Title
Coordination Through Committees and Markets

Authors
Farrell, Joseph
Saloner, Garth

Publication Date
1988-01-11

Peer reviewed

UNIVERSITY OF CALIFORNIA, BERKELEY

Department of Economics

Berkeley, California 94720

Working Paper 8864

COORDINATION THROUGH COMMITTEES AND MARKETS

Joseph Farrell and Garth Saloner

January 11, 1988

Key words: Compatibility, standardization, coordination, cheap talk.

Abstract

We discuss three common mechanisms for achieving coordination, with particular reference to the choice of compatibility standards. The first involves explicit communication and negotiation before irrevocable choices are made: it represents what standardization committees do. The second mechanism, by contrast, involves no explicit communication, and depends on unilateral irrevocable choices: it succeeds if one agent chooses first and the other(s) follow. This is a simple version of "market leadership." We analyze these two mechanisms in a simple model, and show that the committee is more likely to achieve coordination. Moreover, although it is slower, it outperforms the market mechanism, even when we allow for the value of speed. Third, we examine a hybrid of the first two mechanisms, in which both talk and unilateral preemptive actions are allowed. We show that, far from marring its performance, unilateral actions improve upon the committee system. This hybrid system more closely resembles the committee system the more important coordination is, relative to conflict.

JEL Classification: 610, 620

ACKNOWLEDGEMENT

We thank Stanley Besen, Ken Hendricks, Ed Lazear, David Sappington, Carl Shapiro, and two referees for helpful comments; and the National Science Foundation (grants IRI-8712238 and IST-8510162) and the Hoover Institution for financial support.

Joseph Farrell

Department of Economics
University of California
at Berkeley

Garth Saloner

Department of Economics
Sloan School of Management
M.I.T.

1. Introduction

More than a hundred thousand people meet regularly in committees with the goal of reaching agreement on product and interface compatibility standards. The resources devoted to this formal standardization activity have roughly doubled in the last decade.[1] Yet there is disagreement over whether these "standardization committees" are a good way to organize attempts at coordination. In this paper, we introduce a theory of how such committees work, and compare their performance with that of an unaided market.

Committees set standards in a wide range of industries, from lumber to Local Area Networks. The American National Standards Institute (ANSI) has about a thousand corporate members and several hundred affiliated professional organizations. It collects, disseminates, and coordinates standards set by member organizations and by industry groups. ANSI is also the United States' delegate to the International Organization for Standardization (ISO), which works to harmonize standards internationally and to set standards when a national approach seems inadequate. The ISO, for instance, is responsible for the Open Systems Interconnection reference model in mainframe computers, which provides a framework for achieving compatibility.

The computer and telecommunications industries, with their rapid growth, urgent demands for compatibility, rapid innovation of new products and services, and increasing fragmentation, have driven much of the recent growth in formal standardization. Consider the following three examples: First, the International Consultative Committee for Telephone and Telegraph (CCITT) has undertaken an ambitious project, Integrated Services Digital Network (ISDN), to set standards for the rapidly progressing merger of the two industries. There are dozens of active committees working on a wide range of ISDN problems. Second, the Federal Communications Commission (FCC) recently nominated the Exchange Carriers Standards Association, a private organization formed after the divestiture of the Bell Operating Companies from AT&T, to try to negotiate standards that will give all long-distance carriers "comparably efficient interconnection" to enable them to compete on an equal footing. Finally, in the computer industry, the recently-formed Corporation for Open Systems, funded by information-processing companies and other interested parties, aims "..to provide an international vehicle for accelerating the introduction of interoperable multivendor products and services operating under agreed-to open systems interconnection... to assure acceptance of an open network architecture in world markets".[2]

Such careful and explicit cooperation is a natural response to the need for coordination. Yet economists have almost completely ignored this activity, and have focused instead on the coordination that may be achieved in the marketplace without explicit collaboration.

The market mechanism that we examine works by making product choice sequential instead of simultaneous. If an important agent makes a unilateral public commitment to one standard, others then know that if they follow that lead, they will be compatible at least with the first mover, and plausibly also with later movers. This <u>bandwagon</u> mechanism can sometimes achieve rapid and effective coordination[3]. A recent example is the adoption of a protocol for scrambling satellite signals to cable-TV systems. Several alternatives were available, but after Home Box Office, the largest player in the market, chose VideoCipher, other users rapidly followed suit, and coordination was quickly achieved[4]. A similar pattern was typical in US telecommunications before the Bell breakup: Bell made its choices, and the smaller players such as GTE naturally followed.[5]

But the market mechanism does not always achieve standardization. For example, several incompatible AM stereo broadcasting systems are in use and overall adoption has been slow.[6] In VCRs, neither Sony nor the VHS consortium felt obliged to follow the other, and the incompatible systems they marketed have persisted. In color television, three incompatible systems (NTSC, PAL, and SECAM) competed internationally, and no adopter could start an irresistible bandwagon[7]. These examples suggest that the "bandwagon" mechanism for coordinating is imperfect when there is no predetermined leader and when there are different preferences among standards. This result has also emerged from the growing theoretical literature on standardization[8].

Formal negotiation through a committee can avoid some of the problems that mar the performance of the market mechanism. In particular, explicit communication and a commitment not to adopt without agreement prevent the incompatible adoption that often happens if two or more firms try to lead the bandwagon. But these committees too are imperfect coordinators. Often, by the time a committee is convened, participants have vested interests in incompatible positions,[9] and the committee must resolve this conflict. Since the "consensus principle", which is generally accepted in voluntary standard setting, requires committees to seek a stronger consensus than a simple majority vote (though not necessarily unanimity), there may be a battle of wills in committee, while users wait.[10] Such waiting is costly, whether simply because of delay or because eventually the participants can no longer wait and the chance for coordination has been missed.

