Use of Security Bonds for Unconventional Gas Development: an Economic Experiment

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Abstract

Recent developments in drilling technology promise significant benefits from extraction of unconventional gas. At the same time, the deployment of this technology creates serious concerns about the negative effects it may have on agriculture and on the environment. This paper applies a behavioural approach to explore possibilities for improved negotiation outcomes between unconventional gas developers and host landowners using economic experiments in the laboratory. The paper specifically focuses on the role that security bond could have in resolving some of the conflicts surrounding unconventional gas development. The empirical findings from the economic experiments show that a security bond deposited by a developer prior to the commencement of the gas extraction can result with improved negotiation outcomes between developers and host landowners. Our findings suggest that the security bond is effective because it mitigates the effects of loss averse behaviour by landowners that do not hold sub-surface extraction rights.

Keywords: natural resource rent, security bond, unconventional gas, ultimatum game.

JEL codes: Q15, Q35, Q40, Q53.

1 Introduction

Unconventional gas is seen as a source of plentiful and cleaner energy (Mason et al, 2015). Its development promises economic growth in regional areas including significant local employment benefits (Maniloff and Mastromonaco, 2017). Recent study in the US, where most of unconventional gas development has taken place so far, found a significantly positive overall economic welfare effect from that development (Hausman and Kellog, 2015).

However, unconventional gas development can also have potentially devastating impact on agriculture and on the surrounding environment. The threat stems from the technologies involved in extracting unconventional gas: hydraulic fracturing and horizontal drilling (Osborn et al. 2011). These are deemed to be safe by developers (Schafer, 2012), but their environmental record is contested (Lloyd-Smith and Senjen, 2011). Negative environmental effects that have been associated with unconventional gas development includes significant surface water (Olmstead et al. 2013) and groundwater quality impacts (Osborn et al. 2011). There are also serious human health concerns that have been linked to unconventional gas extraction (Hill, 2014). It has been shown that the perceptions about these negative health effects translate into the real estate market, leading to reduced values of residential property that relies on groundwater for its supply (Muehlenbachs et al. 2015). Development of negative social behaviours, such as increased crime rates, have been documented in some local areas that have experienced a boom in unconventional gas development (James and Smith, 2017).

The literature has documented both significant benefits, but also significant problems, related to unconventional gas. How to reconcile unconventional gas development with the need to sustain long-term agricultural productivity and maintaining ecosystems in good health remains an unresolved conundrum.

Internationally, there has been a boom of drilling for unconventional gas (The Economist, 2013). The response from environmental groups has been critical (Mall, 2012). In the EU, some countries (e.g. France) have banned hydraulic fracturing, while others are looking at ways to adequately regulate the unconventional gas industry (European Commission, 2016). In Australia, farming groups and environmentalists are aligned in their opposition against its development (Colvin et al., 2015). This is similar to the situation in Poland (The Guardian, 2015).

One of the key aspects of the problem lies in the disagreement between developers of unconventional gas and the landowners on whose land the gas extraction activities are meant to take place, which is the focus of this paper. The interactions between the developers and host landowners are largely dependent on the legal framework of property rights on sub-surface mineral assets. In countries where sub-surface assets are owned by the owner of the top soil (i.e. the landowner), such as the US, there is a tendency for greater cooperation between developers and landowners. This varies considerably across individual US states, with some states regulating unconventional gas (and oil) extraction more than others (Richardson et al, 2013). Nevertheless, the development of unconventional gas in the US overall has been very rapid. Conversely, in countries like Australia or the members of the EU, where sub-surface mineral rights are owned by the State, there has been unsurpassable conflict between developers and landowners, and unconventional gas development has been brought to a stalemate.

In countries where landowners do not hold sub-surface mineral rights they do not get a fair share of the unconventional gas rent, and are implicitly asked to bear significant uncertainty about how their land rent might be affected by the unconventional gas development. Therefore, it is not surprising that landowners oppose it. In this light, we investigate a specific policy instrument – a security bond – that could mitigate the uncertainty surrounding the unconventional gas development that landowners face.

Security bonds, or sometimes referred to as assurance bonds, are very similar to environmental bonds that have been known in theory and practice for over twenty-five years (Costanza and Perrings, 1990; Shogren et al, 1993). They have been widely used in mining to prevent avoidance of rehabilitation activities in abandoned mines (Boyd, 2001). Security bonds have been implemented in the oil and natural gas extraction industries in the US for decades. They have been also implemented in the US in the context of unconventional gas development (Davis, 2015). Recent literature has examined whether the existing bonding requirements in some parts of the US (e.g. Pennsylvania) are sufficient to incentivize proper environmental care by unconventional gas developers (Kim and Oliver, 2017).

