School of Finance

University of St.Gallen

CREDIT DEFAULT SWAP REGULATION IN EXPERIMENTAL BOND MARKETS

MATTHIAS WEBER
JOHN DUFFY
ARTHUR SCHRAM

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Matthias Weber[†]   John Duffy[‡]   Arthur Schram[§]

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Abstract

Credit default swaps (CDS) played an important role in the financial crisis of 2008. While CDS can be used to hedge risks, they can also be used for speculative purposes (as occurred during the financial crisis) and regulations have been proposed to limit such speculative use. Here, we provide the first controlled experiment analyzing the pricing of credit default swaps in a bond market subject to default risk. We further use the laboratory as a testbed to analyze CDS regulation. 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 bond IPO revenues and does not negatively affect CDS prices or bond prices 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 in 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. The availability of such insurance enables bond financing of risky investments that otherwise might not be able to raise funds due to below investment grade ratings. 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 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). For comparison purposes, according to the World Bank, the value of world GDP in 2007 was just US$57.86 trillion. Thus, it seems that speculative motives rather than insurance alone, played a role in the CDS market. Indeed, credit default swaps covering mortgage-backed securities in particular, have been linked to the financial crisis. As a consequence, the (potential) regulation of such assets has become highly discussed (Ayadi and Behr, 2009; Morgan, 2009; Stulz, 2010; Delatte et al., 2012; Juurikkala, 2012, Augustin et al., 2014).

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. From a financial stability point of view, such speculation can engender additional systematic risk-taking behavior, resulting in an increase in the number of bankruptcies. and possibly lead to the necessity of bailouts by the government. In addition, 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. For example, if the holder of a speculative position in a bond CDS also publishes credit ratings that are partly self-fulfilling, the CDS holder might be tempted to downgrade the bond issuer in an attempt to boost the value of 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 (e.g., the American Insurance Group). 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). Such a regulation was introduced in the EU in 2011 for the sovereign CDS markets.

Despite various proposals to regulate CDS and some implemented regulations, there is little evidence to date about how well CDS regulation works in practice. Analyzing regulations that have not yet (or only recently) been implemented with observational field data is inherently difficult and further complicated by the fact that the fundamental values of underlying assets cannot be directly observed. To address the impact of proposed reforms to the CDS market, we thus use a controlled laboratory experiment as a testbed for the analysis of new regulation.

As laboratory experimentation allows for a level of control that is unattainable in the field, a rich literature on experimental asset markets has evolved.[1] Bossaerts (2009), Noussair and Tucker (2013), and Palan (2013) 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., 2019) 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, Jong et al., 2006, 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. Further, there has been little experimental work analyzing proposed financial regulations in the wake of the Great Recession. Notable exceptions are Armantier et al. (2013) who explore auction design for the U.S. Treasury's disposal of troubled assets and Keser et al. (2017) who experimentally examine rating agency regulation.

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[1]For relatively recent studies, see Haruvy and Noussair (2006), Bossaerts et al. (2007), Haruvy et al. (2007), Bossaerts et al. (2010), Palan (2010), Cheung and Palan (2012), Kirchler et al. (2012), Sutter et al. (2012), Huber and Kirchler (2012), Cheung et al. (2014), Füllbrunn et al. (2014a), Füllbrunn et al. (2014b), Noussair et al. (2016), Bao et al. (2017), Holt et al. (2017), Bosch-Rosa et al. (2018), Crockett et al. (2018), and Kopányi-Peuker and Weber (2018).

Previewing our results, we find that the regulation of CDS that we introduce is indeed successful at increasing CDS usage for hedging purposes while decreasing it for speculative purposes. The regulation we consider does not come at the expense of reduced revenue from initial public offerings (IPO) 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 very 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 traders alike.

The remainder of the paper is organized as follows. Section 2 presents the models underlying the experiment, the experimental design, and the procedures. Section 3 describes the results, and Section 4 concludes.

2 Experimental Design

2.1 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); we therefore keep the description of this market short.

2.1.1 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 the payment of the face value.

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 (a standard IPO mechanism) 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 $1, ..., T-1$, 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, $t = 1, ..., T-1$, is as follows:

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:[2]

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

The parameters are assumed to satisfy $0 < b < 1$, $0 < m < 1 - b$, and $c > 0$.[3]

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

[3]b represents the base risk (which is independent of the IPO price; the default risk is always at least b).

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 the bonds can be calculated for all subsequent periods. The fundamental value of the 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

$$V_t = KP_n^{T-t} + \sum_{m=t+1}^{T} iKP_n^{(m-t)} = KP_n^{T-t} + \sum_{m=1}^{T-t} iKP_n^m$$
$$\overset{\text{for } P_d > 0}{=} KP_n^{T-t} + iK\left(\frac{1 - P_n^{T-t+1}}{1 - P_n} - 1\right).$$
(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 equation (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.[4]

2.1.2 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).[5] The payments are 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

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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).

[4]Details about how to compute the equilibrium can be found in Weber et al. (2018). Depending on the model specification, 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 for the experiment that yields a unique equilibrium.

[5]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.

out nothing.[6] 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 $t = 1, ..., T-1$ 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.

If no default occurs up to and including period T, then no more trading in bonds or CDS occurs: 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).

$$W_t = K \cdot (1 - \text{"no default after "} t) = K \cdot (1 - P_n^{T-t}). \tag{3}$$

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[6]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).

2.2 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 and no credit default swaps are traded. The data from this control treatment are those reported in the earlier paper Weber et al. (2018). There are ten groups of six subjects 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 easily be enforced by regulators; the second part refers to only allowing one class of credit default swaps, namely those 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).[7]

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).

2.3 Experimental Implementation

The experimental instructions and comprehension test questions can be found in 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.

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[7]A more radical approach would have been to also force subjects to sell their credit default swaps once they become uncovered (that is, when a subject sells the underlying bonds), but this would have forced subjects to accept any market price of credit default swaps when they need to sell, which we wanted to avoid.

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.

The timing in the experiment is precisely as in the model in Section 2.1.2. 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. Periods 1 to 10 start with a determination of whether a default occurs. It is not communicated to subjects, however, whether or not a default occurred. Instead, we apply a block design (Fréchette and Yuksel, 2017), in which we always record data on all periods. Subjects' actions are only payoff relevant if no previous default has occurred (this is communicated very clearly to subjects in the experimental instructions). 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 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 the period 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 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 keep the cash-to-asset ratio constant in the trading periods.

The parameterization of the bond market follows that in treatment *DEC* in Weber et al. (2018). 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. The equilibrium price of a CDS in period 0 is 202 points (again rounded to the nearest integer). Figure 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.
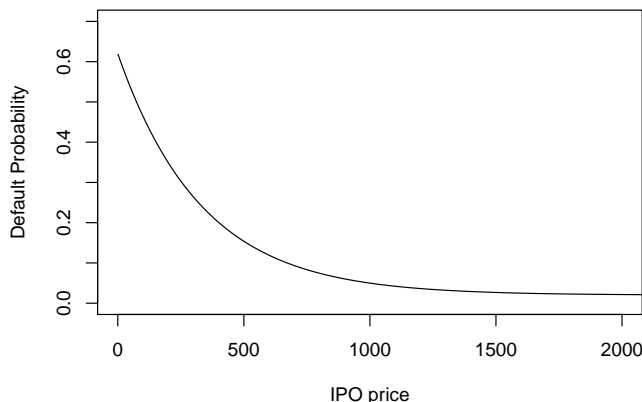

Figure 1: Default Probability Function in the Bond Market

Figure 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.

The endowment that subjects have at the beginning of each round in their cash account is 20650 points in the treatments with CDS and 20000 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, 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.[8]

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

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[8]In the control treatment, the endowment is 20000 points. At the beginning of a round, there are thus 120000 points in total. The ratio of means to available assets (in equilibrium) is then $120000/(25 \cdot 1861) \approx 2.6$. In the CDS treatments, the means consist of the endowment in points $(6 \cdot 20650 = 123900)$ and in credit default swaps (12 in total). The available assets now include bonds and CDS. The corresponding ratio is $(123900 + 12 \cdot 202)/(25 \cdot 1861 + 12 \cdot 202) \approx 2.6$.
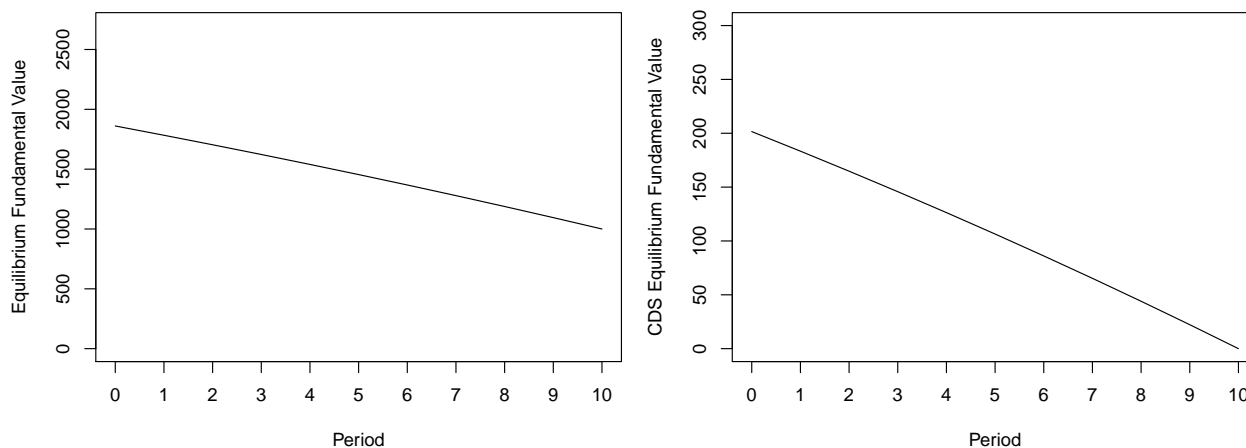
Figure 2: Equilibrium Fundamental Values in Bond and CDS Markets

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.

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. This choice allows us to keep the mechanism and the interface as similar as possible in the initial bond IPO market and in the subsequent trading periods, thus avoiding additional complexity for experimental subjects, and it also gives us a single market price for each trading period. 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.

Figure 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.

Asset A

| I would like to buy this quantity | if the price (per asset) is at most | | I would like to sell this quantity | if the price (per asset) is at least |

show more fields   show more fields

Submit bids and offers

Figure 3: Interface for Entering Bids and Offers in the Double-Sided Call Market

In addition to the interface shown in Figure 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.

2.4 Procedures

In total, we report new data from 114 subjects, nine groups of six subjects in the regulated treatment (*REG*) and ten groups of six subjects in the unregulated treatment (*FREE*). We combine this with data from 48 subjects (eight groups of six) in the control treatment (*CONTROL*, which is treatment *DEC* from Weber et al., 2018). 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. The following description concerns only the new experimental sessions, information on the control treatment can be found in Weber et al., 2018. Sessions lasted about three hours and 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 23 years. Slightly more than half of the participants were majoring in economics and business, slightly more than half were female, and slightly less than half were Dutch.[9]

3   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 Appendix D.

3.1   CDS Regulation and the Number of Covered Positions

As discussed in the introduction, whether CDS are held for hedging or for speculative purposes is of great importance for regulators. From a financial stability point of view, CDS held for hedging purposes are beneficial, while CDS held for mere speculative purposes can be problematic. 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. Mainstream finance and economic theory would predict no difference between the two treatments; in both treatments, all credit default swaps would be held entirely for hedging purposes and would thus be *covered* positions.[10]

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

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[9]In two instances, the software/browser failed, so that the experiment had to end prematurely for two groups. One group in treatment *REG* was excluded completely from the analysis, as the failure happened early in the experiment (in period 5 of the first round). For the other group, number 10 in treatment *FREE*, the failure happened after the first period of the last round. We thus have the full IPO-data for this group and use the data from the regular trading periods in the first three rounds.

[10]This is the case because mainstream theory assumes that market prices are 'correct' in the sense that they reflect fundamental values. In that case, even a minimal amount of risk aversion would lead to the complete absence of speculative CDS holdings.

treatment. This is shown in Figure 4 which reports the fraction of swaps used for insurance purposes, that is, the number of covered positions in both CDS treatments.
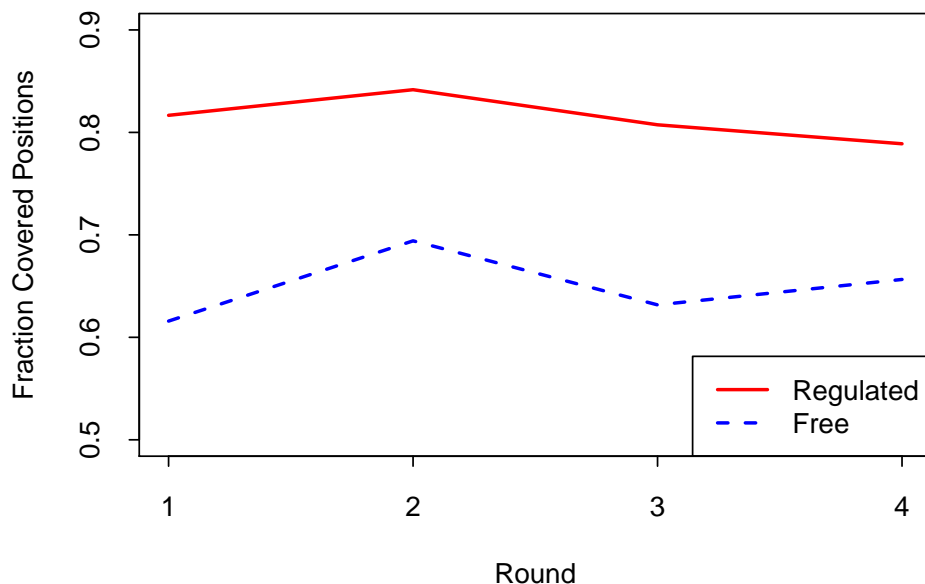

Figure 4: Fraction of Covered CDS Positions

Notes: The graphs shows the fraction of credit default swaps held for insurance purposes. The values are averages across groups.

