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Regulation and the demand for credit default swaps in experimental bond markets[☆]

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ABSTRACT

Credit default swaps (CDS) played an important role in the financial crisis of 2008 leading to calls for regulation. Here, we seek to understand the impact of a CDS regulation that restricts the possibility to hold naked CDS. We use a controlled laboratory experiment analyzing CDS pricing in a bond market subject to default risk. Our results show that the regulation achieves the goal of increasing the use of CDS for hedging purposes while reducing the use of CDS for speculation. This success does not come at the expense of lower initial public offering (IPO) prices for the bonds or worse pricing of bonds or CDS in the secondary market.

1. Introduction

Credit default swaps (CDS) are by far the most common and arguably the most important credit derivative contracts. They allow for the hedging of risky investments, such as bonds that are subject to default risk or subprime mortgage loans. The seller of a CDS (typically a bank or insurance company) provides insurance to the buyer (typically a pension or hedge fund) against the possibility of such a default. In exchange, the buyer pays fees to the CDS seller. CDS can also be used, however, for speculative purposes as is alleged to have occurred prior to the financial crisis of 2008. Indeed, in 2007, the notional value of CDS worldwide peaked at US$61.2 trillion and has steadily fallen ever since to $9.35 trillion as of the end of 2017 (Aldasoro and Ehlers, 2018). Such an incredibly high volume suggests that aside from insurance motives, speculation played a role in the demand for CDS. Speculation in credit default swaps covering mortgage-backed securities in particular are thought to have played a role in the financial crisis. More generally, CDS were often traded in unregulated markets where buyers had no relationships to the underlying assets and were unable to assess risks. While our interest lies in the role of speculation on the demand side of the CDS market, another major risk lies on the supply side. An important concern for policymakers was that CDS sellers might not have sufficient collateral to cover CDS obligations in case a bond issuer would default. In fact, the latter occurred when Lehman Brothers declared bankruptcy and a major supplier (the American Insurance Group, AIG) was unable to cover its CDS contracts and was bailed out by the Federal Reserve. The problems on the supply side are connected to actions on the demand side: the opportunity for CDS sellers to take on excessive risk depends on the existence of high speculative demand on the buyers' side, in excess of the demand for hedging purposes.

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When the financial crisis subsequently gave rise to the European sovereign debt crisis the (potential) regulation of CDS became highly discussed (Ayadi and Behr, 2009; Morgan, 2009; Stulz, 2010; Delatte et al., 2012; Juurikkala, 2012; Augustin et al., 2014). Which role CDS will play during the current crises caused by Covid-19 and the war in Ukraine, and in their aftermath, remains to be seen. The consequences of these crises, including those on government debt, can only be fully assessed in a few years, but the recent increase in bond issuance suggests that CDS may again play an important role.

The possibility to hedge risks using credit default swaps is generally considered to be desirable and the main reason that CDS exist. Speculation with credit default swaps, however, is viewed with a more critical eye as there are a variety of ways in which such speculation might be harmful. For example, speculation with credit default swaps can lead to moral hazard problems if the speculating CDS buyers can influence the underlying value of the asset covered by the CDS.

The regulation of the CDS market is thus a relevant policy issue and some regulatory efforts have been made in the aftermath of the financial crisis. In particular, the G-20 agreed to reforms at their August 2009 meeting that were subsequently codified in the United States in the Dodd-Frank legislation (Carlson and Jacobson, 2014). These reforms were mainly aimed at improving transparency and avoiding excessive accumulation of risk by a single CDS issuer (as, e.g., AIG). Other, more substantive reforms have been proposed but not yet implemented in the United States. The regulation that we focus on here is regulation to insure that credit default swaps are primarily used for hedging purposes, as opposed to speculative motives, for example by restricting CDS purchases to those investors who are exposed to the underlying default risk (as, e.g., discussed in McIlroy (2010)). Germany was the first major country to ban naked credit default swaps in 2010, and this ban was adopted by the rest of the EU in 2011, for CDS related to sovereign bonds.[1] By contrast, the U.S. opted not to ban naked CDS positions in favor of industry-led steering of sales through centralized clearinghouses. Thus, there remains a difference of opinion as to whether bans on naked CDS matter for market liquidity, prices, and the hedging of bond market risk.

Despite various proposals to regulate CDS and some implemented regulations, there is little evidence to date as to whether and how CDS regulation works in practice. Some observers, for example the IMF (2013), acknowledged a lack of evidence on the impact of CDS regulations, but predicted that bans on naked sovereign CDS could "reduce market liquidity to the point that these instruments are less effective as hedges and less useful as indicators of market-implied credit risk". However, the existing theoretical and empirical literature on the effect of naked CDS positions delivers only mixed results. Che and Sethi (2014) argue that naked CDS can be either complements or substitutes to bond (credit) markets improving or reducing liquidity; depending on the environment, multiple equilibria can arise and there may be greater cyclical variations in the cost of debt with naked CDS relative to environments with covered CDS positions. Oehmke and Zawadowski (2017) provide evidence that CDS are held for both hedging and speculative purposes and argue that the primary benefit of CDS is the standardization role that CDS provide; CDS are more common when the underlying bonds are fragmented or have heterogeneous contractual terms that make them difficult to price. Sambalaibat (2022) shows in a dynamic search model with endogenous entry that a ban on naked CDS trading actually reduces bond prices and market liquidity and thereby raises borrowing costs. Similarly, Czech (2021) finds that bond trading volumes (liquidity) are larger when there are CDS for those bonds, and so impairments to liquidity in CDS markets from, say, a ban on naked CDS would likely have some spillover effects on liquidity in the bond market.

Summarizing the state of knowledge about CDS regulations, Stulz (2010) correctly points out that "there is a dearth of serious empirical studies on the social benefits and costs of credit default swaps and other derivatives—not just in the last two years, but in the last several decades". Our study contributes to filling this gap in the literature.[2] Predicting or analyzing the impact of regulations that have not yet or have only recently been implemented with observational field data is inherently difficult and further complicated by the fact that the introduction of the regulations is usually endogenous and the fundamental values of underlying assets cannot be directly observed. To provide first causal results on the impact of proposed reforms to the CDS market, we thus use a controlled laboratory experiment as a testbed for the analysis of CDS regulation.

Our focus is on a bond market in which the risk of default is determined by the prices obtained in an initial public offering (IPO). Traders can insure themselves against a default in a CDS market that runs in addition to the market for bonds. Previewing our results, we find that the regulation of CDS that we introduce is indeed successful at increasing CDS usage for hedging purposes. The regulation we consider does not come at the expense of reduced revenue from IPOs of new bonds. It also does not negatively affect secondary market prices in the bond market, nor in the CDS market. The availability of credit default swaps in general has no decisive influence on bond market prices, neither in the IPO nor in the secondary market; with and without CDS, inexperienced subjects initially underprice the bonds, but with experience they learn to price these bonds well. The credit default swaps themselves, on the other hand, are substantially *overpriced* regardless of whether or not there is regulation and both by experienced and inexperienced subjects alike. The regulation also does not lead to more or less concentration of bond or CDS holdings.

The remainder of the paper is organized as follows. The next section discusses related literature. Section 3 presents the models underlying the experiment, the experimental design, and the procedures. Section 4 describes the results, and Section 5 concludes.

[1] Credit default swaps are called naked if the holder is not exposed to the credit risk associated with the underlying asset (to the extent covered by the CDS).

[2] To the best of our knowledge, there is no previous experimental study of CDS or CDS regulation. The financial crisis did, however, spark a recent literature that experimentally studies other types of financial regulation (see Davis and Korenok (2023) for an excellent overview of this literature).

2. Related literature

There is a large empirical literature examining the pricing of CDS (see Augustin et al. (2014, 2016) for recent surveys). Much of this empirical literature relies on reduced form, no-arbitrage models, as developed e.g., in Duffie (1999), where the incidence of bond default follows a random process, see, e.g., Longstaff et al. (2005), Chen et al. (2008), and Doshi et al. (2013). This literature suggests that much of the pricing of CDS reflects the default risk of the underlying bonds, although other factors, e.g., the market liquidity of CDS themselves (Bühler and Trapp, 2009) and counter-party risk of default by the CDS protection sellers (Arora et al., 2012) can also affect CDS prices. By contrast, our focus in this paper is on the pricing of CDS, as well as the underlying bonds, under different *regulatory regimes*, a topic that is difficult to investigate in the field since, to date, the CDS market has largely escaped regulation (Juurikkala, 2015).

