Discussion Papers in Economics

Does the Market Kill Bad Ideas?
An Institutional Comparison of Committees and Markets in Network Industries

Prabal Roy Choudhury

Debadatta Saha

June 2009

Discussion Paper 09-05

1

Does the Market Kill Bad Ideas? An Institutional Comparison of Committees and Markets in Network Industries

Prabal Roy Choudhury[*]   Debdatta Saha[†]

Abstract

The paper analyzes the problem of protocol coordination between two firms, where one firm has private information about its own protocol. The institutional characteristics of the market and the class of strategies adopted by the firms admit multiple equilibria in the market. Of these, one particular equilibrium has an interior information revelation cutoff for the firm with private information. This demonstrates that the market might not be able to "kill bad ideas", but it does "reward good ideas". In contrast, the institutional design of the committee ensures that the same class of strategies gives rise to a unique equilibrium in the committee, with the informed firm revealing all private information. The committee game results generalize easily to multiple periods as well as to multiple firms and is robust to an exit option. The market game result holds for a certain range of parameter values for multiple firms.

JEL classification: L14, L15, D82, D02.

Keywords: Networks, standardization, coordination, asymmetric information, institutional design

[*]Indian Statistical Institute, New Delhi
[†]Indian Statistical Institute, New Delhi

1 Introduction

In a large number of industries marked with network features, such as telecommunication, internet, software, hardware etc., compatibility among components of the network is essential for completing transactions. For example, the completion of a telephone call requires that there be end-to-end connectivity between the phones and the infrastructure supporting the call. Consumers derive utility from the entire system, rather than from an individual component of the network. The requirement for compatibility is the driving force for standardization of protocols for conducting transactions. However, different network industries vary in the degree of compatibility desired among components and this results in different routes preferred for standardization.

Given that a firm has developed some technology, and wishes to push this as the industry standard, what is the best approach? In this paper, we set out to answer this question. The actual process leading to standardization is a relatively neglected issue in the vast literature analyzing the incentives of firms for standardization and its welfare implications. One early exception is Farrell and Saloner (1988), which investigates the comparative performance of formal committees, markets and hybrid mechanisms in systems markets in achieving standardization. Relative to the market mechanism, the formal committee outperforms in its ability to achieve standardization. Farrell(1996) revisits the problem of coordination in a more realistic scenario of private information about quality of protocols. The question that remains unanswered is the incentive of participants in the standards process to reveal their private information.

The present paper compares different institutions (formal committees, market and hybrid mechanisms) in network industries along two dimensions: in terms of attaining standardization of protocol and providing incentives for revelation of private information. The protocol coordination problem is analyzed in the presence of one-sided asymmetric information. In a two-player game, firm has an incompatible preferred protocol that it would like to be chosen as the standard. However, firm 1 is fully informed about both the private benefits from both the protocols, but firm 2 knows only its own private benefits. This is true of a large number of empirical examples of standardization[1]. At any given point

---

[1] One moot example of this is the Enhanced Data rates over GSM Evolution (EDGE)

of time, there are only a finite number of new ideas that accrue from research and development, and it is rare that many participants in the coordination game have private information.

This paper contributes to the literature on standardization in two ways. First, this paper investigates the incentives for firm 1 with private information (θ) to reveal its information in a two-period protocol coordination problem, with exogenous coordination benefits c. The committee game admits a unique equilibrium in the cutoff class of mixed strategies with complete unraveling of private information. Though high types of θ would like to reveal their types, the low types would not like to reveal. However, with high valuation firms revealing their information, in any candidate interior cutoff equilibrium, firms that are close to, but to the left of the cutoff, will also want to reveal their private information. Else, firm 2 will believe that $\theta = 0$. Thus, private information held by firm 1 unravels. Further, there are two paths to the second period due to the institutional structure of the committee, which is designed to encourage coordination. This ensures that firm 2, without private information (with private benefit b), to base its belief about the other firm's average type over a small range of θ which is assumed to be uniformly distributed over $[0, 1]$. As a result, firm 2 plays more aggressively in the committee enjoying a higher expected payoff than in the market. The latter game, in contrast, has three equilibria: two pure bandwagon formation and one interior information revelation cutoff equilibrium in which firm 1 does not reveal all information. This is driven by the institutional design of the market, whereby there is only one single path to the second period. Firm 2 belief about firm 1's type is based over an average θ imputed over a larger range. Thus, firm 2 plays less aggressively in the market than in the committee.

More interesting is the relation between the payoffs to the firms and coordination probability. The latter is higher in the committee. However, this comes at a higher cost in the form of its reduced ability to reward high type

---

proposal by Ericsson at a GSM meeting for increasing the throughput of data over the GPRS system in mobile phones. All the committee members were aware about the features of the incumbent technology. Ericsson revealed to the GSM committee participants private information about EDGE. Simulations revealed by Ericsson portended tripling of data rates compared to the incumbent technology.

θs. The second important result of the paper is that the market payoff outperforms the committee payoff for firm 1 above a certain cutoff value of θ. This result is in sharp contrast to Farrell and Saloner (1988) and it provides a theory for the choice of institutions for standardization in different network industries. The prediction of this paper is that for values of $\frac{\theta}{c}$ higher than a certain cutoff value, firm 1 will prefer the market for protocol standardization. This is in line with most of the anecdotal evidence of successful standardization in network industries. For example, wireless telecommunications, with a high level of compatibility requirement among different network components, have in fact almost always chosen the committee route for standardization, whereas others with lower levels of coordination benefits, such as email, have followed the market bandwagon formation for standardization.

In a more general context, the central result of the paper is that the market mechanism might not successfully "kill bad ideas" relative to the committee, but it does seem to be able to "reward good ideas" (with $\frac{\theta}{c}$ higher than the the cutoff) better than the formal committee. Intuitively, one might expect that the market bandwagon with little allowances made for coordination would punish "bad ideas" severely and commensurately reward "good ideas". However, the result of our model is that the market seems to perform the latter task better than the former. Some "bad ideas" do have a positive probability as being accepted in the market. This result is driven by the compulsions of mixed strategy equilibria and the institutional design of the market. As there is only a single path to the second period, firm 2 is less aggressive and low values of $\frac{\theta}{c}$ enjoy a positive probability of being chosen as the standard.

The necessary assumptions and the formulation of the structure and timing of the committee and market games is detailed in section 2 of this paper. The perfect Bayesian equilibria of these games involve mixed strategies employed by both the players. In particular, firm 1 is assumed to employ a cutoff point based strategy for information revelation and protocol coordination. Section 3 of the paper tests the robustness of the two-period committee game information unraveling result in a single period exogenous coordination committee game. Exogenous coordination shows that the cost of endogenous committee based coordination results in lower payoffs to both the firms, as noted earlier. Section 4

of the paper generalizes the market and committee game results for any arbitrary number of firms. As the nature of the general n player game is that of a weak-link game, overall coordination falls with large n. Section 5 concludes. The mathematical proofs are consigned to the Appendices in section 6.