Figure 4 clearly shows that more CDS positions are covered in treatment *REG* than in treatment *FREE* in all rounds. These differences are statistically significant; using Wilcoxon-Mann-Whitney tests on the average coverage rates across all four rounds, the *p*-value is 0.027; the *p*-values for the individual rounds 1 to 4 are, respectively, 0.020, 0.014, 0.007, and 0.122. Table 1 summarizes means, medians, and *p*-values of these data.

In sum, the regulation works, with more credit default swaps being used for hedging purposes in the regulated treatment, while more are used for speculative purposes in the unregulated treatment. Though intuitive, this result is *not* trivial; it reflects the fact that the regulation works. 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, as argued in Footnote 10, rational risk-averse traders would not buy uncovered CDS (in equilibrium) in *FREE*. The situation could have arisen that the regulation deters subjects from being

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	0.612	0.694	0.632	0.656	0.650
Median	*REG*	0.850	0.858	0.758	0.833	0.833
	FREE	0.646	0.675	0.583	0.642	0.642
WMW *p*-value		0.020	0.014	0.007	0.122	0.027

Notes: The upper part of the table shows the means and medians of the fraction of covered CDS positions. The bottom row shows *p*-values from two-sided Wilcoxon-Mann-Whitney tests, testing for differences between the treatments (null-hypothesis: no difference).

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. However, we do not observe such behavior.

3.2 CDS Regulation and IPO Revenues

While the regulation is successful in increasing hedging and decreasing speculation, its effect on IPO prices is a priori unclear. 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, e.g., 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. As a benchmark for the IPO pricing, we use the results from our *CONTROL* treatment without any CDS market. As reported in Weber et al. (2018), we observe in that CONTROL treatment that IPO prices are, on average, below the equilibrium price, considerably so in the first rounds of the experiment, but only very mildly so by the last round. In other words, with experience, traders learn to price the IPO close to the equilibrium price.

Figure 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 debt swaps neither improves nor worsens the pricing of the bonds. Note that

the pricing could have been improved, because the introduction of CDS allows traders to hedge risks; the role of risk aversion is then reduced. 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.[11]

In line with the observation from Figure 5, IPO prices are not significantly different across the treatments (not for any of the four rounds, nor for the average across rounds, as tested using a Kruskal-Wallis test). Mean and median IPO prices and *p*-values from the Kruskal-Wallis tests 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.

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	1141	1365	1540	1636	1420
Median	*Control*	1000	1250	1498	1575	1373
	REG	1000	1400	1600	1701	1425
	FREE	1150	1400	1551	1555	1461
KW *p*-value		0.291	0.971	0.879	0.750	0.902

Notes: The upper part of the table shows means and medians of IPO prices. The bottom row shows *p*-values of Kruskal-Wallis tests, testing for differences across the three treatments (against the null-hypothesis of no difference).

3.3 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 mis-pricing, 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

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[11]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.
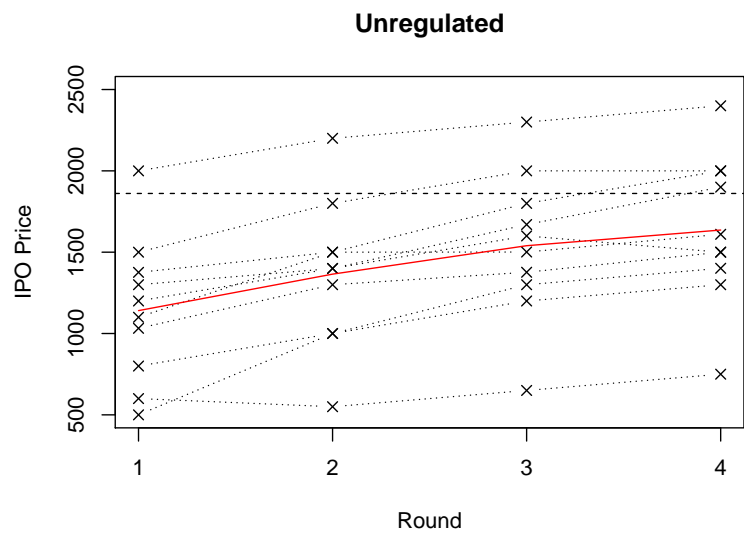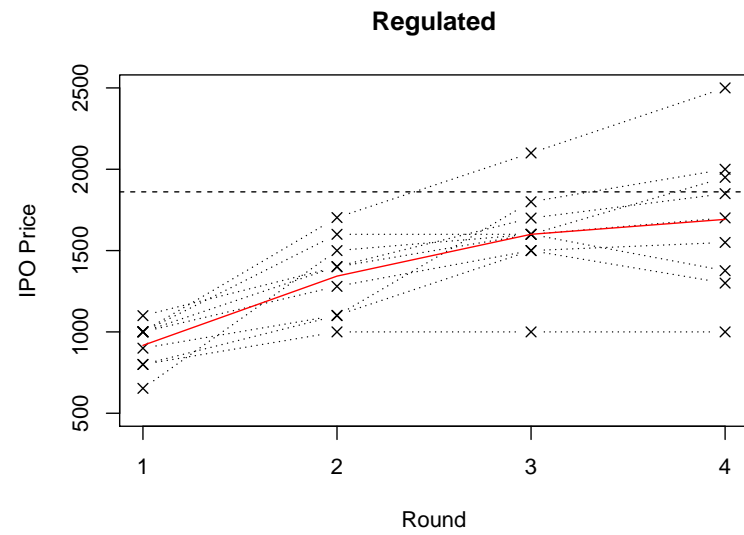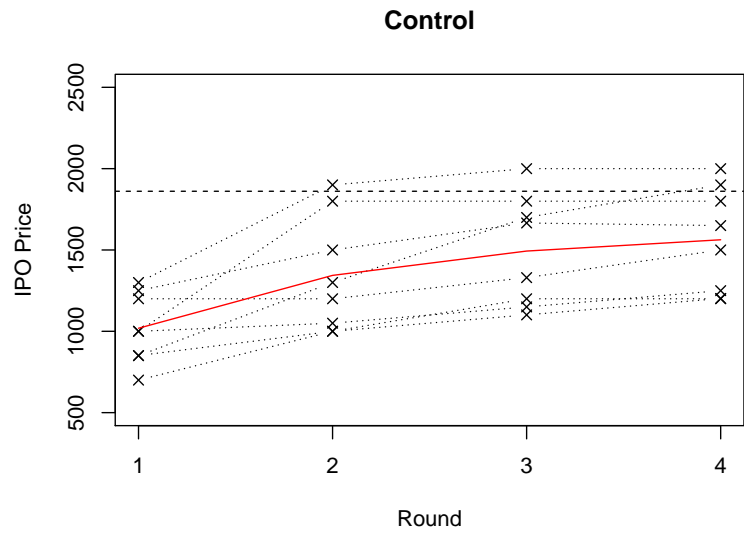
Figure 5: IPO Prices

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et al., 2018). It is defined as

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

(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.

Figure 6 shows the mean relative absolute deviation in the bond and CDS markets in all treatments. Consider first, the secondary bond markets. We observe only minor differences 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 later rounds).
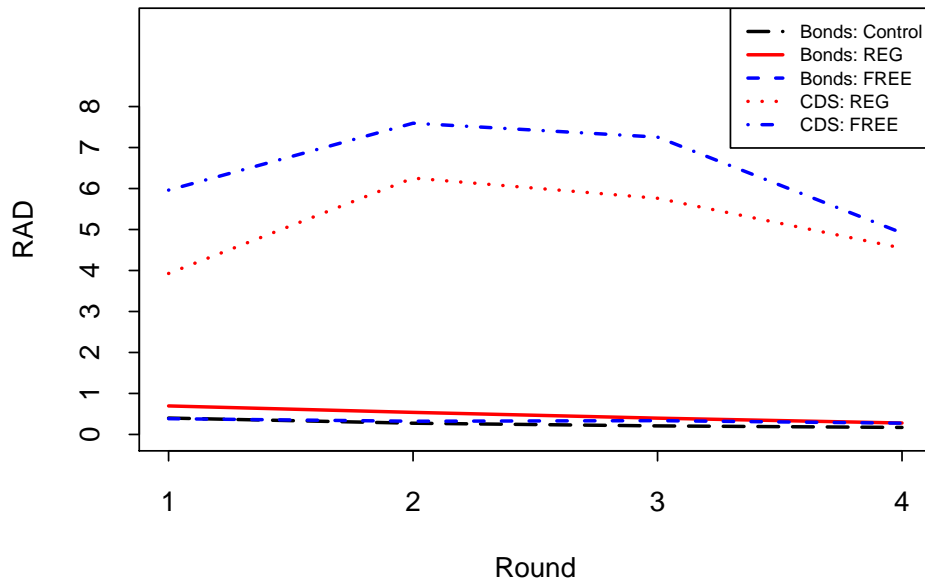

Figure 6: Relative Absolute Deviation of Bond and CDS Markets per Treatment (Averages across Groups)

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 mean that CDS are on average priced at roughly six times the fundamental value in *REG* and seven times the fundamental in *FREE*). This mispricing occurs independently of whether there is regulation or not.[12]

The relative absolute deviation is measured relative to the risk-neutral benchmark, but note that the severe mispricing in the CDS markets cannot plausibly be explained by risk-aversion in a rational way (expected utility theory with asset integration and 'reasonable' levels of risk aversion).[13]

This means that 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 the swaps looks slightly better in *REG* than in *FREE*, but the differences are not statistically significant. Table 3 summarizes the data on the relative absolute deviation and the *p*-values of the statistical tests.[14]

Overall, the evidence on prices in the trading periods suggests that the CDS regulation has no negative impact on the pricing of the assets; (if any, there is a small, positive impact), so that price developments in the CDS markets (and also in the bond markets) do not provide any rationale against the CDS regulation we consider.

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[12]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).

[13]This can be illustrated with the following example. Assume a CARA utility function and that a subject exhibits a risk aversion that makes her indifferent between accepting or rejecting a 50-50 gamble of losing 5 euros or winning 20 (in our view, this is a high level of risk aversion). The corresponding coefficient of absolute risk aversion is approximately 0.1313. Assume for simplicity that the bond default probability is as in the risk-neutral equilibrium. With thus risk aversion, the value of a bond in period 9 for a subject holding no assets is approximately 1093 points as opposed to a risk-neutral fundamental value of 1095 points. The reasons that the valuation with this utility function are so close to the risk-neutral value is that the default risk is low and that utility is close to linear for small stakes. The value of the joint holding of one bond and one CDS is only minimally below the risk neutral fundamental value of $1095 + 22 = 1117$, such that there are no differences if rounded to full points. This is not surprising as a holder of this combination is in period 9 is hardly exposed to any risk, because the CDS covers almost the complete loss in case of default (only the last coupon payment is not covered). For a more general discussion of risk aversion under expected utility theory and why reasonable calibrations cannot explain much risk aversion when stakes are small, see Rabin (2000).

[14]Prices might be affected by the volume of trade, of course. Trade volume in CDS markets (with an average number of trades across rounds, groups and periods of 0.54 in *REG* and 0.63 in *FREE*) appear to be thinner than the bond markets (where the average number of trades is 1.80, 1.53, and 1.45 in *CONTROL*, *REG*, and *FREE*, respectively). In neither market, however, does the number of trades differ significantly across treatments.

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	0.38	0.32	0.34	0.27	0.33
CDS	*REG*	3.93	6.25	5.76	4.55	5.05
	FREE	5.96	7.59	7.25	4.92	6.32
KW *p*-value Bonds		0.191	0.126	0.188	0.556	0.265
WMW *p*-value CDS		0.497	0.968	0.968	0.408	0.837

Notes: The upper part of the table shows the *RAD* in the bond and CDS markets (means across groups). The second-to-last row shows *p*-values of Kruskal-Wallis tests for differences in the bond market RAD between all 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).

4   Discussion and Conclusions

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 much lower, at just 65%. This successful regulation does not come at the expense of the underlying bond market. Both the IPO market and the secondary bond trading remain unaffected by this intervention in the CDS market. Even the CDS market itself is not negatively affected by this restriction on CDS trades.

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. 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. It thus puts the EU regulation in the sovereign CDS markets in good light and suggests that similar regulation may also be useful elsewhere.

References

Aldasoro, I. n. and Ehlers, T. (2018). The credit default swap market: what a difference a decade makes. *BIS Quarterly Review*, June:1–14.

Armantier, O., Holt, C. A., and Plott, C. R. (2013). A procurement auction for toxic assets with asymmetric information. *American Economic Journal: Microeconomics*, 5(4):142–62.

Augustin, P., Subrahmanyam, M. G., Tang, D. Y., Wang, S. Q., et al. (2014). Credit default swaps: A survey. *Foundations and Trends® in Finance*, 9(1–2):1–196.

Ayadi, R. and Behr, P. (2009). On the necessity to regulate credit derivatives markets. *Journal of Banking Regulation*, 10(3):179–201.