Indeed, our approach also differs from the empirical literature on CDS pricing in that we examine CDS pricing using controlled laboratory experiments, building upon the rich literature in experimental asset markets.[3] Bossaerts (2009), Noussair and Tucker (2013), Palan (2013), Powell and Shestakova (2016), and Nuzzo and Morone (2017) review this literature. In most experimental asset markets, trading is limited to a single asset, though some experiments allow for trades in multiple assets (Childs and Mestelman, 2006; Kleinlercher et al., 2014; Duffy et al., 2021) and some studies allow subjects to trade derivative assets (futures, options) on the principal asset of the market (e.g., Forsythe et al. (1982), Friedman et al. (1983), Forsythe et al. (1984), Friedman et al. (1984), Porter and Smith (1995), De Jong et al. (2006) and Palan (2010)). The experiments reported on in this paper build upon an earlier experiment testing the pricing of bonds subject to default risk (Weber et al., 2018). Relative to that experiment, the present paper adds a new market for credit default swaps on the risky bonds, and considers cases where CDS purchases are regulated or not regulated. We are not aware of any experimental literature investigating credit default swaps or, more generally, credit market derivative assets.

Our paper is part of a body of work that uses experimental methods to analyze proposed financial regulations in the wake of the Great Recession. Armantier et al. (2013) explore auction design for the US Treasury's disposal of troubled assets. Fischbacher et al. (2013) investigate the effects of reserve requirements on asset prices. Davis et al. (2014) analyze different mechanisms triggering the conversion of contingent capital. Keser et al. (2017) experimentally examine rating agency regulation. Davis et al. (2022) investigate the interaction of liquidity requirements with bank-run experience. Davis et al. (2020) provide an experiment on liquidity regulation in the presence of different types of shocks. Füllbrunn and Neugebauer (2020) analyze the effect of regulating margin purchases. For a review of this strand of literature, see Davis and Korenok (2023). None of the papers in this literature, however, addresses CDS regulation.

3. Experimental design

3.1. Modeling of the bond and CDS markets

We consider an environment with two markets, a bond market and a CDS market. We first describe our model of the bond market and equilibrium bond prices and we then address the CDS market. The bond market model is taken from Weber et al. (2018).

3.1.1. Bond market model

Each bond has a face value, K, which is paid out to the bond holder if the bond issuer does not default prior to the maturity date in period T. In addition, the bond holder receives a coupon payment of iK in each period so long as the bond issuer has not yet defaulted (i is thus the interest rate). If the bond issuer defaults, the bond holder receives no more coupon payments from the period of default onward and also loses payment of the face value.[4]

Before being traded in the secondary market, the bonds are first auctioned off in an IPO. The prices paid in the bond market IPO are of particular importance to the bond issuer as they determine the costs of the fixed-maturity debt issue. Lower IPO prices correspond to higher costs of the debt issue. The higher the costs of debt, the higher the probability that the bond issuer defaults. As a consequence, the fundamental value of the bond is not exogenous but depends on the price achieved in the IPO (this is the main difference between our bond market model and most asset market models employed in the experimental literature).

The IPO of new bonds is conducted using a uniform-price auction in which participants bid on the price of a bond (with maturity date, face value, and coupon payments fixed and known). In the periods following the IPO, the bonds can be traded on a secondary market where prices are determined by supply and demand as long as there is no default and as long as the maturity date has not yet been reached.

In the initial period 0, the IPO is held; the IPO price is the market clearing price in the auction, denoted by p_{ipo}. In periods $1, \ldots, T-1$, bond market participants can trade bonds in the secondary market. They can buy and sell these bonds, provided that they have bonds to sell or funds to buy bonds. The timing within each period, $t = 1, \ldots, T-1$, is as follows:

[3] For relatively recent studies, see Cheung and Palan (2012), Kirchler et al. (2012), Sutter et al. (2012), Huber and Kirchler (2012), Cheung et al. (2014), Füllbrunn et al. (2014), Noussair et al. (2016), Akiyama et al. (2017), Bao et al. (2017), Holt et al. (2017), Bosch-Rosa et al. (2018), Hanaki et al. (2018), Crockett et al. (2019), Füllbrunn et al. (2020), Huber et al. (2020), Weitzel et al. (2020), Corgnet et al. (2021), Kopányi-Peuker and Weber (2021a,b), Duffy et al. (2022b), and Duffy et al. (2024).

[4] We assume a complete loss of future coupon payments and of the principal repayment for simplicity, the model could easily be adapted to allow for nonzero repayments in the case of default. Similarly, the model features no outside interest for holding money, which could also be introduced easily.

1. It is determined whether the bond issuer defaults.
2. Conditional on no default having occurred in the current period or earlier, the coupon payment is made.
3. The secondary bond market opens and trades can take place (bond sales are thus ex-coupon).

If the final period T is reached (meaning that no default has occurred in period T or earlier), then no more trading occurs and the final coupon payment is paid out together with the face value.

The probability that a bond issuer defaults is endogenous as it depends on the IPO price. The function mapping IPO prices to default probabilities is monotonically decreasing, because a higher IPO price leads to lower financing costs for the bond issuer. This mapping is modeled here using an exponential function[5]:

$$P_d(p_{ipo}) = m\ exp(-c\ p_{ipo}) + b. \quad (1)$$

P_d here denotes the probability that the bond will default in a given period (conditional on no prior default having occurred). The parameters are assumed to satisfy $0 < b < 1$, $0 < m < 1 - b$, and $c > 0$.[6]

The default probability depends on the IPO price, but remains constant after the IPO. For any given default probability P_d, the fundamental value of a bond can be calculated for all subsequent periods. The fundamental value of a bond in period t, V_t, is conditional on no default having previously occurred. The fundamental value (at the time of trading) is then the face value multiplied by the probability of receiving this final payment plus the expected value of the remaining coupon payments. With $P_n := 1 - P_d$ denoting the probability of not defaulting, this yields

$$\begin{aligned} V_t &= K P_n^{T-t} + \sum_{m=t+1}^{T} iK P_n^{(m-t)} = K P_n^{T-t} + \sum_{m=1}^{T-t} iK P_n^{m} \\ &\overset{\text{for } P_d>0}{=} K P_n^{T-t} + iK \left(\frac{1 - P_n^{T-t+1}}{1 - P_n} - 1 \right). \end{aligned} \quad (2)$$

The fundamental value of the bond is endogenous as it depends on the IPO price. However, it is possible to calculate competitive equilibrium prices for the IPO and to use these to arrive at the equilibrium fundamental values with Eq. (2). Of course, the actual fundamental value after period 0 is determined by the realized IPO price. While the equilibrium IPO price does not have a simple closed-form solution, the solution can be easily computed numerically.[7]

3.1.2. CDS market model

In addition to the bond market, there is also a CDS market. There is a fixed supply of CDS, that is, these credit derivatives are not auctioned off (in the experiment, each participant starts with a fixed number of CDS).[8] Assuming a fixed supply in the CDS market is a natural counterpart to assuming a fixed supply of bonds in the bond market. For this paper, the assumption follows naturally, because the focus is on the decisions of (potential) bond and CDS holders and not on the decisions of the entities that issue bonds or sell protection via credit derivatives. The CDS are structured such that one CDS unit pays the holder the face value of the bond, K, in the event that the bond issuer defaults. If the bond issuer does not default and pays out its final coupon payment and face value, the CDS pays out nothing.[9] That is, a CDS is like a tradable insurance paper, covering the face value of the bond. Of course, it is in general also possible that a CDS is not used with a hedging motive but for speculation purposes instead (e.g., when the CDS holder holds no bonds; such positions are called 'uncovered' or 'naked').

To avoid complication, we adopt a sequential market structure. First, the market for bonds opens and trading takes place. Thereafter, the market for CDS opens and trade in CDS takes place. Period 0 in the CDS market is thus just like any other period, since CDS are not allocated in an IPO but are instead already in place from the beginning. The exact timing of bonds and CDS markets in the regular trading periods $t = 1, \ldots, T - 1$ is:

1. It is determined whether the bond issuer defaults.
2. Conditional on no default having occurred in the current period or earlier, the coupon payment is made.
3. The secondary bond market opens and trade can take place (bond trades are ex-coupon).
4. The CDS market opens and trades can take place.