2 Problem Formulation

2.1 Assumptions

Two firms, with two incompatible protocols A and B, are playing a simultaneous game of coordination. Firm 1 prefers protocol A, which gives it a private benefit of θ, whereas firm 2 gets a private benefit of b from its preferred protocol B. Firm 2's benefit b is common knowledge, but firm 1's benefit θ is not. Firm 2 only knows that θ is distributed uniformly over [0,1]. For comparability between A and B, we assume that $\mathbb{E}\theta = b = \frac{1}{2}$. Both firms would like to coordinate jointly on their preferred protocol as the standard. Pure benefits from coordination is captured by c and Ψ_x is the probability of coordination on protocol $x \in \{A, B\}$. As in Farrell and Saloner (1988), $c > b$ and $c > \theta \, \forall \theta$. This assumption captures the fact that in network industries, the most important factor is compatibility and coordination of protocols. Different network industries differ in the extent to which c matters for completing transactions. It is very high in some network industries, like telecommunication, and less strong in some others, like the internet. The ratio $\frac{\theta}{c}$ is crucial for explaining why some industries prefer the committee route whereas others follow the market-mediated standardization.

The compatibility benefits c, $\mathbb{E}\theta$ and b are assumed to be mutually independent of each other. There are no side payments between the players. Most importantly, this paper investigates only ex-ante institutions for standardization. Ex-post mechanisms for standardization, like converters, are ignored[2].

Firm 1, with private information, is assumed to present certifable hard evidence if it decides to reveal its private information. Further, the uninformed firm 2 is assumed to believe that firm 1 is of the lowest type if it does not reveal its private information. The perfect Bayesian equilibria of these games involve

---

[2]As discussed in Farrell and Saloner (1992), converters might reduce welfare from standards rather than improve it

mixed strategies employed by both the players. In particular, firm 1 is assumed to employ a cutoff point based strategy for information revelation and protocol coordination.

2.2 Institutional design of the market and the committee

There is no coordination by fiat in the market. The coordination mechanism in the market is modeled along the lines of Farrell and Saloner (1988). In a two period simultaneous move game, if a firm unilaterally adopts its own protocol in period 1, then there is no further scope for coordination by that firm. A standard can still arise if the other firm switches to this firm's bandwagon. If both firms wait and do not adopt their protocols in period 1, they get another chance in period 2 to coordinate on a single protocol. If both firms insist on their own protocols in period 1, no coordination is achieved. Firms do no get another chance to coordinate in period 2. There is no discounting and payoffs accrue only at the end of period 2. Payoffs from the two periods are not aggregated.

The market lacks a separate instrument for information revelation. The very act of adoption of A by firm 1 reveals information about θ. It is assumed that this information comes with hard evidence. If firm 1 goes the market route to adopt A, then equity funding for A typically requires it to disclose private information about θ. In such instances, the firm releases hard evidence in the form of research reports and simulation results about expected quality and benefits from the proposed protocol.

The committee is a formal non-market institution for achieving standardization. Empirical evidence shows that much of the standards in wireless telecom has been achieved through formal committees. As Farrell and Saloner(1988) note, every year hundreds of technical experts fly to different parts of the world to participate in formal committees for standardization. Participation in a single committee may cost upto USD 2,50,000 annually (Datamation, 1989) and upto 1 percent of revenues of firms (Swann, 1990). Furthermore, formal committee-based standards take around four to five years to be completed as an average (Kolodziej, 1988).

Despite its costs and slow nature of achieving coordination, Farrell and Saloner(1988) show that it does better than the market mechanism in achieving

coordination. However, this result holds in the absence of private information among the committee members. In this paper, the committee is modeled as an institution that not only facilitates coordination on protocol but also provides a forum for firm 1 to reveal its private information. The information revelation stage precedes the coordination stage. Though not in the context of network industries, the papers of Coughlan (2000), Doraszelski et al (2003) and Schulte (2006) model committees which have an explicit stage of sharing private information. Further, these papers deal with private information about a public good, whereas in our paper, the information asymmetry is regarding a private good. In the information revelation stage, firm 1 decides whether to reveal its private information about θ in the committee by presenting hard evidence in the form of formal proposals. This is the norm in most technical standardization committees, where written proposals contain detailed simulation results which are vetted by specialists. The literature on information revelation about a public good in formal committees in non-network industries generally does not model presentation of hard evidence, the exception being Schulte (2006). In our two-period committee game, firm 1 decides whether or not to reveal θ at the beginning of period 1 prior to the coordination game. If firm 1 has not revealed θ in period 1, it gets another chance to reveal information in period 2 before the firms coordinate on protocol.

The committee as an institution encourages coordination. The coordination mechanism in our committee is similar to that modeled by Farrell and Saloner (1988). If the players cannot agree on a standard in period 1 (both the firms either insist on their protocols or both the firms concede in period 1), the committee meets again in period 2. As in the market, if both firms concede in period 1, they get another chance to coordinate on protocol in period 2. In contrast to the market, if both firms insist on their protocols in period 1, the game does not terminate. The committee meets again in period 2 to coordinate on a standard. However, it should be noted that the committee might still fail to achieve coordination even at the end of period 2.

2.3 Structure and timing of the market and committee games

The structure and timing of the market game is as follows: in period 1, firm 1 decides whether to "adopt A" or "wait". The action of adoption of A reveals θ. Simultaneously, firm 2 decides whether to "adopt B" or "wait". If both firms choose to "adopt", the game terminates. The game goes to period 2 only if both firms choose to "wait". In period 2, firm 1 decides whether to "stick to A" wait "switch to B" and firm 2 simultaneously decides whether to "stick to B" or "switch to A".

The payoffs of the market game Γ_m in the two periods is summarized tables 1 and 2. It should be noted that period 1 and period 2 payoffs are not aggregated. Payoffs accrue at the end of the game.

	Wait	Adopt B
Adopt A	$\theta + c$, c	θ,b
Wait	$\pi_1{}^2$, $\mathbb{E}\,\pi_2{}^2$	c, $b + c$

Table 1: Period 1 payoff in the market game Γ_m

	Switch to A	Stick to B
Stick to A	$\theta + c$, c	θ,b
Switch to B	0,0	c, $b + c$

Table 2: Period 2 payoff of the market game Γ_m

In the committee game Γ_c, in each period there are two separate stages: information revelation by firm 1 (reveal θ or not reveal) and deliberation on protocol coordination. After the first stage in period 1, the coordination stage allows the firms either to "insist" or to "concede". If firm 1 does not reveal its θ in period 1, it again gets an opportunity in period 2 to reveal its private information. Subsequently, in the coordination stage, the actions of the firms are either "stick to preferred protocol" or "switch to the other protocol".

The payoffs of first period of the committee game Γ_c is summarized in table 3. The last period payoff matrix is common to both the committee and the market.

