REPUTATION AND IMPERFECTLY OBSERVABLE COMMITMENT: THE CHAIN STORE PARADOX REVISITED*

BY

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Summary

This paper reconsiders Selten's famous 'chain store paradox' and its solution by Kreps and Wilson, which is based on entrants' uncertainty concerning the incumbent monopolist's predisposition to fight entry. Following Milgrom and Roberts, we interpret the predisposition to fight entry as the result of a rationally chosen commitment. However, commitment is imperfectly observable. Other assumptions are maintained. We show that a rational monopolist never fights entry, even if he may commit himself to an aggressive course of action. Entry occurs in all markets and is never fought. Hence, Selten's chain store paradox comes back in full force.

Key words: entry deterrence, game theory, industrial organization, reputation

1 INTRODUCTION

This paper reconsiders Selten's (1978) 'chain store paradox,' and in particular its solution proposed by Kreps and Wilson (1982).

To explain that paradox, suppose an incumbent monopolist is beleaguered in each of its submarkets by potential competitors. These are prepared to enter, one after the other, in a given sequential order. If an entry occurs, the monopolist must decide whether to accommodate or to fight. Fighting is costly for both parties. Therefore, fighting entry in one submarket only pays if it deters entry further down the road.

Obviously, in the last market, the incumbent will always accommodate entry, because there is no one left to be deterred. Thus, entry occurs in the last market, with certainty. Going one step back to the last but one submarket, it follows that fighting is also pointless in that case, because in the subsequent submarket entry cannot be deterred in any case. Repeated application of this argument (backward induction) implies that the incumbent monopolist acts like a sitting duck, and

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accommodates entry, one by one, contrary to what seems to be plausible behavior of entry deterrence and reputation building; hence the paradox.

The subsequent literature on the chain store paradox offered various solutions that promised to bring theory more in accord with observed market behavior (see the brief survey in Fudenberg and Tirole (1991)). The most surprising and influential solution was that by Kreps and Wilson (1982), which is also the basis of the present paper.

Kreps and Wilson assumed that the incumbent monopolist has, with some small probability, an innate predisposition to fight entry. Therefore, potential entrants will watch closely the track record of the monopolist's responses to entry, looking for signs of weakness or strength. In turn, even the weak monopolist may choose to fight entry in the early stages of the game, just in order to raise or at least maintain entrants' beliefs that they are facing a tough monopolist that does not accommodate entry. The surprising result of their analysis was that if the number of submarkets is sufficiently large, entry will be fought, and thus deterred, in the early submarkets, even if the prior probability of facing a monopolist that is predisposed to always fight entry is arbitrarily small.

Though surprising and powerful, this proposed solution of the chain store paradox does, however, beg one fundamental question: where does the assumed predisposition to fight come from? Does it require the assumption of some form of irrationality, or can it be based on rational choice?

Milgrom and Roberts (1982) suggest an explanation of how such a predisposition may emerge from rationally chosen commitments that change the incumbent monopolist's payoffs appropriately:

'In the game actually being played, the established firm may be able to precommit itself to an aggressive course of action and may have done so.' Milgrom and Roberts (1982, p. 303).

Such commitments may take the form of a build-up of capacity[1] or contractual obligations. For example, the incumbent firm may be run by managers whose employment contract offers high rewards for fighting entry. The uncertainty concerning the type of incumbent monopolist would then reflect potential entrants' doubts about the kind of managerial contract or the possibility of contract renegotiations.[2]

The present paper examines whether such an ability to make commitments is actually chosen by a rational incumbent monopolist if commitments are not perfectly observable, because the observation of the sequence of actions to which a commitment has been made is subject to noise.

We employ the Kreps and Wilson framework and assume that the incumbent monopolist is 'tough' with some positive probability. However, unlike in Kreps and Wilson, in our model 'toughness' is not an innate predisposition to fight en-

1 Milgrom and Roberts refer to Dixit (1980) and Spence (1977).

2 Incentive contracts are typically not renegotiation-proof, see Matthews (1995).

try, but an ability to make a commitment. In other words, the tough monopolist has a choice; he must decide whether to use his power of commitment or to remain flexible; but once he has chosen to 'tie his hands,' he must execute that plan. In turn, the 'weak' monopolist may pretend to be committed to execute an announced plan of action, but his words are only 'cheap talk.'