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[5] One can think of this mapping as a *reduced form* representation of the relationship between IPO prices and default probabilities. Weber et al. (2018) also provide a *structural model* wherein a higher IPO price leads to lower default probabilities.

[6] b represents the base risk (which is independent of the IPO price; the default risk is always at least b). m is the maximal bond-price-dependent default probability, that is, the maximally possible increase in the default probability, above the base risk, resulting from the IPO price; $m+b$ is thus the highest possible default probability overall. c determines the curvature of the default probability function (a higher c means that the default probability function approaches the base risk more quickly when the IPO price increases).

[7] Depending on the model parameterization, more than one equilibrium price may arise (e.g., a high-price equilibrium with a low default probability and a low-price equilibrium with a high default probability). As our focus is not on equilibrium selection, we choose a specification that yields a unique equilibrium.

[8] Our choice of a fixed supply of CDS is guided by our interest in the effects of regulation on the demand side of the CDS market. As noted in the introduction, another important risk in CDS markets lies on the supply side. Studying this would require endogenizing the supply side of the market.

[9] In principle, the pre-specified payoff in case of default can be any value. However, it is common that this amount is the face value of the bond or the face value minus the value of the defaulted loan (the value of the defaulted loan being zero in our model).

If no default occurs up to and including period T, trading ceases in the final period T (in that period, no more trading in bonds or CDS occurs) and the bonds pay out the final coupon payment together with the face value, while the CDS become worthless. If a default occurs at some point, the bonds pay no more coupon payments from that period onwards and the face value is lost. However, each CDS pays its holder the bond's face value, K.

Since the fundamental value of the bond is endogenously determined, so too is the fundamental value of the derivative CDS; both fundamental values depend on the IPO price in the bond market, because the default probability in the bond market determines the value of insuring (the face value of) a bond. Given the default probability in the bond market, P_d, (with the same notation of $P_n := 1 - P_d$ as above), the value of a CDS can easily be calculated. The fundamental value, W_t, of a CDS in period t (at the moment when this CDS is traded on the market) is the face value of the bond times the probability of a default in the bond market happening after period t. This fundamental value is conditional on no previous default having occurred (otherwise the CDS pays out K with certainty).

$$W_t = K \cdot (1 - P_n^{T-t}). \tag{3}$$

3.2. Treatments

Our experiment consists of three main treatments. We conduct two treatments in which both bonds and CDS are traded; in one of these treatments, bonds and CDS can be traded without restrictions (the unregulated treatment, $FREE$) and in another treatment, CDS are regulated (treatment REG). In addition, we compare these two treatments to a control treatment in which only bonds are traded and there are no credit default swaps. The data from this control treatment are those reported as treatment DEC in Weber et al. (2018). There are eight groups (i.e., markets) in $FREE$, nine groups in REG, and eight groups in the $Control$ treatment.

Our aim is to analyze the effects of CDS regulation that aims at increasing the fraction of covered positions. We have opted to implement this regulation in treatment REG in the following way. (1) Subjects are only allowed to buy credit default swaps if they hold underlying bonds: as one CDS insures one bond, subjects may buy any number of credit default swaps up to the number of bonds that they currently hold. (2) If a default occurs, subjects only receive money for covered positions, naked credit default swaps do not pay out. This is a natural way of modeling the regulation as it enforces a hedging motive at two natural time points, when buying a swap and when redeeming it for payment. Both parts can be enforced by regulators.[10]

Equilibrium fundamental values in the bond market are identical in all three treatments. Equilibrium fundamental values in the CDS markets are equal in the two treatments with credit default swaps (the equilibrium fundamental values are discussed in the following section).

3.3. Experimental implementation

Our experimental implementation does not aim at mirroring the exact market microstructure of bond and CDS trading in a particular real-world market (the key advantage of the laboratory is not the realism of the setting but the high level of control). Instead, our aim is to use well-understood trading mechanisms, which are identical for bonds and CDS markets (and similar for the bond IPO) and which minimize complexity for subjects. We therefore opt for double-sided call market mechanisms for both markets (and a similar one-sided call market auction mechanism for the bond IPO). This implementation also has the advantage that it leads to a single market price for bonds and another for CDS in each trading period. Whether variations of the market microstructure details lead to results that are different from the results reported in this paper can be analyzed in later papers.[11]

The experimental instructions and comprehension test questions can be found in Online Appendices A to C. Subjects are randomized into groups (markets) of six at the beginning of the experiment. The group composition remains constant over the course of the experiment.[12]

Each group participates in four rounds of multiple periods (period 0, followed by nine regular trading periods, and the final period 10 in which no more trade occurs). Except for the experience that subjects gain by trading, these rounds are identical (that is, all parameters are identical, subjects start with the same endowments, etc.). At the end of the fourth round, one round is randomly chosen for payment. Subjects' points earned from the chosen round were exchanged into euros at a fixed and known rate of 1000 points = 1 euro.

[10] Note that such regulation does not require the authorities to have perfect information about all investors' bond and CDS holdings at all time periods. Enforcement is also possible if regulators can occasionally check the holdings of investors (comparable to a train conductor checking tickets). An easy way for a partial implementation of the second point would be only allowing credit default swaps with physical settlement (as opposed to those with cash settlement, where the underlying bond does not need to be delivered by the CDS holder for payout).

[11] Various different mechanisms are used for bond IPOs and for bond and CDS trading (see, e.g., Brenner et al. (2009) and Biais and Green (2019)). A real-world market with similar features to our implementation is the Israeli corporate bond market, where bond IPOs use a uniform price auction mechanism and the secondary market trading takes place at the Tel Aviv Stock Exchange (Abudy and Wohl, 2018).

[12] The advantage of smaller groups is that (for a given budget) data from more groups can be collected, which facilitates conclusions based on statistical significance. Potential disadvantages from small groups are that markets are thinner (Bossaerts and Plott, 2002) and that (if groups become too small) subjects may not act as price takers. Six subjects per market should be sufficient for price taking behavior (in line with the experimental literature showing that subjects in groups of four or more behave as do subjects in larger groups; Huck et al., 2004). We would only consider the thinness of the markets to be problematic if that feature of our design interacted in some way with our treatment interventions, which we consider unlikely (levels of prices in the experiment do not carry over to the world outside the laboratory anyways, it is the direction of treatment effects that is of primary interest).

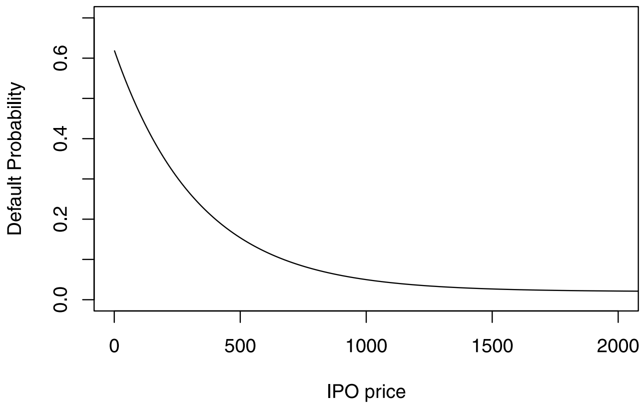

Fig. 1. Default probability function in the bond market.

The timing in the experiment is precisely as in the model described in Section 3.1.2. Markets begin in period 0 with the IPO of bonds. The total number of bonds is 25. In period 0, after the IPO has been completed, subjects can trade credit default swaps with each other. Credit default swaps are already in place at the beginning of each round, with each subject holding two.[13] Each of periods 1 to 10 start with a determination of whether a default occurs or not. Given the IPO price, there is an associated default probability and if the random number drawn for each period (from a uniform distribution on $[0, 1]$) is less than or equal to that default probability, then a default occurs; otherwise there is no default. However, whether or not a default occurs is not immediately communicated to subjects. Instead, we adopt the block random termination design of Fréchette and Yuksel (2017), in which we record data for all periods 1 to 10. Subjects' actions in these periods are only payoff relevant if no previous default has occurred (this is communicated very clearly to subjects in the experimental instructions).[14] Next, coupon payments are made. Then, in periods 1 to 9 only, the secondary bond market opens and subjects can trade bonds. Subsequent to bond market trading, the credit default swap market opens in which subjects can trade credit default swaps. The tenth period is the final period, in which no more trade occurs (a default at the beginning of period 10 is still possible; if no default occurs, the coupon payment and the face value of the bond are paid out). The credit default swaps only pay out if a default occurs in a round. Subjects are informed about the outcomes of a round immediately after the round ends. More specifically, they are informed about (i) whether a default occurred in any of the 10 periods and if so in which period; (ii) their holdings of cash, bonds, and CDS at the point of default or at the end of the round; and (iii) how many points they earned in the round.