	Concede	Insist on B
Insist on A	$\theta + c, c$	$\pi_1{}^2, \mathbb{E}\pi_2{}^2$
Concede	$\pi_1{}^2, \mathbb{E}\pi_2{}^2$	$c, b + c$

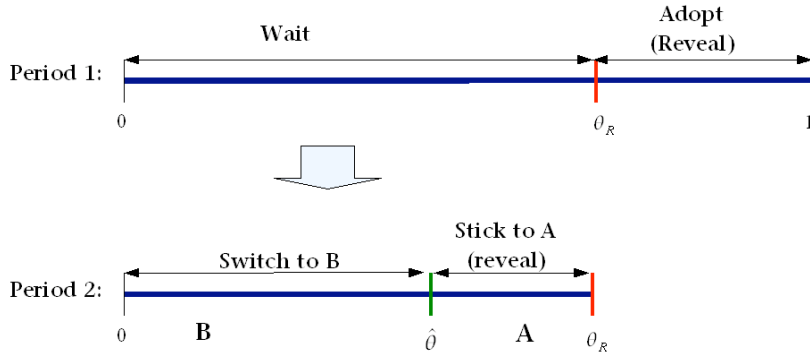Table 3: Period 1 payoff of the committee game Γ_c

Figure 1: Market Game

2.4 Strategies in the market and committee games

We are looking for equilibria in mixed strategies[3]. Firm 2 plays a mixed strategy:

q_1 = Pr{Firm 2 adopts B‖Game is in period 1}

q_2 = Pr{Firm 2 insists on B‖Game is in period 2}. Firm 1 is assumed to employ a cutoff-point based strategy in the market game. We use the cutoff point-based strategy for firm 1 because it arises naturally in this kind of coordination games with asymmetric information. Due to the institutional design of the market, the protocol coordination cutoff coincides with the information revelation cutoff. In period 1, firm 1 "adopts A" with probability $p_1(\theta) = 1$ iff $\theta \geq \theta_R$

and in period 2, firm 1 sticks to A with probability $p_2(\theta) = 1$ iff $\theta \geq \hat{\theta}$. The market cutoff strategy is summarized in figure 1.

In the committee, firm 1's information revelation cutoff is separate from its coordination cutoff. In first stage of period 1, firm 1 reveals θ iff $\theta \geq \theta_R$. If

---

[3]Mixed strategy equilibrium is payoff-dominated by pure strategy equilibria in both the committee and the market games. However, as noted by Farrell and Saloner (1988), mixed strategy equilibrium, as opposed to equilibria in pure strategies, allow for the possibility of coordination failure. Furthermore, mixed strategy equilibrium risk dominates the pure strategy equilibria.
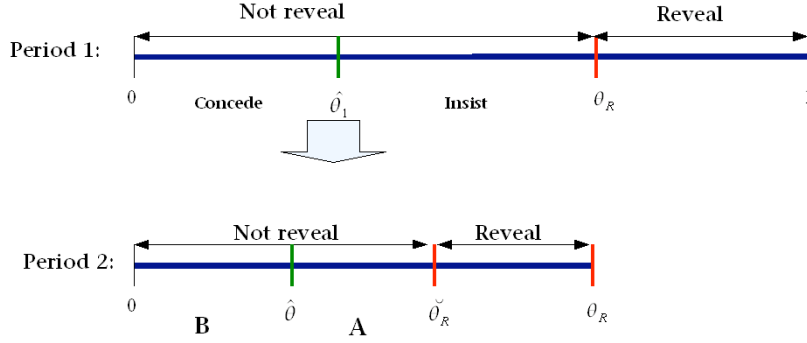
Figure 2: Committee Game

firm 1 reveals θ in the first stage, then it plays insist with probability p_1 in the second stage. Otherwise, it insists on A with probability $p_1(\theta) = 1$ iff $\theta \geq \hat{\theta}_1$. In a similar manner, firm 1 reveals θ iff $\theta \geq \breve{\theta}_R$ in the first stage of period 2. If firm 1 reveals θ, then it plays insist with probability p_2 in the second stage. Otherwise, it insists on A with probability $p_2(\theta) = 1$ iff $\theta \geq \hat{\theta}$. The committee cutoff strategy is summarized in figure 2.

2.5 Equilibria in the market and committee games

Using the assumptions and the structure and timing mentioned above, we characterize the perfect Bayesian equilibria of the market and the committee games.

2.5.1 Market game

Proposition 1. *The market game has multiple equilibria, two of which involve pure bandwagon formation for either protocol and a third interior cutoff equilibrium.*

Proof. The proof is summarized in Appendix 1. $\qquad\square$

The pure bandwagon formation equilibria are characterized by both firms coordinating on either protocol A or protocol B, with equilibrium payoffs $\theta + c$ or c to firm 1 and c or $b + c$ to firm 2.

The equilibrium cutoff stragegies are:

$$\theta_R = \frac{2(c-b)}{3c-b} \qquad \hat{\theta} = \frac{(c-b)}{2c} \cdot \theta_R$$
$$q_1 = \frac{c+\hat{\theta}}{2(c-\theta_R)+c+\hat{\theta}} \qquad q_2 = 0.5 + \frac{(c-b)}{4c^2} \cdot \theta_R$$

10

The equilibrium payoffs are:

$$\pi_1 = \chi_{\{\theta \in [0,\hat{\theta})\}}[(1-q_1)cq_2 + cq_1]$$
$$+\chi_{\{\theta \in [\hat{\theta},\theta_R)\}}[(1-q_1)(\theta + (1-q_2)c) + cq_1]$$
$$+\chi_{\{\theta \in [\theta_R,1]\}}[\theta + (1-q_1)c]$$

$$\pi_2 = (1-\theta_R)c + (\theta_R - \hat{\theta})[(1-q_1)(1-q_2)c$$
$$+(1-q_1)q_2 \cdot b + q_1(c+b)] + \hat{\theta}(b+c)$$

The equilibrium coordination probabilities are:

$$\Psi_A = \begin{array}{ll} 1-q_1 & \theta \in (\theta_R, 1] \\ (1-q_1)(1-q_2) & \theta \in (\hat{\theta}, \theta_R] \\ 0 & \theta \in [0, \hat{\theta}] \end{array}$$

$$\Psi_B = \begin{array}{ll} 0 & \theta \in (\theta_R, 1] \\ q_1 & \theta \in (\hat{\theta}, \theta_R] \\ q_1 + (1-q_1)q_2 \text{ if} & \theta \in [0, \hat{\theta}] \end{array}$$

Some features of this interior cutoff equilibrium are worth noting.

Lemma 1. $q_2 > 0.5 > q_1$ *for all values of c.*

Firm 2 plays a more aggressive strategy in period 2 than in period 1 as $q_2 > q_1$. The reason is that if the game goes to period 2, firm 2 updates its belief about firm 1 from $\theta \in [0,1]$ to $\theta \in [0,\theta_R]$, where $\theta_R < 1$.

Lemma 2. $\Psi_B > \Psi_A \ \forall \ \theta \leq \theta_R$.

For $\theta \leq \theta_R$, firm 1 waits in period 1 with probability 1 and the game goes to period 2 with probability $1 - q_1$. In period 2, firm 2 plays a more aggressive strategy so that probability of coordination is higher on protocol B than on A.

Lemma 3. *Both q_1 and q_2 are decreasing in c.*

As coordination benefit increases, firm 2 plays a less aggressive strategy.

Lemma 4. *Both $\hat{\theta}$ and θ_R are increasing in c*

As the coordination benefit increases, firm 1 plays a less aggressive strategy. Most importantly, the complete unraveling of private information does not occur in this interior cutoff equilibrium. This result arises mainly due to the nature of beliefs of firm 2, the nature of equilibrium strategies and the two period time horizon of the game. In this two-period setup, the mixed strategy equilibrium allows firm 1 to be able to form the bandwagon in favor of A with probability $(1 - q_1) < 1$ above the cutoff point θ_R in period 1 and $(1 - q_1)(1 - q_2) < 1$ for values of $\theta \in (\hat{\theta}, \theta_R)$ in period 2. Complete revelation of information even for very high values of θ does not compensate firm 1 with the certainty that the market standard will be in favor of A. Whether an interior information revelation cutoff remains as the number of periods increase is an open question.

2.5.2 Committee Game

The committee game admits a unique equilibrium with complete unraveling of private information in the class of strategies analyzed.