Both the market (bandwagon) and the formal (committee) system, then, are imperfect. Which is better? What does that depend on? What are the advantages and disadvantages of each? These questions are not only of academic interest: practitioners are often unsure of the relative merits of the two approaches. For example, the FCC has sometimes suggested that more standardization decisions should be "left to the market,"[11] - a view echoed by Dr Theodor Irmer, Director of the CCITT, at a recent conference[12]. Yet Irmer himself is widely regarded[13] as the driving force behind ISDN, the epitome of formal standardization; and, as mentioned above, the FCC urges committee standardization for "open network architecture". These apparent contradictions pose a major public-policy problem: what, if anything, should government do to help the standardization process? What advice can economists give? What can we say about the relative merits of the different ways to organize standardization?

1.1 Methodology

A full comparison of the merits of formal and informal standardization would be complicated because committees do many things. They share information, engage in active product design, negotiate compromises, test for compliance with agreed-upon standards,[14] and test proposed standards for performance. Participants' accounts[15] of such committees typically emphasize these engineering functions, and say little about how the bodies deal with conflicts. By contrast, we focus entirely on conflict and ignore committees' other roles.

We study the case in which everyone would prefer any proposed coordinated (standardized) outcome to the result of each going his own way[16], but they disagree on which of the coordinated outcomes is better. Such conflict is common for many reasons. Sometimes it arises because different participants plan to serve different segments of the market. For example, in videotex, some users want a graphics capability such as that provided by NAPLPS[17], which some systems provide; but other users would prefer the lower cost and greater speed of an ASCII system. In other cases, there may be no important conflict among users, but one vendor has a competitive advantage in a particular system, most likely one that it developed and in which it may retain proprietary rights, or at the least an advantage of experience. For example, in AM stereo, users are essentially indifferent among the competing systems, but each vendor has a vested interest in its own system, and this has prevented agreement on a standard. Alternatively, there may be legitimately different opinions about which standard would be best for the entire industry in the long run. Finally, at the international level, nations may hope to protect domestic firms by pressing for certain standards.[18] In any case, we suppose that there is conflict: if not, then agreement will likely be rapid and easy under almost any institutional structure.

In such a problem, where each agent prefers a different coordinated outcome, each agent's best strategy depends on that chosen by the other(s). If your rival insists on his proposal, then it is wise to yield; but perhaps he is only bluffing, and will yield if you insist on yours. Such strategic choices are the subject-matter of game theory. Indeed the problem has the payoff structure of the classic "battle-of-the-sexes".[19] Game theory has been slow to model problems of coordination, however, because Nash equilibrium assumes it away: it is an equilibrium for us both to choose my preferred standard, and another for us to choose yours.

These pure strategy Nash equilibria, however, are quite unrealistic without a convincing story of the mechanics of coordination. It is absurd to claim, by choice of solution concept, that either I will know to yield while you hold firm or vice versa, and that there will be no confusion, no bluffs, and no accidents. At the least, we can demand a model of the process or institutions that leads to such remarkable coordination.

To model institutions that promote coordination, therefore, we must use a solution that allows for some failure of coordination. Such a failure might be expected to arise if there is no pre-play negotiation and if the players are symmetric so that (at least ex ante) they can be expected to behave in the same way. An obvious way to model such symmetric behavior is by focusing on the symmetric equilibrium, which involves mixed strategies: Each player sometimes insists on his/her own way, and sometimes yields.

We model three processes of coordination and compare their relative speed, efficacy, and payoffs. First, we consider what happens when the players can meet and talk (many times) in order to agree on a joint action. Modeling the committee in this way produces a many-period game, which, it turns out, itself has the basic structure of a "battle-of-the-sexes" game each period. The overall game is a "war of attrition".[20] Analyzing its symmetric (mixed-strategy) equilibrium yields a description of the effectiveness of committee negotiation.

The second coordination process we model is that of pure action: the market or bandwagon process. We model that process as another many-period game, which again has the basic structure of the battle-of-the-sexes in each period. The overall game is a "grab-the-dollar" game, in which one player gains if he grabs first but they each lose if they grab simultaneously;[21] again we analyze the mixed-strategy equilibrium.

The last coordination process we consider is a "hybrid" in which players use both bandwagon and committee strategies. In any period, as well as negotiating in committee, an agent can also commit to a course of action in the market. The reason for considering a hybrid is that if all other agents are talking and not adopting, then any one agent can seize the lead by unexpectedly adopting. If players cannot commit themselves not to do that, then only the fear that another agent will simultaneously try to do the same prevents any one agent from adopting. Therefore a "pure" committee system in which no one acts until agreement is reached is an equilibrium only if the players can commit themselves to it.

1.2 Summary of the Model and Results

We consider a model where the players have a choice between two incompatible new technologies or systems: A and B. There are two agents (firms or users), whose preferences are as follows: it is common knowledge[22] that agent 1 prefers A, and agent 2 prefers B; but each would prefer to adopt its less preferred option than be incompatible. Thus, agent 1 is best-off if both he and agent 2 choose system A; his next preference is for them both to choose B; next is the outcome where he chooses A and 2 chooses B; the worst is if 1 chooses B and 2 chooses A.

We begin by comparing the pure committee and bandwagon systems. In Section 2, we consider the case in which there is a fixed date by which decisions must be made, but nothing is gained by making decisions earlier; activity before the "deadline" is solely for the purpose of coordination.[23] This allows us to analyze the reliability of the mechanisms without worrying about their speed. Simple calculations would suffice to compare the outcomes with only one or two periods before the deadline, but we wish to extend the model beyond that. To do so, we use dynamic programming to reduce each many-period game, with its plethora of (normal-form) strategies, to a 2-by-2 game in which some of the payoffs are endogenous. A simple game-theoretical result then enables us to compare equilibrium payoffs.