Subjects have two different accounts, a cash account and an interest account. The money in the cash account can be used for transactions, while the money in the interest account cannot (while it fully counts towards the earnings of a round). Coupon payments go to the interest account while money spent for buying assets or received for selling assets is booked on the cash account. We make this distinction to avoid an inflow of cash during the course of the experiment (for evidence that an inflow of cash can fuel bubbles, see, for instance, Razen et al. (2017)).

The parameterization of the bond market is as follows. The face value of the bond is $K = 1000$ and the interest rate is $i = 0.12$. The parameters of the default probability function are $b = 0.02$, $m = 0.6$, and $c = 0.003$. This leads to a unique equilibrium with an equilibrium IPO price in the bond market of 1861 points (rounded to the nearest integer). The equilibrium default probability is about 0.022 per period. This means that the probability to observe a default in a round of ten periods is in equilibrium about 0.202. The equilibrium price of a CDS in period 0 is 202 points (again rounded to the nearest integer). Fig. 1 shows the probability default function in the bond market; it shows that a higher price in the IPO leads to a lower default probability.

Fig. 2 shows the equilibrium fundamental values in the bond and CDS markets. Note that the actual fundamental values in the trading periods are endogenous in both markets as they depend on the (endogenous) probability that the bond issuer will default.[15]

The endowment that subjects have at the beginning of each round in their cash account is 20 650 points in the treatments with CDS and 20 000 points in the control treatment. In the CDS treatments, subjects in addition start out with two CDS each. The total number of CDS in a market is thus 12 and is lower than the number of bonds, which is 25. Because we have fewer CDS than bonds,

[13] The number of CDS in our experiment is lower than the number of bonds. This choice is conservative in the sense that it makes it relatively difficult for the regulation to be successful, because all CDS could also easily be held for hedging purposes in the treatment without regulation. The larger the number of CDS, the more likely that CDS in the *FREE* treatment are held without covering a bond (this argument can be extended to cases where the number of CDS is endogenously determined, at least in settings in which sellers have the incentive to sell many CDS).

[14] Our block random termination design is optimally suited to analyze treatment differences, because it insures that there are observations in all periods and rounds across all treatments. However, the block random termination is not well-suited to analyze the effects of experienced defaults on pricing in later rounds, because the defaults are not experienced immediately when they occur.

[15] Subjects were not communicated the fundamental values of bonds and CDS, but they had the information with which the fundamental values of bonds or CDS could be determined (however, the task is too complex for subjects to solve). We chose this setting, because in the world outside the laboratory, there is also a lot of information, while the calculation of the fundamental value is often complex or impossible.

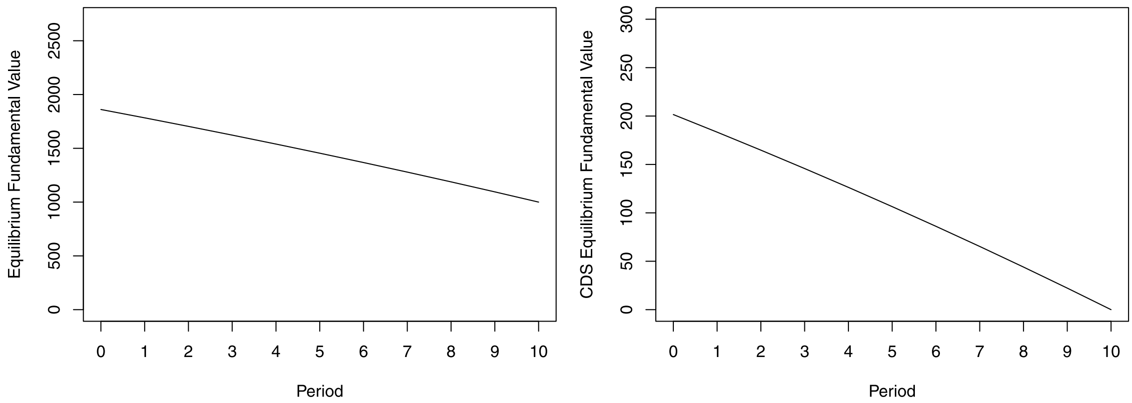

Fig. 2. Equilibrium fundamental values in bond and CDS markets. Notes: The left panel shows the equilibrium fundamental value in the bond markets, the right panel shows the equilibrium fundamental value in the CDS markets.

not all bond holdings can be insured. As a consequence, even in the regulated treatment there are always some subjects holding bonds who are allowed to bid for CDS. The monetary endowment is chosen such that the ratio of total means to assets at the equilibrium price is equal across treatments.[16] The framing of the two types of assets is neutral. That is, the terms "bonds" and "credit default swaps" are not used. Instead, the assets are referred to as Asset A (bonds) and Asset B (credit default swaps).

We use a one-sided call market auction mechanism in the bond IPO and a two-sided call market for trading outside of the IPO for both bonds and credit default swaps (keeping mechanism and interface as similar as possible in the bond IPO and secondary markets for bonds and CDS).[17] In the bond IPO, each subject submits a full demand schedule, that is, subjects specify for self-chosen prices how many bonds they would like to buy at those prices. The computer then constructs an aggregate demand curve from these individual demand curves. The IPO price is determined by the price at the intersection of this aggregate demand curve with the vertical supply curve (as the number of bonds is fixed at 25). Thus, the IPO price is the highest market price for which all 25 bonds can be sold. If more than 25 bonds are demanded at that market price, all bids above that price are successful while it is randomly determined which bids at the market price are rewarded. In the double-sided call markets of trading periods 1–9, subjects simultaneously submit both demand and supply schedules (that is, they can both buy and sell assets). The market price is determined by the intersection of aggregate demand with aggregate supply (in case there is a vertical overlap of aggregate demand and aggregate supply, the midpoint of the corresponding interval is used as market price). If there is excess demand or excess supply at the market price, all bids above or offers below the market price are serviced, while it is randomly determined which bids or offers exactly at the market price are successful. Fig. 3 shows the computer interface in the double-sided call market. The interface for the bond IPO is very similar but offers no possibility to enter a supply schedule.

In addition to the interface shown in Fig. 3, subjects always see which round and period they are in, how many points they have in their cash account, how many points they have in their interest account, and how many assets of each type they are holding. Furthermore, they see the market prices in the previous periods of the same round (with a note "no trade occurred" if there was no market price in a period). Bids and offers that cannot be executed are inadmissible (bids for more assets than there are, bids at prices that a subject cannot afford with the holdings in the cash account, offers of more units of an asset than the subject possesses). Furthermore, subjects cannot trade with themselves (that is, a subject's highest bid must be lower than her lowest offer). If subjects make inadmissible bids or offers, they cannot proceed but receive a warning with an explanation of why their bids or offers are inadmissible. Subsequently, they can adjust their bids and offers.

3.4. Procedures

In total, we report data from 150 subjects. In the new treatments, there are nine groups of six subjects in the regulated treatment (REG) and eight groups of six subjects in the unregulated treatment ($FREE$). We combine this with data from eight groups of

[16] In the control treatment, the endowment is 20 000 points. At the beginning of a round, there are thus 120 000 points in total. The ratio of means to available assets (in equilibrium) is then $120\,000/(25 \cdot 1861) \approx 2.6$. In the CDS treatments, the means consist of the endowment in points ($6 \cdot 20\,650 = 123\,900$) and in credit default swaps (12 in total). The available assets now include bonds and CDS. The corresponding ratio is $(123\,900 + 12 \cdot 202)/(25 \cdot 1861 + 12 \cdot 202) \approx 2.6$.

[17] While most corporate bonds and CDS are traded in over the counter (OTC) dealer markets, we abstract from dealer intermediation here and for simplicity we use the same call market mechanism for both the IPO and the secondary market. As Duffie (2012) observes, OTC markets are less transparent than centralized market exchanges yet persist due to the out-size profits dealers make from market opaqueness. Attanasi et al. (2016) confirm experimentally, that efficiency and prices are lower in OTC markets as compared with centralized auction markets. Further, there are examples where IPOs and secondary trading of corporate bonds occur in a manner similar to our design, namely the Tel Aviv Stock Exchange (TASE) where IPOs of corporate bonds are conducted using a uniform auction mechanism and the secondary market is conducted on the TASE (though only the opening is a call market), see Abudy and Wohl (2018) for details. The call market mechanism that we adopt is known to be about as efficient as a continuous double auction mechanism for the pricing of assets (see Friedman (1993)) and has other advantages, namely that it is easier to explain and generates a single market price.

