 2007)



4. Credit Default Swaps

4.1.1 Basics

Credit default swap (CDS) has become the most widely used credit derivative over the past seven years. Despite the fact that in 1999, the International Swap and Derivatives Association (ISDA) published a revised credit swap documentation in order to standardize the terms of these contracts, the lack of transparency during the recent financial crisis became a matter of debate and concern to regulators and market participants.

Credit default swap is a bilateral contract in which a protection buyer pays a periodic fee, called “premium” or “spread”, and/or an upfront payment, in return for a contingent payment by the protection seller in case of the occurrence of a credit event affecting the reference entity or a portfolio of reference entities. The reference entity is usually a corporation, a bank, a government or other financial institutions. The definitions and the relevant obligations when contracting a CDS are tailored to the counterparties’ needs. Credit default swaps are trading in the over- the counter market and maturities usually run between one to ten years. Credit default swaps can be used as a building block for other credit securities.

As mentioned before, in chapter 2, for credit derivatives in general, there are some important terms when conducting a CDS contract:

1. The Reference Entity.
2. The Reference Assets.
3. The definition of the Credit Event.
4. The Notional Principal.
5. The Credit Default Swap Spread or “Premium”.
6. The Maturity date of the CDS contract.
7. The Default Payments and its settlement.

• Settlement of the CDS contract: The CDS contract can be settled by either physical or cash settlement.

In a physical settlement, the protection buyer is required to deliver the reference assets to the seller and the protection seller to pay the notional amount to the protection buyer.

In a cash settlement, after the occurrence of the credit event, the protection seller pays to the protection buyer an amount equal to the difference between Par value and the market price of the reference asset. In particular, the cash payment amount is the CDS spread multiplied by the notional, adjusted for the day count fraction.

4.1.2. Credit Default Swap Types

There are three main types of CDSs:

1. Single-name Credit default Swap: This is a contract which offers credit protection for a single corporate or a sovereign entity. For example, suppose two parties enter a 10 year CDS contract for a reference entity's bond on March 2010 and the protection buyer agrees to pay 70 basis points annually in return of the occurrence of a credit event. The notional amount is settled to 10 million dollars. So, the protection buyer will pay 70,000 dollars annually to the protection seller. If there is no credit event until March 2012, the protection buyer will have paid 3 annual payments till March 2012. On the other hand, if a credit event occurs and in case of a cash settlement, agreed by the two parties and a post credit event market value of the bond to 30 dollars per unit for a par value 100 dollars, the protection seller will pay 7 million dollars to the protection buyer. Usually, in a typical CDS contract, the reference entity which looks for protection, sets up a special purpose vehicle (SPV) to serve as the one counterparty. The underlying assets owned by the reference entity can be loans, bonds or other securities. Thus, there is a distinction between bond CDS and loan CDS (LCDS). However, similar mechanisms are applied to both types of contracts.

2. CDS indices: These contracts consist of a pool of single-name CDSs. Each entity in the index has an equal share of the notional amount. There are two main CDS indices: CDX and iTraxx. CDX indices contain North American and Emergency Market companies, while iTraxx contains companies from the rest of the world. They are both marketed by Markit Group Limited. This is a completely standardized contract; therefore, the degree of transparency for this type of CDS is highest. CDS indices continue to be traded even after a credit event has happened, but with lower notional amounts. There also exists one other type of CDS index contracts, which are known as synthetic CDOs.

Table 2: Differences between iTraxx and CDX

Source: Markit

	iTraxx	CDX
Region	Europe and Asia	North America and Emerging Markets
Credit Event	Bankruptcy, Failure to Pay, Modified Restructuring	Bankruptcy, Failure to Pay
Currency	Europe – EUR Japan – JPY Asia ex-Japan – USD Australia – USD	USD, EUR
Reference Entities	Liquidity – A liquidity poll decides inclusions and exclusions	Dealer Poll – Dealers select reference entities to be added and removed (ratings, liquidity, corporate actions)
Business Days	London and TARGET Settlement Day	USD – New York and London EUR – London and TARGET Settlement Day

Table 3: CDS Indices

Source[9]: Markit

CDX	Most liquid baskets of names covering North American Investment Grade, High Yield, and Emerging Markets single name credit default swaps.
ITraxx	Most liquid names covering Europe, Asia, Australia and Japan.
LCDX (US)	North American benchmark for first lien leverage loan CDS. 100 references entities, referencing 1st lien loans listed on the Syndicated Secured List.
LevX	European benchmark for leveraged loans CDS. They are constructed from the universe of European corporates with leveraged loan exposures.
ABX (US)	The most liquid CDS on home equity BS. The ABX.HE index is used by banks and asset managers that want to hedge asset-backed exposure or take a position in this asset class.
VMBX (US)	A synthetic index referencing 25 commercial mortgage-backed securities. The CMBX Indices were created in response to the rapid pace of growth in the CDS and CMBS market, providing investors with a standardized tool to gain exposure to this asset class.
SovX	Family of sovereign CDS indices covering countries across the globe
MCDX (US)	These indices refer to U.S. Municipal credits covering revenue and general obligations

3. Basket Credit Default Swaps: These contracts are similar to indices as they consist of a basket of assets. Typical baskets contain five to ten reference entities. The trigger for a payment to the protection buyer is the nth credit event. In addition, the market offers a variety of other CDS contracts, such as first-to-default CDSs (FTD), second-to default CDSs (STD) and credit default swaptions.

- As for the FTD products, if no member in the portfolio suffers a credit event during its lifetime, the buyer will deliver all the coupons properly until maturity; otherwise, the issuer will deliver a payment to the protection buyer. In creating a basket of reference entities, it is important to select entities which have similar risk profile. Since a FTD is triggered by one credit event it will be as risky as the riskiest asset. Baskets are a default correlated product. Consequently, correlated assets tend not only to default but also to survive together. However, the size of the potential loss remains the same, since the investor cannot lose more than par minus the recovery value of the FTD asset.