We find that the committee unambiguously outperforms the bandwagon system, but that the difference in payoffs vanishes in the limit as the number of periods goes to infinity. Although the payoffs become equal in the limit, the limiting behavior of the systems differs. In a committee, with many periods to go, nothing is likely to happen for a long time: almost certainly, neither player will yield until the deadline approaches. In the bandwagon game, by contrast, early action is likely: in fact, there is always a finite expected time to a definitive outcome, and with many periods a decision is essentially certain before the deadline.

The bandwagon outcome, however, although rapid, is not necessarily good: often, simultaneous and incompatible adoption mars the bandwagon's coordination. The committee is less likely to reach an outcome before the deadline, but if it does so then the outcome is certainly coordinated. If the deadline arrives with no committee decision, then coordination is still possible by chance, but so are the other two outcomes, one of which (player 1 adopts B and 2 adopts A) is worse than anything that can happen in the bandwagon game with many periods.

Thus, although the committee does better than the market when there is no value attached to speed, it is slower. One might expect, therefore, that allowing for the importance of speed might reverse our conclusion. And speed is often important: an earlier decision is often privately and socially better.[24] We represent this in Section 3 by discounting the payoffs by a constant factor for every period in which no coordination is attained. Using an analytical technique similar to that used in Section 2, we find again that the committee system gives unambiguously better payoffs in equilibrium. Intuitively, the greater speed of the bandwagon system is outweighed by the fact that the committee system causes fewer errors.

In Section 4, we show that our results are robust to the introduction of asymmetric payoffs between the players.

In Section 5, we consider the hybrid system. Since this game is in some sense a mixture of those in the pure bandwagon and committee games, we might expect an intermediate payoff. In fact, however, we show that the hybrid game gives strictly greater payoffs even than the "pure" committee system! Intuitively, the reason is that if neither player starts a bandwagon, they have a chance to talk (and thus another chance to coordinate) before the next stage of the game; similarly, if they fail to reach agreement in the committee, there is a chance of coordination in the marketplace. Thus they have "two chances" to coordinate each period. One might feel that this is "unfair:" that we should instead model the hybrid as (perhaps) alternating bandwagon-style and committee-style moves. But we believe that the hybrid's vigor revealed in this result is genuine: if the two processes do not destructively interfere with one another (as our model suggests they do not), then it is in fact desirable to have both employed simultaneously. This result suggests that, while committees are better than the pure bandwagon system, they are even better if they can be subverted by preemptive action outside the committee!

In the hybrid equilibrium, both jointly and unilaterally determined outcomes may be observed. We ask how the parameters determine which kind of outcome is more often observed, and show that the more coordination benefits matter, relative to conflict, the more the hybrid will empirically resemble a committee system.

These results are surprisingly strong, given the complexity of the processes involved. In the Conclusion, we discuss a number of qualifications and caveats, as well as suggestions for future research.

2. The Model

2.1 Assumptions and Description

We denote the value of being on one's preferred system by a, and the additional value of successful coordination by c. The case of interest is where $c > a > 0$, since otherwise each simply adopts his own preferred alternative. These preferences can be represented in the following payoff matrix, a modified version of the battle-of-the-sexes:[25]

		Player 2: A	Player 2: B
Player 1	A	a+c, c	a, a
	B	0, 0	c, a+c

Figure 1: The Final Game

We begin by describing the mixed-strategy equilibrium of this game, which we call the "final game," since it must be played if no agreement is reached before the deadline. To make player 1 indifferent between his first and second actions, as he must be in mixed-strategy equilibrium, we require that $p(a + c) + [1 - p]a = p.0 + [1 - p]c$, where p is the probability that player 2 chooses system A. Hence $p=(c-a)/2c$, so that $p < 1/2$: each player chooses his preferred system more than half of the time in the mixed-strategy equilibrium.

The value of this mixed-strategy equilibrium to each player is then easily calculated as:

$$V^o \equiv (c + a)/2 < c.$$

We think of this value as representing the players' payoffs from failing to agree before the deadline. Notice that V^o is actually <u>less</u> than each player's less-preferred pure-strategy equilibrium outcome, so that either player would in fact prefer to give in rather than receive V^o. However, in equilibrium, each holds out to some extent for his better payoff. While this outcome, V^o, may seem an unduly pessimistic forecast, that is probably because, in our experience, it is rare for there to be no coordinating mechanism at all. Since V^o represents the outcome _if the coordination mechanism fails_ completely, we find it entirely reasonable.[26]

2.2 Committee Game with n Periods

Now suppose that, before the game of Figure 1 must be played, the players have n chances to reach verbal agreement. That is, each can (simultaneously) announce "insist" or "concede"; if just one insists then he gets his way (this is an equilibrium of the subgame, and seems the plausible one[27]), while if both insist or if neither does then they meet again the following period. If no agreement has been reached after n periods then they play the mixed-strategy equilibrium of Figure 1.

To analyze this game, we could write out a large payoff matrix for the normal-form game: each player has two choices at each date, which he can condition on history. But we can more usefully describe the players' behavior in the first period in terms of a two-by-two matrix, using an endogenous "continuation payoff" in that matrix. In particular, if both "insist," so that no agreement is reached, they each get $V(n-1)$, the value of having $(n-1)$ meetings remaining. If both "concede," it is less clear what we should assume. For the moment, we will be a little harsh on the players and suppose that they get $V(n-1)$ in that case too.[28] Therefore the "reduced-form" payoff matrix is:

		Player 2	
		Concede	Insist
Player 1	Insist	a+c, c	V(n-1), V(n-1)
	Concede	V(n-1), V(n-1)	c, a+c

Figure 2: Committee Game with n Periods Remaining

If $V(n-1) < c$, as is certainly the case when $n = 1$ ($V(0)$ is V^o derived above), then this game has the same general "coordination-game" form as the original (Figure 1). That is, the diagonals are better for both players than the off-diagonals, but they differ on which of the two diagonals is better. The value of the mixed-strategy equilibrium of this game is:

$$V(n) = p(n)(a + c) + [1 - p(n)]V(n - 1) \qquad (1a)$$

$$= p(n)V(n - 1) + [1 - p(n)]c. \qquad (1b)$$

Since by inductive hypothesis $V(n - 1) < c$, it follows that $V(n - 1) < V(n) < c$. Since the numbers $V(n)$ form an increasing sequence bounded from above, they must converge to a limit, say V^*, as $n \to \infty$. From (1a), $p(n) = [V(n) - V(n-1)]/[a + c - V(n-1)] \to 0$ as $n \to \infty$. Hence, from (1b), $V^* = c$.