Fig. 3. Interface for entering bids and offers in the double-sided call market.

six in the control treatment (*Control*, which is treatment *DEC* from Weber et al. (2018); the earlier experiment used the same subject pool, group size, and procedures as used in the new experiment; subjects who had participated in *Control* were excluded from participating in *FREE* and *REG*). The experiment was programmed in PHP/MySQL and conducted in English at the CREED laboratory of the University of Amsterdam. Subjects were recruited from the CREED subject pool. Sessions lasted about three hours in the CDS treatments and around two and a half hours in the control treatment. The average payment was about 30 euros, including a show-up fee of seven euros. After the experiment, subjects had to fill out a short questionnaire asking for a few demographic variables. Subjects were primarily undergraduate students with an average age of about 22 years. A bit more than half of the participants were majoring in economics or business, a bit more than half were female, and a bit less than half were Dutch.[18]

3.5. Hypotheses

With our experiment, we intend to analyze the following research questions. We usually have one-sided alternative hypotheses in mind, which we describe in the text below. As one could also come up with different alternative hypotheses, we will later always conduct two-sided statistical tests. Therefore, our formal statement always comprises only the null hypothesis. This null hypothesis generally states that there are no differences between treatments.

Q1: *Does the regulation work?*

As discussed in the introduction, whether CDS are held for hedging or for speculative purposes is of great importance for regulators. The main aim of the CDS regulation is to increase the fraction of covered positions (or equivalently to reduce the fraction of speculative naked positions). While it would be surprising if the regulation we introduce in our *REG* treatment led to a *lower* fraction of covered positions than in the unregulated *FREE* treatment, it is a priori not clear that such regulation should result in an *increased* fraction of covered positions. Bond holders can switch to naked positions in the REG treatment, as when they sell their bonds but not their CDS, and if these CDS were badly mispriced, rising rapidly above fundamental, the extent of such naked positions could grow over time, though this would amount to very risky speculative behavior. If we assume some minimal amount of risk aversion, mainstream finance and economic theory would predict no difference between the REG or FREE treatments: in both treatments, all credit default swaps would be held entirely for hedging purposes and would thus be *covered* positions. This is the case because the theory assumes that market prices are correct in the sense that they reflect fundamental values; even a minimal amount of risk aversion would lead to the complete absence of speculative CDS holdings, because the value of a CDS would always be higher for an individual with a bond that the CDS would cover than for an individual without such a bond.

This benchmark of no treatment effect serves as our null hypothesis:

H_{10}: The fraction of covered holdings is the same in *FREE* and *REG*.

[18] In a few instances, there were software/browser problems. Three groups had to be removed completely from the analysis (for two groups incorrect values were saved and displayed during the whole experiment; for one group failure happened in period 5 of the first round). Removing these three groups left the 25 groups reported here. For one of these 25 groups, a failure happened after the first period of the last round. We thus have the full IPO-data for this group and also use the data from the regular trading periods in the first three rounds (this is group number 8 in treatment *FREE*).

Q2: *How does CDS regulation affect IPO prices?*

If the costs of financing for bond issuers are increased by the presence of the CDS regulation, then the regulation could potentially yield more harm than good, for instance leading to a greater likelihood of bond defaults. Such reduced IPO prices in our REG treatment could arise if the regulation deters subjects from the markets altogether because they fear the complexity of the CDS regulation or because they are afraid that the regulation renders the CDS market less liquid so that they may not be able to properly hedge their bond holdings. Comparing the $Control$ treatment with the CDS treatments, the possibility to hedge could lead to higher IPO prices in the CDS treatments. We test the following null hypothesis:

H_{20}: IPO prices are the same across treatments.

Q3: *How does CDS regulation affect pricing in the secondary markets?*

One may expect that the bonds are priced more accurately (that is, closer to the fundamental value) in $FREE$ than in REG (or $Control$) based on the following argument. In experimental markets, the possibility to engage in short selling has been shown to reduce mispricing (e.g., Haruvy and Noussair (2006) and Weitzel et al. (2020)). In our experiment, short selling of bonds is not possible. The introduction of unregulated CDS, however, relaxes the short selling constraint; similarly to short selling of bonds, holding naked CDS allows to exploit mispricing that occurs because of an underestimation of the credit default risk. Thus:

H_{30}^{bonds}: Bond mispricing in the secondary market is the same across treatments.

When presenting our results, we will also consider whether mispricing of CDS differs across treatments. One may argue that the absence of regulation leads to more opportunities for market participants to exploit CDS mispricing in $FREE$ than in REG (as there are no constraints on the trading of the assets in $FREE$) and therefore to more accurate CDS prices in $FREE$. This yields:

H_{30}^{CDS}: CDS mispricing is the same in $FREE$ and REG.

Q4: *How does CDS regulation affect the concentration of asset holdings?*

By itself, the introduction of CDS provides a means of insuring bonds. Thus, more risk-averse subjects might be willing to hold bonds. This would suggest lower concentration of bond holdings in the CDS treatments relative to the $Control$ where there are no CDS. Treatments $FREE$ and REG both allow for insurance, while the former may also attract speculators in the CDS market. For this reason, fewer bonds may be available for insurance purposes and we hypothesize that fewer investors will hold bonds under $FREE$. We test:

H_{40}^{bonds}: The concentration of bond holdings is the same across treatments.

As for CDS holdings, one might expect CDS holdings to be less concentrated in the treatment without regulation simply because more investors (those with insurance motives and those with speculation motives) will want to hold them. Moreover, in REG a fear of not being able to sell CDS when necessary (e.g., because the regulation might be binding for those who would like to buy those CDS), may lead some subjects to shy away from holding CDS entirely, which would lead to a further concentration of CDS holdings. On the other hand, in the $FREE$ treatment, it may be possible that very few subjects who overvalue the CDS buy up the majority of these assets (without holding the same quantity of bonds), which would lead to more concentrated CDS holdings in the $FREE$ treatment. We test:

H_{40}^{CDS}: The concentration of CDS holdings is the same in $FREE$ and REG.

4. Results

In this section, we present the main experimental results. Graphs of prices in all periods and rounds for all groups separately can be found in Online Appendix D. All conducted statistical tests are two-sided. Unless indicated otherwise, the level of observation is at the group level, so that the observations can be treated as statistically independent (variables per round either exist only once per round, such as the IPO price, or they are aggregated across the different periods of a round).

Sections 4.2 and 4.3 deal with the pricing of the bonds. While we measure mispricing relative to the risk-neutral benchmark, note that substantial deviations from this benchmark cannot plausibly be explained by risk aversion in a rational way (expected utility theory with asset integration and 'reasonable' levels of risk aversion).[19] We discuss the effects of CDS regulation on the concentration of bond holdings in Section 4.4. Finally, in Section 4.5 we show that there is little cross-treatment variation in default probabilities or actual defaults, but defaults are frequent enough that participants likely perceive the CDS as valuable.

[19] Such rational valuations are close to the risk-neutral value, because utility is close to linear for small stakes. For a more general discussion of risk aversion under expected utility theory, and why reasonable calibrations cannot explain very risk-averse choices when the stakes are small (as is the case in our experiment), see Rabin (2000).

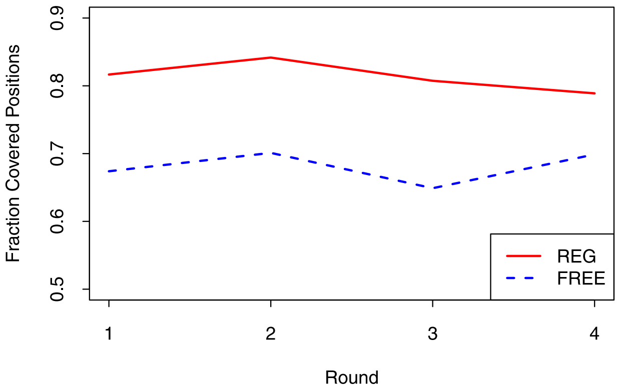

Fig. 4. Fraction of covered CDS positions. Notes: The graphs shows the fraction of credit default swaps held for insurance purposes. The values are averages across groups.