There could be various types of security bonds, but in its simplest form it refers to a situation where a developer deposits a given amount in a holding account. This amount is held until the operation is finished and the regulator is satisfied that there have been no negative effects on the productivity of agricultural land, or other environmental consequences and regulatory breaches, in which event the amount is returned to the developer. If the regulator finds that environmental consequences or regulatory breaches have occurred, the amount is forfeit, and it is used by the regulator to rectify, – in whole or in part –, those negative consequences.

While economics experiments have been used extensively in environmental and ecological economics research over the last twenty years (Shogren and Hurley, 1999; Sturm and Weimann, 2006) there was only one study we were able to identify that specifically examined environmental bonds using experimental methods (Cornwell and Costanza, 1994). The study found that environmental bonds are effective in mitigating uncertainty related to environmental damages. A somewhat similar concept of 'deposit-refund' schemes has been investigated using economic experiments, but in the context of international climate treaties (Cherry and McEvoy, 2013).

The current paper is the first to use economic experiments to evaluate security bonds as a policy instrument for regulating unconventional gas exploitation. The experiments were conducted to specifically test the role that security bond can play as a mechanism to mitigate uncertainty.

The paper proceeds as follows: the following section provides an overview of the institutional and regulatory arrangements that govern unconventional gas development in countries where landowners do not hold sub-surface extraction rights. This is the context upon which we base the experimental design. Experimental methods and procedures are described in section 3, which is followed by a section that presents the results obtained from the experiments. The ultimate section draws conclusions from this study.

2 Background

In order to understand the nature of the strategic interactions between unconventional gas miners and landowners, it is necessary to discern the institutional and legislative underpinnings that currently govern exploitation of sub-surface mineral assets in many jurisdictions around the world (e.g. UK, Poland, China, Australia), where the ownership of those assets is separate to the ownership of surface agricultural land. This study is focused on the situation in those jurisdictions. The property right frameworks in those countries are very different to the property rights in the US. In the US, the sub-surface mineral rights are typically owned by the owner of the surface land rights. Under such property rights regime the joint owner of surface and sub-surface rights can, at least in theory, appropriate the rents from both surface assets (i.e. agricultural land rent), and the rent from sub-surface assets (i.e. resource rent on natural gas). Consequently, the joint owner is inclined to accept unconventional gas development on, and underneath their land, driven by the prospect of receiving substantial resource rent income from it. The fact that the US has led the way in unconventional gas development is to a large extent a result of this property rights structure.

In contrast, in most other jurisdictions around the world, the public, or the Crown, owns the sub-surface mineral rights, which are explicitly separate from the surface land rights. Under this property rights framework, the government (representing the public) has incentives to encourage unconventional gas development due to the prospect of receiving resource rent income, but the local landowners have no such incentive whatsoever, as they are not entitled to any share of the rent on the natural gas. The fact that we observe staunch opposition by landowners to unconventional gas development in so many non-US jurisdictions around the word is to a large extent a result of this property rights framework. The empirical analyses undertaken through the economic experimental procedures presented further below were designed with this property right framework in mind.

Where the landowner does not hold sub-surface rights, there are generally very limited avenues by which they can attempt to negotiate compensation for any possible future losses with the unconventional gas miner (Swayne, 2012). This is because governments issue gas exploitation rights to miners, and consequently miners have legal instruments to enforce those rights (Swayne, 2012). In this sense, subsurface rights dominate surface rights, meaning that landowners cannot invoke property rights as a defence against possible damages.

This suggests that regulatory procedures that govern the relationship between unconventional gas developer and the host landowner seem to favour the developers. In addition, there is a significant uncertainty that the landowner faces in terms of possible negative effects that unconventional gas mining might have on the productivity of their land, now or in the future. These possible negative effects are well described elsewhere, and we refer to those sources for details (e.g. Lloyd-Smith and Senjen, 2011; Phelan and Jacobs, 2016, Mason et al., 2015). The evidence presented in the literature shows that there are serious concerns about current and future agricultural land productivity in areas with unconventional gas development, mostly due to threats from soil degradation, water quality deterioration, groundwater depletion, and surface landscape disturbance.

As a result, the observed situation in the field has been that most landowners strongly oppose unconventional gas development on and underneath their land. They do not enter into negotiations with unconventional gas miners, which has resulted in a virtual stop of unconventional gas developments over the last several years in many countries (The Guardian, 2015, Colvin et al. 2015).

The ensuing empirical work presented in this paper simulates the possibility of including an environmental bond clause within a negotiated agreement between host landowners and unconventional gas develops, which has a key effect of shifting the burden of the uncertainty about the possible reduction of land rent due to diminished land productivity, from being entirely born by the landowner to being at least partially shared by the unconventional gas developer. We hypothesize that the introduction of such a clause is likely to improve the outcomes from negotiations around unconventional gas and that we might see greater rate of entering into an agreement between landowners and unconventional gas developers. We test this hypothesis using experimental methods.