Thus, when there are many periods of negotiation, there is very little concession early on ($p^* = 0$). The cumulative effect of the negotiation is to give each player almost as good a payoff as if they agreed immediately on the system he prefers less. The net effect is as if only the compatibility benefits are achieved, on average, and the benefits on which they disagree are dissipated in imperfect coordination. Of course, this does not mean that the outcome gives each player c with certainty; instead, they jointly get (2c+a) some of the time and 2a or 0 when coordination fails.

When a is small, coordination is achieved most of the time; when a is close to c, coordination fails so often as to dissipate almost a third of the possible payoffs.

We can also examine the limiting[29] overall probabilities of specific outcomes. Let x^* be the probability of agreement before the deadline. Then the limiting payoff to the two players together is x^* times their joint payoff if they agree, plus the complementary probability times their expected payoff from the one-shot game, V^o, i.e., the limiting payoff is $x^*(2c + a) + (1 - x^*)V^o$, which must be equal to 2c. Hence (substituting for V^o), $x^* = (3c - a)/(3c + a)$.

Thus if a is small there is almost certain to be agreement in advance; if a is almost equal to c there is about a one-half probability of agreement in advance. If there is no agreement in advance, there is of course one last chance, as indicated in the analysis of the final game above. The overall probability of coordination is therefore

$$x^* + (1 - x^*)2p(1 - p) = (3c^3 - a^3)/(c^2(3c + a)),$$

where here p is the probability of choosing one's less-preferred standard in the one-shot game. The probability that 1 ends up on A and 2 on B is

$$(1 - x^*)(1 - p)^2 = a(c + a)^2/2c^2(3c + a).$$

And the probability that 1 ends up on B and 2 on A is

$$(1 - x^*)p^2 = a(c - a)^2/2c^2(3c + a).$$

We thus see:

<u>PROPOSITION 1: V(n) is strictly increasing in n: more rounds of coordination are better. As n increases, V(n) converges to c. In early rounds of negotiation, there is almost no concession. Later on, concessions are more likely.</u>

2.3 Bandwagon Game With n Periods

Now consider the game with unilateral adoption rather than negotiation as the coordinating principle. Just as above, we reduce the dynamic game to a two-by-two game with an endogenous payoff entry, and find that we can say a good deal about the outcome from that. Each player's expected payoff, W(n), is the value of the mixed-strategy equilibrium of the game:

		Player 2: Wait	Player 2: Commit to B
Player 1	Commit to A	a+c, c	a, a
	Wait	W(n-1), W(n-1)	a+c, c

Figure 3: Bandwagon Game with n Periods Remaining

Unlike the game in Figure 2, this game can end with incompatibility before the deadline: when both players (simultaneously) commit to their own preferred technology, each gets a.

If q is the probability that a player waits, we get:

$$W(n) = q(n)(a + c) + [1 - q(n)]a = q(n)W(n - 1) + [1 - q(n)]c.$$

Again by induction, $W(n - 1) < W(n) < c$. Since $q(n)[2c - W(n)] = c - a$, $q(n)$ increases in n, towards some limit, q^*. Let $W(n)$ converge to W^*. Then

$$W^* = q^*(a + c) + [1 - q^*]a = q^*W^* + [1 - q^*]c,$$

whence (since W^* cannot be $a + c$), $W^* = c$, and $q^* = (c - a)/c$. In contrast to the committee case, then, the outcome is likely to be determined early on. While this has good aspects, it is also dangerous: by contrast, in the committee system, incompatibility is never inevitable until the end.

As above, we can calculate the overall probabilities of various eventual outcomes. For large enough n, the distribution of outcomes is close to that which would result if we simply had many periods with each side playing q^* in each period. Thus if y is the probability of coordination before the deadline, we have $y = 2q^*(1 - q^*) + q^{*2}y$, whence $y = 2(c - a)/(2c - a)$. With the remaining probability $(1 - y)$, player 1 adopts A and player 2 adopts B.

PROPOSITION 2: In a long game, the committee is less likely to achieve an outcome before the final period, but is more likely to achieve coordination than the bandwagon system.

Although the limiting payoffs for the players are the same (c) in the two systems, Proposition 2 shows that the committee is socially superior if firms have less incentive than they should to achieve compatibility. Conversely, if there is too much private incentive to standardize, so that 2c exceeds the social benefit from compatibility, then the bandwagon system is socially superior in the limit.

We have shown that as the number of periods available for coordination increases without limit, the two methods of coordination give equal payoffs (c) in the limit. But in practice "periods" are often quite long: for committees, a period is the time that passes between meetings, often several months.[30] For bandwagons, a period is the length of time between a firm's irrevocable commitment to a system and its rival's unambiguous observation of that commitment. That too may easily be months, since it is easy to see that if players were to believe verbal announcements of commitment then it would always be in a player's interest to make them, whether true or not. In terms of these fairly long periods, there is often little time available, so we next compare committees and bandwagons with finitely many periods.