- A Credit Default Swaption is an option on a CDS, which gives its holders the right but not the obligation to enter in a forward-start CDS contract. By using default swaptions, investors have the opportunity to express views on the future level of credit default spreads. Like in equity options, there are four positions when using option contracts on CDS instruments[10]. A Payer option can be viewed as a put option on credit. As credit quality deteriorates, spreads widen and the investor makes profits. Alternatively, a payer option can be also viewed as a call option on spreads. As credit quality deteriorates, CDS spreads widen

[9] For a detailed description of cds indices see "Markit Credit Indices a Primer "(2010).

[10] For a more detailed description of credit default swaptions see the "Lehman Brothers Guide to Exotic Credit Derivatives".

and profit rises. Similarly, a receiver option is both a call on credit and a put on spreads.

Table 5: Default Swaption Types

This figure summarizes the key features of the different swaption types.

Product	Payer default swaption	Receiver default swaption
Description	Option to buy protection	Option to sell protection
Exercised if	CDS spread at expiry > strike	CDS spread at expiry < strike
Credit view	Short credit forward	Long credit forward
Knockout	May trade with or without	Not relevant

Table 6: Bullish and Bearish Views on Credit using Options

Source: Citigroup

The first table shows four positions using options (payoffs assume no default). The second table shows the payoffs for the four positions in case of default. The payoffs described in the two positions are altered in case of credit event or not. Maximum losses on selling a payer depend on whether there is a knockout provision or not.

	Bullish	Bearish
Less Risk	Buy Receiver Own Call on Credit make money if CDS narrows. Maximum loss is premium	Buy Payer Own Put on credit. Make money if CDS widens. Maximum loss is Premium
More Risk	Sell Payer Short Put on Credit. Keep premium if CDS narrows. Maximum loss i s Notional.	Sell Receiver Short Call on Credit. Keep premium if CDS widens. Maximum loss is price value-premium.

	Bullish	Bearish
Less Risk	Buy Receiver Lose Premium	Buy Payer If no knockout earn (100-recovery)% x notional-premium
More Risk	Sell Payer If no knockout, lose (100-recovery)% x Notional-premium. If knockout, keep premium.	Sell Receiver Keep Premium

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4.1.3. Applications

The CDSs and the securities synthesized from them offer a wide range of applications:

▪ Investors can use such products in order to leverage credit exposure and earn a higher yield.

▪ These contracts can be proved a very useful tool for those who want to hedge credit risk or wish to take short credit views. Thus, they serve hedging and trading purposes (by involving lower transaction costs and providing regulatory capital relief).

▪ These products can be customised to fit the investors' needs regarding size, maturity and other aspects.

▪ Investors can also enjoy the leveraging of the spread premium by taking spread views on a credit.

▪ They make the credit market more efficient by providing liquidity and bringing standardisation.

4.2 Market concerns and credit cycles

The most common concern on the CDS market, as in all OTC markets, remains the counterparty exposure. Counterparty risk is the risk that one of the two parties to a transaction will default. For example, a CDS seller is exposed to the risk that the buyer will fail to meet its obligations regarding the premiums, while the protection buyer risks the protection it has purchased and being forced to replace his position at a certain cost. Counterparty risk reflects this replacement cost of a contract with a positive market value. This positive value is the additional cost of conducting the same trade with the original spread. Investors tend to manage counterparty risk by exchanging collateral. However, the available data, their quality and the methodologies used to monitor and quantify that risk prove not to be an effective tool. Furthermore, several features of CDS market help to transform the counterparty risk to systematic risk:

1. The fact that the CDS market is concentrated around some few, large players, usually banks, such as JPMorgan, Morgan Stanley, Deutsche Bank and Goldman Sachs which trade actively among themselves. This, together with liquidity risk consists of great challenge for regulators who strive to assess counterparty risk effectively and prevent concentration.

Figure 6: Top risks related to the cds market

Source: BSC survey

This figure shows the top risks related to the cds market's participants and the relation between them.

Notes: 1) Notional amounts of CDSs bought and sold exceeding 500 billion euro.

2) Notional amounts of CDSs bought and sold exceeding 200 billion euro.

Large Banks 1	Medium-sized Banks 2	Small Banks
Counterparty Risk		Counterparty Risk
	Reduction of Liquidity	High Correlation between underlying and counterparty
	Oddities in the auction	process(recovery rates..)

2. The interconnected nature of this market[11], regarding the high correlation between protection sellers and market participants. The participants know their direct counterparties, but not the parties related to them. Consequently, the failure of one party can raise spreads on the others (as it happened with Lehman Brothers when filed for bankruptcy in September 2008). R Cont (2009) showed that the structure of the market plays a significant role to market contagion.

3. The fact that after 2008 banks have become net sellers of protection to financial institutions and sovereign governments. The CDS market increased from USD 133 billion in December 2004 to USD 5.7 trillion in December 2008. However, in the second half of 2008, following the failure of Lehman Brothers, the size of the market declined significantly. Changes in exchange rates and banks' active role in the so called "termination cycles" made the whole situation even worst. Many developed countries initiated measures in order to contact with the problem by guarantying of banks' liabilities and assets. This means that the risk transferred from the banks to governments and as a result, the sovereign CDS premia raised rapidly creating new opportunities and risks in the market. Before the inception of the crisis, banks used to be only net buyers of CDS protection. Now, a bank tends to sell protection not only against financial reference entities but against its own sovereign government as well (see Chart 1). Consequently, its ability to honour the contract is closely related to the financial wealth of that government. Thus, a chain of linked exposures is created. The development of this new market segment has implications for the financing of the economy and the functioning of the markets.

[11] For a more detailed explanation of the interconnectedness in the cds market and the correlation between counterparties see: "Credit Default Swaps and Counterparty Risk" (chapter 4) European Central Bank (2009).