3 Methods and procedures

We investigate the negotiations between unconventional gas developers and host landowners by running an economic experiment in a laboratory. Economic experiments allow researchers to control the decision-making environment, and to therefore focus on particular economic behaviours of interest (Smith and Walker, 1993).

The aim of this experiment was to simulate the negotiation between gas developers and landowners, with and without uncertainty, and with and without a security bond, as closely as could reasonably be achieved in an experimental setting. The experiment abstracts away from the contextual complexity that surrounds unconventional gas mining, and focuses on the stylised effect of the uncertainty, and on the security bond as an instrument for its mitigation. This experiment explores the effect that reducing the uncertainty of detrimental impacts attributable to unconventional gas mining is likely to have on the negotiations between unconventional gas developers and landowners.

We modelled these negotiations by modifying the Ultimatum Game (Hoffman et al., 1994), which is one of the standard 'games' used in behavioural / experimental economics (Thaler and Mullainathan, 2008, Bearden, 2001). The standard Ultimatum Game (UG) consists of two players: a 'Proponent' and a 'Respondent'. There is a certain amount on the table that can be shared between the two, based on an offer for sharing that the 'Proponent' makes and the 'Respondent' accepts or rejects. Formally, the Proponent proposes a division of the amount (π) in which she receives $d_1 = \pi - w$ where $w \in [0, \pi]$ and the Respondent receives $d_2 = w$. The 'Respondent' then accepts or rejects. If the Proponent's offer is rejected, both players are left with nothing. The Proponent's strategies are S_1={0,…π} and the Respondent's strategies are S_2={Accept, Reject}. The proposed allocation $\boldsymbol{d} = (d_1, d_2)$ theoretically results with two subgame perfect equilibria $(\pi, 0)$, and $(\pi - w, w)$ (Gale et al. 1995). In the first subgame perfect equilibrium (SPE), the Proponent takes all, and the Respondent accepts. The intuition here is that the Respondent is left no better or worse off under the proposed split with everything going to the Proponent, so a rational Respondent would be indifferent between accepting or rejecting. In the second SPE, the Proponent offers an arbitrarily small non-zero amount of w and the Respondent accepts, leaving both parties strictly better off. However, both of these SPE, and especially the first one, are not supported by experimental evidence, with Respondents consistently found to reject zero or very low offers (Camerer and Thaler 1995). Experimental evidence points to significant presence of the norms of fairness and altruism, and finds that people subject to playing ultimatum games typically converge to a more or less equal split of the amount between the Proponent and the Respondent (Levine, 1998; Thaler, 1998).

In our experiment, the unconventional gas developer was modelled as a Proponent and the landowner as a Respondent. In this setup the Proponent has an initial endowment that may be interpreted as the unconventional gas developer's budget out of which they can pay the landowner, in exchange for their consent to development. The 'offer' that the Proponent is making to the Respondent may reflect the portion of the unconventional gas rent that the developer is willing to share with the landowner in exchange of gaining access to their land. Alternatively, the offer may also be seen as a compensation payment reflecting the expected reduction in the agricultural land rent accruing to the landowner, as a result of the adverse effects from unconventional gas operations.[1] In this context, and in line with the standard UG game, the success of an unconventional gas development depends on the decision of the landowner to accept or reject the offer, effectively simulating whether or not an agreement between the landowner and the gas miner has been reached.

In this light, the design of the standard UG was modified to better reflect the likely behaviour exhibited in negotiations between unconventional gas developers and landowners. The modifications to the UG game reflect the fact that in negotiations around unconventional gas and in the case of an agreement being reached, the unconventional gas miner will make a profit from gas extraction, and the landowner could sustain a loss in agricultural productivity and environmental amenity, although the magnitude and severity of any loss is unknown *ex ante*. To account for this feature, we alter the standard UG setup, so that in the case that a Respondent accepts a proposed offer, the Proponent gains an amount of *$R*, while the Respondent is subject to a loss, \$*X*. This loss can be certain, uncertain, or compensated by the proceeds from a security bond. We build the three treatments around this setup.

In the case of an offer rejection, a zero payoff to both players, as is assumed in the standard UG does not adequately reflect the situation under actual negotiations around unconventional gas. Therefore in our experiment, if an offer were rejected, the Proponent and the Respondent walk away with their initial endowments of \$$Y_p$ and \$$Y_r$.

[1] We discuss this distinction further in the results section (Table 3).

Table 1 shows the theoretically expected payoffs for the Proponent and the Respondent under the three experimental treatments. The treatments were devised based on the loss to the landowner (Respondent) attributed to unconventional gas mining being certain (Control Treatment), uncertain (Uncertainty Treatment), and compensated by a security bond (Bond Treatment).