To do so, compare Figures 2 and 3 above. Call "commit" in the bandwagon game, and "insist on your preferred system" in the committee game, the "tough" strategies; and call "wait" in bandwagons and "concede" in committee, "soft" strategies. In each game, if (at some stage) just one player is tough, then his most-preferred outcome happens. If both sides are tough, then in the bandwagon game they are committed to incompatibility; in the committee game, they simply continue to the next period. Finally, if both are "soft," then in both regimes the game continues, but with less time to reach agreement. So both the committee and bandwagon games have the form:

		Player 2	
		Soft	Tough
Player 1	Tough	a+c, c	z, z
	Soft	w, w	c, a+c

<u>Figure 4: General Class of Coordination Games</u>

Since V(n-1) > a, if we assume inductively that V(n - 1) > W(n - 1), then the off-diagonal elements z and w are both higher in the committee game than in the bandwagon game. If the equilibrium value of a game were monotonically increasing in the payoffs, we could conclude by induction that the committee is always better than the bandwagon. Unfortunately, it is easy to construct examples of games in which one can increase certain payoffs and actually reduce the equilibrium payoff, since equilibrium strategies change. However, it is straightforward to prove:

<u>PROPOSITION 3: The mixed-strategy equilibrium payoff of the game in Figure 4 is increasing in w and z if w < c and z < c.</u>

To see this, suppose in contradiction, that w increases but the value of the game decreases. Since c > w, from the bottom row this implies that Player 2 must be playing left with higher probability than before. But in that case Player 1 can do better than before by playing top (since a+c > z). Similarly for z. We therefore conclude:

PROPOSITION 4: With a finite fixed horizon, the committee unambiguously outperforms the bandwagon system.

Recall that we assumed that if both players concede in the committee game then they have failed to coordinate. As we mentioned above, this seems unduly harsh. If both players show a willingness to concede it seems more reasonable that some coordinated action be achieved. In that case w in Figure 4 is even higher in the committee game so that, by Proposition 3,[31] the committee does even better. This is the sense in which departing from our "harsh" assumption only strengthens our result.

3. Allowing for the Value of Speed

In Section 2 we assumed that players care only about what eventually happens, not about when. This assumption is sometimes reasonable, but often time is valuable and players would rather reach agreement sooner than later. Since the committee is slower, one might expect that this could reverse the result of the previous section. In this section, we investigate this conjecture. Specifically, we suppose that payoffs are discounted by $\delta < 1$ for each period that decisions are postponed. Another motivation for this version of the model is that we need no longer assume a deadline.

In the committee system, each period (until agreement is reached) the players face a game of the form:

		Player 2: Concede	Player 2: Insist
Player 1	Insist	a+c, c	δV, δV
	Concede	δV, δV	c, a+c

Figure 5: Infinite Horizon Committee Game with Discounting

where V is the value of being at the beginning of a period without agreement.[32] Similarly, in the bandwagon system, each period the game has the form:

		Player 2	
		Wait	Commit
Player 1	Commit	a+c, c	a, a
	Wait	δW, δW	c, a+c

Figure 6: Infinite Horizon Bandwagon Game with Discounting

where W is the value of being in that game. Since we now have a stationary system, we cannot work by induction as in Section 2. Instead, to compare these equilibria, consider the class of games:

		Player 2	
		Soft	Tough
Player 1	Tough	a+c, c	t, t
	Soft	δU, δU	c, a+c

Figure 7: General Infinite Horizon Game

where U(t) is the mixed-strategy equilibrium value of the game. Let r(t) denote the probability that player 2 plays soft. Then

$$U(t) = r(t)(a + c) + [1-r(t)]t \qquad (2a)$$

$$= r(t)\delta U(t) + [1-r(t)]c. \qquad (2b)$$

Rearranging (2b) and differentiating gives

$$U'(t) = cr'(t)(\delta-1)/[1-r(t)\delta]^2.$$

Since $\delta < 1$, this means that U'(t) and r'(t) have opposite signs.

Differentiating (2a),

$$U'(t) = r'(t)(a + c - t) + [1 - r(t)].$$

If $a + c > t$, for U'(t) and r'(t) to have opposite signs it must be that:

PROPOSITION 5: U(t) is increasing, and r(t) is decreasing, in t.

Now, $\delta V > a$ or else the players would never agree to play the committee game at all. Therefore, the "t" in the committee period-game exceeds that in the bandwagon period-game, and so:

PROPOSITION 6: The committee system is unambiguously better than the bandwagon system when there is no fixed deadline but delay is costly.

Since r(t) is decreasing in t, "tough" behavior is more common in the committee system. However, it is less harmful.

This is, of course, very much like the behavior of the two systems in the analysis with a fixed deadline but many periods. In fact the infinite horizon problem with $\delta = 1$ and the finite horizon problem with n infinite are identical, as can be seen by comparing the period-by-period payoff matrices. We thus see that the two systems perform equally well (though descriptively differently) when time is of no concern; but the committee system is better when time is important.

This may seem surprising, since the committee is slower. One might think that the slower, more reliable system would seem less attractive when we allow for the value of time. However, as we lower δ from 1, the committee players no longer play tough with probability one, and so the committee acts much more quickly than before. Bandwagon players also become less patient, of course, and so they too resolve matters more quickly: but this increases the chance of uncoordinated outcomes.

4. Asymmetric Players

Firms of different sizes derive different relative benefits from compatibility: a large firm gains relatively little by being compatible with a small firm, while the small firm finds it more important (Katz and Shapiro (1985)). On the other hand, a large firm might care very much in absolute terms which standard it adopts. Since only the ratio c/a matters for a player's behavior, we might naturally expect a large firm to have smaller c/a than a smaller rival. We show that asymmetries of this kind do not change our welfare result, in either the finite-horizon or the infinite-horizon model.