Chart 1: Circularity of bank and sovereign risk

Source: BSC survey

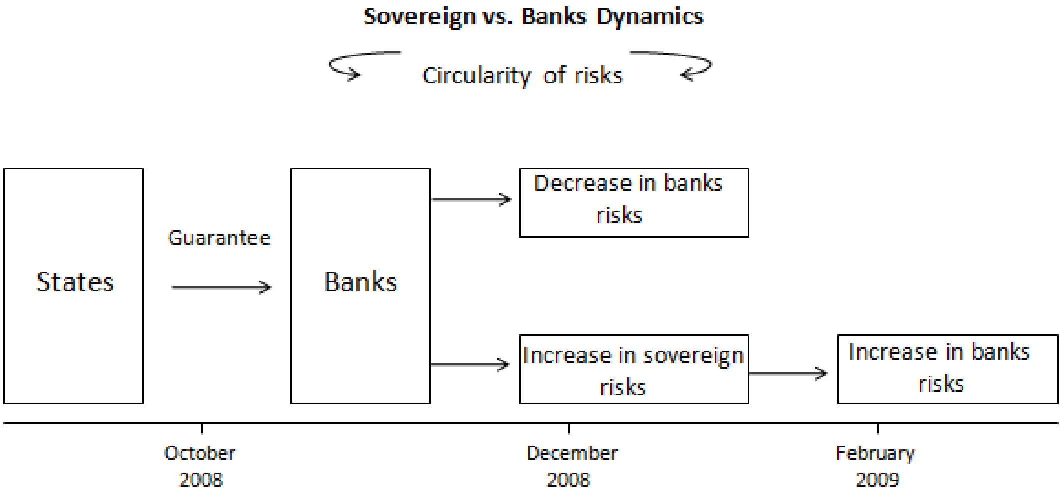
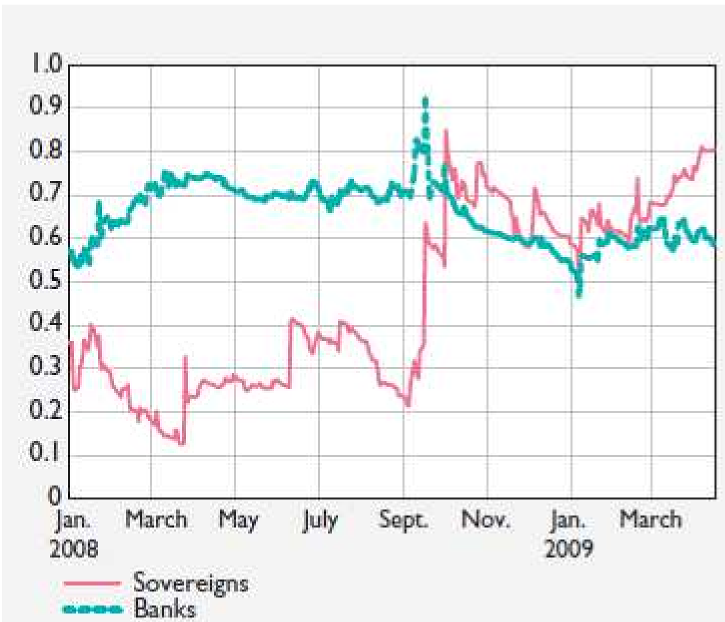


Chart 2: Average correlation between cds premia

Source: Banque de France

This chart illustrates the correlation between sovereign cds premia. After Lehman Brothers having filed for bankruptcy the two cds premia are comparable to one another reflecting the interconnection of participants in the cds market.



4.3 Credit Default Swaps and the Greek Debt Crisis

The CDS market has grown much faster than any other credit derivative market. Obviously, the current financial landscape seems very fluid and the recent rise in sovereign premium impacts several parts of world economy.

Greece has recently requested a special rescue package from other Eurozone countries and the IMF owing to its budget deficit (according to Eurostat data has a fiscal deficit of 13.6% of its GDP), poor growth and high debts. Therefore, it seems reasonable that at the moment, Greece has little ability to finance its deficit and debts without assistance. The credit quality of Greek debt deteriorated to the level of "junk" status by the credit rating agencies. This means that investors demand a high interest rate from Greece in order to bear the risk of default. As a consequence, the changes in the cds rates reflect the increasing demands for protection as the creditworthiness of the borrower deteriorates. It has been widely argued that speculation with cds has a harmful effect in raising Greece's borrowing costs. However, as it has been shown from research of Professors Darell Duffie and Zhipeng Zhang[12], there is empirical evidence that there is no relationship between the amounts of credit default swaps held on these issuers and their costs, considering also the fact that the net amounts of cds referencing these issuers is a small fraction of their debt outstanding. Thus, there is no indication that volatility in European credit spreads is any higher than it would have been if the cds market did not exist.

Portugal, Spain (which have most in common with Greece), Italy and Ireland are some other Euro-area countries having similar problems with controlling their own finance. It is a fact that the concern of the Eurozone countries is focused right now on protecting the stability of the euro, as the troubles of one country has direct effects on the functioning of the Eurozone economy. In fact, around 70% of Greek government bonds are held abroad, mainly in Europe. In particular, foreign banks' exposure to[13] Greece, Portugal and Spain reaches the 1.2 trillion euro, with German banks holding almost the 20% of total.

All in all, it appears that for all that efforts of governments and central banks the global economy's problems have yet to be solved. Despite the efforts for rescues of struggling governments such as of Greece and Ireland, the banks are still weak and the global imbalances have not gone away.