In Table 1, Y_p denotes the endowment for the Proponent, and Y_r the endowment of the Respondent. w is the value of the offer. R is the profit to the Proponent from undertaking the action enabled by Respondent's acceptance. X is the value of the reduction in Respondent's payoff, whereas E represents the expectation operator. B is the value of the security bond, and Br is the value of the refund that the Proponent can expect to get on the bond. When the value of the bond B is set to be equal to the expected reduction in Respondent's payoff, $E(X)$, i.e. $B = E(X)$, as was the case in this experiment, the expected value of the bond refund is zero. By the same token, the expected reduction in Respondent's payoff and the value of the Bond cancel each other out in the payoff for the Respondent under the Bond treatment (Table 1). The following parameter values were used in the experiment: Y_p = \$15; R = \$15; Y_r = \$22; X = \$5 under the control, and $E(X)$ = *\$5* under the uncertainty and the bond treatments; B = \$5. [2] We explain the individual treatments in greater detail below.

[2] The parameterisation is justified in the following way: Initial endowments were set so that all participants had an equal chance of attaining an equal payoff subject to playing optimally: the Proponent starts with \$15 and can gain additional \$15 if their offer is accepted. The Respondent starts with \$22 and loses \$5 if they accept the offer. So, the offer has to be at least \$5 to be accepted. Under the assumption of fairness, one would expect that the offer would be around \$6.5 on average in the control treatment, as in this case both players end up with the same payoff: proponent, \$15 – \$6.5 + \$15 = \$23.5, and respondent, \$22 + \$6.5 – \$5 = \$23.5. Under the control treatment, we find that the mean offer is \$6.81 (Table 2), which is very close to \$6.5 that one would expect. This provides us with some assurance about the internal validity of the experiment.

3.1 Control Treatment

In the control treatment, both players were aware that if the Respondent accepted the Proponent's offer, there would be a certain reduction of $\$X$ to the Respondent's payoff. If an offer is accepted, the total payoff to the Respondent would be their initial endowment of $\$Y_r$, plus the amount offered by the Proponent, minus a certain loss of $\$X$ (Table 1, Footnote 2). Similar to the standard Ultimatum Game, there are two SPE for this modified Ultimatum Game. In the first SPE the Proponent offers $\$X$ and the Respondent accepts leaving the Respondent no better or worse off than rejecting the offer (Table 1, Footnote 2). The second SPE, where the Proponent offers an arbitrary amount w greater than $\$X$ is of greater interest. The theoretical expectations about behaviour of the Proponent and the Respondent under the control treatment are that no offers below $\$X$ will be made, and that any offer greater than $\$X$ would be accepted, resulting in payoffs ($Yp - w + R$; $Yr + w - X$), where $w \geq X$.

3.2 Uncertainty Treatment

In the uncertainty treatment, the reduction to the Respondent's pay-off was not certain, but was determined by a computerised random number generator that drew from a discrete uniform distribution in the range [0,10], i.e. $X \sim$ u(0, 10). This was done in order to examine the effect that uncertainty has on the behaviour of the Proponent and the Respondent. If an offer was accepted, the expected reduction of the Respondent's payoff was $E(X)$ = \$5. In the instructions, participants were informed that the reduction amount can be any randomly drawn dollar amount between \$0 and \$10 (inclusive) and that the expected reduction to the Respondent's payoff, should they accept, will be \$5.

The expected payoffs to both the Proponent and the Respondent, for a given offer, are the same as the certain payoffs from a given offer in the Control treatment (Table 1). The only difference is that the payoff to the Respondent in now expected instead of certain. The theoretical SPE for this treatment are the same as the Control, that is the Proponent offers an amount equal to $E(X)$ or higher, and the Respondent accepts.

3.3 Bond Treatment

This treatment was designed to test whether introducing a security bond could mitigate the effects of uncertainty on the negotiations between landowners and unconventional gas developers. The Bond treatment differs from the Uncertainty treatment in that a bond, B, equal to the amount of the expected loss $E(X)$ = \$5 is taken from Proponents whose offers are accepted. This amount is earmarked for compensating the Respondent's uncertain payoff reduction up to, and including the amount of \$5. The uncertain payoff reduction was determined in the same way as in the Uncertainty treatment, from a uniform distribution with an expected value of \$5. If the randomly drawn reduction was less than \$5, the remaining amount was refunded back to the Proponent. If the random reduction was more than \$5, then the bond was used to offset the first \$5, and the Respondent's payoff was reduced by the remaining amount. However, on average, the bond completely offsets the expected reduction in Respondent's payoff (Table 1).