Consider first the finite-horizon model. The key step of the proof is to generalize Proposition 3 to the case of asymmetric payoffs: the rest of the proof goes through as before. Consider therefore the following game:

		Player 2	
		Soft	Tough
Player 1	Tough	a_1+c_1, c_2	z_1, z_2
	Soft	w_1, w_2	c_1, a_2+c_2

Figure 8: General Class of Asymmetric Coordination Games

We must show that each player's mixed-strategy equilibrium payoff in this game is increasing in the four variables w_1, w_2, z_1, and z_2. Consider any one of these variables, say w_1. Suppose that player 2 plays soft with probability r. If r increases in w_1, then by playing tough player 1 does better payoff when w_1 is larger, since $a_1 + c_1 > z_1$. If r decreases in w_1, then, by playing soft, player 1 does better when w_1 is larger, since $w_1 < c_1$. Either way, therefore, player 1's payoff is increasing in w_1. The proof for the other variables is identical.

Next, consider the infinite-horizon model. The key step of the proof is Proposition 5; the rest of the proof goes through as before. Consider therefore the following payoffs.

		Player 2	
		Soft	Tough
Player 1	Tough	a_1+c_1, c_2	t_1, t_2
	Soft	δU_1, δU_2	c_1, a_2+c_2

Figure 9: General Class of Asymmetric Coordination Games

We must show that each player's payoff in the mixed-strategy equilibrium in this game is increasing in both t_1 and t_2. Since $\delta U_i < c_i$, arguments analogous to those immediately above establish our result.

Thus within our model the welfare comparison results are robust to asymmetric payoffs. Yet our argument for focusing on the mixed-strategy equilibrium seems less compelling when payoffs are asymmetric: a pure-strategy equilibrium might become focal. In particular, if $a > c$ for one player, then our analysis no longer applies: that player has a dominant strategy and consequently the other can only concede. This is plausibly an important advantage of size.

5. Hybrid Coordination

The committee system as analyzed above demands that participating agents be committed not to adopt their proposed solutions unilaterally, before the committee reaches a decision. Otherwise, if other players are mired in talk, one agent can simply commit, and thus obtain his most preferred outcome, since it is common knowledge that the others then will follow his bandwagon.

Often, however, such commitment is not available, not credible, or not undertaken. It is commonplace for committee deliberations to be spurred, threatened, disrupted, and reversed by marketplace developments when a participant refuses to await a cooperative decision or violates one. Thus the "pure" committee system which we have analyzed is an abstraction.

The pure bandwagon game too is an abstraction. Agents in a market with large compatibility benefits will seldom determine in advance that they will not communicate. So, although we find it helpful to analyze the pure cases, it is also important to analyze what happens when both mechanisms coexist.

We model this hybrid game as follows: In each period, each player has three choices. He can irrevocably adopt his preferred solution, hoping that the other will then follow. Or, if he refrains from that, he can go to committee where he has his usual options of "insist" and "concede". The game in which each player chooses among these three actions, and that in which they first decide whether to adopt and then, if they go to committee, whether to insist or concede, are equivalent. This is because adoption is an irrevocable commitment. We use the two stage formulation for simplicity.

In the infinite horizon formulation with discounting, we can represent the two stages of the hybrid game as follows:

First stage:

		Player 2: Committee	Player 2: Adopt
Player 1	Adopt	a+c, c	a, a
	Committee	H′, H′	c, a+c

Second Stage:

		Player 2: Concede	Player 2: Insist
Player 1	Insist	a+c, c	δH, δH
	Concede	δH, δH	c, a+c

Figure 10: The Hybrid Game

Here, H is the value of the hybrid game at the beginning of a period, while H' is the value of the hybrid game in any period after both players have decided not to adopt in that period.

Note that the first stage has the typical structure of the bandwagon game, while the second stage has that of the committee game. One might be tempted to conclude that the payoffs are also a hybrid of those found in the pure games. Suprisingly, the payoffs in the hybrid game are the highest of all! To see this we consider games of the form:

		Player 2	
Player 1		a+c, c	δt, δt
		δt, δt	c, a+c

Figure 11: Symmetric Infinite Horizon Game

Let the value of this game be X(t) and let the probability with which Player 2 plays "left" be f(t). Simple calculations show that $X(0)=(a + c)c/(a + 2c) > 0$, and that $X(c) = f(t)\delta c + [1 - f(t)]c < c$. Finally, we can show that $0 < X'(t) < 1$: Observe first that $f(t)(a + c) + (1 - f(t))\delta t = f(t)\delta t + (1 - f(t))c$, and so $f(t) = (c - \delta t)/(a + 2(c - \delta t)) < 1/2$. Therefore, since $X(t) = f(t)\delta t + [1 - f(t)]c$, we have $X'(t) = \delta f(t) + f'(t)(\delta t - c)$, which (after some calculation), equals $\delta f(t)[1 + a/(a + 2(c - \delta t))]$. Now, since $\delta < 1$ and $f(t) < 1/2$, $X'(t) \leq 1$. Also, by inspection, $X'(t) > 0$. Therefore we have:

PROPOSITION 7: If X(t) is the value of the game in Figure 11, then $X(0) > 0$, $X(c) < c$, and $0 < X'(t) < 1$.