Table 1
Fraction of covered CDS positions.

	Treatment	Round 1	Round 2	Round 3	Round 4	Mean R1–R4
Mean	REG	0.817	0.842	0.807	0.789	0.814
	$FREE$	0.674	0.701	0.649	0.699	0.679
Median	REG	0.850	0.858	0.758	0.833	0.815
	$FREE$	0.675	0.708	0.592	0.692	0.689
WMW p-value		0.060	0.043	0.020	0.266	0.048

Notes: The upper part of the table shows the means and medians of the fraction of covered CDS positions (across groups; the last column shows mean and median of the mean fraction of covered position per group across rounds). The bottom row shows p-values from two-sided Wilcoxon–Mann–Whitney tests, testing for differences between the treatments (null-hypothesis: no difference). The numbers of observations are 9 (REG) and 8 ($FREE$).

4.1. CDS regulation and the fraction of covered positions

In our experiment, the regulation of the CDS market is effective. That is, the fraction of covered positions is considerably higher in the regulated treatment than in the unregulated treatment. This is shown in Fig. 4 which reports the fraction of swaps used for insurance purposes, that is, the fraction of covered positions in both CDS treatments.

Fig. 4 shows that more CDS positions are covered in treatment REG than in treatment $FREE$ in all rounds. These differences are on the whole statistically significant. Table 1 summarizes means, medians, and p-values of two-sided Wilcoxon–Mann–Whitney tests. This allows us to reject H_{10}.

In sum, the regulation works, with more credit default swaps being used for hedging purposes in the regulated treatment than in the unregulated case, while the reverse holds for swaps held for speculative purposes. Though intuitive, this result is *not* a trivial, mechanical result; it reflects the fact that the regulation works.

As discussed above, in theory, the regulation could also have been ineffective or even led to the opposite result. In REG, uncovered positions can easily occur if CDS holders do not sell their CDS holdings after having sold their bonds. At the same time, in $FREE$, rational risk-averse traders should not buy uncovered CDS if prices are equal to expected payoffs. The situation could also have arisen that the regulation deters subjects from being active in the CDS market (for example because of the added complexity in that market or because subjects fear that the buying restrictions would suppress CDS prices so that they do not even attempt to sell their holdings), thereby leading to a lower fraction of covered positions in the regulated treatment. We, however, do not observe such behavior.

4.2. CDS regulation and IPO prices

Fig. 5 shows IPO prices in all treatments, including the $Control$. We observe very similar price development in all treatments. In particular, it seems that the introduction of credit default swaps neither improves nor worsens the pricing of the bonds.

Comparing the two CDS treatments, we observe that pricing in the treatment with regulation REG is very similar to pricing in the $FREE$ treatment. The figure also suggests that there is no difference across the three treatments concerning how fast subjects learn.[20] In general, IPO prices are significantly lower than equilibrium predictions in the early rounds of all treatments (tested with

[20] In this way, the CDS treatments also provide additional robustness for the findings reported in Weber et al. (2018). That paper shows that underpricing of the IPO in early rounds and learning leading to near-equilibrium prices in the final round, are robust features of the bond market across a variety of different treatments. This paper shows that these findings are even robust to adding additional markets in which credit default swaps are traded, with or without regulation.

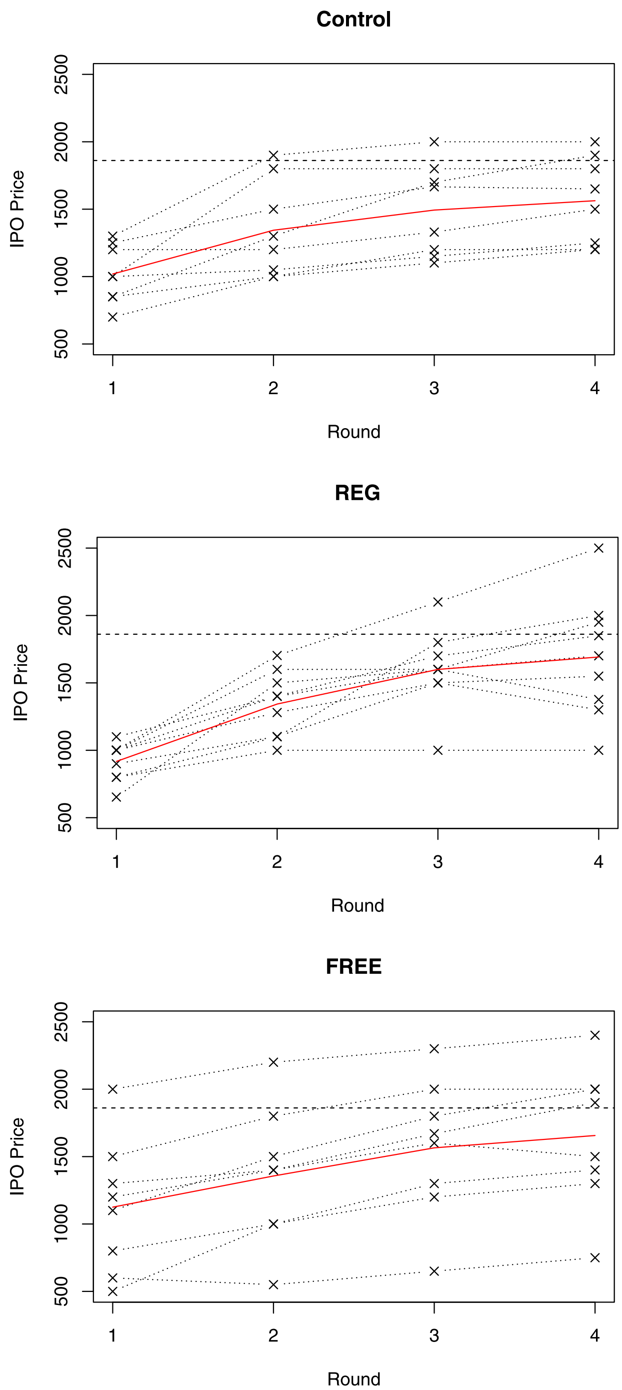

Fig. 5. IPO prices. Notes: Thin dotted lines denote the average IPO price per round in each of the markets. The thicker (red) line shows the mean price across markets and the horizontal dashed line indicates the equilibrium IPO price.

Table 2
IPO prices.

	Treatment	Round 1	Round 2	Round 3	Round 4	Mean R1–R4
Mean	*Control*	1019	1344	1493	1563	1355
	REG	917	1343	1600	1692	1388
	FREE	1125	1356	1565	1656	1426
Median	*Control*	1000	1250	1498	1575	1373
	REG	1000	1400	1600	1701	1425
	FREE	1150	1400	1635	1700	1496
KW p-value		0.523	0.974	0.880	0.698	0.920
WMW p-value		0.333	0.923	0.961	1.00	0.773

Notes: The upper part of the table shows means and medians of IPO prices (across groups; the last column shows mean and median of mean IPO prices per group across rounds). The second-to-last row shows p-values of Kruskal–Wallis tests, testing for differences across the three treatments (null-hypothesis: no difference). The last row shows p-values of two-sided Wilcoxon–Mann–Whitney tests, testing for differences between the two CDS treatments (null-hypothesis: no difference). The numbers of observations are 8 ($Control$), 9 (REG) and 8 ($FREE$).

two-sided Wilcoxon signed-rank tests), but they cease to be significantly different (at least at the five-percent level) in the last round.[21]

In line with the observation from Fig. 5, IPO prices are not significantly different across the treatments (not for any of the four rounds, nor for the average across rounds; this holds for Kruskal–Wallis tests, testing differences across all three treatments and for Wilcoxon–Mann–Whitney tests, testing for differences between the two CDS treatments only).[22] Mean and median IPO prices and p-values can be found in Table 2. We conclude that there are no negative side effects from introducing the CDS market or the regulation of that market on the revenues of bond issuers. Thus, we cannot reject H_{20}.