Bao, T., Hommes, C., and Makarewicz, T. (2017). Bubble formation and (in)efficient markets in learning-to-forecast and optimise experiments. *The Economic Journal*, 127(605):F581–F609.

Bosch-Rosa, C., Meissner, T., and Bosch-Domènech, A. (2018). Cognitive bubbles. *Experimental Economics*, 21(1):132–153.

Bossaerts, P. (2009). The experimental study of asset pricing theory. *Foundations and Trends in Finance*, 3(4):289–361.

Bossaerts, P., Ghirardato, P., Guarnaschelli, S., and Zame, W. R. (2010). Ambiguity in asset markets: Theory and experiment. *Review of Financial Studies*, 23(4):1325–1359.

Bossaerts, P., Plott, C., and Zame, W. R. (2007). Prices and portfolio choices in financial markets: Theory, econometrics, experiments. *Econometrica*, 75(4):993–1038.

Carlson, J. and Jacobson, M. (2014). New rules for credit default swap trading: Can we now follow the risk? Economic Commentary 2014-11, Federal Reserve Bank of Cleveland.

Cheung, S. L., Hedegaard, M., and Palan, S. (2014). To see is to believe: Common expectations in experimental asset markets. *European Economic Review*, 66:84–96.

Cheung, S. L. and Palan, S. (2012). Two heads are less bubbly than one: Team decision-making in an experimental asset market. *Experimental Economics*, 15(3):373–397.

Childs, J. and Mestelman, S. (2006). Rate-of-return parity in experimental asset markets. *Review of International Economics*, 14(3):331–347.

Crockett, S., Duffy, J., and Izhakian, Y. (2018). An experimental test of the lucas asset pricing model. *The Review of Economic Studies*, 86(2):627–667.

Delatte, A.-L., Gex, M., and López-Villavicencio, A. (2012). Has the cds market influenced the borrowing cost of european countries during the sovereign crisis? *Journal of International Money and Finance*, 31(3):481–497.

Duffy, J., Rabanal, J. P., and Rud, O. A. (2019). Exchange-traded funds in laboratory asset markets. Working Paper.

Forsythe, R., Palfrey, T. R., and Plott, C. R. (1982). Asset valuation in an experimental market. *Econometrica*, 50(3):537–567.

Forsythe, R., Palfrey, T. R., and Plott, C. R. (1984). Futures markets and informational efficiency: A laboratory examination. *Journal of Finance*, 39(4):955–981.

Fréchette, G. R. and Yuksel, S. (2017). Infinitely repeated games in the laboratory: Four perspectives on discounting and random termination. *Experimental Economics*, 20(2):279–308.

Friedman, D., Harrison, G. W., and Salmon, J. W. (1983). The informational role of futures markets: some experimental evidence. In Streit, M. E., editor, *Futures markets: Modelling, managing and monitoring futures trading*. Oxford: Basil Blackwell.

Friedman, D., Harrison, G. W., and Salmon, J. W. (1984). The informational efficiency of experimental asset markets. *Journal of political Economy*, 92(3):349–408.

Füllbrunn, S., Neugebauer, T., and Nicklisch, A. (2014a). Underpricing of initial public offerings in experimental asset markets. NiCE Working Paper 14-107.

Füllbrunn, S., Rau, H. A., and Weitzel, U. (2014b). Does ambiguity aversion survive in experimental asset markets? *Journal of Economic Behavior & Organization*, 107:810–826.

Haruvy, E., Lahav, Y., and Noussair, C. N. (2007). Traders' expectations in asset markets: Experimental evidence. *American Economic Review*, 97(5):1901–1920.

Haruvy, E. and Noussair, C. N. (2006). The effect of short selling on bubbles and crashes in experimental spot asset markets. *Journal of Finance*, 61(3):1119–1157.

Holt, C. A., Porzio, M., and Song, M. Y. (2017). Price bubbles, gender, and expectations in experimental asset markets. *European Economic Review*, 100:72–94.

Huber, J. and Kirchler, M. (2012). The impact of instructions and procedure on reducing confusion and bubbles in experimental asset markets. *Experimental Economics*, 15(1):89–105.

Jong, C. d., Koedijk, K. G., and Schnitzlein, C. R. (2006). Stock market quality in the presence of a traded option. *Journal of Business*, 79(4):2243–2274.

Juurikkala, O. (2012). Credit default swaps and the eu short selling regulation: a critical analysis. *European Company and Financial Law Review*, 9(3):307–341.

Keser, C., Özgümüs, A., Peterlé, E., and Schmidt, M. (2017). An experimental investigation of rating-market regulation. *Journal of Economic Behavior & Organization*, 144:78–86.

Kirchler, M., Huber, J., and Stöckl, T. (2012). Thar she bursts: Reducing confusion reduces bubbles. *American Economic Review*, 102(2):865–883.

Kleinlercher, D., Huber, J., and Kirchler, M. (2014). The impact of different incentive schemes on asset prices. *European Economic Review*, 68:137–150.

Kopányi-Peuker, A. and Weber, M. (2018). Experience does not eliminate bubbles: Experimental evidence. Tinbergen Institute Discussion Paper 2018-092/II.

McIlroy, D. (2010). The regulatory issues raised by credit default swaps. *Journal of Banking Regulation*, 11(4):303–318.

Morgan, G. (2009). Legitimacy in financial markets: credit default swaps in the current crisis. *Socio-Economic Review*, 8(1):17–45.

Noussair, C. N. and Tucker, S. (2013). Experimental research on asset pricing. *Journal of Economic Surveys*, 27(3):554–569.

Noussair, C. N., Tucker, S., and Xu, Y. (2016). Futures markets, cognitive ability, and mispricing in experimental asset markets. *Journal of Economic Behavior and Organization*, 130:166 – 179.

Palan, S. (2010). Digital options and efficiency in experimental asset markets. *Journal of Economic Behavior & Organization*, 75(3):506–522.

Palan, S. (2013). A review of bubbles and crashes in experimental asset markets. *Journal of Economic Surveys*, 27(3):570–588.

Porter, D. P. and Smith, V. L. (1995). Futures contracting and dividend uncertainty in experimental asset markets. *Journal of Business*, 68(4):509–541.

Rabin, M. (2000). Risk aversion and expected-utility theory: A calibration theorem. *Econometrica*, 68(5):1281–1292.

Singh, M. and Andritzky, J. (2005). Overpricing in emerging market credit default swap contracts: Some evidence from recent distress cases. IMF Working Paper No 05/125.

Stöckl, T., Huber, J., and Kirchler, M. (2010). Bubble measures in experimental asset markets. *Experimental Economics*, 13(3):284–298.

Stulz, R. M. (2010). Credit default swaps and the credit crisis. *Journal of Economic Perspectives*, 24(1):73–92.

Sutter, M., Huber, J., and Kirchler, M. (2012). Bubbles and information: An experiment. *Management Science*, 58(2):384–393.

Weber, M., Duffy, J., and Schram, A. (2018). An experimental study of bond market pricing. *Journal of Finance*, 73(4):1857–1892.

A Online Appendix: Experimental Instructions for the Regulated Treatment

Instructions

Welcome to this experiment! Please read these instructions carefully as they explain how you earn money from the decisions that you make. You will be paid privately at the end, after all participants have finished the experiment. On your desk you will find a calculator and scratch paper, which you can use during the experiment.

During the experiment you are not allowed to use your mobile phone or other electronic devices. You are also not allowed to communicate with other participants. If you have a question at any time, please raise your hand and someone will come to your desk.

The experiment consists of four identical rounds. Each round consists of 11 periods, numbered from 0 to 10. Your earnings for each of the four rounds will be in points. **At the end, only your earnings from one randomly chosen round will be paid out to you! The points from the chosen round will be exchanged into euros at the exchange rate 1000 points = 1 euro.** In addition you will receive a show-up fee of 7 euros.

All participants will be randomly divided into groups of 6 people. The group composition will not change during the experiment. You will not know the identity of any group member nor will they know your identity even after the experiment is over. The following describes what you will be doing in each of the four rounds.

Market Setting

You will start the round with an endowment of 20 650 points (your "cash"). During most of the experiment, you will be given an opportunity to trade assets with the other participants in your group (there are two types of assets, assets of type A and assets of type B). In total there are 25 assets of type A and 12 assets of type B. In each period, there will first be a market in which asset A can be traded and after a market in which asset B can be traded.

Holding assets can give you earnings in a way that will be explained below.

If you want to buy some of these assets you can enter the number of assets you want to buy (bid for) at a certain price using the computer interface. You can state as many different bid prices and quantities as you like.

Example (the numbers here provide no indication of what you should enter in the experiment): Imagine that you would like to buy 12 assets if the price per asset is at most 356 points, 7

assets if the price is larger than 356 but no more than 688 points, and only 2 assets if the price is larger than 688 points but no more than 911.5 points. To indicate this, you can enter numbers into the computer interface as follows (if you wanted to enter more numbers you could click on the "show more fields" button):

[Figure 7 appears here in the experimental instructions.]

I would like to buy this quantity	if the price (per asset) is at most
12	356
7	688
2	911.5

show more fields

Figure 7: Input fields of the computer interface. [Not labeled in the instructions.]

If the market price turns out to be 600 points, you will then receive 7 assets for 600 points each (thus NOT 2 plus 7, i.e. the quantities that you enter are for the total number you want to buy at a certain price).

If you want to sell assets you previously bought, you can do something similar. You can enter the number of assets that you want to sell (offer quantity) and the offer price that you would like to receive for those units (the interface will be almost identical to the buying example above). You can again enter multiple combinations of quantities and prices.

The bids and offers that you can enter into the computer interface are restricted as follows:

- You can only enter positive integer number as quantities.
- You can only enter positive numbers as prices (if you want to enter a decimal, use a point and not a comma).
- You cannot try to sell more assets than you have at that moment. Similarly, you cannot try to buy more assets than there are available (which is 25 minus the number of assets you have for assets of type A and 12 minus the number of assets you have for assets of type B).
- You cannot enter bids that you would not be able to pay for (with the amount of cash you have).

- You cannot enter multiple bids to buy assets with the same quantity or the same price.
- Similarly you cannot enter multiple offers to sell assets with the same quantity or the same price.
- You cannot try to buy more assets for a higher price than you would want to buy for a lower price (i.e., if you enter for example the quantity 20 with the price 1850, you cannot enter the quantity 10 with the price 1480 in the fields for your bids to buy assets).
- Similarly you cannot try to sell more assets at a lower price than you would sell at a higher price.
- Finally, all of your sell offers must be at a higher price than your bids to buy (i.e. you cannot sell to yourself).

Market Price and Actual Trades

The market price in each period is determined by supply and demand. This means that the price will be chosen that makes the most trades possible. All trades are then carried out at this single market price, which is centrally determined for your group in each period.

Explanation: Imagine you enter that you would like to buy 6 assets if the price is at most 1500 points and one other participant enters that she would like to buy 9 assets if the price is at most 1500. Imagine further that nobody else in the market enters a buying bid at 1500 points or a higher price. This means that *all participants of the market together* would like to buy 15 assets if the price is at most 1500 points per asset. The aggregation of the buy orders can be done for all prices and yields the market demand schedule. This demand schedule contains the information of all buy orders for *all participants of the market together* and can be represented by a step function as below. On the horizontal axis you can see the total quantity demanded for each price on the vertical axis (this is a very simple example and the quantities and numbers provide no indication of what you should enter in the experiment). In the graph of this simple example you can see that all participants of the market together are willing to buy up to 75 assets at a price of 500 points per asset, only 50 assets at a price of 1000 points per asset, and only 15 assets at a price of 1500 points per asset.

[Figure 8 appears here in the experimental instructions.]

A similar schedule can be derived for the supply side of the market, aggregating all the sell offers. When drawn in the same graph, the supply schedule is an increasing step function.
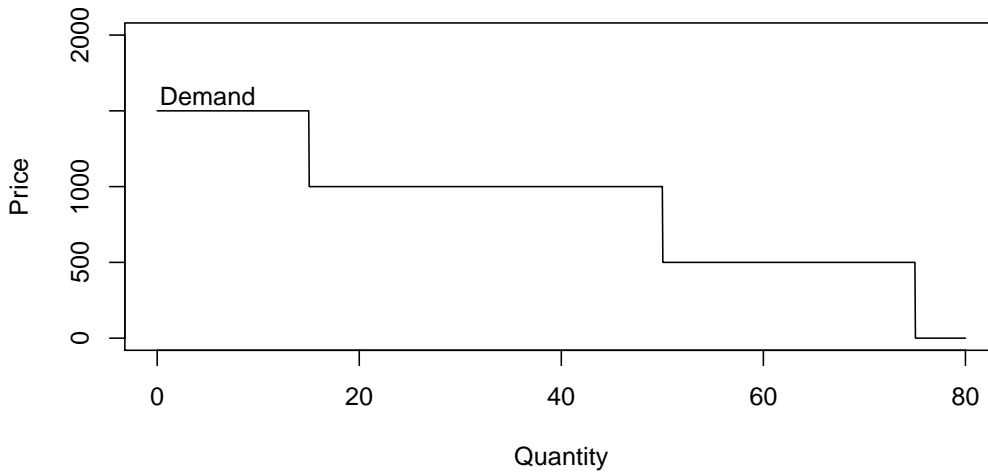
Figure 8: Demand schedule. [Not labeled in the instructions.]