[12] See Testimony to United States House of Representatives, "Credit Default Swaps on Government Debt: Potential Implications of the Greek Debt Crisis" of Darrell Duffie (2010)
[13] Quoted in " Greece's sovereign-debt crisis" The Economist , April 15 2010

Chart 3: Sovereign CDS premia for developed countries

Source: Banque de France

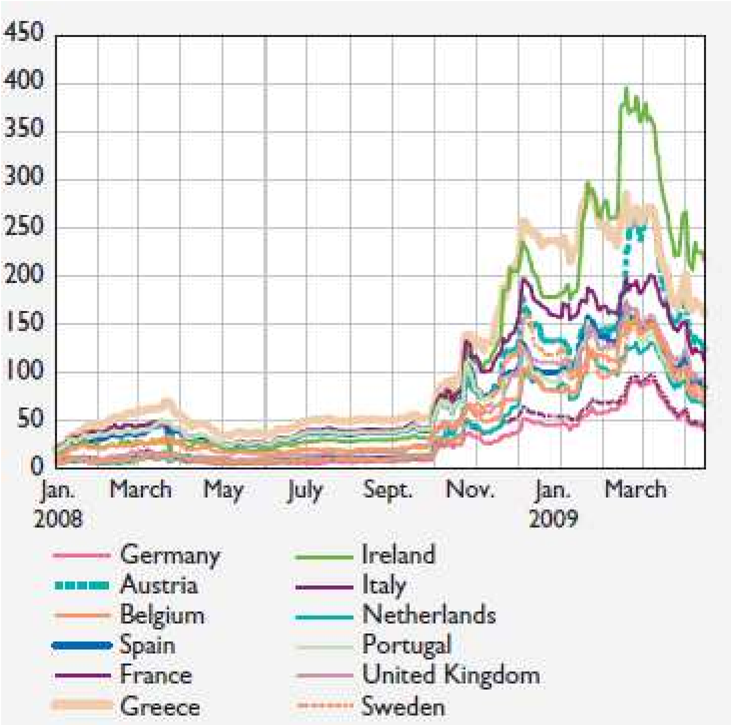
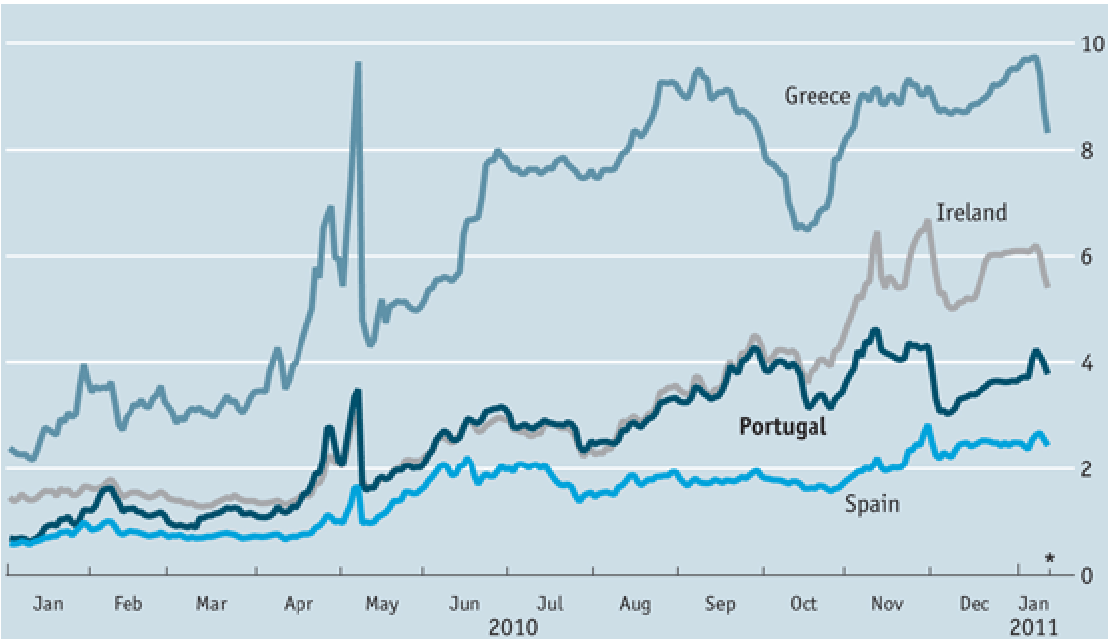


Chart 4: Bond Spreads

Source: Bloomberg

The chart[14] shows the ten-year government-bond spreads over German Bunds (percentage points).



14 Quoted in "This little piggy went to market", The Economist online, January 12, 2011

5. Credit default Swaps
An Application to Greek Government Bonds

5.1 Basics about Credit Default Swaps

As already presented in part A, a Credit Default Swap is a contract between a protection buyer and a protection seller. The buyer of the agreement buys protection against the risk of default by a certain company, called the reference entity. In case of the occurrence of a credit event, the buyer has the right to sell the bond, which is known as the reference obligation, issued by the reference entity for its par value (also known as the notional principal). As long as there is no default by the underlying reference entity, the buyer will have to make periodic payments to the seller, often expressed in basis points[15] per year and called credit default swap spread. If a credit event happens, the buyer of the contract is required to pay a part of the cds spread that has accrued since the last payment date. He receives a payment and the contract is settled by either physical or cash settlement. When there is a physical settlement, the protection buyer delivers the bonds to the seller in return for their par value. In case of a cash settlement, the buyer of the cds receives an amount equal to the difference between the face value and the market value of the bond, as a portion of the notional principal. Consequently, dealers should then determine the recovery value of the reference obligation after default.

Once the reference entity defaults, the lender has the right to claim a sum of money from the borrower and while there exist several variations for it, this sum is usually par plus accrued interest up to the date of default. This amount is known as the claim amount. This means that the payoff from a typical cds contract is:

$$L - RL\,[1 + A\,(t)] = L\,[1 - R - A\,(t)] \qquad (1)$$

where L is the notional principal, R is the recovery rate, and $A(t)$ is the accrued interest on the reference obligation at time t, as a percent of its face value. The recovery rate is the percentage of the face value of the bond that is paid to the party exposed to the risk. Recovery rates play a critical role in credit risk modelling. They cannot be implied from market data and estimates are difficult due to lack of data. So, there is usually an offset.