In contrast to the Uncertainty treatment, where only the Respondent faces uncertainty, in the Bond treatment the Proponent also faces uncertainty. The payoff for the Proponent whose offer is accepted was: their endowment (\$15) minus their offer, plus the \$15 payoff from the profitable activity, minus a Bond of \$5, plus a Bond refund (if any) (Table 1). The payoff for the Respondent who accepts an offer was: their endowment ($22) plus the offer, minus the expected loss ($5, drawn from a discrete uniform distribution in the same way as under the Uncertainty treatment), plus compensation for loss of up to $5 drawn from the bond (Table 1).[3]

One theoretical SPE in this treatment was an offer of $0 that is accepted, given that the expected loss is on average fully offset by the bond, and so a rational, risk-neutral and loss-neutral Respondent would be indifferent between accepting or rejecting. The second theoretical SPE was an offer arbitrarily greater than $0 that is accepted.[4] If no offers are made or accepted, then the Proponents' and Respondents' payoffs are simply their initial endowments.

3.4 Procedures

The experiment took place at a major Australian university. A total of 92 participants were recruited from a pool of registered university students, using ORSEE (Greiner, 2015).

As the experiment involved participants interacting with one another, care was taken to ensure that the individuals and their role (as either Proponent or Respondent) was completely anonymous. The lab was arranged as a series of partitioned computer terminals and upon entering the laboratory, participants were randomly assigned to a

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[3] Further research could explore variations in the way the bond remuneration is structured and how that may further change the outcome of the negotiations. For example, the outcome when a bond from the Proponent is used to remediate reduction in excess of $5 instead of up to $5. In such a variant, the spread of risk is symmetrical, but the expected payoffs are flipped favouring the Proponent. Such experimental variations could test how sensitive the design of a bond scheme is to risk averse or loss averse behaviour of Respondents and Proponents. We thank an anonymous reviewer for pointing out this possibility.

[4] Under the assumption of fairness, one would expect offers around, $1.5 on average, which would be accepted, yielding expected payoffs of (23.5, 23.5) (Table 1, Footnote 2). We did observe considerably higher mean offer value for this treatment (Table 2). We discuss possible reasons for this in the Results section below.

cubicle. All strategic interactions between Proponents and Respondents were programed using the zTree software (Fischbasher, 2007). The zTree program was also used to randomly allocate a Proponent or Respondent to each computer terminal. It was also ensured that participants did not partake in more than one session and that any materials (including instructions) were retained in the lab upon completion.[5]

The experimental sessions consisted of three components: the modified UG with the three treatments described above, a risk elicitation task similar to Holt and Laury (2002), and a questionnaire that tested participant's understanding of experimental tasks. The modified UG consisted of five rounds of play with the same partner followed by another five rounds with a re-matched partner. Participants were randomised, such that they were paired with a different player for each match. Each participant was randomly assigned as a 'Proponent' or 'Respondent' and maintained this role throughout the session. To control for end game effects (Andreoni, 1988), the participants were told that there would be up to 10 rounds per match, but were not told the exact number of rounds.

Participants were paid for one round of the UG task, in addition to being paid for the risk elicitation task. This payment schedule was chosen to mitigate wealth effects (Cherry et al, 2002). Since behaviour can be affected by wealth, participants' decisions may be affected if payments accrue throughout a session, so it was important to minimise these effects. For the UG task, separate random number generator was used to determine the round of play upon which the payment would be made. Separate random number generators determined the payment round and the lottery

[5] Full set of instructions given to participants and screenshots of computer screens as seen by participants are provided in the Supplementary Material.

outcome for the risk elicitation task. The average cash payment to participants was $24 AUD for a 60 minute session.

4 Results

Using the data collected from the economic experiment described above, we first examine the effect of the treatments on the size of offers made and on the proportion of accepted offers. This is followed by a discussion on the possible drivers of observed behaviour, aided by results from a regression analysis.

4.1 Magnitude and proportion of accepted offers under the three treatments

Table 2 shows several measures of the magnitude of offers (mean, minimum, maximum, mode and median) and the proportion of offers that were accepted by the Respondents under the three treatments: Control, Uncertainty, and Security Bond. The table shows that 75 per cent of the offers made in the Control treatment were accepted. This proportion was only 68 per cent under the Uncertainty treatment. The proportion of accepted offers rose to 74 per cent under the Bond treatment, an acceptance rate comparable to that of the Control treatment, where there was no uncertainty about the loss experienced by Respondents. These offer acceptance rates should be considered in conjunction with the magnitude of the offers made under the three treatments. For example, under the Uncertainty treatment the acceptance rate was relatively low at 68 per cent, despite the relatively high mean offer value of $7.33. This compares to a higher acceptance rate of 75 per cent for the Control treatment, with a corresponding average offer of only $6.81.

The differences in the proportion of accepted offers are statistically significant between treatments. The Uncertainty treatment had significantly lower proportion of offers acceptance than the Control (t = 2.484, p<0.001), and the Bond treatment (t=2.378, p<0.001). As expected, the differences in the proportion of accepted offers between the Control and the Bond treatment were not statistically significant.