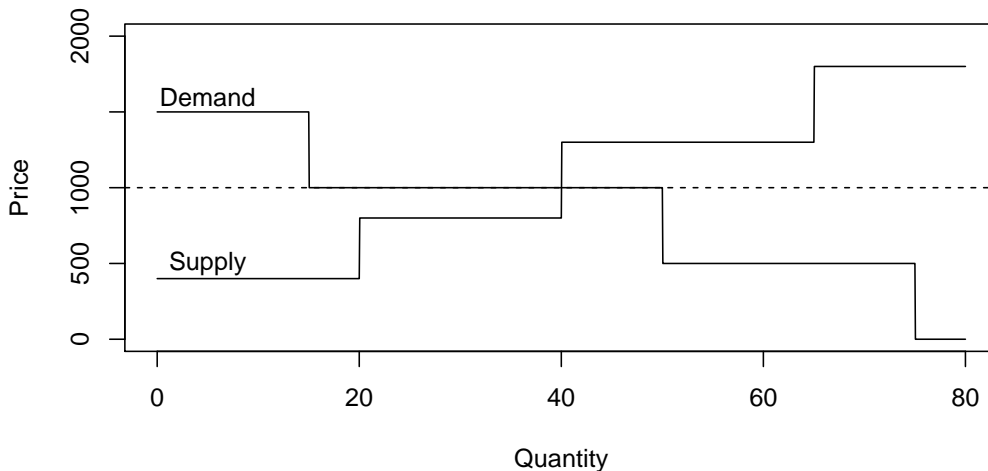[Figure 9 appears here in the experimental instructions.]

Figure 9: Demand and supply schedules. [Not labeled in the instructions.]

The market price is the price at which the two curves intersect (in this example 1000). Note that at this price, 10 more assets are demanded than supplied (50 assets are demanded while only 40 are supplied). In this case a random selection of 10 bids *from all the bids at the market price* would not be fulfilled (it is similarly possible that there is more supply at the market price than demand).

In some rare cases there can also be a whole interval of prices at which most trades can be carried out and the demand and supply schedule overlap vertically. In such cases the middle of the interval will be the market price. If no bids or offers are made at all or if

all bids to buy are at lower prices than all offers to sell there will be no trade and also no market price.

You will always be told the market price after the trading. You will not be told the total number of trades in the market (except if there are none).

Properties of Asset A

There will be no trading in period 10. If you hold assets of type A in period 10, you will receive 1000 points for each asset, provided that the assets have not defaulted (more on this below).

In each of the periods 1-10 you receive interest payments on your asset A holdings (if they have not defaulted). The interest payment per asset is 12% of the final value (1000 points), which means that you will receive 120 points for each asset A you hold in a period. These earnings will be paid to a separate account – they are part of your earnings for the round, but you cannot use those points to buy more assets.

Asset A has a special property. There is a constant possibility of "default". At the beginning of each period (from period 1 on to period 10) it is determined whether a default occurs or not. How this probability of default is determined will be explained shortly. If a default occurs, all assets will become completely (!) worthless for all periods remaining in the round. This means that from the period of default onward there will be no interest payments and there will be no payoff of 1000 points per asset after period 10.

Period 0 Trading of Asset A and Probability of Default

The first period of each round is a special period (period 0). In this period, none of the participants holds any of the 25 assets of type A. You can try to buy them as in the regular periods 1,2,...,9, but instead of buying them from other participants you will buy them directly from the experimenter. The computer interface is similar to the computer interface in the regular periods (i.e. you can enter the number of assets you want to buy at a certain price). The experimenter only sells assets in period 0 and does not interfere with the market thereafter. The experimenter will sell all assets in this period, for the highest unique price at which all of them can be sold (if there is not enough demand to sell all assets even at a minimal price, the experimenter will sell as many assets as are demanded).

The outcome of this period 0 is important not only because it distributes the type A assets amongst the participants in the group. It also determines the probability that these assets default in each of the other periods. The higher the market price is in period 0, the lower is the probability that there will be a default (this probability is determined in period 0 and stays constant once period 0 is over). The following graph

shows you the exact relationship between period 0 price and default probability. On the horizontal axis you can see possible period 0 prices and on the vertical axis you can see the default probability that would result from each price.

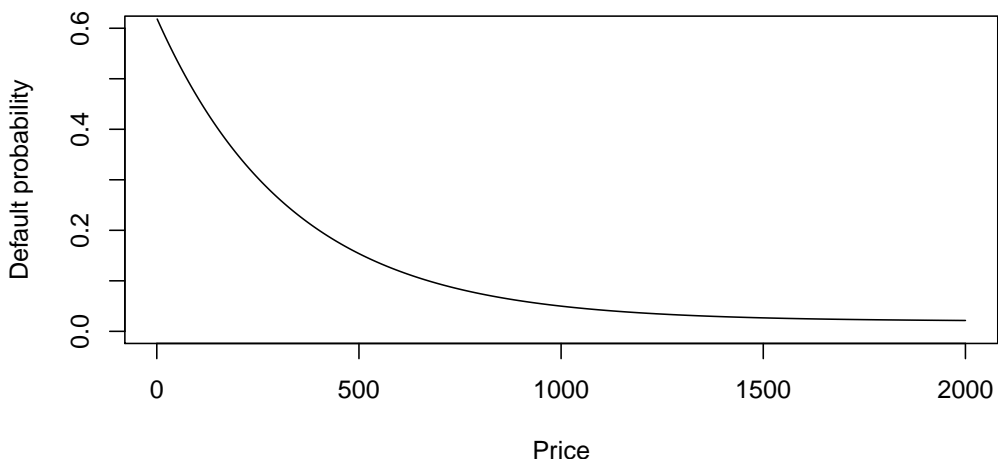[Figure 10 appears here in the experimental instructions.]

Figure 10: Default probability function. [Not labeled in the instructions.]

The following short table gives you some period 0 prices and the corresponding default probabilities.

[Table 4 appears here in the experimental instructions.]

Table 4: Values Default Probability Function. [Not labeled in the instructions.]

Price	1	100	200	400	600	800	1000	1500	2000	3000	5000
Prob.	0.618	0.464	0.349	0.201	0.119	0.074	0.050	0.027	0.021	0.020	0.020

At the beginning of each of the regular periods, the computer program determines whether or not there is a default *for the whole market* using the default probability determined by the price in period 0.

Properties of Asset B

In the beginning of a round, each participant has 2 assets of type B. Type B assets are traded in the same way as assets A, but for type B assets period 0 does not play a special role (type B assets are traded in period 0 in the same way as in any of the periods 1,...,9).

Type B assets do not pay any interest and they are not exchanged for points in period 10. However, they become valuable if there is a default of type A assets. If you have type A assets when a default makes them worthless, type B assets you possess may give you points. You will receive 1000 points for each type B asset as long as you hold more type A assets than type B assets or an equal number of both types. If you have more type B assets than type A assets at the time of default you will receive 1000 points times the number of type A assets. You will receive nothing for the remaining type B assets. For example, assume that at the time of default, you hold 4 assets of type A. If you have 2 assets of type B you will receive 2000 points. If you hold 4 assets of type B you will receive 4000 points and if you hold 6 assets of type B you will also receive 4000 points.

There is a special rule for buying type B assets. In any period, you may not buy so many type B assets that you would have more of them than of type A assets. If you have for example 8 assets of type A and 4 assets of type B at a certain point, you can try to buy at most 4 type B assets. This does not mean that you cannot end up having more type B assets than type A assets – you may for example have equally many type A and type B assets at some point and then decide to sell type A assets, which would leave you with more type B assets than type A assets. However, as explained before, the type B assets in excess of type A assets will not pay you 1000 points in case of default of type A.

Information on Defaults

Although it will be determined at the beginning of each period whether there is a default in this period or not, we will not tell you whether or not a default has occurred! You will always continue the experiment as if no default has ever occurred – only after each 11 period round we will tell you if there was a default or not and if so, in which period the (earliest) default occurred. Your earnings for that round are then determined as of the period the default occurred (your earnings are your cash holdings and the points earned in your interest account at the time of default, plus the earnings from your type B assets – your type A assets at the time of default do not affect your earnings in any way). This means that any action you took after the default occurred does not affect your earnings (but when you take the decisions you don't know whether a default had previously occurred).

Summary of the Information

- 4 identical rounds
- 10 regular periods per round
- 20 650 points cash to buy assets per round
- Period 0 is special and the price of type A assets determines the default probability.

- If there is a default all type A assets become completely worthless. Earnings are then based on interest paid before the default, cash holdings at the time of default, and earnings from type B assets.
- If there is a default, you receive 1000 points for each type B asset you have at the time of default if you have at least as many type A assets as type B assets. If you have more type B assets than type A assets you will receive 1000 points times the number of type A assets you have.
- Each type A asset pays 120 points interest per period (if the asset is not in default).
- Points earned on type A assets in the interest account cannot be used to buy assets.
- If there is no default, then in period 10 each type A asset is exchanged for 1000 points. Type B assets are not exchanged for points in period 10.
- You cannot buy so many type B assets that you would have more of them than of type A assets.
- We don't tell you during a round if there is a default, you always continue as if there is none. However, the default is used to determine your round earnings.

B Online Appendix: Comprehension Test Questions in the Regulated Treatment

We reproduce the test questions here and add checkmarks to indicate correct answers. Note that subjects had to answer all questions on a given screen correctly to proceed to the next screen. If they did not answer all questions correctly and tried to proceed to the next screen, they received the following error message: "You did not answer all questions correctly. Take another look at the instructions or raise your hand if you need help."

B.1 Screen 1

In period 0, the experimenter tries to sell all 25 type A assets. Imagine that all of the other 5 participants in your market enter only one bid each and that all of their bids are equal, specifying a quantity of 2 and a price of 1500. Imagine that you enter the following three bids:

Quantity 4 and Price 2000,

Quantity 8 and Price 900,

Quantity 25 and Price 50.

What will be outcomes of this?

  (a) All others receive 2 type A assets each and pay a price of 1500 points per asset. You receive 15 type A assets, some for a higher price than 1500 points, some for a lower price.
  (b) All others receive 2 type A assets each and you receive 15 type A assets. Everyone pays 50 points per asset. ✓
  (c) All others receive 2 type A assets each and you receive type A 4 assets. Everyone pays 1500 points per asset.
  (d) All others receive 2 type A assets each and you receive 25 type A assets. Everyone pays 50 points per asset.

In period 0 in the market for asset A, imagine that 4 of the other 5 participants in your market enter only one bid each and that all of their bids are equal, specifying a quantity of 5 and a price of 800. The fifth other participant and you both enter a quantity of 10 and a price of 600. What will be outcomes of this?

(a) The market price will be 600. The 4 participants that entered the same bids receive 5 type A assets each, you and the person entering the same bid as you will receive 5 type A assets each.

(b) The market price will be 800. The 4 participants that entered the same bids receive 5 type A assets each, you and the person entering the same bid as you will receive 5 type A assets each.

(c) The market price will be 600. The 4 participants that entered the same bids receive 5 type A assets each, you and the person entering the same bid as you will receive 5 type A assets *together* (who receives how many exactly will be determined randomly). ✓

(d) The market price will be 800. The 4 participants that entered the same bids receive 5 type A assets each, you and the person entering the same bid as you will receive 5 type A assets *together* (who receives how many exactly will be determined randomly).

Imagine that you want to buy 25 assets in total if the price is at most 204 points per asset. If the price is larger than 204 points but at most 788 points you want to buy 13 assets in total. If the price is larger than 788 points but at most 1800.5 points you want to buy 8 assets. What do you enter into the corresponding part of the computer interface?

(a) Quantity: 25, Price 204, Quantity 13, Price 788, and Quantity 8, Price 1800.5. ✓
(b) Quantity: 8, Price 1800.5, Quantity 5, Price 788, and Quantity 12, Price 204.

B.2   Screen 2

In periods 1 to 9 you can trade the asset with the other members of your group. You can enter bids to buy assets and offers to sell assets. Imagine that you consider both, buying and selling assets of one type. Which of the following is correct?

(a) You cannot try to buy assets at a higher price than the lowest price at which you are willing to sell assets of the same type. ✓
(b) You can try to bid for as many assets as you like at any price. If the market price turns out to be high, your cash holdings may become negative.
(c) You can make sell offers for the same quantity at different prices.

In the very beginning of each period from period 1 to 10 it will be determined whether there is a default. If there is a default, what happens to the assets of type A?

(a) The assets will not pay any interest anymore for the remaining periods of this round. In the last period they will nevertheless be exchanged into 1000 points per asset.

(b) The asset will not pay any interest anymore for the remaining periods of the round and participants will not receive any points for the assets in the last period. ✓

The default probability depends on the market price of asset A in period 0. Which of the following is NOT correct?

(a) After period 0 has ended, the probability that there is a default is fixed for the rest of the round.
(b) You can see in the corresponding graph in the instructions how the price in period 0 determines the probability of default.
(c) When a new round starts, the default probability in the round before does not matter anymore for the new round.
(d) The default probability for each period is determined in the period before. ✓

Imagine that in period 6 you hold 7 type A assets. Other members of your group each offer to sell 3 units at a price of 1100 and ask to buy 6 units at a price of 1000. You offer to sell 7 units at a price of 1151 and ask to buy 6 units at a price of 1149. What trades are you involved in, in period 6?

(a) You sell 7 units at a price of 1151.
(b) You sell 7 units at a price of 1149.
(c) You sell 7 units at a price of 1100.
(d) You sell 7 units at a price of 1000.
(e) You buy 6 units at a price of 1000.
 (f) You buy 6 units at a price of 1100. ✓
(g) You buy 6 units at a price of 1149.
(h) You buy 6 units at a price of 1151.