In the following, we apply a risk-neutral pricing model (among the reduced form models), proposed by Hull and White (2000) with some simplified assumptions to real data of Greek bonds. After calculating the distance between the cds spread observed on the market and the theoretical cds spread for Greek bonds, we use

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[15] A basis point is a unit of measure which is used in finance. One basis point is equivalent to 0.01% in decimal form. In most cases, it describes changes in interest rates or bond yields.

the model for estimating recovery rates and the risk-neutral default probabilities for these bonds.

5.2 Credit Risk Modelling

In the literature, there are two main approaches to model credit risk, the structural form models and the reduced form models. The first approach uses the value of the firm to characterize and determine the default, while the second one is based on the idea of modelling directly the probability of default.

Structural models were initially presented by Black and Scholes (1973) and Merton (1974). According to that type of models, a firm defaults if its assets' value are below a certain boundary, in other words if the firm's asset value fall below its debt value. For this reason, these models are also called firm-value models. There have been extensions in many ways to the work of Black-Scholes and Merton, by Black-Cox (1976), Longstaff and Schwartz (1995), Schonbucher (1996), Zhou (1997) and others. The main advantage of structural models is that they model default as a result of the firm's structural characteristics, so that the models are consistent with the reality of default. Therefore, they can be used in corporate structure analysis and as a tool to structure the debt and equity of a company. However, there are also some critics against this approach. Actually, they are hard to be calibrated since it is difficult to find available high frequency firm's data and they are not computationally easy.

The second approach to modelling default is the reduced form approach where the link between default and the structural features of the firm is abandoned. That is to say, in reduced form models, the default is exogenous and the probability of default is modelled independently from what causes the credit event. While in most structural models recovery is given endogenously, in reduced form models we need to make an assumption on it. By using this type of models, the probability of default is easy to be calibrated and can be extracted from market data. Obviously, this is the clear advantage that reduced form models have over structural models. Furthermore, credit instruments (the debt values) of different maturities can be computed independently. In contrast to structural form models, the credit event is determined as the first event of a Poisson process (which is a discrete statistical process) that at time t has a value N_t, with a probability of a jump from one integer to the next occurring over a small time interval d_t is given by

$$\Pr[Nt + dt - Nt = 1] = \lambda\, dt \qquad (2)$$

where λ is known as the intensity parameter in the Poisson process or hazard rate.

Jarrow-Turnbull (1995) and Duffie-Singleton (1999) models are the main representatives of the reduced form approach. Both types are arbitrage free and their stochastic behaviour is modelled under risk-neutral probability assessments[16].

In practice, models implementations are being used by leading companies and the industry that incorporate features from both approaches. In addition to the models mentioned above, there also exist: spread-based models and hazard models.

Both reduced form and structural models have their own advantages and disadvantages. Consequently, there exist no good model for all type of contracts and situations but what model should we choose it depends on what it is to be used for.

5.3 Hull and White Model

Hull and White (2000) provide a methodology for valuing credit default swaps when the payoff is contingent on default by a single reference entity and there is no counterparty default risk[17].

As a first step, the model generates estimates of the risk-neutral default probabilities that the reference entity will default at different future times. The concept is based on a set of bond prices (we assume a set of N bonds issued by the reference entity at the same date and with different maturity dates) and a set of Treasury[18] bond prices, taking into account the assumption that the difference between a T-year defaultable bond yield and a T-year Treasury par yield reflects the possibility of default. That is to say, the only reason a defaultable bond sells for less than a Treasury bond, which is promising similar cashflows, is the risk of default. By assuming independency between interest rates, default probabilities and recovery rates and by assuming that the claim and the recovery rates are known in advance, they show the risk-neutral default probabilities obtained from observed bond prices to be:

$$pj = \frac{Gj - Bj - \sum_{i=1}^{j-1} p_i \, a_{ij}}{a_{ij}} \qquad (3)$$

where:

[16] By risk-neutral probabilities we mean probability assessments under which the market value of a security is the expectation of the discounted present value of its cashflows, using the compounding short rate for discounting. Generally speaking, risk-neutral probabilities are used for the arbitrage-free pricing of assets.

[17] In a later paper entitled “Valuing Credit Default Swaps II: Modelling Default Correlation” the analysis is extended to situations where there is counterparty default risk and the payoff is contingent to default by multiple reference entities.

[18] The Treasury bonds are the benchmark default-free bonds.

pj is the risk-neutral default probability of the reference entity (jth bond) defaulting at different future times

Bj is the price of the jth bond today,

Gj is the price of the jth default-free bond today (with the same cashflows as the jth bond),

aij is the present value of the loss on a defaultable bond, relative to the value of a default-free bond at time t_i and it can be shown that :

$$a_{ij} = v(t_i)\,[\,F_j(t_i) - R_j(t_i)\,C_j(t_i)\,] \qquad (4)$$

where:

$v(t_i)$ is the present value of \$1 received at time t_i, with certainty

$F_j(t_i)$ is the forward price of the jth risk-free bond at time t_i,

$C_j(t_i)$ is the claim for the jth bond in case of default at time t_i,

$R_j(t_i)$ is the recovery rate on that claim

After estimating the risk-neutral default probabilities of the reference entity, the present value of the expected payments made by the buyer of the swap and the present value of the expected payoff must be calculated. Clearly, the value of the credit default swap to the buyer is the present value of the expected payoff minus the present value of the payments and the cds spread can be computed by setting this expression equal to zero. Thus, the cds spread can be described as:

$$S = \frac{\int_0^T [\,1 - R\,(1 + A(t))]\; q(t)v(t)dt}{\int_0^T q(t)\;[u(t) + e(t)]dt + \pi u(t)} \qquad (5)$$

where:

T is the life of the cds contract,

$q(t)$ is the risk-neutral default probability density[19] at time t,

[19] The analysis to derive equation (3), which describes the risk-neutral default probabilities only on bond maturity dates, is extended to allow defaults at any time. Therefore, q(t)dt describes the probability of default between times t and t + Δt as seen at time zero. We will refer to q(t) as the default probability density.