This finding suggests that the introduction of a security bond is mitigating the uncertainty to the Respondent, by shifting some of that uncertainty to the Proponent. As a result, we observe that Respondents are more prone to accept the offers made under the Bond than under the Uncertainty treatment, where they are bearing all the risk about the possible loss that they might experience.

Looking further into the detail on the offers made by Proponents, Table 2 presents the summary statistics for the offers made and the variability of the offers under each treatment. All proponents in each treatment made an offer to a Respondent every round. This was the case for both stage 1 (the first five rounds before re-matching of the Proponent with another Respondent occurred) and stage 2 (the five rounds after the re-matching occurred).

The introduction of uncertainty in the second treatment resulted in higher offers from proponents being made (a mean offer value of $7.33) compared to the Control treatment (a mean offer value of $6.81). Despite the higher offer value, there was a lower proportion of accepted offers from Respondents, reflecting the uncertainty that they face, and their possible loss aversion. Given that the expected loss under the uncertainty treatment was $5, which was equivalent to the certain loss of $5 under the control treatment, one would expect that completely rational, risk neutral, and non-loss averse Respondents would accept higher proportion of offers in the uncertainty treatment compared to the control, given the higher mean offer value.

However, the uncertainty treatment involves a possibility of a relatively large loss of 10 (as well as a possibility of no loss at all). If Respondents are assumed to be loss averse, —and the literature has shown that this is a reasonable assumption in many cases (e.g. Tversky and Kahneman, 1991), — then we would expect a lower proportion of offers to be accepted in the uncertainty treatment despite the higher mean offer value. The experimental findings support our *ex ante* expectations that uncertainty reduces landholders' readiness to agree to gas mining on their property due to increased possibility of a loss that, in their view, is not adequately compensated. We pursue this further when we discuss possible behavioural drivers for the results.

The effect of the introduction of the bond, in the corresponding treatment, is notable. The mean offer value under this treatment was $4.18, however this should be evaluated in relation to the value of the bond itself. Table 3 might aid the reasoning here, and will also be useful for the later discussion. As is shown in the table, the mean offer value under the Bond treatment is over and above the expected loss, so in effect, it is comparable to a mean offer value of $9.18 in the other two treatments. Based on this, one can say that the introduction of a security bond had an effect of increasing the offers made by Proponents, and by doing so, mitigating the effect of the uncertainty. The uncertainty mitigating effect of the Bond treatment is indicated by the almost equivalent offer acceptance rate under the Bond treatment and the Control treatment, where no uncertainty was present under the latter.

The information presented in Table 3 can also be used to comment on the importance that participants might place on the sharing of the rent from unconventional gas and on the reduction in land rent that might eventuate as a result of gas mining. The expected payoff displayed in Column 5 in Table 3 can be interpreted as the payoff attributable to a share of the rent from unconventional gas, as it represents the value of the mean offer under each of the treatments net of the value of the certain or expected loss (in terms of reduction in land rent). The portion of the offer that is above the loss can be interpreted as the share of the rent on gas that the developer is offering to the landowners. From Table 3, it is evident that this share is greatest under the Bond treatment, followed by the Uncertainty and then the Control treatment.

In contrast, the minimum payoff displayed in Column 6 of Table 3 can be interpreted as an 'uncompensated' land rent reduction, as they represent maximum possible land rent reduction net of all payments received under the mean offer, and any compensation received under the security bond. Negative values in Column 6 indicate that there is indeed an 'uncompensated' land rent reduction, whereas non-negative values indicate that all potential land rent reduction has been compensated by the offer and/or the security bond. The observed values show that there is no 'uncompensated' land rent reduction under the Control treatment, with the Bond treatment showing only small amount of 'uncompensated' land rent reduction, and the Uncertainty treatment showing significantly higher possible reduction that is not compensated. This last point, combined with the argument of loss aversion (briefly discussed above and further elaborated below) can be used to explain the lowest proportion of offers accepted under the Uncertainty treatment. The maximum possible loss is the greatest under this treatment, and the 'uncompensated' reduction of land rent is also greatest under this treatment, so Respondents are less keen to accept offers than in the other two treatments. This is despite the maximum possible payoff being the highest in this treatment (Column 7, Table 3). This finding is in line with the findings widely reported in the literature on loss aversion.

Further, we directly compare the Control and the Bond treatments. The Control offers a lower share of the gas rent to the Respondents, but it also does not have any associated 'uncompensated' reduction of land rent. The Bond treatment carries with it a high share of the gas rent, but has also a small 'uncompensated' reduction of land rent. Given that virtually the same proportion of offers were accepted in the Control and in the Bond treatment, the finding that a high share of the rent was required to offset the 'uncompensated' reduction of land rent under the Bond treatment, implies that the share of the gas rent is perhaps relatively less important to the Respondents / landowners than the 'uncompensated' loss of land rent. This is in line with the arguments around loss aversion to be discussed below.