Moreover, we assume that, if a commitment to a plan of action has been established, or it was pretended to have been made, the responding entrants cannot perfectly observe that plan, because their observations are subject to noise, due to apprehension of possible misunderstanding, blurred detection, or communication error.[3]

All other assumptions of Kreps and Wilson are maintained. We show that these plausible modifications have drastic implications. In particular, commitment power becomes useless, and reputation effects break down. Selten's (1978) chain store paradox comes back in full force.

Our results complement earlier work on the role of commitment power and observability in games of complete information. Schelling (1960) was the first to stress that commitment power is useless unless the actions to which a player has committed himself can also be observed by the responding parties.[4] Many years later, Bagwell (1995) added the even more surprising result that commitment power is useless even if the responding parties can observe the prior choice of actions, whenever that observation is subject to arbitrarily small noise. Relative to this strand of literature, our results show that imperfectly observable commitment can also be detrimental to the value of commitment power in sequential games of *incomplete* information.

The set-up of the paper is as follows. In section 2 we state the game. The analysis begins, in section 3, with the extreme case when the action plan to which the 'tough' incumbent monopolist has committed himself is unobservable or completely uninformative. This analysis is then extended in section 4 to allow for imperfect observability. The paper closes with a discussion of limitations and extensions.

3 A particularly dramatic example of communication error occurred during the last days of the East German regime. One day before the Berlin wall came down, a leading member of the 'Politbüro' made a misleading announcement concerning the planned easing of travel restrictions that happened to be covered live on East German TV. That announcement was generally misunderstood to mean that the wall shall be opened effective the following day. As a result, an enormous number of people rushed to the border checkpoints, which could not be kept closed.

4 Schelling uses the example of a Stackelberg-Cournot market game, and shows that the Stackelberg leader, who has commitment power, is reduced to a Cournot player if he cannot also communicate his commitment to a choice of actions to the follower.

2 THE GAME

Consider the chain store game by Kreps and Wilson (1982), in which the incumbent monopolist is 'tough' and thus predisposed to fight entry, with some small probability. We extend it in two ways: rather than assuming that 'toughness' means an irrational predisposition to fight, we interpret toughness as an ability to rationally commit to execute a complete plan of action; moreover, we assume that entrants cannot perfectly observe that commitment, once it has been chosen.

As illustrations, one may suppose the monopolist writes an imperfectly observable contract with a third party; but only the 'tough' monopolist has access to a reliable third party, that forces him to actually stick to the terms of that contract, whereas the 'weak' monopolist's contract is only cheap talk. Or one may consider imperfectly observable capacity as a commitment device, and assume that the 'weak' monopolist has set up 'dummy' capacity, just like during WW II, the British Army drew up dummy tanks in order to mislead German air reconnaissance about the strength of its tank corps. In the latter case, entrants (imperfectly) observe capacity, but they cannot be sure whether the capacity signal that they observe concerns either real or dummy equipment.

Players The players are the incumbent monopolist m that serves a fixed sequence of markets: $N, N-1, ..., 1$, where $N \geq 2$, and a set of potential entrants denoted by the market into which they may enter, $n \in \{N, N-1, ..., 1\}$, in this sequence. (Like in Kreps and Wilson, time is indexed backwards; entrant $n-1$ succeeds n, and N is the first and 1 the last market.)

The incumbent monopolist m is either 'weak' (w) or 'tough' (t). The only difference between the two types is that t makes an irreversible commitment to a complete sequence of actions at the outset of the game, whereas w optimizes in each market. The monopolist knows his type; entrants do not.

Actions/Strategies Entrants either 'enter' (E) or 'stay out' (O) of their respective markets. The monopolist responds to entry with either 'fight' (F) or 'accommodate' (A). The corresponding action sets are $A_n = \{E, O\}$, $n = N, ..., 1$, and $A_m = \{F, A\}$. The entrants' and w's strategies are reactions to the history of the game h, which is the sequence of past actions. In addition, the monopolist chooses a plan of action, as explained below.

Sequence of Moves

Nature draws type t with probability $p^0 \in (0, 1)$ and type w with probability $1 - p^0$.