R is the expected recovery rate on the reference obligation in a risk neutral word,

$A(t)$ is the accrued interest on the reference obligation at time t as a percent of face value,

$u(t)$ is the present value of the payments at time t at the rate of $1 on payments dates

π is the risk-neutral probability of no credit event during the life of the cds contract

5.4.1 Theoretical Framework

In this study, we adopt the Hull and White (2000) reduced form model and we work in a discrete time framework. We assume a complete market and an arbitrage-free economy with no transaction costs. Following that, the price differences between the defaultable Greek bond and the risk-free German Bund are due only to credit risk. Since we will compute the risk-neutral default probabilities working in a discrete time framework, this means that defaults can happen exclusively on bond's cashflows dates, which means that in our case the accrued interest is always equal to zero. Consequently, we have to make an assumption of the claim amount in true conformity with this concept. We suppose the claim amount to be the value of the bond soon after the presumed date of default and not the face value of the bond plus accrued interest. Moreover, we claim that interest rates, default events and recovery rates are mutually independent and that there exist no default counterparty risk. As in Hull and White paper, we also assume that all bonds have the same seniority in the event of default and that the expected recovery rate is independent of time.

As far as the bond's yield vector is concerned, we assume a variant of the expectation hypothesis. We need a yield vector of one period to maturity for Greek and German bonds, as well as for the zero-coupon Greek bond. The expectation hypothesis states that different term bonds can be viewed as a series of 1-period bonds, with yields of each period equal to the expected short-term interest rate for that period. We collect the yields of bonds with different times to maturity. Due to lack of data, we make even more simplified assumptions. For instance, suppose we need the zero-coupon yield vector ($z_{t,t+1}$, $z_{t,t+2}$, $z_{t,t+3}$) . If we cannot find a one period zero coupon for t+1 or t+2, we assume that: $z_{t,t+1}$= $z_{t+1,t+2}$= =$z_{t+2,t+3}$. Even though this is not the only way to look at the problem, the disadvantages must be balanced against the fact that this theory explains to a great extent the observation that yields usually move together.

By taking into account these parameters, we first compute the distance between the theoretical cds spread and the cds spread observed on the market and we then acquire estimates for the recovery rates and the risk-neutral default probabilities on these bonds by minimizing the function which generates this distance.

The Mat lab codes by which we estimate the recovery rates and the risk-neutral default probabilities comes as follows:

Function 1
Get_Distance_new

```
function dist_obs_theor = get_Distance_new (input_variables, RF_Yield_Vector, Maturity, Frequency, Face_Value, Claim_Vector, Observed_Spread)
RN_Def_Prob = input_variables (1:Maturity, 1);
Rec_Rate = input_variables (Maturity+1), 1);
spread = getCDS_spread_star ( RN_Def_Prob, RF_Yield_Vector, Maturity, Frequency, Face_Value, Rec_Rate, Claim_Vector);
dist_obs_theor = 0.5* ( spread-Observed_Spread) * ( spread-Observed_Spread);
```

Function 2
get_CDS_spread_star

```
function CDS_spread = get_CDS_spread_star (RN_Def_Prob, RF_Yield_Vector, Maturity, Frequency, Face_Value, Rec_Rate, Claim_Vector)
% computes the CDS spread when the payoff is the Face Value – Rec_Rate * Claim and the payments until default or maturity=w * Face_Value
% get rik-neutral probabilities
% initialize vectors of present Values of expected payments and payoffs
CDS_payment = zeros (Maturity, 1);
CDS_payoff = zeros (Maturity, 1);
% get vectors of present values of expected payments and payoffs according to the characteristics of the CDS (warning: these might change analogously to the CDS we will actually find DATA for)
for i = 1:Maturity;
CDS_payment (i, 1) = (1 – RN_Def_Prob (i, 1)) / (1 +
```

```
RF_Yield_Vector(Maturity))^ i ;
CDS_payment (i, 1) = CDS_payment (i, 1) * Face_Value ;

CDS_payoff (i, 1) = RN_Def_Prob (i, 1) / (1 + RF_Yield_Vector ( Maturity)) ^ i;
CDS_payoff(i,1)=CDS_payoff(i,1)*(Face_Value–
Rec_Rate*Claim_Vector(Maturity)) ;
end;
% get CDS spread
CDS_spread = sum (CDS_payoff) / sum (CDS_payment);
if CDS_spread <=0 || CDS_spread >=1
CDS_spread = 0;
disp ( ‘the value is wrong’)
end
```

Function 3
getRecoveryRate_new

```
Function [RN_Def_Prob_final, RecoveryRate, fval, exitflag, output ] =
getRecoveryRate_new (RF_Yield_Vector, Maturity, Frequency, Face_Value,
Claim_Vector, Observed_Spread)
LB = zeros (Maturity + 1, 1);
LB (Maturity + 1, 1) = 0.5;
UB = ones (Maturity + 1, 1);
Initial_Values = 0.4 * ones (Maturity + 1, 1);
Initial_Values (Maturity + 1, 1) = 0.5;
[input_variables,fval,exitflag,output]=fmincon(@(input_variables)get_Distance_ne
w (input_variables, RF_Yield_Vector, Maturity, Frequency, Face_Value,
Claim_Vector, Observed_Spread), Initial_Values, [ ], [ ], [ ], [ ], LB, UB );
RN_Def_Prob_final = input_variables (1:Maturity, 1);
RecoveryRate = input_variables ( Maturity +1, 1);
```

where:

input_variables refer to the risk-neutral default probabilities and the recovery rate of the defaultable bond, i.e the Greek bond

RF_Yield_Vector is the yield vector (of one period to maturity) of the risk-free bond, i.e. the German Bund,

Maturity is the maturity of the Greek bond,

Frequency refers to the frequency of the interest that is to be paid, whether semi-annually or annually,

Face_Value is the face value of the Greek bond,

Claim_Vector refers to the claim vector (of one period to maturity) of the defaultable bond,

Observed_Spread is the cds spread referencing the Greek bond as quoted on the market and,

Rec_Rate is the recovery rate on the Greek bond.