B.3 Screen 3

If you hold type A assets at some point you may receive interest payments. Which of the following is correct?

(a) You can use the money from your interest account to buy assets in later periods.
(b) For each type A asset you are holding in a period you receive an interest payment of 120 points (if there has been no default before). ✓
(c) A type A asset only pays interest in the period right after you bought it, even if you hold it for multiple periods.

There are rounds and periods in this experiment. Which of the following is correct?

(a) There are 4 rounds in the experiment (each consisting of 10 regular periods and period 0). When you start a new round you have 20650 points in cash, 0 points in your interest account, no assets of type A, and 2 assets of type B. ✓

(b) In each of the regular periods you have 20650 points of cash to buy assets with.

(c) Type A assets only last for one period, once the interest of a type A asset has been paid the asset always loses its value.

In each period there is the possibility of a default that makes all type A assets completely worthless. What happens when such a default occurs?

(a) You will immediately be informed that the default occurs, your earnings are determined and your group will continue straight with the next round.

(b) You will only be informed after the end of the round that this default occurred. Without you knowing it, the further actions you take during the rest of the round will no longer influence your earnings of the round. ✓

B.4 Screen 4

If there is a default, you can earn points with the type B assets you have. Which of the following is correct?

(a) For each type B asset you have at the time of default you receive 1000 points – but only if you have at least as many type A assets as type B assets, otherwise you receive less. ✓

(b) You will only be informed at the end of a round if a default occurred before. The number of type B assets you have after period 10 determine your earnings if a default occurs, also if this default occurs in an earlier period.

(c) You receive interest for each period that you have held a type B asset before the default occurs.

(d) You cannot earn points with type B assets if a default occurs. If no default occurs, each type B asset is exchanged for 1000 points at the end of the round.

You can trade with type B assets. Which of the following is correct?

(a) As in the case of trade with type A assets, also the price of type B assets in period 0 determines the probability of default of the assets.

(b) Each participant has 2 type B assets in the beginning of each round. Type B assets are traded in period 0 exactly in the same way as in periods 1,...,9. ✓

(c) In each period, type B assets are traded before type A assets.

There are some restrictions on buying and selling assets. Which of the following is NOT correct?

(a) You cannot try to buy more assets than there are (at most 25 assets of type A and 12 assets of type B).
(b) You cannot try to sell more assets than you have.
(c) You cannot have more assets of type B than of type A. ✓
(d) You cannot try to buy so many assets of type B that you would have more of them than of type A assets.

Assume that a default occurs in period 5. In that period, you hold 5 assets of type A and 8 assets of type B. In period 10 you hold 9 assets of type A and 9 assets of type B. How much will you receive for your type B assets in this round altogether?

(a) 0 points
(b) 1000 points
(c) 5000 points ✓
(d) 8000 points
(e) 9000 points

C   Online Appendix: Differences in Instructions and Test Questions between Treatments

Instructions and test questions are very similar between treatments. Below, the differences between treatments *REG* and *FREE* are detailed. The full instructions and test questions of the control treatment from Weber et al. (2018) can be found in the online appendix to that paper. In short, the instructions in the control treatment are very similar to the ones reproduced here, without any mention of asset B (and referring to asset A just as the asset).

C.1   Differences in Instructions

The instructions in the unregulated treatment are very similar to the instructions in the regulated treatment. Only the explanations about the regulations concerning type B assets are left out. To be precise, the instructions are different in the following points:

- The second paragraph under the heading "Properties of Asset B" reads "Type B assets do not pay any interest and they are not exchanged for points in period 10. However, they become valuable if there is a default of type A assets. If there is a default, which makes type A assets worthless, you will receive 1000 points for each type B asset at the time of default."
- The third paragraph under the heading "Properties of Asset B" in the regulated treatment is removed in the unregulated treatment.
- The sixth bullet point in the summary reads "If there is a default, you receive 1000 points for each type B asset you have at the time of default."
- The second to last bullet point in the regulated treatment is removed in the unregulated treatment.

C.2   Differences in the Comprehension Test Questions

The first three screens of test questions are identical in both treatments. Screen 4 is as follows in the unregulated treatment:

If there is a default, you can earn points with the type B assets you have. Which of the following is correct?

(a) For each type B asset you have at the time of default you receive 1000 points. ✓
(b) You will only be informed at the end of a round if a default occurred before. The number of type B assets you have after period 10 determine your earnings if a default occurs, also if this default occurs in an earlier period.
(c) You receive interest for each period that you have held a type B asset before the default occurs.
(d) You cannot earn points with type B assets if a default occurs. If no default occurs, each type B asset is exchanged for 1000 points at the end of the round.

You can trade with type B assets. Which of the following is correct?

(a) As in the case of trade with type A assets, also the price of type B assets in period 0 determines the probability of default of the assets.
(b) Each participant has 2 type B assets in the beginning of each round. Type B assets are traded in period 0 exactly in the same way as in periods 1,...,9. ✓
(c) In each period, type B assets are traded before type A assets.

There are some restrictions on buying and selling assets. Which of the following is NOT correct?

(a) You cannot try to buy more assets than there are (at most 25 assets of type A and 12 assets of type B).

(b) You cannot try to sell more assets than you have.

(c) You cannot have more assets of type B than of type A. ✓

Assume that a default occurs in period 5. In that period, you hold 5 assets of type A and 8 assets of type B. In period 10 you hold 9 assets of type A and 9 assets of type B. How much will you receive for your type B assets in this round altogether?

(a) 0 points

(b) 5000 points

(c) 8000 points ✓

(d) 9000 points

D   Appendix (for Online Publication): Graphs of Prices in all Markets

Figures 1 to 8 show the market prices in the bond markets in all rounds and periods for all groups (Figures 7 and 8 show these graphs of the control treatments without CDS from Weber et al., 2018). Each row corresponds to one group, starting with the first round on the left and ending with the fourth round on the right. Market prices are shown with red circles. Red crosses show the mean of the highest bid and the lowest offer price when no trade is carried out but when both bids and offers are present. The equilibrium fundamental value is drawn with a solid black line and the price leading to the highest possible expected earnings for all subjects together is drawn with a dashed black line. Furthermore, the actual fundamental value within a round (which depends on the price in the IPO and is different across groups and rounds) is drawn with a dotted blue line. As there is no more trade in the tenth period, periods only reach from 0 (the IPO) to 9. The fourth round of group 10 does not show prices for most periods due to the software failure described in Footnote 9.

Figures 9 to 14 similarly show the market prices in the CDS markets. Here, period 0 is just a regular trading period, as there is no IPO of credit default swaps. Equilibrium and actual fundamental value (the latter depending on the IPO price in the bond market) are again drawn with a solid black line and a dotted blue line. There is no black dashed line, as such a similar "collusive equilibrium price" does not exist in the CDS market (as there is no IPO).
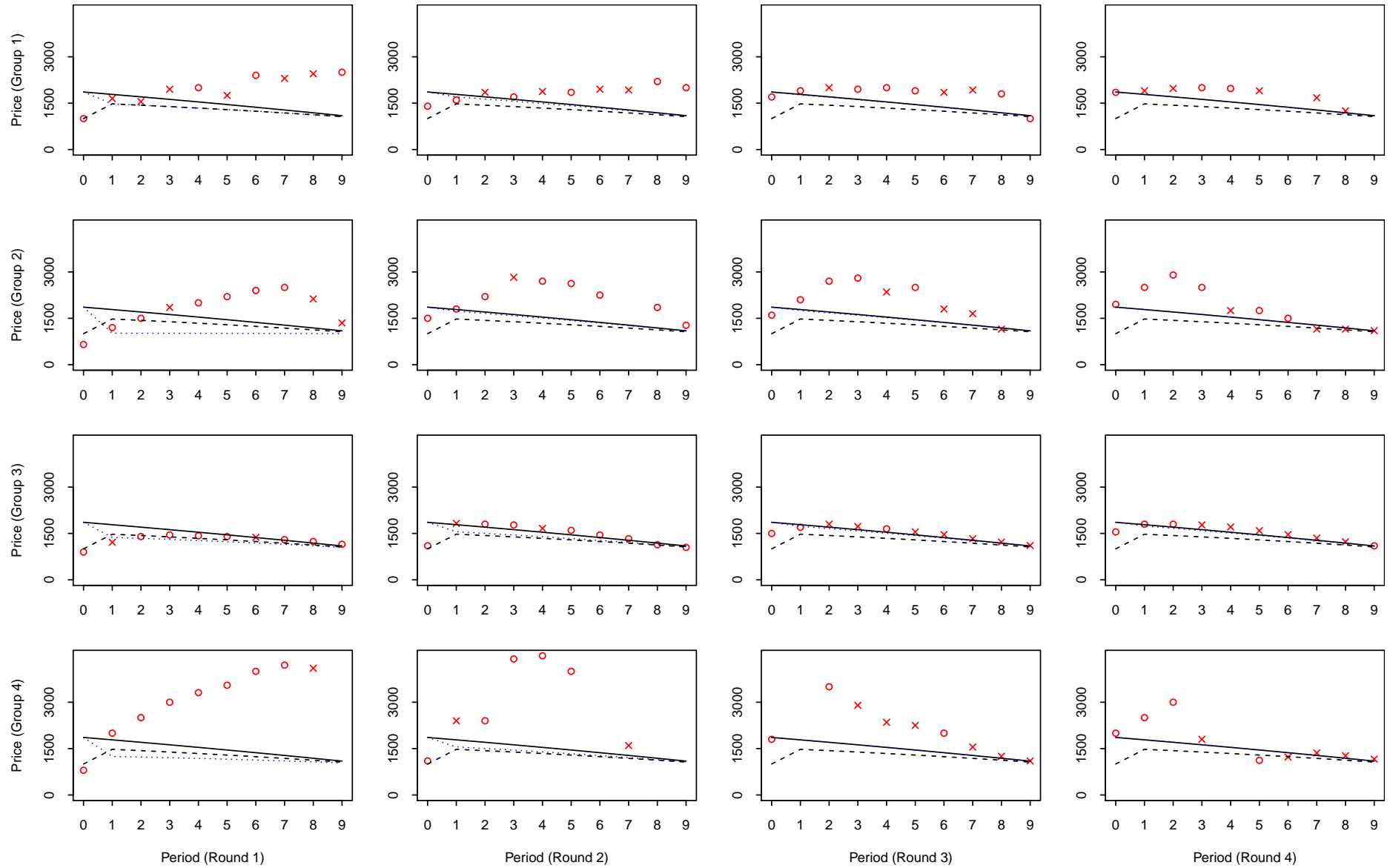
Figure 1: Bond Market Prices in all Periods and Rounds, Groups 1 to 4, Treatment *REG*
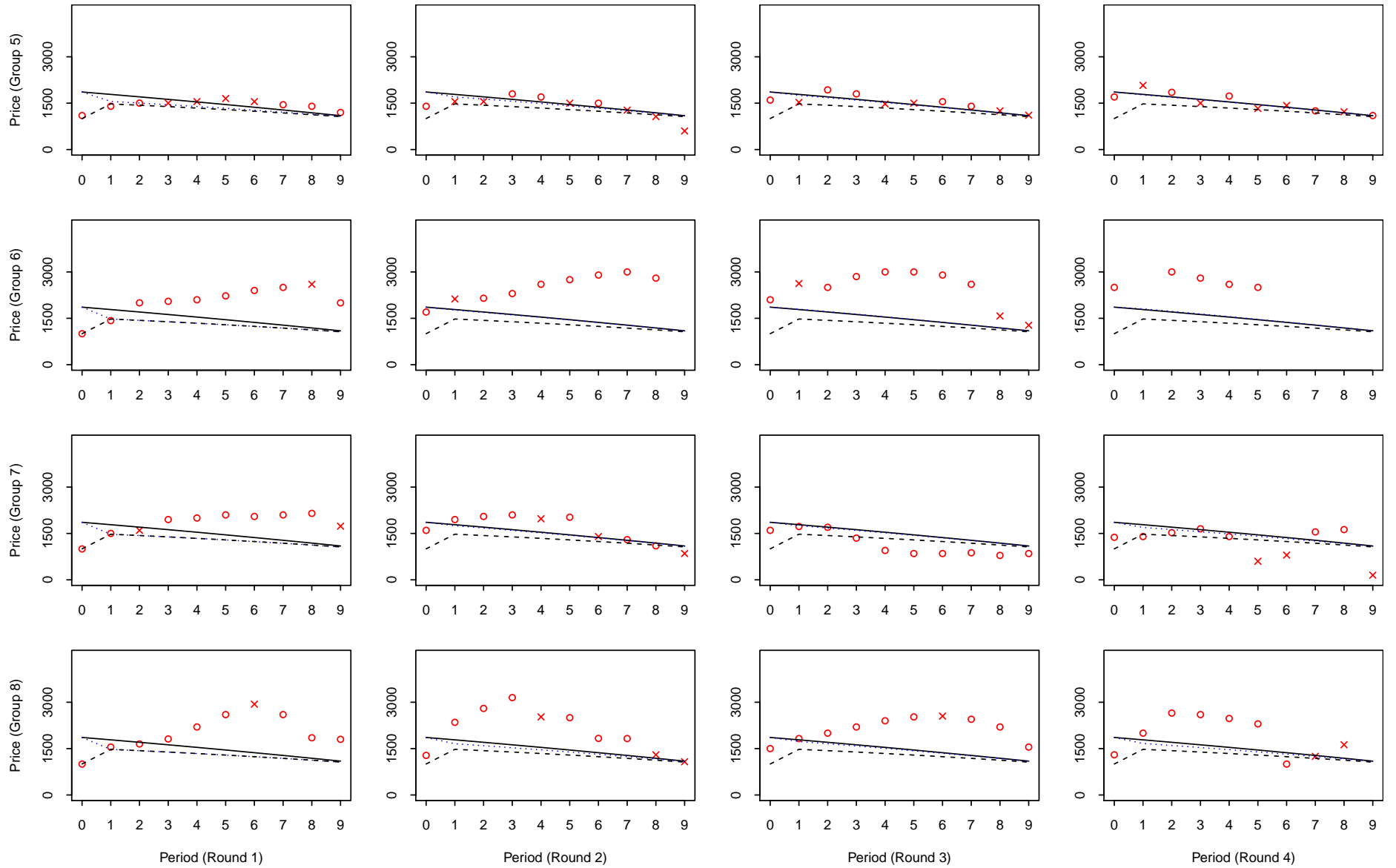
Figure 2: Bond Market Prices in all Periods and Rounds, Groups 5 to 8, Treatment *REG*
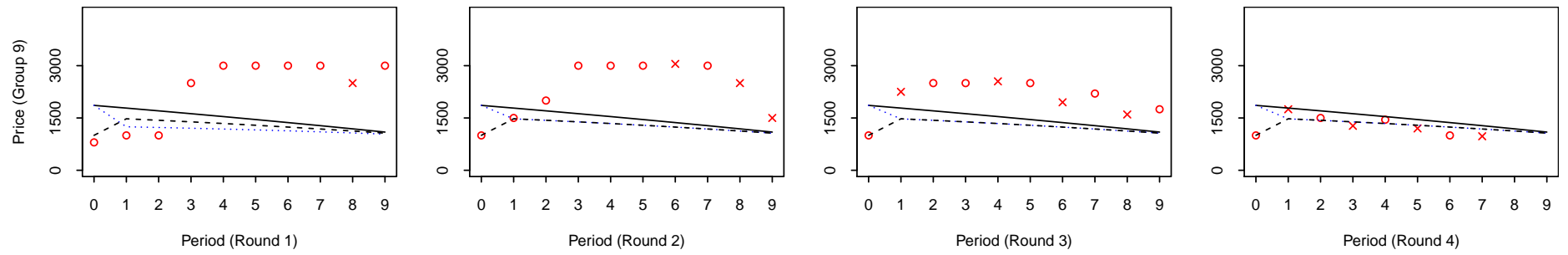
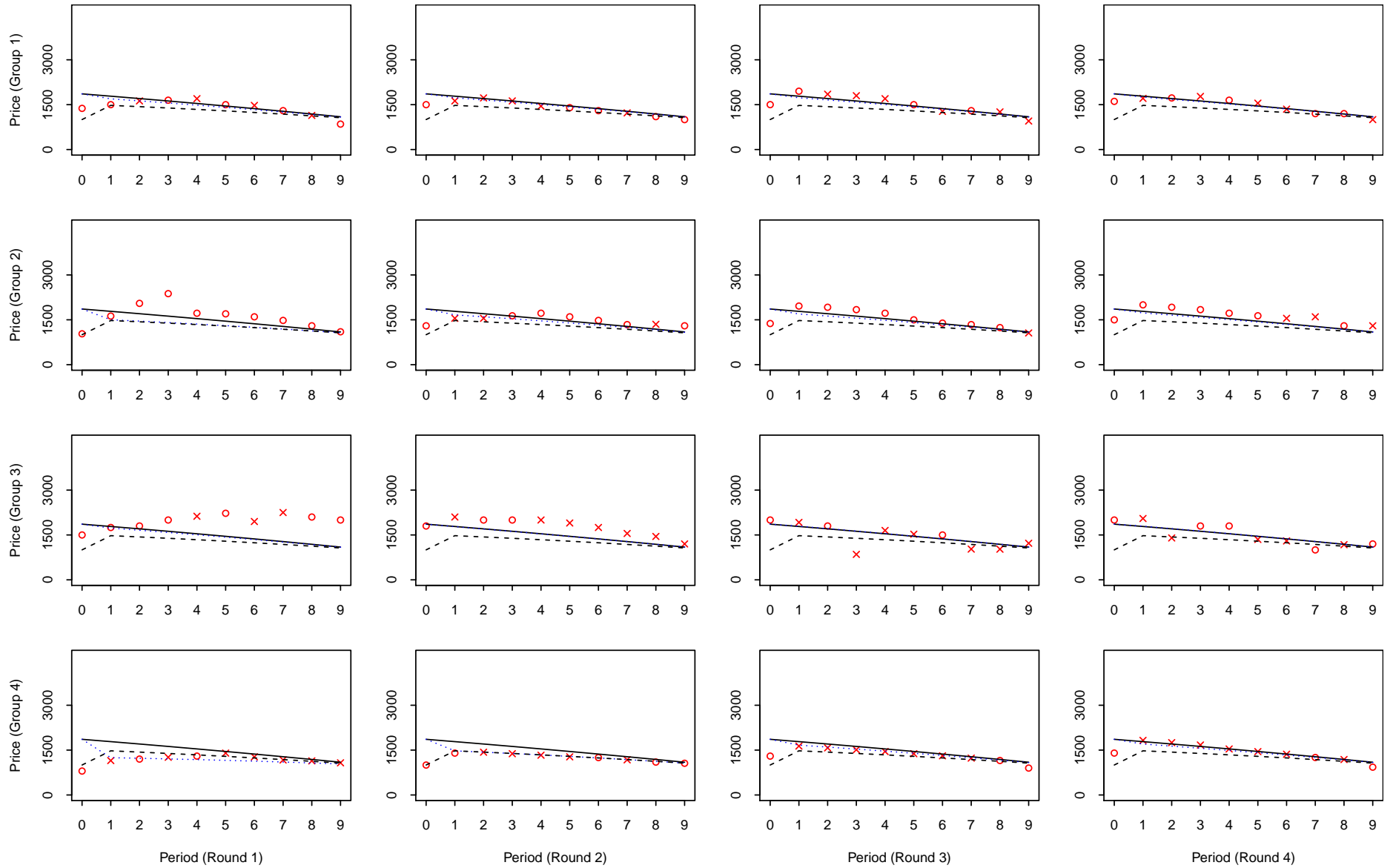Figure 3: Bond Market Prices in all Periods and Rounds, Group 9, Treatment *REG*