Stage 1 The monopolist chooses an action plan $a^i = (a^i_N, a^i_{N-1}, ..., a^i_1)$, $i \in \{t, w\}$, from the product set $\mathcal{A} = (A_m)^N$; t is irreversibly committed to act accordingly in each market. Whereas w is not bound by it; for him, the action plan is only ‘cheap talk.’

Stage 2 All players observe either a blurred signal $s \in \mathcal{A}$ of the action plan a^i, or no signal at all. N either enters or stays out of market N; mixed strategies are permitted. His entry decision is observed by all players.

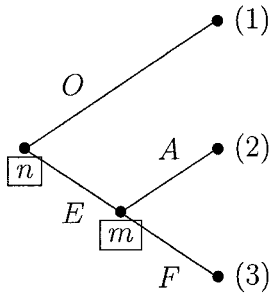
Stage 3 If entry has occurred, monopolist w responds with either F or A; mixed strategies are permitted. Whereas monopolist t executes his plan of action, a^t. If no entry has occurred, the monopolist is not called upon to move. The monopolist’s action is observed by all players.

Repetition Stages 2-3 are repeated in each successive market, from $N-1$ to 1.

Payoffs Players’ payoffs in each market n depend upon their moves in that market, as summarized in Figure 1. Take note, if no entry takes place, the incumbent earns a monopoly profit $c > 1$, whereas if entry occurs, the monopolist can either accommodate and split the market (earning him 0 and the entrant $b \in (0, 1)$), or respond aggressively and force losses upon entrants $(b-1<0)$ at a cost (-1) to himself. Therefore,

– Fight only pays if it deters entry in at least one subsequent market (due to $c-1>0$).
– Entry only pays if the monopolist accommodates with sufficiently high probability (due to $b-1<0$).

For simplicity, discounting is ignored.



	Payoff Entrant (n)	Payoff Monopolist (m)
(1)	0	c
(2)	b	0
(3)	$b-1$	-1

$c > 1,\ b \in (0,1)$

Figure 1 – Stage payoffs

Beliefs At the outset of the game, potential entrants assess the monopolist to be tough with probability $p^0 = \Pr\{t\}$ which is common knowledge. This probability is sufficiently small so that entry is never deterred in a one-shot version of the game $(p^0 \in (0, b))$. (Note: if $p^0 > b$, then the entrant would already stay out in the one-shot game.)

As is well known, the chain store game by Kreps and Wilson has a unique equilibrium only if one adopts certain equilibrium refinements that eliminate certain 'implausible' off-equilibrium beliefs. In this regard we follow Kreps and Wilson and make the following assumptions.

Assumption 1 *Once the monopolist is recognized with certainty as w, this belief remains unshakable*.

Assumption 2 *Whenever an action is observed that deviates from t's equilibrium plan a^t, all subsequent entrants infer that they face w with certainty.*

Finally note, if *t* is precommitted to fight entry in every market, or if he has commitment power and commitment is perfectly observable, our game coincides with Kreps and Wilson (1982), because the player who can irreversibly commit to a complete plan of action and is able to perfectly communicate his intentions to entrants will rationally commit to always fight entry. However, as we show in the following, imperfect observability of the plan of action to which a commitment has been made makes commitment power useless, and thus destroys the Kreps and Wilson solution.

3 COMMITMENT WITHOUT OBSERVABILITY

In this section we consider the extreme case in which entrants do not observe the plan of action or, equivalently, that the signal is completely uninformative.

To understand the complexity of that game, suppose for the moment that it is played only once. Then the entrant is not sure whether he plays a simultaneous moves game – which is the case if he deals with *t* – or a sequential moves game – which is the case if he faces the monopolist *w* who reacts to entry. The simultaneous moves game has two Nash equilibria: (*O*, *F*) and (*E*, *A*), whereas the sequential moves game has one and only one subgame perfect equilibrium: (*E*, *A*).

Now add finitely many repetitions. Then, the simultaneous moves game has a plethora of subgame perfect equilibria[5] whereas the sequential moves game still has exactly one.

Entrants are not sure which game is actually played. Together with assumptions 1 and 2 (which eliminate certain implausible beliefs), this uncertainty gives rise to a unique sequential equilibrium.