Proposition 2. *The equilibrium in the committee game is unique in the class of cutoff strategies, with firm 1 revealing its private information.*

Proof. Suppose that firm 1 reveals θ for $\theta \geq \theta_R$ in period 1 and for $\theta \geq \breve{\theta}_R$ in period 2. Detailed calculations in Appendix 2 show that $\theta_R = \breve{\theta}_R = 0$ implying that firm 1 reveals all private information in both periods. This equilibrium is unique as this result holds even when we solve the game with the contrarian strategy that firm 1 reveals θ for $\theta \leq \theta_R$ in period 1 and $\theta \leq \breve{\theta}_R$ in period 2. In that case, $\breve{\theta}_R = \theta_R = 1$. This implies that firm 1 reveals all information in both periods. $\square$

The intuition for the "unraveling" of private information is that high valuation firm 1 have an incentive to reveal θ, otherwise firm 2 will impute an average valuation and play more aggressively. However, by the same token, low valuation firms may not want to reveal information. However, with high valuation firms revealing their information, in any "candidate interior cutoff equilibrium", firms that are close to, but to the left of the cutoff, will also want to reveal their private information. Thus, private information held by firm 1 unravels.

At the end of period 2 in the committee game, equilibrium payoffs are $\pi_1 = \frac{(c+\theta)(3c-\theta)}{4c}$ and $\pi_2 = \frac{(c+b)(3c-b)}{4c}$. Firm 1 insists on A with probability $p_1 = p_2 = p = \frac{b+c}{2c} > 0.5$ and firm 2 insists on B with probability $q_1 = q_2 = q = \frac{\theta+c}{2c} > 0.5$. Overall probability of coordination is $\Psi = p(1-q) + q(1-p) + q(1-q)(2p^2 - 2p + 1) + p(1-p)(2q^2 - 2q + 1)$.

Lemma 5. *q is increasing in θ.*

This arises due to the nature of the mixed strategy equilibrium in both periods. Even if firm 1 reveals its type in the last period, then

$$\pi_1(\theta) = p\{(1-q)(\theta+c) + q \cdot \theta\} + (1-p) \cdot (qc)$$

For $0 < p < 1$, q will increase with θ.

Lemma 6. *p and q are decreasing in c.*

As c increases, both firms play less aggressively.

Lemma 7. *For a given value of θ, $\frac{\partial \Psi}{\partial c}$ is positive.*

As the benefits of coordination increase relative to private benefits, overall probability of coordination increases.

Proposition 3. *The committee game is robust to an exit option: All information is revealed even in a hybrid committee game with an exit option.*

Proof. In this hybrid game, the firms decide in stage 1 whether or not to join the committee. If both firms decide to join the committee, then the usual two period committee game is played. Otherwise, if one firm decides to exit while the other firm prefers to go the committee route, the assumption is that the bandwagon forms in favor of the firm playing the exit option. If both firms choose to exit, they simply collect their private benefits from their respective protocols and lose out on the benefits of coordination. The first stage payoff is shown in table 4.

If both firms choose "committee", then the payoffs $\pi_i^c \,\forall\, i = (1,2)$ are the payoffs from the usual two period committee game Γ_c. The relevant question is whether the first stage exit option changes firm 1's incentives to reveal its private

	Committee	Exit
Exit	$\theta + c,\ c$	θ, b
Committee	$\pi_1^c, \mathbb{E}\pi_2^c$	$c,\ b + c$

Table 4: Stage 1 payoffs of the hybrid game Γ_h

information in this hybrid committee game Γ_h. As sketched in Appendix 3, firm 1 reveals all information in the committee in this hybrid game. □

Hard evidence, the nature of the strategies used by the firms, the nature of beliefs held by firm 2 and the mutual independence of c and the private benefits drive this result. As firm 1 presents only hard evidence, it cannot bluff about its private information. High types of firm 1 would always want to reveal its type in order to increase its chances of forming the standard, given that θ, b and c are independent of each other. If it does not reveal θ, then firm 2 believes that firm 1's valuation is of the lowest type in the range [0,1]. Therefore, firm 1 does not have any incentive to hide information even in a committee with an exit option.

2.6 Comparative performance of institutions

Figure 3 compares the equilibrium payoffs from the committee game and the interior cutoff equilibrium in the market game. Firm 2's expected payoff is higher in the committee than in the market. More importantly, firm 1's market payoff outperforms the committee payoff only for values of $\theta > \theta_x(c)$. For $c = 2$, $\theta_x = 0.628$. The interesting implication for this result is that firm 1 with value of $\theta > \theta_x(c)$ will be discouraged from joining the committee. The market seems to "rewards good ideas" better than the committee. This result is not only in marked contrast of Farrell and Saloner (1988), it explains some interesting instances of standardization in different network industries. Mobile phones and email addresses are the two common identifiers of any individual in most countries at present, and interestingly the successful standardization of these technologies was driven by two different institutions. The "cellular revolution" is a success story of committee-driven standards, whereas internet email flourished through a market-based bandwagon.
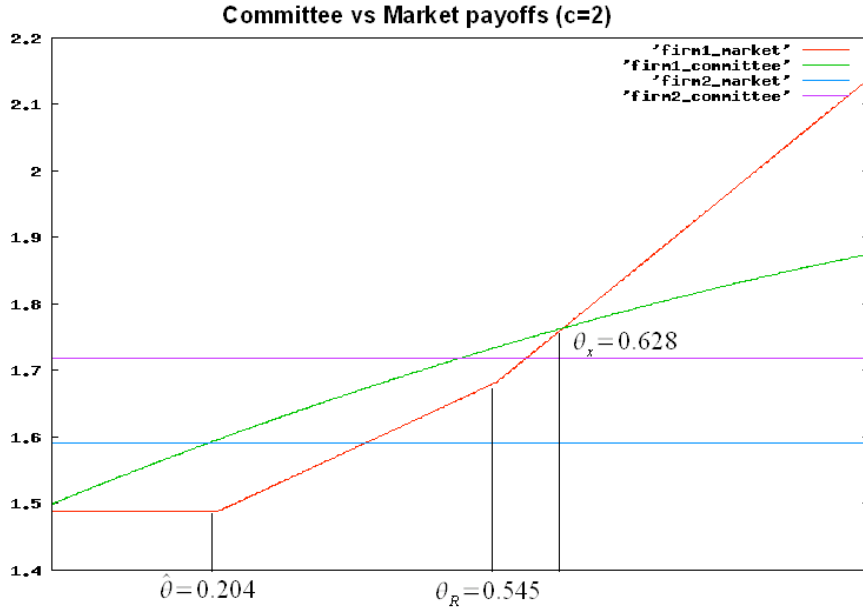
Figure 3: Committee vs Market payoffs

Successful standardization of the mobile air interface has resulted in mobile phones becoming ubiquitous even in developing countries[4].The mobile story is the result of the massive coordination undertaken by the GSM committee founded by the CEPT (European Union) in 1982. Pre-GSM, there were a number of incompatible wireless telecommunication protocols such as Digital AMPS (US) and NMT (Scandinavia) coexisting in the market. Any mobile phone operating on a particular standard required specific network equipment to support any telephone call. The result was that an early mobile phone like the Motorola DynaTac 8000X (AMPS) cost as much as USD 3995 (1980 prices). The GSM standard has resulted in very low handset costs (the cost of a Nokia 1150 phone to a mere USD 40 at current prices) and low costs of service. The GSM story is by no means unique; other successful standards by the committee route include Universal Serial Bus (by computer peripheral manufacturers), MPEG/JPEG (for still and motion picture digitization), etc. These are industries where a large number of independent components have to function in tandem with each