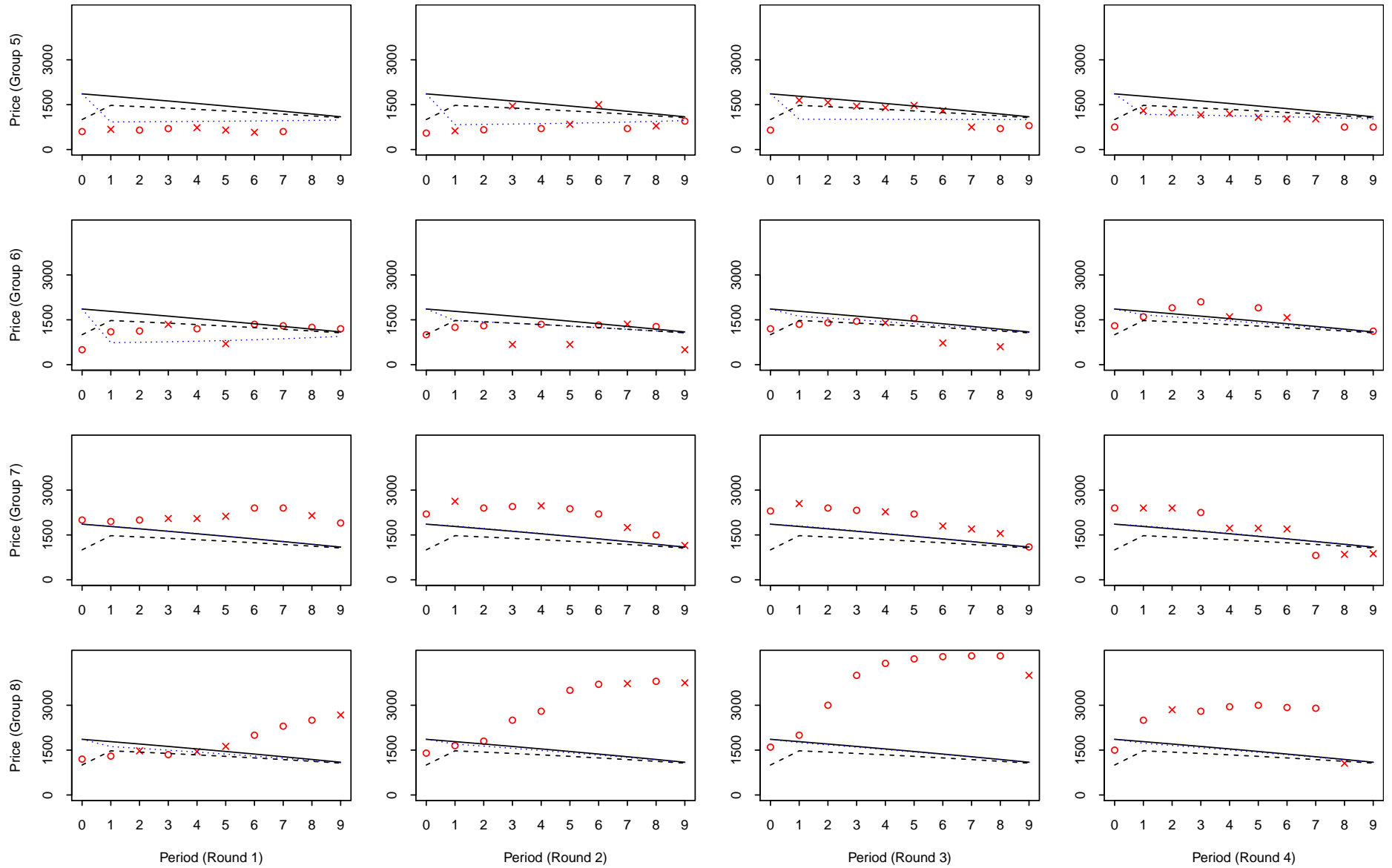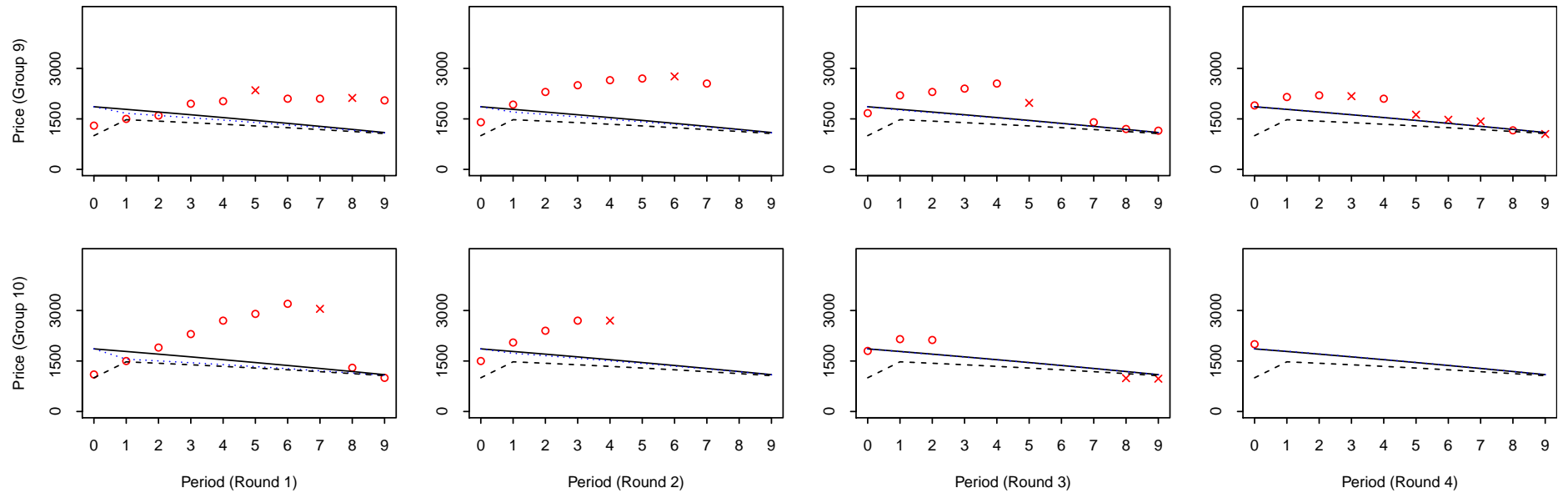Figure 4: Bond Market Prices in all Periods and Rounds, Groups 1 to 4, Treatment *FREE*