5 As Trockel (1986) pointed out, the finitely repeated simultaneous moves game has subgame perfect equilibria where actions are chosen that differ from the equilibrium actions of the associated one-shot game at least in some periods. Some of these equilibria can be viewed as reputational. This reflects a general property of finitely repeated games with multiple equilibria of the associated one-shot game.

Lemma 1 *Suppose t's commitment is not observable. Then the chain store game has no sequential equilibrium where t fights entry in some market.*

Proof Suppose, *per absurdum*, that *t*'s equilibrium plan of action commits him to fight entry in some market. Let k be the last market where he is committed to fight. Then the equilibrium strategies must have the following additional properties that will be proved below. These properties are:

1) In all markets $n < k$, entry occurs with certainty regardless of entrants' beliefs concerning the monopolist's type. Of course, this does not apply to $k = 1$, i.e. when there are no markets left down the road.

2) In market k, the weak monopolist w accommodates entry with certainty.

3) Entrant k stays out with certainty, provided the monopolist had responded to entry according to *t*'s equilibrium plan in all preceding markets, if there were any.

4) In all markets $n > k$ (if there are any), monopolist w mimics t and behaves exactly according to *t*'s equilibrium plan of action.

Putting these pieces together, one easily arrives at a contradiction: By 4) on the equilibrium path entrants do not update their prior beliefs concerning the monopolist's type until market k. Given these beliefs and the fact that w accommodates entry in market k by 2), it follows that k enters with certainty (as $p_0 \in (0, b)$) if in all preceding markets the monopolist responded to entry according to *t*'s equilibrium plan – which however contradicts property 3).

We now prove properties 1) to 4).

1) In equilibrium w accommodates in market 1, just like t. Therefore, in market 1 entry/accomodate occur with certainty. By backward induction this property extends to all markets $k - 1, k - 2, ..., 2, 1$.

2) Since entry occurs anyway in all markets $n < k$, w could only lose by fighting entry in market k.

3) Suppose k enters with positive probability, even though the monopolist had always behaved according to *t*'s equilibrium plan. Then, t would be better-off with a different plan which prescribes accommodation in market k, since entry occurs thereafter anyway, by 1). This contradicts the assumption that the given plan is an equilibrium plan.

4) If monopolist w has mimicked t up to market $k + 2$, then he will also mimic in market $k + 1$ because that prevents entry in market k, by 3). Repeated application of this argument to market $k + 3$ etc. up to market N proves the assertion. Q.E.D.

Proposition 1 (No Observability) *Assume t's commitment is not observable. Then, the chain store game has a unique sequential equilibrium outcome: entry occurs in all markets and is never fought.*

Proof By lemma 1 we know that in a sequential equilibrium t accommodates entry in all markets. Using a standard backward induction argument implies that w also accommodates entry in each market and that each entrant enters with certainty, regardless of beliefs concerning the monopolist's type. In turn, a commitment to 'always accommodate' is t's best reply to this strategy of entrants. Q.E.D.

4 COMMITMENT WITH IMPERFECT OBSERVABILITY

The above result also holds if commitment is imperfectly observable. In the following we formalize the notion of imperfect observability, introduce some assumptions concerning the signal quality, and then generalize proposition 1.

The monopolist has chosen a plan of action $a \in \mathcal{A}$ at the outset of the game. This plan is imperfectly observable in the sense that after a is chosen all players observe a signal $s = (s_N, s_{N-1}, \ldots, s_1) \in \mathcal{A}$, which is common knowledge. That signal conveys information concerning the monopolist's plan of action subject to some imperfection. It has the following properties:

Assumption 3 (Full Support) *For each given action plan $a \in \mathcal{A}$, players observe each conceivable plan with positive probability* (*the support of the probability distribution of s is independent of a*)*:*

$$\Pr\{S = s \mid a\} > 0, \quad \forall s \in \mathcal{A}, \forall a \in \mathcal{A}\ . \tag{1}$$

Assumption 4 (Small Error) *The signal is almost perfect in the sense that the true action plan is observed almost with certainty:*

$$\Pr\{S = a \mid a\} = 1 - \varepsilon, \quad \forall a \in \mathcal{A}, \tag{2}$$

where ε is positive but close to zero.

Of course, only t is bound by his choice of actions. Therefore, s can only be indicative of the actions to be executed by t; the action plan of w is purely 'cheap talk.'