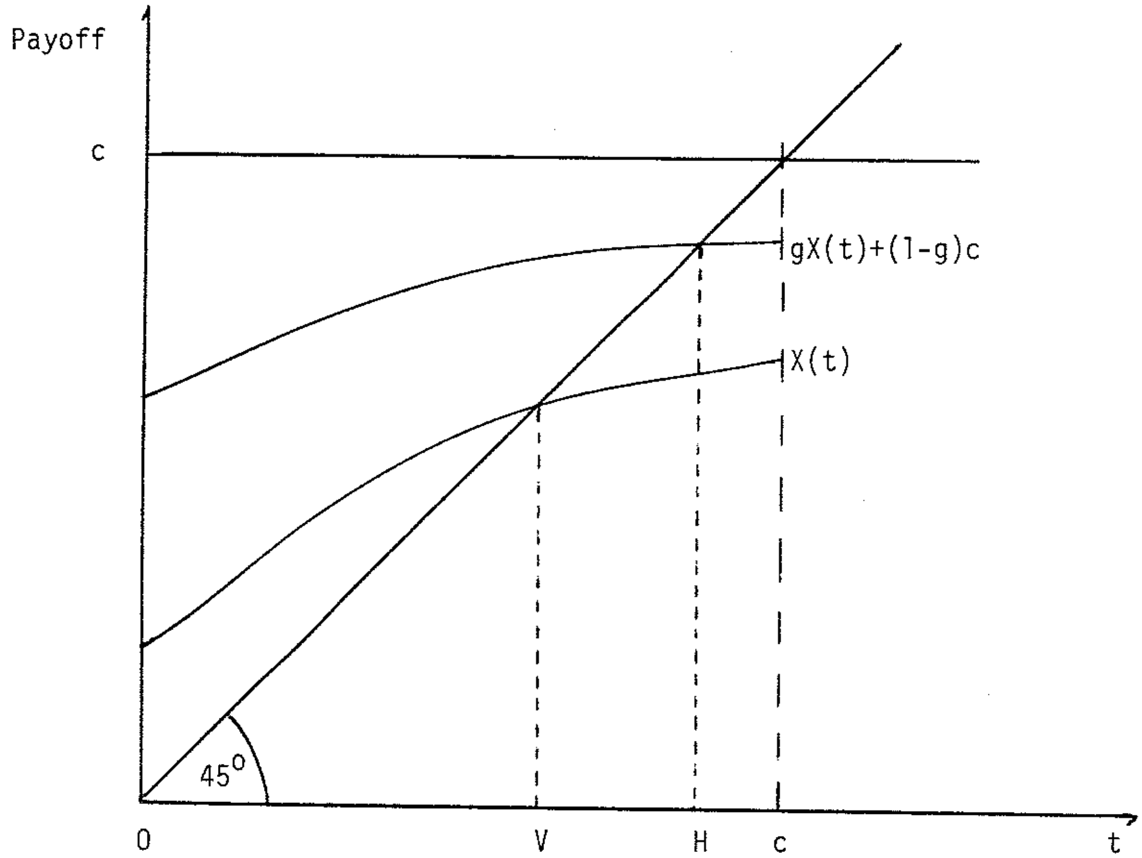

Figure 12: Committee and Hybrid Games Compared

Therefore, $X(t)$ is as illustrated in Figure 12. $X(t)$ has a unique fixed point. By inspection of Figure 5, it is the value of the committee game, V.

Now consider the hybrid game in Figure 10. From the first stage, we have $H = gH' + (1 - g)c$, where g is the probability the players play "committee". Comparing the second stage with the game in Figure 11, we see that $H' = X(H)$. Combining these expressions gives $H = gX(H) + (1 - g)c$. Therefore $t = H$ satisfies $t = gX(t) + (1 - g)c$. Since $g > 0$ and $V < c$, the right-hand-side of this equation is plotted on Figure 12. From this we see: PROPOSITION 8: The hybrid system outperforms the committee, and therefore is the best of the three coordination mechanisms considered.

An intuition for this result is that the hybrid system gives two chances for coordination each period rather than just one. We can evaluate player 1's payoff by assuming that he plays committee in the first stage. His expected payoff, H, is thus a mixture of c (which he gets if player 2 adopts) and H' (which he gets if player 2 also chooses committee). The pure committee game and the second stage of the hybrid game differ only in that δH replaces δV in the continuation cells. If $H > V$, then the second stage of the hybrid game has a higher payoff than the pure committee game, i.e., $H' > V$. In that case, H is a mixture of two payoffs, both of which exceed V, and so itself exceeds V. This suggests that an equilibrium can have $H > V$ and that it might be hard to have $H < V$. This intuition is confirmed by the proof above.

A different intuition for the result is the following: Suppose that at the first stage both players were going to choose committee with probability one, but decide instead to each play "adopt" with a very small probability, e. They then risk committing to incompatibility, but the probability of this is only e^2 - a second-order effect. On the other hand, with probabilty $2e(1-e)$ - a first-order effect - only one of them adopts, giving a strictly higher payoff. So if, as it turns out, the equilibrium value of e (i.e., $1 - g$) is not too large, then they are better off.

Since Proposition 8 shows that there is no ex ante incentive to avoid the hybrid system, and since (as we argued at the beginning of this section) the hybrid system will arise naturally, an important question is when observed outcomes will more closely resemble committee or bandwagon mechanisms: that is, when most decisions are in fact taken jointly or unilaterally. This amounts to comparative statics on the equilibrium probability g of playing "committee" in the hybrid game with respect to the basic parameters c and a, which matter only through c/a. We normalize c and think of variations in a: an increase in a represents an increase in the importance of conflict relative to coordination.

Consulting Figure 10, we have four equations for the variables H, H', g, and h, where h is the probability of conceding in the second stage:

$$H = a + gc = gH' + (1 - g)c,$$

$$H' = h(a + c) + (1 - h)\delta H = h\delta H + (1 - h)c.$$

Holding c fixed and changing a by da, we take total derivatives of these equations to get:

$$dH = da + c\ dg$$

$$dH = g\ dH' - (c - H')dg$$

$$dH' = h\ da + (c + a - \delta H)dh + (1 - h)\delta\ dH$$

$$dH' = \delta x dH - (c - \delta H)dx.$$

Substituting for dH and dH', and rearranging, we get two equations in da, dg, and dx:

$$\{1 - g[x + \delta(1 - x)]\}da + \{2c - H' - g\delta c(1 - x)\}dg$$
$$= g(c + a - \delta H)dx \qquad (3a)$$
$$\{1 - g\delta x\}da + \{2c - H' - g\delta xc\}dg$$
$$= - g(c - \delta H)dx. \qquad (3b)$$

From (3b), dg/da and dx/da have opposite signs. Hence from (3a), $dg/da < 0$ and $dx/da > 0$. This yields:

PROPOSITION 9: Where coordination is relatively more important, committee action is more common.