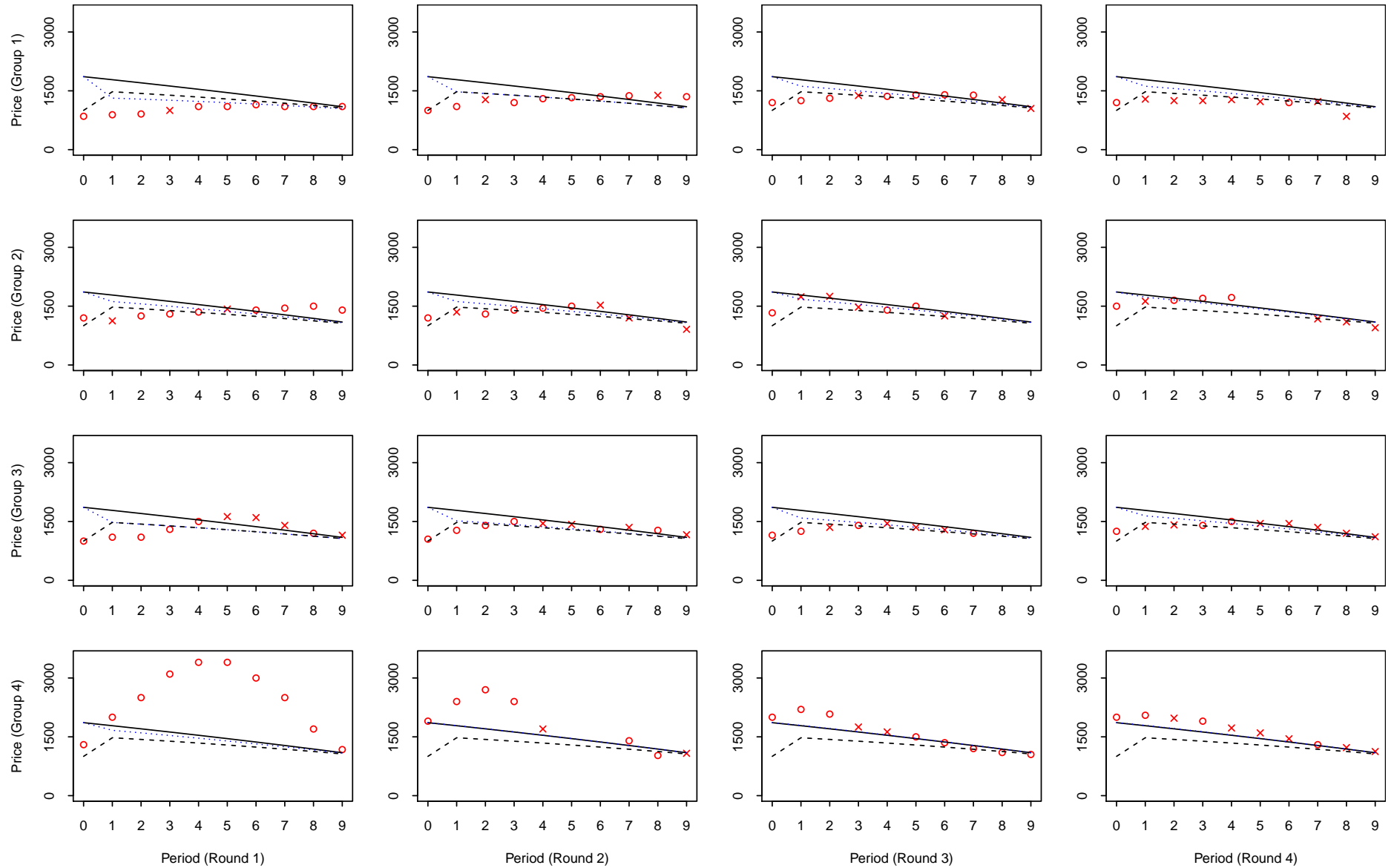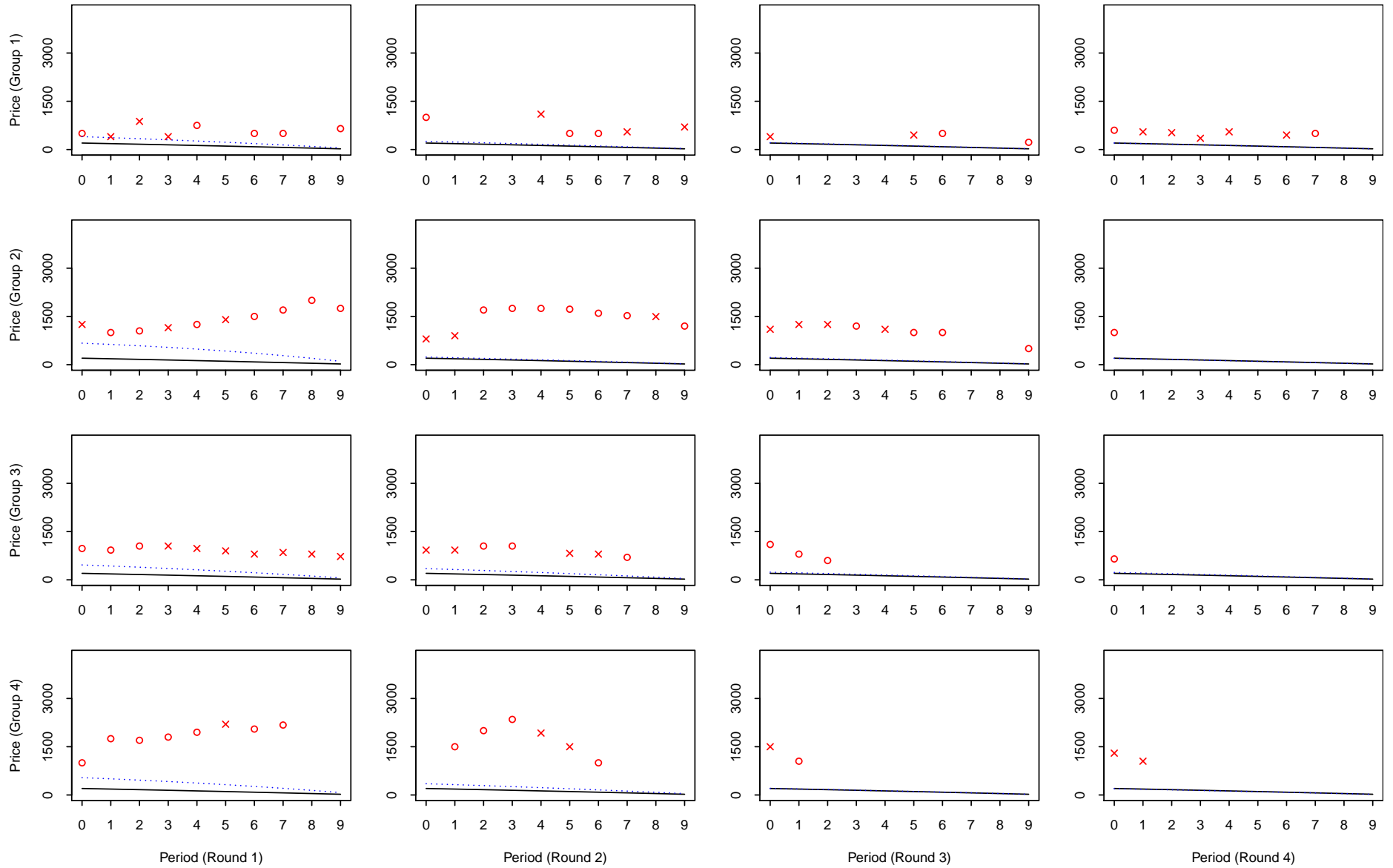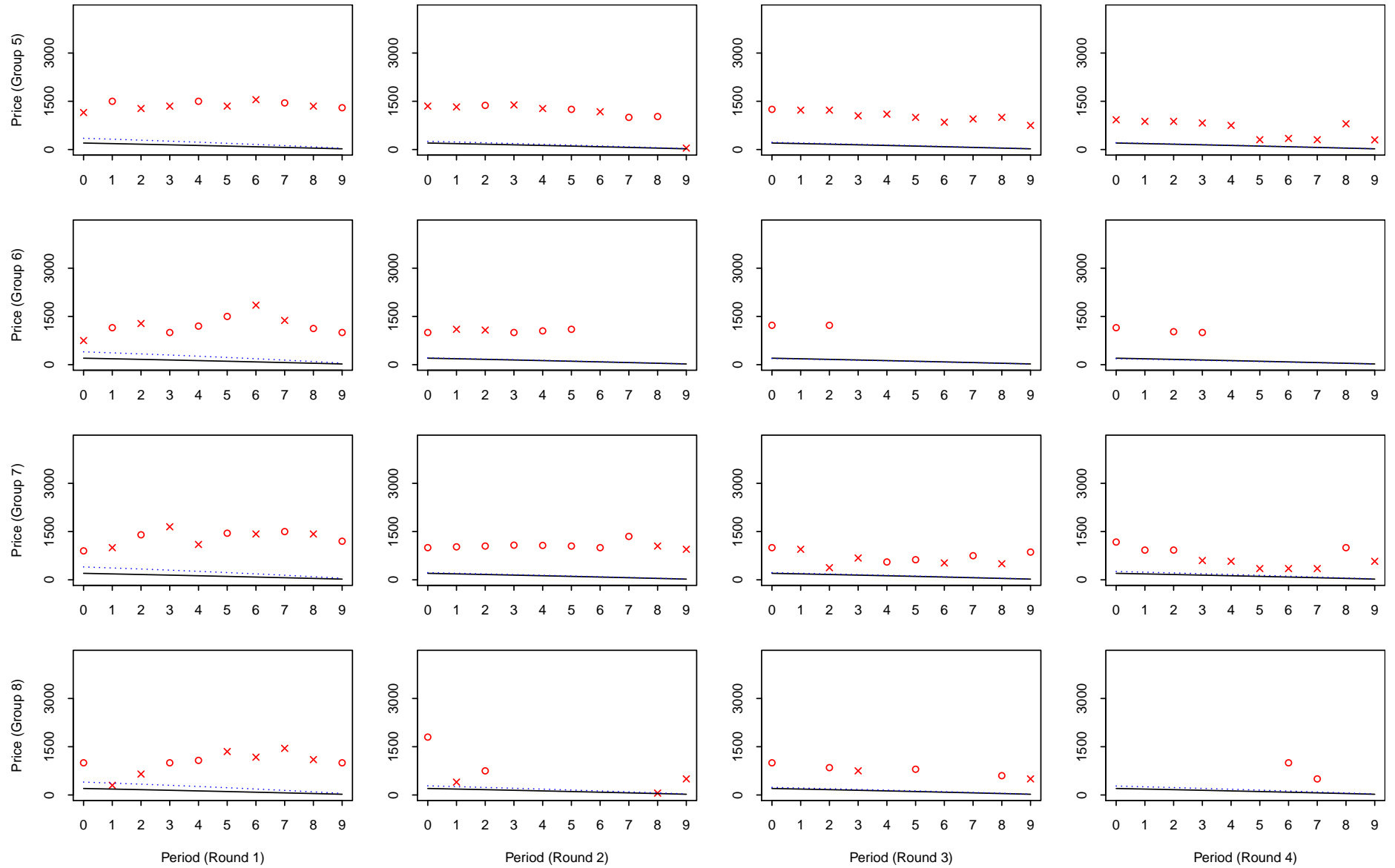Figure 5: Bond Market Prices in all Periods and Rounds, Groups 5 to 8, Treatment *FREE*
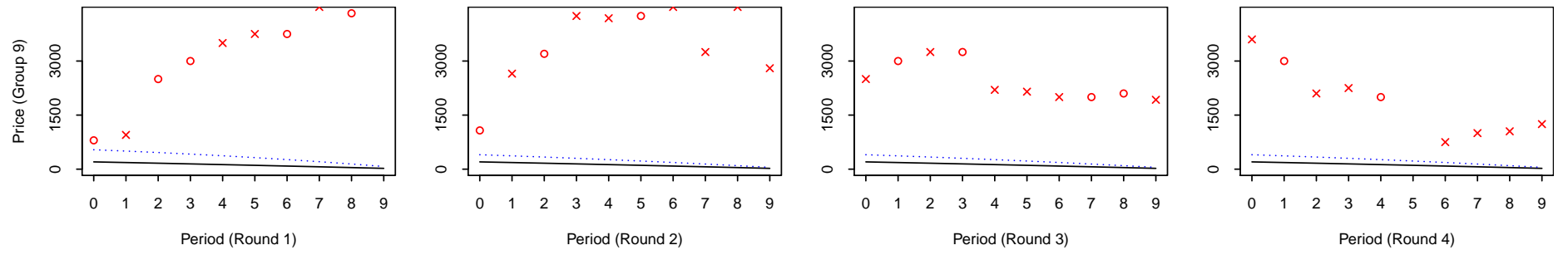
Figure 6: Bond Market Prices in all Periods and Rounds, Groups 9 to 10, Treatment *FREE*

Figure 7: Bond Market Prices in all Periods and Rounds, Groups 1 to 4, Treatment without CDS (Weber et al., 2018)