The signal s is not only indicative of monopolist t's actions but also of the monopolist's type. Entrants' assessment of the monopolist's type, evaluated after the signal is observed, depends upon s and the prior belief p^0. Denote the equilibrium plans of action of t and w by a^t, a^w, respectively. Consistency of beliefs with the underlying equilibrium action plans (a^w, a^t) requires (using Bayes' rule) that entrants' beliefs concerning the type of incumbent monopolist they face at the first market N satisfies the following belief-consistency requirement:

$$p_N(s) = \Pr\{\text{monopolist is type } t \mid S = s\}$$
$$= \frac{p^0 \Pr\{S = s \mid a^t\}}{p^0 \Pr\{S = s \mid a^t\} + (1 - p^0) \Pr\{S = s \mid a^w\}} . \tag{3}$$

By the full support assumption this posterior probability is defined everywhere and $p_N(s) \in (0, 1)$, $\forall s$.

Similarly, define entrants' beliefs concerning t's plan of action

$$\mu(a, s) = \Pr(\text{monopolist } t \text{ is committed to plan } a \mid S = s\} . \tag{4}$$

Consistency of beliefs requires that they confirm on the equilibrium path.

Lemma 2 (Action Plan Inference) *Entrants' beliefs concerning t's plan of action is independent of the observed signal:*

$$\mu(a, s) = \begin{cases} 1 & \text{if} \quad a = a^t \\ 0 & \text{otherwise} \end{cases} \qquad \forall s \tag{5}$$

(*where a^t denotes t's equilibrium plan of action*).

Proof Suppose, in equilibrium t has made a commitment to the action plan a^t. Due to the full support assumption, entrants observe each possible signal $s \in \mathcal{A}$ with positive probability. Hence, μ is confirmed on the equilibrium path only if entrants apply probability 1 to the event that t has chosen a^t for each possible signal. This proves (5). Q.E.D.

Therefore, beliefs concerning t's action plan are discontinuous. If the signal is imperfect, one has $\mu(a^t, s) = 1$, for all $s \in \mathcal{A}$, even if the signal imperfection is arbitrarily small, whereas under perfect observability $\mu(a^t, s) = 1$ if and only if $s = a^t$.

Lemma 3 (Type Inference) *Suppose t's equilibrium action plan prescribes to fight entry in some market, and assume that the signal distortion ε is sufficiently small. Then, w announces the same plan as t, and entrants' beliefs concerning the monopolist's type are independent of the observed signal, $p_N(s) = p^0$, $\forall s$.*

Proof Let

$$\varepsilon < \min\left\{\frac{p^0(1-b)}{p^0(1-b) + b(1-p^0)} , \frac{b(1-p^0)}{p^0(1-b) + b(1-p^0)}\right\} . \tag{6}$$

Assume, *per absurdum*, that $a^w \neq a^t$. In conjunction with (1), (2), and (3) one obtains (note: the inequality in the second line holds since $\Pr\{S = a^t \mid a^w\} + \Pr\{S = a^w \mid a^w\} \leq 1$):

$$\begin{aligned} p_N(a^t) &= \frac{p^0 \Pr\{S = a^t \mid a^t\}}{p^0 \Pr\{S = a^t \mid a^t\} + (1 - p^0) \Pr\{S = a^t \mid a^w\}} \\ &\geq \frac{p^0 \Pr\{S = a^t \mid a^t\}}{p^0 \Pr\{S = a^t \mid a^t\} + (1 - p^0)(1 - \Pr\{S = a^w \mid a^w\})} \\ &= \frac{p^0 (1 - \varepsilon)}{p^0 (1 - \varepsilon) + (1 - p^0)\, \varepsilon} \\ &> b \end{aligned} \tag{7}$$

$$\begin{aligned} p_N(a^w) &= \frac{p^0 \Pr\{S = a^w \mid a^t\}}{p^0 \Pr\{S = a^w \mid a^t\} + (1 - p^0) \Pr\{S = a^w \mid a^w\}} \\ &\leq \frac{p^0 (1 - \Pr\{S = a^t \mid a^t\})}{p^0 (1 - \Pr\{S = a^t \mid a^t\}) + (1 - p^0) \Pr\{S = a^w \mid a^w\}} \\ &= \frac{p^0 \varepsilon}{p^0 \varepsilon + (1 - \varepsilon)(1 - p^0)} \\ &< b\,. \end{aligned} \tag{8}$$

Suppose $s = a^t$ is observed. Then $p_N > b$ and w can prevent entry in each market simply by accommodating whenever t accommodates – without ever having to fight (note: there is then no updating of beliefs, and p_N applies to all markets $n = N, N - 1, \ldots$). Given t's plan of action, this is the best that can possibly happen to w.