5.2 Possible drivers of observed behaviour

5.2.1 Risk Aversion

Aversion to risk has consistently been observed in laboratory lottery experiments and field experiments in the natural environment (e.g. Eckel and Grossman, 2008). We expected to find that Respondents are typically risk averse and that this aversion reduces their willingness to accept offers that have a more uncertain payoff. The results observed under the Uncertainty treatment as compared to those observed under the Control and the Bond treatments are consistent with this expectation. Introducing uncertainty from the Control to the Uncertainty treatment significantly reduced the number of accepted offers. On the other hand, the Bond treatment reduces the spread of the payoffs to Respondents while increasing the uncertainty to the Proponents compared to the Uncertainty treatment. As a result, the Respondents accepted greater proportion of offers under the Bond treatment.

There was another interesting feature worth exploring: the bond taken from the Proponents under the Bond treatment only covered half of the maximum possible reduction in land rent. This allows us to see whether there is some risk tolerance among Respondents, or whether all risk must be eliminated for the bond to work. We find that a bond that only covers half of the maximum potential loss was enough to raise acceptances significantly higher to a level comparable to the Control treatment.

We further analyse the impact of an individual's level of risk aversion on the acceptance of individual offers using a random effects panel data model. An index of risk as measured by a standard risk elicitation experiment (Holt and Laury, 2002) is used as an explanatory variable in a regression where a binary variable Accept (1=offer accepted, 0=offer rejected) was the response variable. The magnitude of the offer made (Offer), and a treatment indicator variable (Treatment) were the control variables in the regression.

Table 4 presents the results. The estimated coefficient on the index of risk aversion was not significant at $p<0.05$ suggesting that the risk index elicited from the Respondents did not have a significant effect on the likelihood of accepting offers.

We consequently ran another regression, where we aimed to examine the effect of Proponents' risk preferences on the magnitude of the offers that they make. We did this by regressing the magnitude of offer made (Offer) on the risk aversion index elicited from Proponents, controlling for the round of play (Round). Only data from the Bond treatment were used in this regression, as Proponents only faced uncertainty under this treatment. The results indicate a significant marginal effect of Proponents' risk index on the magnitude of offers made (Table 5).

5.2.2 Learning

The rematching of players after period 5 allows us to explore the effects that participant learning had on observed behaviour. An observed rise or fall in average offers after a rematch would indicate that subjects are changing their strategy due to their learning from the first stage of play. While there was a modest increase in offers in the second stage (after the re-matching), this increase of offers is not statistically significant. The evidence suggests that Proponents are not significantly changing their offers with experience, which testifies to the internal validity of the experiment.

5.2.3 Loss Aversion

We further explore the possibility that Respondents were not necessary avoiding risky offers, but were instead avoiding losses in the form of 'uncompensated' land rent reduction, as discussed above. In the Control and the Bond treatment, the offer must be at least $5 to avoid any loss to the Respondent. For the Uncertainty treatment however, the offer must be at least $10 to avoid any potential loss. The results show that only 15 per cent of offers in the Uncertainty treatment were equal to, or greater than $10. This compares to 53 per cent of offers in the Bond treatment that were at least $5. Put differently, 85 per cent of offers made under the Uncertainty treatment entailed a possibility of experiencing a loss by the Respondent. Invoking the notion that Respondents behave so as to avoid a possible loss, it is no surprise that offer acceptance rate for the Uncertainty treatment were significantly lower than that for the other two treatments (Table 2), despite the Uncertainty treatment also carrying the largest best possible payoff under the mean offer value (Table 3, Column 7). As discussed above, the security bond reduces the potential for 'uncompensated' loss to the Respondents so that they are more likely to accept offers then in the Uncertainty treatment, even if they get a lower potential maximum payoff.

6 Conclusions and Policy Implications

6.1 Policy Implications for Unconventional Gas Development

Successful negotiations between the developers/miners, landowners, as well as the community at large represented by the government, are key for breaking the stalemate around unconventional gas development in many counties around the world. Introducing alternative rules and regulations to these negotiations could help alleviate negotiation breakdown. One example of an alternative regulation is adding a security bond as a formal clause in the agreement to be negotiated between gas developers and host landowners.

To test the effects of the security bond, we designed three experimental treatments based on a modified Ultimatum Game: a Control, where the acceptance of an offer by a Respondent entailed experiencing a loss of a given magnitude for sure, so this was effectively a 'certainty' treatment; an Uncertainty treatment, where the acceptance of an offer entailed experiencing an uncertain loss, with the expected value equal to the loss under the Control treatment, but a relatively large variance of the loss; and a Bond treatment, where a bond equal to the amount of the expected loss – which was the same in magnitude as in the other two treatments – was taken from the Proponent and was used to compensate the Respondent for the loss experienced on average.