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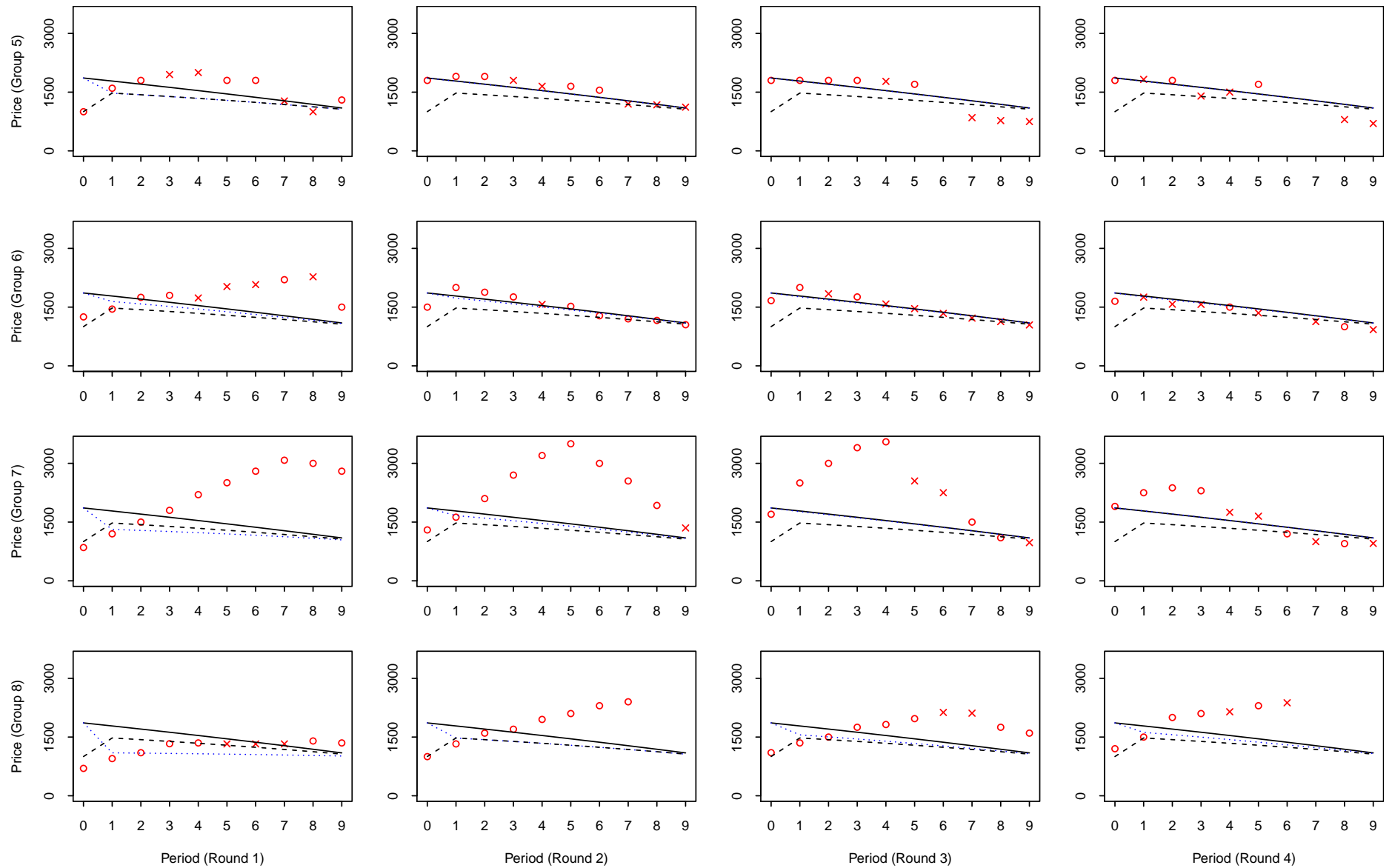
Figure 8: Bond Market Prices in all Periods and Rounds, Groups 5 to 8, Treatment without CDS (Weber et al., 2018)

Figure 9: CDS Market Prices in all Periods and Rounds, Groups 1 to 4, Treatment *REG*

Figure 10: CDS Market Prices in all Periods and Rounds, Groups 5 to 8, Treatment *REG*

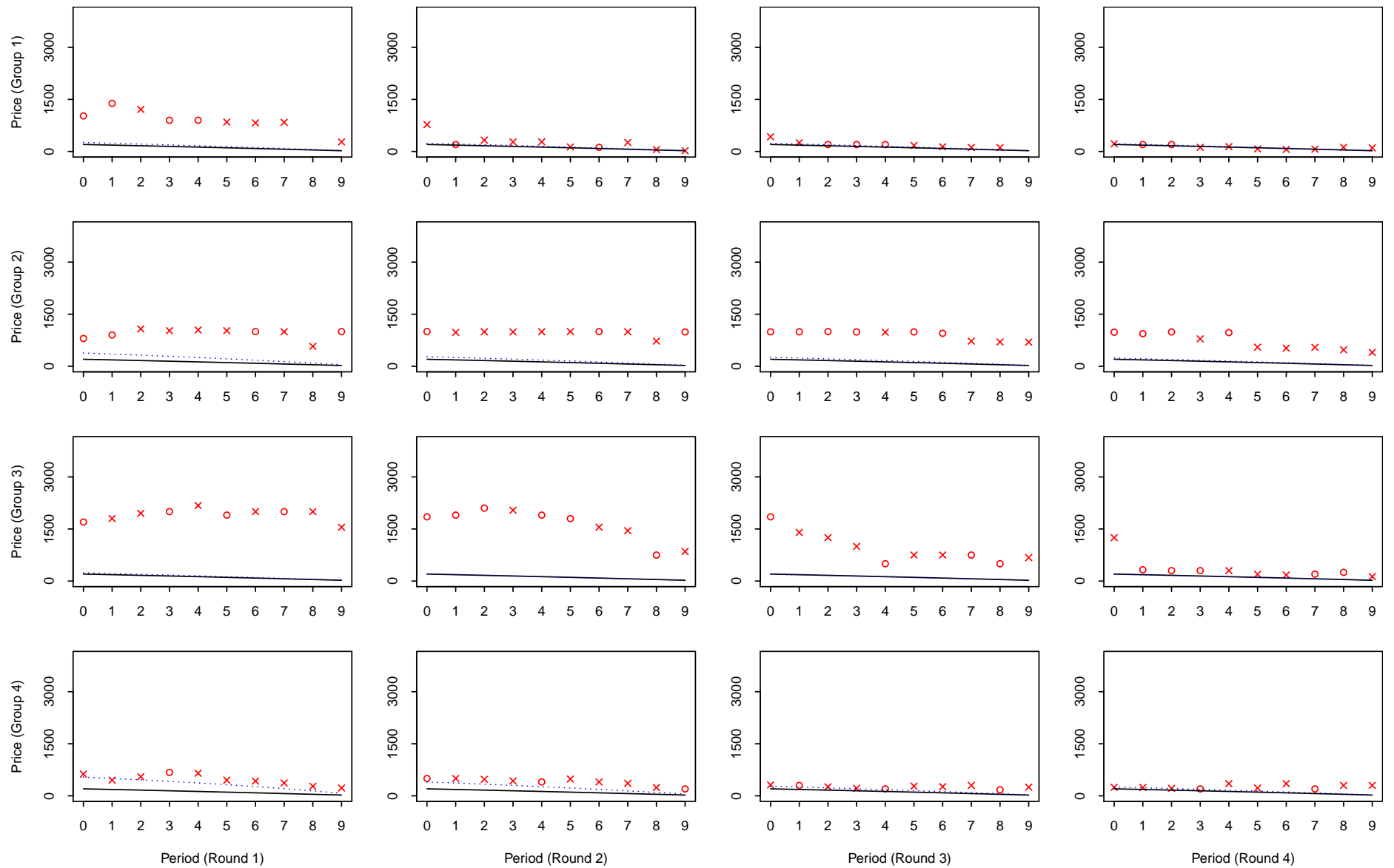Figure 11: CDS Market Prices in all Periods and Rounds, Group 9, Treatment *REG*

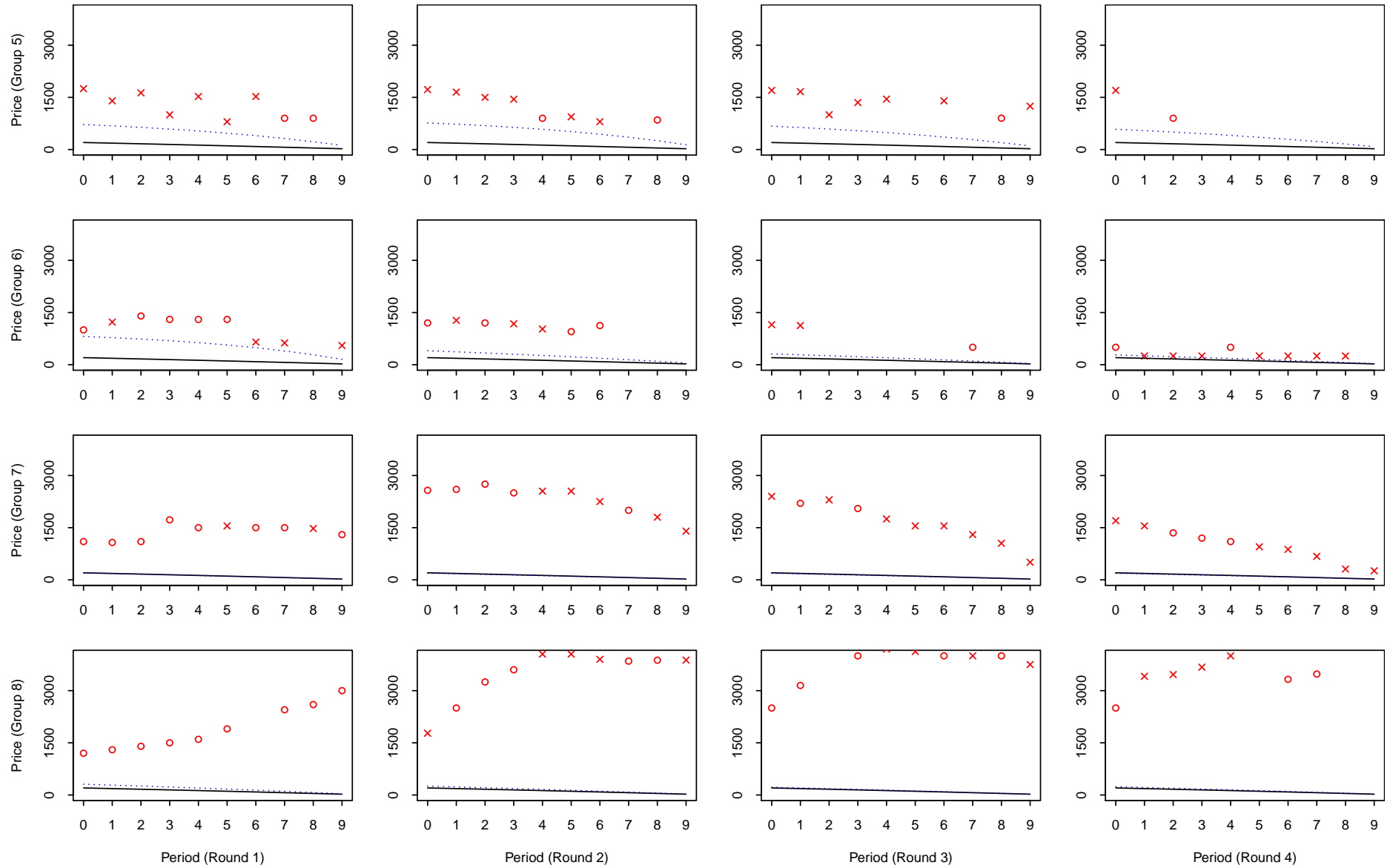Figure 12: CDS Market Prices in all Periods and Rounds, Groups 1 to 4, Treatment *FREE*

Figure 13: CDS Market Prices in all Periods and Rounds, Groups 5 to 8, Treatment *FREE*
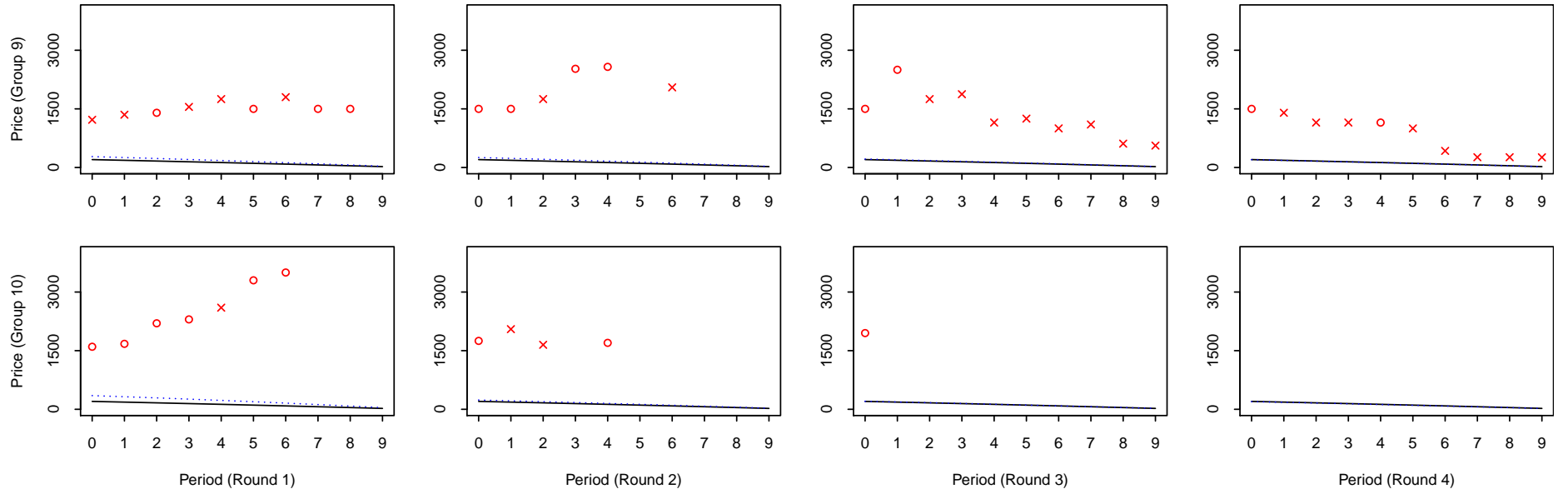
Figure 14: CDS Market Prices in all Periods and Rounds, Groups 9 to 10, Treatment *FREE*