Suppose $s = a^w$ is observed. Then, $p_N < b$, by (8). Let k be the last market where t fights. Then, by an argument similar to the reasoning in Lemma 1, w accommodates in market k, and k stays out only if his probability assessment of facing t has increased sufficiently so that $p_k \geq b$. But such updating of beliefs can only have happened if entry occurred in some market to which w responded with a mixed strategy. (Otherwise, there is no updating of beliefs in the right direction, in which case $p_k \leq p_N < b$ and k enters with certainty.) Responding to entry with a mixed strategy entails the risk that w reveals his type in which case entry occurs with certainty in all subsequent markets. Therefore, w's payoff is lower than in the case when $s = a^t$ is observed.

Since the signal is almost perfect (assumption 4), w can gain by switching from a^w to a^t – which contradicts the assumption that a^w is an equilibrium plan of action. Q.E.D.

Proposition 2 (Imperfect Observability) *Suppose t's commitment is imperfectly observable in the sense of assumptions 3-4 and (6). Then, the chain store game has a unique sequential equilibrium outcome: entry occurs in all markets and is never fought.*

Proof It is obvious that $a^t = a^w = (A,..., A)$, $a_n^w = A$, $\forall n$, $e_n = E$, $\forall n$ (for all histories) is a sequential equilibrium. In order to show that it is the only one, suppose *t*'s action plan prescribes fight in at least one market. In lemma 2 and lemma 3 both *w* and *t* make the same announcement, and the observed signal of their announced action plan is completely ignored. Therefore, the game with imperfectly observable signals collapses to the game without observability, that was already solved in proposition 1. Accordingly, entry is never fought in equilibrium. Q.E.D.

Why is it that lemma 2 and 3, and hence proposition 2, do not also apply if commitment is perfectly observable? Surely, the weak monopolist would announce the same plan of action as the tough one. Therefore, the announcement of the action plan cannot lead to any updating of beliefs concerning the monopolist's type, as in lemma 3. However, there is one crucial difference: The announced action plan then perfectly informs entrants about the action plan pursued by *t*, in the strong sense of $\mu(s,s) = 1$, for all $s \in \mathcal{A}$. This alone assures that if *t* commits to fight entry in each market, the game is equivalent to the game analyzed by Kreps and Wilson, which assures that entry is deterred at no cost in almost all markets, even if the incumbent is 'weak.'

5 DISCUSSION

The present paper has reconsidered the solution of the chain store paradox by Kreps and Wilson (1982) and Milgrom and Roberts (1982). We introduced two modifications that seem plausible. First, rather than assuming that the tough monopolist has an innate predisposition to fight entry, we assumed that he has access to a commitment mechanism and rationally chooses from different commitments. Second, we assumed that the commitment to a certain plan of action, if it occurs or has been pretended to occur, is imperfectly observable, due to a small probability of misunderstanding or communication error. While the first modification alone preserves the Kreps and Wilson solution, the addition of imperfect observability completely erodes the value of commitment, and brings back Selten's (1978) chain store paradox in full force, even if the signal imperfection is arbitrarily small.

One limitation of our analysis is that we excluded the possibility of commitment to a *random* plan of action. In his analysis of the role of observability in complete information commitment games Bagwell (1995) pointed out that his game has several equilibria if one allows for randomization over commitments. One of these mixed strategy equilibria preserves the value of commitment, but not the other. A similar multiplicity issue may come up in our framework. However, since our pure strategy equilibrium is strict whereas mixed strategy equilibria are necessarily weak, common equilibrium refinements are biased in favour of the equilibrium presented here.[6]

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6 In the framework of Bagwell's model, Van Damme and Hurkens (1997) have developed an equilibrium selection principle that actually favours that particular mixed strategy equilibrium that preserves the value of commitment.