Function 1 is constructed to estimate the distance between the theoretical cds spread and the cds spread observed on the market. This function takes seven input arguments; the vector of input variables which refer to the risk-neutral default probabilities and the recovery rate of the Greek bond (with this order), the risk-free yield vector of one period to maturity of the German Bund, the maturity, the frequency of the interest to be paid, the face value and the claim vector of the defaultable Greek bond. It returns the distance between the two cds spreads as the half of the square of their actual distance.

In order to compute the cds spread we use function 2. This is a function which takes seven input arguments; the risk neutral default probabilities of the reference obligation, i.e. the Greek bond, the risk-free yield vector, the maturity, the frequency of the interest to be paid, the recovery rate and the claim vector referencing the Greek bond. The credit default swap spread is the only output argument. At the same time, the function examines if the estimated cds spread is a value between 0 and 1.

At last, function 3 is designed to acquire estimates for the risk-neutral default probabilities and the recovery rates on the Greek bond. This function takes six input arguments; the risk-free yield vector, the maturity, the frequency of the interest to be paid, the face value and the claim vector of the Greek bond and the cds spread observed on the market. It returns the estimates for the default probabilities and the recovery rates on the bond and a structure output with information about the method used to derive these estimations. In order to produce these estimates we use fmincon which is a Mat lab function. Fmincon attempts to find a constrained minimum of a scalar function or several variables starting at an initial estimate. This is generally referred to as constrained nonlinear optimization. Fmincon solves problems of the form:

$$\min_{x} f(x) \text{ subject to:}$$

$$A*x <= B$$

$$Aeq*x = Beq$$

$$C(x) <= 0$$

$$Ceq(x) = 0$$

$$LB <= 0 <= UB$$

Consequently,[input_variables,fval,exitflag,output]=fmincon((@(input_variables) get_Distance_new(input_variables, RF_Yield_Vector, Maturity, Frequency, Face_Value, Claim_Vector, Observed_Spread), Initial_Values, [ ], [ ], [ ], [ ], LB, UB) defines a set of lower and upper bounds on the design variables in input variables (which refer to the risk-neutral default probabilities and the recovery rate), so that the solutions are always between the LB and the UB. In our case we set A=[ ], B=[ ], Aeq=[ ] and Beq=[ ] as no equalities exist. Exitflag is an integer which identifies the reason the algorithm is terminated.

5.4.2 Practical Implementations of the Programme: Data and Results

Following this line of work, in this part of the study, the analysis is carried out to estimate the risk-neutral default probabilities and the recovery rate of two five-year government Greek bonds that are denominated in euros, with annual coupon payments and without convertibility or callability characteristics. The bond data and the data on actual credit default swap spreads have been collected from DataStream database and refer to Greek and German bonds (the first representing the defaultable bond and the latter the benchmark default-free one) issued about at the same time and with similar maturity dates. As mentioned earlier, the process requires estimates of the risk–free yield vector of one period to maturity, and estimates of the amount claimed by bondholders in the event of default. Thus, the data for each bond include prices of bonds with several maturities but all issued about the same date. We then test the sensitivity of the results by changing the lower bound on the recovery rate of the defaultable bond while keeping everything else the same.

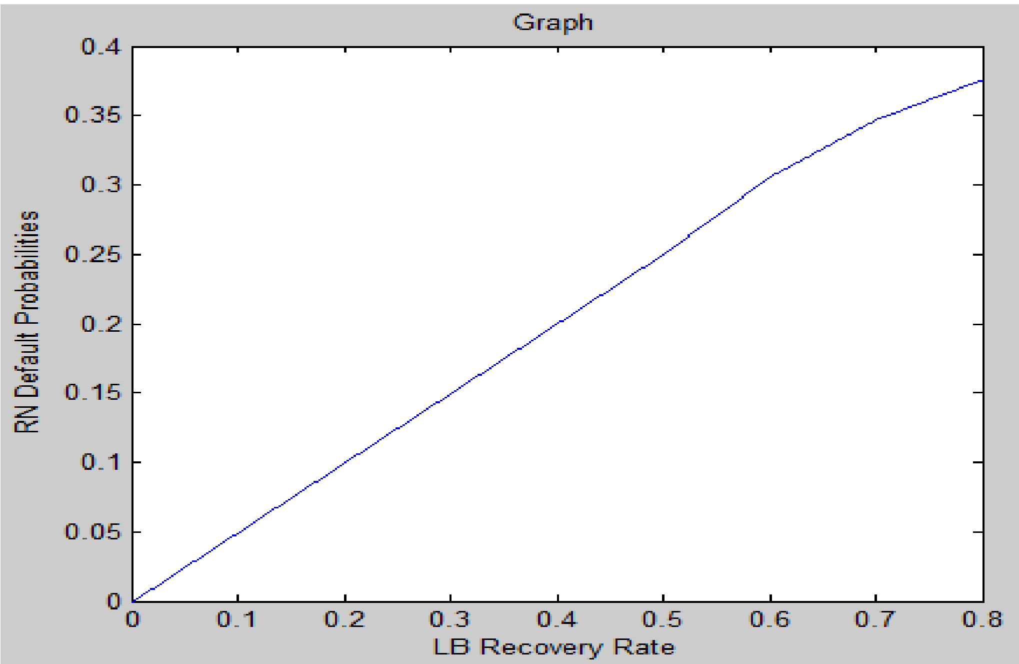
We first consider a five-year bond issued on February 18, 2004 by the Greek government with a coupon rate of 3.5%. The observed spread for the five-year credit default swap is 16.89 basis points, a very low price which indicates that in that time Greece had no “credibility problems”. We calculate the risk-free yield vector for the German bond and the amount claimed by bondholders in the event of default with methods that have already been stated. We change the lower bound on the recovery rate from 0.5 to 0.8 while keeping everything else the same. Indeed, the first runs of the model verify the assumptions of work as expected, that the probabilities of default are positively correlated to the assumption about the lower bound on the recovery rate. This is illustrated in Figure 7. Table 7 provides the estimated risk-neutral default probabilities and recovery rate.