---

[4]In 2007, the worldwide revenue from text messaging was USD 100 billion; more than the revenues from Hollywood, global music sales and sales of PC and console games in the United States combined.

other, giving rise to very high compatibility benefits. In terms of our model, this would imply that $\frac{\theta}{c}$ is quite low in these industries. It is unlikely that any firm would have a value of θ high enough relative to the high value of c in this industry. In contrast to the GSM standard in wireless telephony, the SMTP (Simple Mail Transfer Protocol) standard used for 95 percent of the world's email traffic was a market-driven process. In fact, in the US government under the aegis of the ISO established the X.400 committee for electronic message transfer in 1980. By 1992, when the complicated final X.400 recommendation was published, SMTP was already established as the standard for email in the internet. A second stunning market success was the widespread adoption and market-domination of Ethernet, vastly overshadowing its competitors (Token Ring and Token Bus were promoted by IBM and GM respectively), due to its simplicity and ease-of-use. The internet applications and Ethernet are examples of high $\frac{\theta}{c}$.

Proposition 4. *The ratio $\frac{\theta}{c}$ determines the institution delivering standardization of protocol. Higher is this ratio, the more likely it is that standardization will be achieved through a market-based bandwagon. The lower the ratio, the committee route is more likely.*

Very high θ relative to c is indicative of drastic change. Designing a formal committee which will accomodate such a drastic change through a consensual manner is practically very difficult. Such a drastic change in standards would therefore appear through the market mechanism which does not require a consensual approach for forming an industry standard.

2.7   Comparative Statics and Comparison of Results

There are two separate comparisons which warrant attention: comparing the committee game results with the market game and within each game, comparing the coordination effect with the information effect.

Regarding the first comparison, coordination is higher in the committee game than in the market game due their institutional structures. Essentially, there are two different paths with two different histories to the second period in the committee game, whereas there is only a single path to the second period in the

market game. This gives the firms an additional path for coordination in the committee game relative to the market. Further, the two different paths in the committee game enable firm 2 to impute an average value of θ over a smaller range in the committee game in contrast to the market game. Coupled with an off-the-equilibrium path belief that $\theta = 0$ if it does not reveal, no type of firm 1 can imitate to be a higher type by witholding information in the committee game. As a natural consequence, the equilibrium mixed strategy q for firm 2 to "insist" is higher in the committee game than in either period of the market game.

In an attempt to isolate the coordination effect from the information effect, we construct a hypothetical game Γ_i, which is identical to the market game with the same information structure as the committee. We decompose the payoff difference in the committee game Γ_c and the market game (interior cutoff equilibrium) using Γ_i:

$$\pi_j(\Gamma_c) - \pi_j(\Gamma_m) = [\pi_j(\Gamma_c) - \pi_j(\Gamma_i)] + [\pi_j(\Gamma_i) - \pi_j(\Gamma_m)], \; j = \{1, 2\}$$

The first term captures the coordination effect and the second term captures the information effect in the payoff difference. For firm 1, the information effect outweighs the coordination effect for $\theta > \theta_x(c)$. However, the coordination effect is always higher than the information effect for firm 2.

The committee design in Farrell and Saloner (1988) performs better than the market. The novelty of this result derives from the fact that the committee functions more slowly than the market and yet it provides better results as far as compatibility is concerned.These results rest on the absence of asymmetric information among participants in the standards process and the lack of uncertainty about the quality of the competing protocols. This paper changes the framework of Farrell and Saloner (1988) by incorporating asymmetric information about quality. This brings about a significant change in the results. For firm 1, which has private information, the market mechanism outperforms the committee for $\theta > \theta_x$. Hence, the unambiguous superiority of the committee over the market as in Farrell and Saloner(1988), which is highly unrealistic empirically, breaks down.

The result in our paper is more in line with Farrell (1996), which incorporates asymmetric information about protocol quality in the coordination game.

The paper finds that even though the protocol with the highest quality is chosen as the standard, the war of attrition committee design does not in general outperform a market-like 'random choice' mechanism. Unlike our paper, Farrell (1996) finds that when the quality variable is uniformly distributed over a closed and bounded interval, the war of attrition never outperforms the random choice mechanism. In our paper, the market mechanism outperforms the committee only for values of $\theta > \theta_x$ even though θ is uniformly distributed over [0,1]. Additionally, Farrell (1996) does not study the incentives for information revelation. In our paper, within the cutoff class of strategies, the unique equilibrium of the committee involves complete information revelation. In the market, however, full information revelation does not occur in the interior cutoff equilibrium of the market game Γ_m.

3 Exogenous coordination: robustness of the committee game information unraveling result

The coordination mechanism in the committee Γ_c is designed to be endogenous. In most empirical examples, coordination involves an exogenous third party like a government agency or an impartial industry forum. For instance, in the case of wireless telecommunication, the IEEE (Institute of Electronic and Electrical Engineers, an autonomous body of industry professionals) is actively involved in the standardization process. In this section, we explore the robustness of the information revelation result in a single period model with exogenous coordination. We consider the case where a government agency exogenously facilitates coordination by deciding on one of the two incompatible protocols A or B in case the firms cannot reach a consensus in a single period. In particular, in the absence of consensus, the government intervenes with probability p and resolves the conflict by choosing A as the standard with probability λ. The timing of this committee game Γ_g is that the government agency declares first declares p and λ. Firm 1 then decides whether or not to reveal θ. Thereafter, the firms play the coordination game, the payoff matrix for which is given in table 5.

where $\mu_1 = \lambda(\theta + c) + (1 - \lambda)c$, $\mu_2 = \lambda c + (1 - \lambda)(b + c)$

Proposition 5. *In the unique perfect Bayesian Nash equilibrium of Γ_g, firm*

	Switch to A	Stick to B
Stick to A	$\theta + c,\ c$	$p\mu_1 + (1-p)\theta, p\mu_2 + (1-p)b$
Switch to B	$p\mu_1 + (1-p)\theta, p\mu_2 + (1-p)b$	$c,\ (b+c)$

Table 5: Payoff of the committee game Γ_g

1 reveals all private information given any p and λ chosen by the exogenous agency.

Proof. Following the same methodology as in the proofs of Propositions 1 and 2, the unique Bayesian Nash equilibrium of this game involves $\theta_R = 0$ indicating that firm 1 reveals its private information. $\square$

The reason for the unraveling of private information is the same as in the committee game Γ_c. The time dimension of the game has no impact on information revelation as Γ_c is a two-period game, whereas Γ_g is a one-shot game. Firm 1's payoff is $\pi_1 = p(\lambda\theta + c) + (1-p)\theta + \frac{z(z-\theta)}{(2z-\theta)}$, where $z = c - p(\lambda\theta + c - \theta)$. Firm 2's payoff is $\pi_2 = \frac{(b+c-\kappa)}{b+2(c-\kappa)}c + \frac{(c-\kappa)}{b+2(c-\kappa)}(b+c)$, where $\kappa = p(b+c-b\lambda) + (1-p)b$.