Fig. 5 also suggests that the standard deviation of IPO prices is somewhat higher in the $FREE$ treatment than in the other treatments in the early rounds. Such a difference would speak in favor of the regulation. However, this difference becomes small in the later rounds, and it is only statistically significant in the first round.[23]

4.3. CDS regulation and prices in the secondary markets

We now turn to the pricing of assets across the periods of a round. As a measure of mispricing, the relative absolute deviation (RAD) is a commonly used measure (the measure is introduced in Stöckl et al. (2010) and adapted to allow for periods without trade in Weber et al. (2018)). It is defined as

$$RAD = \frac{1}{T^*} \frac{\sum_{\{t|trade\ in\ t\}} |M_t - V_t|}{\bar{V}^*}. \tag{4}$$

In this definition, M_t is the market price in period t, V_t the fundamental value in period t, T^* the number of periods with trade and thus with a market price (we take market prices from periods 0 to $T-1$; that is, in the bond market we include the IPO price together with all secondary market prices, in the CDS market, period 0 is a regular trading period), and $\bar{V}^*$ the average of the fundamental values across the periods with trade.

Fig. 6 shows the mean relative absolute deviation for prices in the bond and CDS markets in all treatments. Consider first the secondary bond markets. We observe only minor differences in mispricing across the three treatments. As we observed for the IPO prices above, the secondary market bond prices across all periods of a round are similar across all treatments. There is a slight downward trend in the relative absolute deviation, in line with learning in the secondary market. Overall, subjects price the bonds well (especially so in the later rounds). Table 3 summarizes the data on the relative absolute deviation and the p-values of the statistical tests. These results for the bonds market do not allow us to reject H_{30}^{bonds}.

In contrast, credit default swaps are heavily mispriced, on average by a multiple of their fundamental value (the values on RAD together with the fact that the mispricing generally represents overpricing means that CDS are on average priced at roughly six times their fundamental value in REG and more than eight times their fundamental in $FREE$). This mispricing occurs independently of whether there is regulation or not (note that severe mispricing of credit default swaps at a multiple of the estimated fundamental value has also been observed in the field; Singh and Andritzky, 2005). As mentioned above, such severe mispricing cannot plausibly be explained by risk-averse rational decisions.

Thus, subjects who rely on credit default swaps to insure their bonds pay an excessively high risk premium for that insurance. Similarly, subjects who speculate with credit default swaps are paying extravagantly high prices in order to do so. The pricing of

21 In the first round, p-values are 0.014 (*Control*), 0.009 (*REG*), and 0.016 (*FREE*). In the second round, these numbers are 0.021, 0.004, and 0.030, respectively. In the third round, they are 0.023, 0.148, and 0.024. In the last round, the p-values are 0.055, 0.301, and 0.441.

22 As example, for the Kruskal–Wallis test in round 1, the used observations are all IPO prices from the first round (i.e., in all three treatments). For the Wilcoxon–Mann–Whitney in round 1, the used observations are all IPO prices from the first round in the treatments REG and $FREE$.

23 Standard deviations of IPO prices are 215, 356, 340, and 323 in the four rounds of $Control$, 141, 241, 292, and 446 in REG, and 495, 512, 512, and 519 in $FREE$ (rounded to integers). Differences are only statistically significant in the first round, when testing with Fligner-Killeen tests (for a comparison of all three treatments and for a comparison of the two CDS treatments; differences of the first-round comparison between $Control$ and $FREE$ are marginally significant).

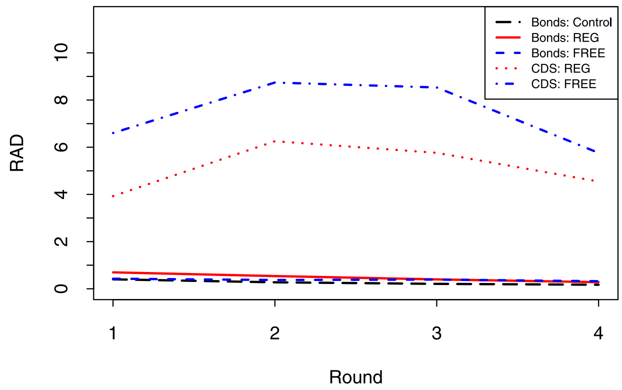

Fig. 6. Relative absolute deviation of bond and CDS markets per treatment (averages across groups).

Table 3
Mean relative absolute deviation.

	Treatment	Round 1	Round 2	Round 3	Round 4	Mean R1–R4
Bonds	*Control*	0.40	0.27	0.21	0.17	0.26
	REG	0.70	0.54	0.40	0.28	0.48
	FREE	0.43	0.37	0.39	0.32	0.38
CDS	*REG*	3.93	6.25	5.76	4.55	5.18
	FREE	6.60	8.74	8.53	5.76	7.49
KW p-value bonds		0.226	0.170	0.179	0.334	0.211
WMW p-value bonds		0.114	0.277	0.423	0.758	0.423
WMW p-value CDS		0.321	0.673	0.541	0.710	0.481

Notes: The upper part of the table shows RAD in the bond and CDS markets (means across groups; the last column shows the mean of the mean RAD per group). The lower part first shows p-values of Kruskal–Wallis tests for differences in the bond market RAD between all three treatments and two-sided Wilcoxon–Mann–Whitney tests in the bond markets between the two CDS treatments. The last row shows p-values of two-sided Wilcoxon–Mann–Whitney tests, testing for differences in CDS RAD between the two CDS treatments. The null-hypothesis for all tests is that there is no difference between treatments. The numbers of observations are 8 ($Control$), 9 (REG) and 8 ($FREE$).

the swaps looks slightly better in REG than in $FREE$, but the differences are not statistically significant. Thus, we do not reject H_{30}^{CDS}. Overall, the evidence suggests that the CDS regulation has no negative impact on the accuracy of the pricing of the assets (if any, there is a small positive impact), so that price developments in the bond and CDS markets do not provide a rationale against the CDS regulation we consider.

Prices might in general be related to the volume of trade. Trade volume in CDS markets (with average numbers of trades across rounds, groups and periods of 0.54 in REG and 0.65 in $FREE$) appear to be thinner than in bond markets (with average numbers of trades of 1.80, 1.53, and 1.29 in $Control$, REG, and $FREE$, respectively). Statistical tests for differences across treatments are not significant (when testing across all three treatments with Kruskal–Wallis tests in the bond markets or when testing between the two CDS treatments with Wilcoxon–Mann–Whitney tests in the bond or CDS markets, at significance level 0.05).

It is notable that the CDS are very over-priced in our experiment, while bonds are not. Our current design does not allow us to carefully unravel the mechanisms underlying these differences, however we can speculate on some possible explanations. First, derivative assets are hard to price (it is easier to develop an intuition for the price of a bond than for the price of a derivative like a CDS). Second, even if some participants do not find it difficult to price the derivatives, they may believe that others have a hard time doing so. This can lead to speculation at higher prices. Third, CDS are scarcer than bonds in our experiment and this could lead to higher prices per se, although it does not seem reasonable that such an explanation could justify the pricing of CDS so far above their equilibrium levels. Fifth, the price discovery mechanism (the IPO) at the beginning of the bond markets may have helped subjects to price the bonds more accurately than the CDS (for which there were no IPOs). Finally, subjects may have misjudged the risk of default to be greater than it actually was, which would in turn justify higher CDS prices. Future research, with further design changes, is needed to explore such explanations.

4.4. CDS regulation and the concentration of bond and CDS holdings

Next, we consider the concentration of bond and CDS holdings. From a policy perspective, less concentration of bond and CDS holdings is desirable, as more concentrated holdings are associated with lower liquidity and greater systemic risk (e.g., Brunetti et al. (2018)). To measure whether very few subjects tend to hold all the bonds and CDS or whether these are distributed relatively evenly across subjects, we use the (normalized) Herfindahl–Hirschman index (HHI). This index measures concentration, with zero signifying that a variable is equally distributed among all subjects, while one signifies that a variable is concentrated at one subject

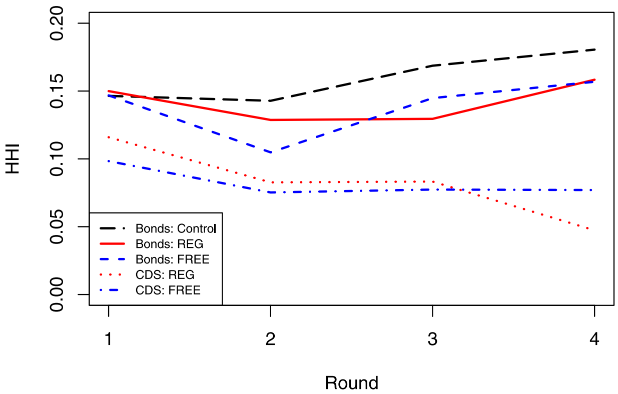

Fig. 7. Herfindahl–Hirschman indices per round (averages across groups).