The findings indicate that loss aversion may be a significant factor influencing negotiations around unconventional gas development, as Respondents seem to have valued minimisation of the 'uncompensated' loss more than a larger potential positive payoff. As the bond significantly reduces this 'uncompensated' loss in comparison to the Uncertainty treatment, we find that the Bond treatment has similar rate of successfully completed negotiations (accepted offers) as the Control treatment. The implication is that the primary concern of landowners might be the minimisation of the possible loss of land rent, and that the appetite to get a share of the rent from the natural gas might be secondary. This can be used to conclude that the security bond can be an effective instrument to mitigate the loss aversion of landowners affected by unconventional gas development, and that its implementation could result in a greater proportion of negotiations concluding successfully.

6.2. Conclusions

Several conclusions can be drawn from the analysis presented above. When landowners have property rights over the subsurface assets, as is the case in US, they are less likely to oppose unconventional gas development, as they receive at least a portion of the natural resource rent on the extracted gas. In contrast, when landowners do not have property rights over the subsurface assets, as is the case in Australia, China, Poland and UK, just to mention few countries as examples, they have all the incentives to oppose unconventional gas development. They do not get anything from the gas development, and could potentially experience significant reduction in the value of the natural resource rent on their land as a result of the implementation of technologies used in unconventional gas extraction. In this case, unconventional gas development crucially depends on successful negotiations between the developers and landowners.

Environmental bonds have been widely used as a policy instrument in mining and in other industries. They are also used in some jurisdictions in the context of unconventional gas mining. The findings from this study show that the use of security bonds in jurisdictions where there is a separate ownership of surface and sub-surface rights might be an effective way to break the deadlock in negotiations between gas developers and landowners. Breaking that deadlock does not mean that the unconventional gas development should go ahead without additional safeguards ensuring that wider environmental implications from it are not going to overshadow the benefits promised by unconventional gas extraction. It only allows for a more rational social discourse leading to improved negotiation outcomes between some, but certainly not all, key stakeholders in that discourse. The security bond gives landowners greater confidence to engage in negotiations that could lead to a more equitable exploitation of unconventional gas resources between developers and landowners, ultimately leading to potential benefits for the interested parties and to society.

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Table 1. Payoffs for an accepted offer for the Proponent and the Respondent under the Control, Uncertainty and Bond treatments.

	Payoffs	
Treatment	Proponent	Respondent
Control	$Y_p - w + R$	$Y_r + w - X$
Uncertainty	$Y_p - w + R$	$Y_r + w - E(X)$
Bond	$Y_p - w - B + Br + R = Y_p - w - B + R$	$Y_r + w - E(X) + B = Y_r - w$

Note: For a rejected offer the payoff is Y_p for proponent and Y_r for respondent under all treatments.

Table 2. Summary statistics for the offers made

	Control	Uncertainty	Bond
Accepted offers %	75	68	74
Mean offer	6.81	7.33	4.18
Minimum offer	0	3	0
Maximum offer	10	12	7
Mode offer	6	6	5
Median offer	7	7	5
Mean Payoff Proponent	21.00 (3.70)	19.91 (3.72)	19.34 (4.66)
Mean Payoff Respondent	23.53 (1.59)	24.08 (3.14)	24.60 (2.42)
Total Payoff	44.50 (4.33)	43.99 (5.41)	45.60 (8.44)

Note: Standard Deviations in parentheses.

Table 3. Respondent's losses and payoffs from the mean offer under the three treatments

	Mean Offer	Certain/expected loss	Maximum loss	Minimum loss	Certain/expected payoff (1)-(2)	Minimum payoff (1)-(3)	Maximum payoff (1)-(4)	Accepted offers (%)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Control	6.81	5	5	5	1.81	1.81	1.81	75
Uncertainty	7.33	5	10	0	2.33	-2.67	7.33	68
Bond	4.18	0	5	0	4.18	-0.82	4.18	74

Table 4. Estimation results from a random effects panel-data logit model. Dependent variable 'Accept'.

Variable	Coefficient	Std Error	Z-val	*P-val*
Constant	-9.257	2.330	-3.97	0.0000
Offer	1.456	0.255	5.70	0.0000
Risk index (Respondents)	0.114	0.229	0.50	0.6160
Treatment	1.497	0.520	2.88	0.0040

Table 5. Estimation results from a random effects panel-data model, Bond treatment only. Dependent variable 'Offer'.

Variable	Coefficient	Std Error	Z-val	*P-val*
Constant	6.679	0.566	11.79	0.0000
Risk index (Proponents)	-0.198	0.082	-2.41	0.0160
Round	0.252	0.193	1.31	0.1900