Table 7

LB for recovery rate / Coupon's Payments dates	0.5		0.6		0.7		0.8	
1	0.2405		0.3001		0.3439		0.3741	
2	0.2454		0.3032		0.3456		0.3756	
3	0.2501	0.9925	0.3061	0.9939	0.3473	0.9939	0.3763	0.9956
4	0.2517		0.3090		0.3489		0.3770	
5	0.2592		0.3118		0.3505		0.3777	

Figure 7

This figure plots the mean default probability value of the five-year bond issued on February 18, 2004 by the Greek government for different choices of the lower bound of the recovery rate.



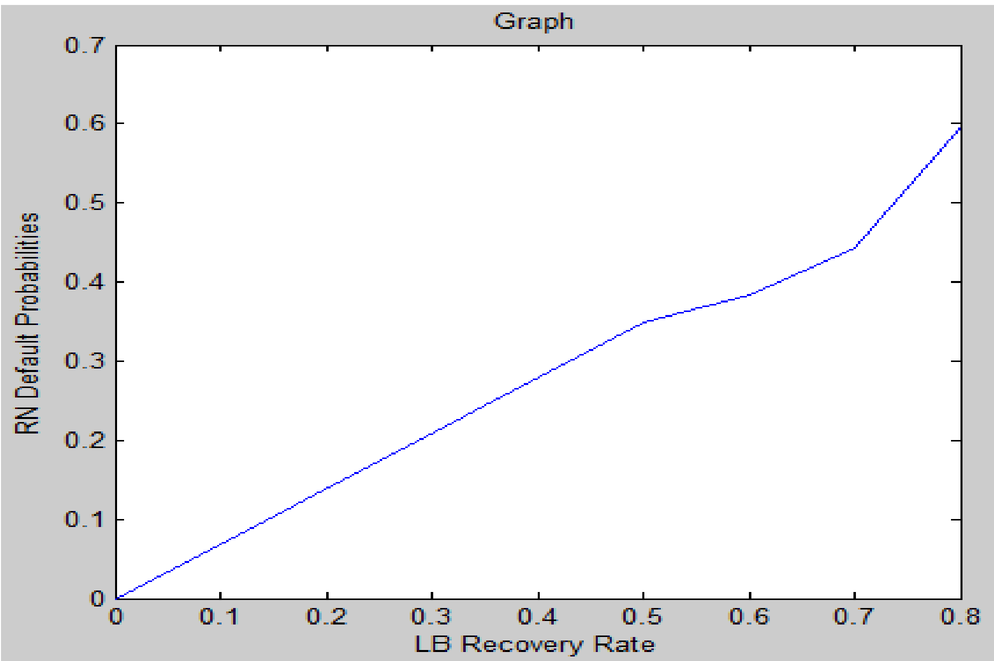
We work in the same way considering now a five-year bond issued on January 28, 2009 by the Greek government with a coupon rate of 5.5%. The spread for the five-year credit default swap is 1047.094 basis points as it has been observed on April 2011. We set the risk-neutral default probabilities of the two first coupon payment dates to be equal to zero and we attempt to estimate the default probabilities and the recovery rate for the remaining time. Table 8 provides the estimated results.

Table 8

LB for recovery rate / Coupon's Payments dates	0.5	0.6	0.7	0.8
1	0	0	0	0
2	0	0	0	0
	0.5936	0.6384	0.7	0.8026
3	0.3487	0.3831	0.4437	0.5992
4	0.3499	0.3835	0.4427	0.5947
5	0.3510	0.3839	0.4417	0.5963

Figure 8

This figure plots the mean default probability value (of the last three coupon payment dates) of the five-year bond issued on January 28, 2009 by the Greek government for different choices of the lower bound of the recovery rate.



5.4.3 Interpretation of Results

In this study, our main objective is to acquire estimates for both the risk-neutral default probabilities and the recovery rate on Greek bonds. The analysis above also enables us to better understand how default probabilities differ by the choice of the lower bound on the recovery rate. Although the assumptions we have made are unlikely to be perfectly true in practice, the model can be as close to reality as it can get.

After May 11th, just after the European Stabilization Mechanism (ESM) was announced, the market's view of the probability of default is lower than before any European plan have been made known publicly, but higher than any other time. The results we have presented in Table 8 show the high default probabilities for the five-year bond issued on May, 2009 by the Greek government. We also get the chance to observe that we exhibit increasing default probabilities over time. This implies that investors assume a lower risk of default in the near future and an increasing default probability over time. As already pointed out, we also test the sensitivity of our estimates to assumptions about the lower bound on the recovery rate and we reach the conclusion that the higher the lower bound is, the greater is the impact on default probabilities.

However, with all these relaxed assumptions, there is a long way until we conclude that the model represents the real world. Some explanations arise for that. First, the approach we have presented is based on the assumption that interest rates, default probabilities, and recovery rates are independent. As mentioned by Hull and White these assumptions are unlikely to be perfectly true in practice. There are errors when the default-free bond zero curve is non-flat and when rates are very high. Moreover, due to lack of data, the only available information for Greek and German bonds do not exactly match. By this I mean that in order to estimate the risk-neutral probabilities of default for a Greek bond, we also need a German bond issued at the same date and promising the same cashflows. This is feasible not to a great extent, so we use bonds with similar and not exactly the same characteristics. Furthermore, the bond prices we use to retrieve the risk-free yield vector contain other information than credit risk. This, together with the methods we followed to acquire these estimates rise significant doubts about the validity of our final results.

6 Conclusion

With all these relaxed assumptions, we managed to follow the Hull and White reduced-form model and produce estimates for the risk-neutral default probabilities and the recovery rate of two five-year Greek bonds. It is clear that the model is a limited reflection of the real world. Nobody can say for sure what the future will bring and what all mathematical models don't sufficiently take into account is human behaviour.

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