4 Extension to multiple players

The results of the market game holds qualitatively if the number of firms with a preference for technology B increase. In the general case, suppose that there is only one firm 1 with private information θ about technology A and n identical firms with a preference for technology B playing the coordination game for two periods. We assume that the firms realize the coordination benefits c only if all of them can agree on a particular standard (A or B). Though this is a very stringent requirement, there are a number of anecdotal evidence bearing testimony to this condition [5]. A more relaxed condition would entail $c = c(n)$ with $c'(n) > 0$ and $c(m) < c(n)\ \forall m < n$. In our case, $c(m) = 0$ if $m > 0$. As shown in Appendix 4, at least one interior information revelation cutoff exists in [0,1] as long as $\frac{b}{c}^{\frac{1}{n-1}} < (1 - q_1)$, where q_1 is the probability with which firms preferring B insist in period 1. For $b = 0.5$ and $c = 2$, this condition is satisfied for $n = 277$. Relaxing our norm for standard formation (either $c(m) > 0$ for

---

[5] Chapter 11 Bankruptcy rules

$0 < m < n$) would ensure that an equilibrium would exist for larger values of n. Further, as the number of firms increase, it is realistic to assume b and θ to be decreasing functions of n. As the number of firms increase, this leads to a squeeze in the market share of individual firms. Thus, the condition for existence is more easily met as the number of firms go up.

The committee game result is also robust to an increase in the number of players who are informed. The unique equilibrium is that firm 1 reveals all private information in each period, as shown in Appendix 5.

5   Conclusion

This paper examines two different routes to ex-ante standardization: the formal committee system and the market bandwagon. An earlier result by Farrell and Saloner(1988) finds that the slower committee game achieves better coordination than the market. In our paper, we add another dimension of private information to this coordination game. This modification in the theoretical model changes the results significantly. The framework of this paper allows us to categorize different network industries in terms of the ratio $\frac{\theta}{c}$. The higher this ratio, the higher is the possibility that the market will succeed in standardizing protocol, as in the case of email protocol standardization. The lower the ratio, as in wireless telecommunication, the larger is the prevalence of committee-driven standards. The unique full information disclosure equilibrium in the committee game is robust to an exit option (hybrid mechanism) and also with an in-built exogenous coordination mechanism. The committee as well as the market game results hold qualitatively for arbitrary number of players. However, the robustness of the interior cutoff equilibrium to an increase in the number of periods is agenda for future work.

6   Appendices

6.1   Appendix 1

Proposition 1. *The market game has multiple equilibria, two of which involve pure bandwagon formation for either protocol and a third interior cutoff equilib-*

rium.

Proof. Consider the first equilibrium with bandwagon on A. Firm 1 adopts A in period 1 and the game does not go to period 2. For $0 < q_1 < 1$, we require $c = b$, which contradicts our assumption that $c > b$. In order to maximize firm 2's profits $\mathbb{E}\pi_2 = (1 - q_1)c + bq_1$, which is linear in q_1, we should set $q_1 = 0$, which implies that firm 2 will switch to firm 1's protocol A in period 1. This equilibrium is supported by the off-the-equilibrium path belief that $\theta = 0$ if some type of firm 1 deviates and the game goes to period 2. By similar logic and off-the-equilibrium path beliefs, we get the other corner cutoff equilibrium with bandwagon on B. A third equilibrium emerges in the 2-period market game with an interior information revelation cutoff. Then, with reference to the payoff matrix in table 2, we get:

$$\mathbb{E}\pi_1(\theta) \;=\; q_2 c + p(\theta)[\theta + c - 2q_2 c] \tag{6.1.1}$$

$$\mathbb{E}\pi_2 \;=\; c\mathbb{E}_\theta p(\theta) + q_2[b + c - 2c\mathbb{E}_\theta p(\theta)] \tag{6.1.2}$$

For $0 < p(\theta) < 1$, $\quad \hat{\theta} = (2q_2 - 1)c$ and for $0 < q_2 < 1$, $\quad \mathbb{E}_\theta p(\theta) = \frac{b+c}{2}$. Firm 1's strategy is $p(\theta) = 1 \; \forall \, \theta \in (\hat{\theta}, \theta_R]$. This implies:

$$\frac{b + c}{2} \;=\; \int_{\hat{\theta}}^{\theta_R} 1 \cdot f(\theta)d\theta, \text{ where } f(\theta) = \frac{1}{\theta_R} \tag{6.1.3}$$

$$\Rightarrow q_2 \;=\; \frac{1}{2} + \frac{c - b}{4c^2} \cdot \theta_R \tag{6.1.4}$$

$$\Rightarrow \mathbb{E}\pi_1^2 \;=\; \theta + \frac{c}{2} - \frac{c - b}{4c} \cdot \theta_R \tag{6.1.5}$$

In period 1, from table 1,

$$Max \mathbb{E}\pi_1^1 = p_1(\theta)[(1 - q_1)(\theta + c) + q_1\theta] + (1 - p_1(\theta))[(1 - q_1)\pi_1^2 + q_1 c]$$

which yields:

$$q_1 = \frac{-\frac{c-b}{4c} \cdot \theta_R - \frac{c}{2}}{\mathbb{E}\pi_1^2 - 2c} \tag{6.1.6}$$

For $0 < q_1 < 1$, we require $\theta_R < c$. Now,

$$\begin{aligned}
\mathbb{E}\pi_2 \;=\;& (1 - \theta_R)[(1 - q_1)c + q_1 b] + (\theta_R - \hat{\theta})[(1 - q_1)\{(1 - q_2)c + q_2 b\} \\
& + \; q_1(b + c)] + \hat{\theta}[(1 - q_1)q_2 + q_1](b + c)
\end{aligned}$$

Substituting the values of $\hat{\theta} = (2q_2 - 1)c$ and q_2 from (6.1.4), the coefficient of q_1 in the right-hand side of the last equation is $(1 - \theta_R)(b - c) + \theta_R \cdot \frac{(c+b)^2}{4c} + \theta_R \cdot \frac{(c^2 - b^2)}{4c}$,

which must be set equal to zero for $0 < q_1 < 1$. This gives us an interior value of θ_R as $\theta_R = \frac{2(c-b)}{3c-b}$. As $c \to \infty$, we get the limiting value of θ_R as $2/3$. This analysis holds for all values of $c > \theta_R$. It should be noted that it is not possible for $\theta_R > c$ as in that case $c < b$. Hence, this is a valid interior information revelation cutoff. In this equilibrium, firm 2 believes that as long as $\theta > \theta_R = \frac{2(c-b)}{3c-b}$, firm 1 will adopt A in the first period itself. $\qquad\square$

6.2 Appendix 2

Proposition 2. *The equilibrium in the committee game is unique in the class of cutoff strategies, with firm 1 revealing its private information.*