Table 4
Herfindahl–Hirschman indices per round (averages across groups).

	Treatment	Round 1	Round 2	Round 3	Round 4	Mean R1–R4
Bonds	*Control*	0.15	0.14	0.17	0.18	0.16
	REG	0.15	0.13	0.13	0.16	0.14
	FREE	0.15	0.10	0.14	0.16	0.14
CDS	*REG*	0.12	0.08	0.08	0.05	0.08
	FREE	0.10	0.08	0.08	0.08	0.08
KW p-value bonds		0. 553	0.713	0.524	0.845	0.809
WMW p-value bonds		0.541	0.423	0.815	0.758	1.000
WMW p-value CDS		0.743	0.963	0.606	0.289	0.888

Notes: The upper part of the table shows the HHI in the bond and CDS markets (means across groups of the HHI of subjects' mean holdings across the periods of a round; the last column shows the mean of these values across rounds 1 to 4). The lower part first shows p-values of Kruskal–Wallis tests in the bond market HHI between all three treatments and two-sided Wilcoxon–Mann–Whitney tests in the bond markets between the CDS treatments. The last row shows p-values of two-sided Wilcoxon–Mann–Whitney tests, testing for differences in CDS HHI between the two CDS treatments. The null-hypothesis for all tests is that there is no difference between treatments. The numbers of observations are 8 ($Control$), 9 (REG) and 8 ($FREE$).

with zeros for the other subjects (for asset holdings, a value of zero would be obtained if all subjects held exactly the same number of assets, while a value of one would be obtained if one subject held all assets). The normalized Herfindahl–Hirschman index of a vector of non-negative variables $s = (s_1, \dots, s_n)$ is given by

$$H^*(x) = \frac{\left(\sum_{i=1}^n x_i^2\right) - 1/n}{1 - 1/n},$$

with $x = (x_1, \dots, x_n) = (s_1/\sum_{j=1}^n s_j, \dots, s_n/\sum_{j=1}^n s_j)$.

Fig. 7 shows the normalized Herfindahl–Hirschman index for the different rounds of the experiment. The lines show averages across groups of the HHI of subjects' average holdings across the periods of a round, separately for the different treatments and bond and CDS markets.

Turning first to the bond markets, the concentration of bond holdings in the two treatments with CDS is basically identical. Thus, whether CDS markets are regulated or not seems to have no impact on the distribution of bond holdings. The concentration of bond holdings in the two treatments with CDS is slightly lower than in the control treatment. Note, however, that the differences are not statistically significant (Table 4 summarizes the data and the p-values of the statistical tests). The results do not allow us to reject H_{40}^{bonds}.

In the CDS markets, the concentration of holdings is very similar between the two CDS treatments. Only in the fourth round, is there a modest (and statistically insignificant) difference, with slightly higher concentration of CDS holdings in the unregulated treatment than in the regulated treatment. Overall, CDS holdings are not more concentrated in one treatment than in the other. Therefore, we do not reject H_{40}^{CDS}.

4.5. Defaults

In this section, we report on default probabilities and the actual incidence of defaults.[24] Table 5 shows the average default probabilities across groups for the different treatments and rounds. Recall that the per-period default probability is endogenous (it

[24] This subsection was suggested by an anonymous reviewer, for which we are grateful.

Table 5
Default probabilities and defaults (averages across groups).

	Treatment	Round 1	Round 2	Round 3	Round 4	Mean R1–R4
Default probability	*Control*	0.054	0.036	0.030	0.028	0.037
	REG	0.062	0.033	0.027	0.027	0.037
	FREE	0.063	0.045	0.036	0.032	0.044
Defaults	*Control*	0.25	0.50	0.25	0.25	0.31
	REG	0.44	0.11	0.33	0.33	0.31
	FREE	0.50	0.25	0.25	0.25	0.31

Notes: The upper part of the table shows the default probabilities in the different rounds (means across groups; note that the default probability is the probability for a default in any given period of the round, conditional on no default having occurred prior). The lower part shows the fraction of groups with a default in a given round. The numbers of observations are 8 (*Control*), 9 (*REG*) and 8 (*FREE*).

is a function of the IPO price) and that it is the probability that a default occurs in any period of the round, conditional on no default having occurred earlier in that same round. The equilibrium default probability is 0.022, and this implies that the likelihood of a default in any round (which can last up to 10 periods) is 0.202.

Default probabilities are very similar across treatments. The average default probability across all rounds is 0.037 in *Control* and *REG* (when rounded to three digits) and only slightly higher (0.044) in *FREE*. By chance, the differences become even smaller when looking at actual defaults (which are just a noisy consequence of the default probabilities). There are 10 defaults in a total of 32 rounds both in *Control* and *DEC* (31.25%) and 11 defaults in a total of 36 rounds in *REG* (30.56%). Table 5 shows the fraction of groups that experienced a default in the different rounds.

We do not provide statistical tests of differences in the number of defaults across treatments, because they are just noisy consequences of the default probabilities. Similarly, we do not test for differences in default probabilities across treatments, because the default probabilities are a monotonic transformation of IPO prices, and thus non-parametric tests yield the same results as the tests in Table 2, which are all non-significant.[25]

5. Concluding remarks

Credit Default Swaps were long seen as a useful tool to hedge risks in complex markets. Alan Greenspan, former chair of the Federal Reserve of the United States has been quoted to say: “The credit default swap is probably the most important instrument in finance. .... What CDS did is lay-off all the risk of highly leveraged institutions .... on stable American and international institutions” (*Financial Times*, Feb. 8, 2008). The financial crisis that started in 2008 made many start to doubt this point of view. In fact, CDS were often seen as one of the major causes of this crisis. In the *Financial Times* article in which this Greenspan quote appeared, the writer (risk consultant Satayjit Das) concludes that “CDS contracts may not actually improve the overall stability and security of the financial system but actually create additional risks”.

Many economists intuitively oppose government regulation that interferes in markets. The idea that markets are efficient and that government intervention causes deadweight losses is widely shared. Yet, some economists supported such intervention in CDS markets in the years after the crisis hit (see Stulz (2010) for a discussion). This discussion, however, has been hindered by a lack of evidence on how regulation affects CDS markets. Our paper addresses this gap. We use laboratory control to isolate the effects of a widely propagated intervention, a ban on holding CDS for speculative purposes. We investigate the effects of such a policy on the markets concerned.

In our experiment, CDS regulation achieves its purpose. When the regulation is in place, over 81% of CDS held are paired with a holding of the underlying bond. That is, more than 80% of the CDS serve as an insurance against default of the bond to which they are linked. When there is no regulation, this percentage is significantly lower, at just 68%. This successful regulation does not come at the expense of the underlying bond market. Both the IPO market prices and the prices in the secondary bond market remain unaffected by this intervention in the CDS market. Even prices in the CDS market are not negatively affected by this restriction on CDS trades. The regulation also does not affect the concentration of bond holdings; CDS holdings are not more concentrated when the regulation is in place.

CDS regulation is of crucial political and economic importance. Much more research is needed to fully understand the workings of CDS markets and their regulation. An obvious first step mentioned above (in the introduction) is to investigate risks on the supply side of the CDS market. It may also be interesting to investigate whether CDS are priced more accurately in a setting in which CDS supply

[25] To be precise, this holds only when testing the different rounds separately with these non-parametric tests. For the means across rounds, the tests do not yield identical results, but these tests (Kruskal–Wallis and Wilcoxon–Mann–Whitney) also yield non-significant results for default probabilities.

Test results are not identical if a test is used where distances play a role instead of just ranks (e.g., a t-test). It would for example be possible that a higher standard deviation of IPO prices (as can be inferred from Fig. 5) leads to a statistically significant difference in default probabilities. However, when we test for differences in default probabilities between *REG* and *FREE* with a t-test, we do not observe any significant differences (neither for the rounds separately, nor for means across rounds).

is endogenous. On the demand side, our framework can be extended to study how defaults, expectations of defaults, or changes in the default probability structure affect the bond and CDS markets. More generally, we believe that theoretical models, empirical work with observational data, and controlled experimental studies all play important roles in this quest. Our first experimental paper on markets with CDS suggests that CDS regulation to decrease speculation can be beneficial without having harmful side effects.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.euroecorev.2024.104745.

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