Proof. Suppose firm 1 reveals its type in the last period. With reference to the payoff matrix shown in table 2, the equilibrium payoffs are $\mathbb{E}\pi_1^2(\text{reveal}) = \frac{1}{2}(\theta + c) = \theta + (1 - q_2((\text{reveal}))c$ and $\mathbb{E}\pi_2^2(\text{reveal}) = \frac{1}{2}(b+c)$, with $q_2((\text{reveal})) = \frac{\theta+c}{2c}$. If firm 1 does not reveal its θ, then firm 1's strategy is a function of its type θ. Given firm 2's updated belief that firm 1's types are distributed uniformly over $[0, \breve{\theta}_R]$, firm 1 's cutoff rule: $\forall \theta \in [0, \hat{\theta})$, $p_2(\theta) = 0$ and $\forall \theta \in (\hat{\theta}, \breve{\theta}_R]$, $p_2(\theta) = 1$, firm 1's payoff is:

$$\mathbb{E}\pi_1^2 = cq_2 + p_2(\theta)(\breve{\theta}_R + c - 2q_2c)$$

For a mixed strategy equilibrium with $0 < p_2(\theta) < 1$, we require $\hat{\theta} = 2(q_2 - 1)c$. Firm 2's expected payoff, with the expectation taken over $\theta \in [0, \breve{\theta}_R]$, is:

$$\mathbb{E}\pi_2^2 = c\mathbb{E}_\theta p_2(\theta) + q_2[a + c - 2c\mathbb{E}_\theta p_2(\theta)]$$

For a mixed strategy equilibrium involving $0 < q_2 < 1$, we require $\frac{b+c}{2c} = \mathbb{E}_\theta p_2(\theta)$. Using the value of $\hat{\theta} = 2(q_2 - 1)c$ and simplifying, we get $q_2 = \frac{1}{2} + \frac{c-b}{4c^2} \cdot \breve{\theta}_R \Rightarrow \mathbb{E}\pi_2^2((\text{notreveal})) = \breve{\theta}_R + (1 - q_2((\text{notreveal}))c = \breve{\theta}_R + \frac{c}{2} - \frac{c-b}{4c} \cdot \breve{\theta}_R$. In equilibrium, $\mathbb{E}\pi_1^2(\text{not reveal}) = \mathbb{E}\pi_1^2(\text{reveal})$.

$$
\begin{aligned}
\mathbb{E}\pi_1^2(\text{not reveal}) - \mathbb{E}\pi_1^2(\text{reveal})] &= [\breve{\theta}_R + (1 - q_2(\text{reveal})] \\
&\quad - [\breve{\theta}_R + (1 - q_2(\text{not reveal})c] \quad (6.2.1) \\
\mathbb{E}\pi_1^2(\text{not reveal}) - \mathbb{E}\pi_1^2(\text{reveal}) &= -\frac{c+b}{4c} \cdot \breve{\theta}_R \quad\quad (6.2.2)
\end{aligned}
$$

From (6.2.1) it is obvious that in equilibrium $q_2((\text{reveal}) = q_2((\text{notreveal})$. Firm 2's second period equilibrium strategy is independent of information revelation

by firm 1. Further, unless $\breve{\theta}_R = 0$, the expression in (6.2.2) is negative. However, $\breve{\theta}_R = 0$ implies that all information is revealed in period 2. Therefore, on the equilibrium path, firm 2 believes that all types of firm 1 will reveal information. Off-the-equilibrium path, we assume that firm 2 believes that firm 1 will not reveal only if his type (θ) is very low, say $\theta = 0$. If $\theta = 0$, then $\mathbb{E}\pi_1^2(\text{not reveal}) = \frac{c}{2} \leq \mathbb{E}\pi_1^2(\text{reveal}) = \frac{\theta + c}{2}$. Therefore, even for $\theta = 0$, revealing is as good as not revealing for firm 1.

In period 1, if firm 1 reveals its type in period 1, we can solve for the mixed strategy equilibrium of the game described in table 3. It is easy to check that $q_1 = \frac{\theta + c}{2c}$. Hence, $\mathbb{E}\pi_1^1(\text{reveal}) = \frac{c^2 - \theta^2}{4c} + \frac{\theta + c}{2}$. If firm 1 does not reveal its type in period 1, then the strategy of firm 1 becomes a function of its type and we have to solve for the Bayes Nash equilibrium of the game with the payoff matrix given in 3. Firm 2 believes that firm 1 will "insist on A" if $\theta \in (\hat{\theta}_1, \theta_R]$ and "concede" if $\theta \in [0, \hat{\theta}_1)$. The payoffs of the firms are:

$$\mathbb{E}\pi_1 = \frac{\theta + c}{2} + q_1 \frac{c - \theta}{2} + p_1(\theta)[\frac{\theta + c}{2} - cq_1] \tag{6.2.3}$$

$$\mathbb{E}\pi_2 = \frac{b + c}{2} + p_1(\theta)\frac{c - b}{2} + q_1[\frac{b + c}{2} - c\mathbb{E}_\theta p_1(\theta)] \tag{6.2.4}$$

For a mixed strategy equilibrium, $0 < p_1(\theta) < 1$, (6.2.3) requires that $\hat{\theta}_1 = (2q_1 - 1)c$. Further, (6.2.4)) implies that $\frac{b+c}{2c} = \mathbb{E}_\theta p_1(\theta)$. Using the value $\hat{\theta}_1 = (2q_1 - 1)c$, mixed strategy equilibrium with $0 < q_1 < 1$ in (6.2.3) requires that $q_1 = \frac{1}{2} + \frac{c-b}{4c^2} \cdot \theta_R$. With this value of q_1, $\mathbb{E}\pi_1^1(\text{not reveal}) = \mathbb{E}\pi_1^1(\text{reveal})$ implies $\theta_R + c - q_1((notreveal)\frac{\theta_R + c}{2} = \theta_R + c - q_1((reveal) \Rightarrow \frac{\theta_R + c}{2} - (\theta_R + c)(c + b)\theta_R = 0$. This requires $q_1((reveal) = q_1((notreveal)$ and $\theta_R = 0$. Therefore, all information is revealed in both periods. This equilibrium is supported by off-the-equilibrium path belief of firm 2 that firm 1 will not reveal its θ only if $\theta = 0$. □

6.3 Appendix 3

Proposition 3. *The committee game is robust to an exit option: All information is revealed even in a hybrid committee game with an exit option.*

Proof. Firm 1's strategy is to play "exit" for all values of $\theta > \theta_E$, and to play "committee" for all values of θ below θ_E. If the game goes to the committee

stage, then firm 1 reveals its information for all values of $\theta \in (\theta_R, \theta_E]$ and does not reveal any information for all values of $\theta \leq \theta_R$. If firm 1 does not reveal any information in period 1 of the committee game, then it "insists on A" with probability $p(\theta) = 1$ for all values of $\theta \in (\hat{\theta}, \theta_R]$ and with probability $p(\theta) = 0$ for all values of $\theta \in [0, \hat{\theta}]$. Suppose both firms choose to play "committee". As proved in the committee game Γ_c, in the second period of this game, firm 1 reveals all information, with mixed strategy equilibrium payoffs: $\mathbb{E}\pi_1^2 = \frac{2c(\theta+c)}{3c-\theta} + \theta$ and $\mathbb{E}\pi_2^2 = \frac{(2c-b)(b+c)}{3c-b}$. We now check whether firm 1 reveals all information in period 1. If firm 1 does reveal all information in period 1, then its payoff is $\mathbb{E}\pi_1^1(\text{reveal}) = (1-q_1)(\theta+c) + q_1\left(\frac{(2c(\theta+c))}{(3c-\theta)} + \theta\right)$, where $q_1 = \frac{2c(\theta+c)-c(3c-\theta)}{4c(\theta+c)-(2c-\theta)(3c-\theta)}$. If firm 1 does not reveal its information, then the Bayesian Nash equilibrium payoff of firm 1 is $\mathbb{E}\pi_1^1(\text{not reveal}) = \chi_{(0<\theta\leq\hat{\theta})}((1-q_1)^*\pi_1^2 + cq_1^*) + \chi_{(\hat{\theta}<\theta\leq\theta_R)}((1-q_1)^*(\theta+c) + \pi_1^2 q_1^*)$, where $\hat{\theta} = \theta_R \cdot \frac{\epsilon}{b+2\epsilon}$, $\epsilon = c - \frac{(2c-b)(b+c)}{3c-b}$ and $q_1^* = \frac{\delta_1}{\delta_2}$, $\delta_1 = c(cb^4 - 2b^3c^2 + 5b^2c^3 - 4bc^4 + 4c^5 - \theta_R b^4 + 3\theta_R cb^3 - 5\theta_R b^2c^2 + 5b\theta_R c^3 - 2\theta_R c^4$ and $\delta_2 = 2b^4c^2 - 4b^3c^3 + 10b^2c^4 - 8bc^5 + 8c^6 - 5\theta_R cb^4 + 15\theta_R c^2b^3 - 25\theta_R b^2c^3 + 25\theta_R bc^4 - 10\theta_R c^5 + b^4\theta_R^2 - 4cb^3\theta_R^2 + 6b^2c^2\theta_R^2 - 4bc^3\theta_R^2 + c^4\theta_R^2$. In equilibrium, the marginal θ must be indifferent between revealing and not revealing. In other words, $\mathbb{E}\pi_1^1(\text{reveal}) = \mathbb{E}\pi_1^1(\text{not reveal})$ which requires $\theta_R = 0$. Thus, firm 1 reveals all information in this hybrid committee game. $\qquad\square$

6.4 Appendix 4

Proposition 4. *There exists at least one interior information revelation cutoff in the market game with multiple players for low values of the ratio $\frac{b}{c}$ for any value of n, where b and c are decreasing and increasing with n respectively*

Proof. Let $s_k^n = \prod_{j=1}^n q_k^j$ be the probability that all the n players insist on B in period k. Let $\tilde{s}_k^n = \prod_{j=1}^n (1 - q_k^n)$ be the probability that none of the n players insist in period k. The jth firm's aggregate profit is:

$$
\begin{aligned}
\mathbb{E}\pi_j = (1-\theta_R)(\tilde{s}_1^n c \quad &+ \quad q_1^j b) + (\theta_R - \hat{\theta})(s_1^n(b+c) \\
&+ \quad (1-s_1^n)(\tilde{s}_2^n c + q_2^j b)) + (\hat{\theta} - 0)(s_1^n(b+c) \\
&+ \quad (1-s_1^n)(s_2^n c + q_2^j b) \qquad\qquad (6.4.1)
\end{aligned}
$$

The first order condition for maximization is:

$$-(1-\theta_R)\tilde{s}_1^{n-1}c + b \quad + \quad (\theta_R - \hat{\theta})(b+c-z_1)s_1^{n-1}$$
$$+ \quad \hat{\theta}(b+c-z_2)s_1^{n-1} = 0 \qquad (6.4.2)$$
$$\Rightarrow g(\theta_R, q_k^j; b, c, n) = 0 \qquad (6.4.3)$$

where, $z_1 = \tilde{s}_2^n c + q_2^j b$ and $z_2 = s_2^n c + q_2^j b$.

We can express $\hat{\theta}$ and $q_2^j \ \forall j = 1, ..., n$ in terms of θ_R using the first order condition for optimization in period 2 for firm 1 and the jth firm:

$$\mathbb{E}\pi_2^\theta = p_2(\theta)[\tilde{s}_2^n(\theta+c) + (1-\tilde{s}_2^n)\theta] + (1-p_2(\theta))s_2^n c$$
$$\Rightarrow \hat{\theta} = (s_2^n - \tilde{s}_2^n)c$$
$$Max \ \mathbb{E}_\theta \pi_2^j = \mathbb{E}_\theta[q_2^j s_2^{n-1}(1-p_2(\theta))c + q_2^j b + (1-q_2^j)p_2(\theta)s_2^{\tilde{n}-1}c]$$
$$\Rightarrow \hat{\theta} = \frac{(s_2^{\tilde{n}-1}c - b)\theta_R}{(s_2^{n-1} + s_2^{\tilde{n}-1})c}$$

For an interior $\theta_R \in (0,1)$, we check whether $g(\theta_R, q_k^j; b, c, n) < 0$ in (6.4.3) at $\theta_R = 0$ and $g(\theta_R, q_k^j; b, c, n) > 0$ at $\theta_R = 1$. The latter condition holds easily. The reason is that z_1 and z_2 are weighted averages of b and c and is therefore less than $b+c$ and $\theta_R - \hat{\theta} > 0$. However, at $\theta_R = 0$, $g(\theta_R, q_k^j; b, c, n) < 0$ only if $\frac{b}{c}^{\frac{1}{n-1}} < (1-q_1)$ assuming that $q_1^j = q_1 \ \forall j$. The lower is the ratio $\frac{b}{c}$, the more likely is this condition to hold for a given value of n. If b is decreasing in n and/or c is increasing in n, this condition holds for larger values of n. $\qquad \square$

6.5 Appendix 5

Proposition 5. *There exists at least one equilibrium with full information revelation in both periods in the committee game with n uninformed players.*

Proof. With the same definitions for s_n^k and $\tilde{s}_n^k$ as in the previous Appendix 4, we can show that the in equilibrium in the second period $\mathbb{E}pi_1((notreveal)) = \mathbb{E}pi_1((reveal)) \Rightarrow \breve{\theta}_R + c - (1-s_n^2((notreveal))c = \breve{\theta}_R + c - (1-s_n^2((reveal))c \Rightarrow s_n^2((notreveal))c = s_n^2((reveal))c$. This result is identical with the two-person game, which yielded $\breve{\theta}_R = 0$. Hence, there exists atleast one equilibrium with $\breve{\theta}_R = 0$. Similarly, in the first period, equilibrium requires $s_n^1((notreveal))c = s_n^1((reveal))c$, indicating that $\theta_R = 0$. Thus, there exists an equilibrium in both periods with complete information revelation.

□

References

[1] Berg, J., and Schumny, H., (eds), *An Analysis of the Information Technology Standardization Process* Amsterdam: North-Holland, 1990.

[2] Coughlan, P., *In Defense of Unanimous Jury Verdicts: Mistrials, Communication and Strategic Voting*, American Political Science Review, June 2000, 94(2), 375-393.

[3] Doraszelski et al., *Communication and Voting with Double-Sided Information*, Contributions to Theoretical Economics, 2003, 3(1), Article 6.

[4] Farrell, J., *Choosing the rules for formal standardization*, mimeo, University of California, Berkeley, 1996.

[5] Farrell, J. and Saloner, G., *Coordination through committees and markets*, RAND Journal of Economics, Summer 1988, 19(2), 235-252.

[6] Farrell, J. and Saloner, G., *Converters, Compatibility and the Control of Interfaces*, Journal of Industrial Economics, March 1992, XL(1), 9-35.

[7] Majumdar, S., Vogelsang, I. and Cave, M., (eds),*Handbook of Telecommunications Economics, vol. 1 and 2*, North-Holland, 2005

[8] Kolodziej, S., *Egos, Infighting, and Politics: Standards Process Bogged Down*, Computerworld, September 7, 1988, 1722.

[9] Schulte, E., *Information Aggregation and Preference Heterogeneity in Committees*, JEPS Working Paper No. 06-003, October 2006.