As evidence for this proposition, we cite the two information-technology industries mentioned in the Introduction: computers and telecommunications. While compatibility is important in computers, it is overwhelmingly important in telecommunications. Proposition 9 is therefore consistent with the observation that unilateral action is more often observed in computers than in telecommunications.

6. Conclusion

Problems of coordination arise in many important economic and other contexts. For example, coordination among potential entrants to an industry is an important assumption of the usual theory of entry,[33] aggregate demand and employment decisions involve coordination by firms and workers[34], the theory of economic development emphasizes coordination in the development of different sectors,[35] and efficiency in monopolistic competition can require coordination by manufacturers of complementary products[36].

Active coordination can take at least four forms. In addition to the two studied above, there are two others: tradition and authority. Certain kinds of animals[37] traditionally return to a fixed place at a fixed time of year for mating. But this method breaks down when faced with new problems for which tradition gives inadequate guidance. Coordination by authority happens if one player is nominated in advance to choose, and others then defer to him. But there may be no authority figure in a given interaction, or there may be more than one. We can sometimes nominate "government" as a universal authority figure, but even that breaks down in international problems, and works only poorly when the government is ill-informed.

If there is no predetermined authority, players may try to find one or to choose one fairly, as for instance by tossing a fair coin. Indeed, in our model, they would prefer that to the mechanisms we study. However, agreement by coin-tossing requires a commitment to abide by the result and not to demand another toss if the first is unfavorable. Of course, a committee system requires the same commitment, but since committee deliberations take time and in some cases are scheduled only infrequently (plenary sessions of the International Telecommunications Union are held every four years), it is unattractive to demand a new start (getting payoff V) rather than gracefully acceding (with payoff $c > V$).

The means of coordination studied in this paper, committees and bandwagons, are particularly relevant where neither tradition nor an authority structure creates a decisive asymmetry. We have compared them descriptively and normatively, and have evaluated a hybrid system in which both actions and words are used. We found the latter more effective than either pure system. Comparative statics on the relative frequency (in hybrid equilibrium) of resolution by committee and by unilateral action are in accord with at least one obvious piece of evidence.

For simplicity we used a mixed-strategy equilibrium to analyze the process of coordination. Perhaps the best way to view such an equilibrium is as a description of a Bayesian equilibrium in a model with different "types" of players (in our case, different values of c/a) playing pure strategies that depend on the player's type. If some types of players on each side have a > c, then "mixed" behavior will be observed, and there will be a "marginal type" who, like the players in mixed-strategy equilibrium, is indifferent between his two strategies.

However, problems arise in the mixed-strategy representation. In particular, the comparative statics of behavior with respect to asymmetries are unappealing. For instance, the mixed-strategy equilibrium predicts that the frequency with which a player concedes depends on his opponent's payoffs, not on his own: this is because his opponent's indifference between strategies must be maintained. Moreover, there is no learning about the rival's payoffs, as there is in Bayesian equilibrium.

Consequently, a Bayesian analysis would be a desirable extension of this work. Such an extension could address some important further questions. For instance, one advantage of the mechanisms observed in reality and considered here, over such possibilities as tossing a coin, is that if the two players have private information about their potentially different values of a, then our mechanisms make it likely that the bigger a wins (a desirable feature), while coin-tossing would not do so. In a Bayesian analysis one could ask which mechanism makes it most likely that the best system is adopted.

Our analysis has also ignored several important aspects of committees and markets, which a fuller theory should address. We have modeled a choice between two fixed alternatives, but in fact committees often identify and agree on compromises. Participants are often engineers who share information and view the committee as a design process, and pursue an "ideal technology" sometimes with little regard to their firm's economic interests.

In addition to compromise on particular issues, participants often compromise by trading concessions on one issue for concessions on another. One form of this is that a firm proposing a standard for joint adoption often offers or is asked to license any related patents at nominal royalties: this reduces the element of vested interest and thus facilitates agreement. Similarly, if the same firms interact repeatedly, then they may informally trade concessions on different product standards.

Without committees, repeated market interactions can facilitate intertemporal compromise in much the same way. The other forms of compromise mentioned, however, seem to depend on explicit communication and channels for agreement such as committees.

All these observations seem to strengthen our welfare conclusion that committees are always desirable. We conclude with two caveats suggesting that this is perhaps not always so. First, commitment is seldom immediate and absolute. If design decisions are cheaply reversible,[38] the losses from "mistakes" may be small compared to the benefits from untrammeled experimentation and the direct costs of committees in a large industry. Second, our analysis was based on an abstract "period"; we showed that a committee makes better use of each period than does a bandwagon, but in general the two mechanisms may have different period lengths. If the relevant period for bandwagon activity is much shorter than that for the committee, then our welfare comparison might be reversed. It should not be forgotten, however, that the interval between committee meetings is a choice variable.

REFERENCES

Besen, S.M. and L.L. Johnson, "Compatibility Standards, Competition, and Innovation in the Broadcasting Industry," The Rand Corporation, R-3453-NSF, November 1986.

Besen, S.M. and G. Saloner, "Compatibility Standards and the Market for Telecommunications Services," in Technology and Government Policy in Computers and Telecommunications, R. Crandall and K. Flamm, editors, The Brookings Institution, forthcoming.

Crane, R., The Politics of International Standards, Norwood, N.J.: Ablex, 1979.

Crawford, V., and H. Haller, "Learning to Cooperate," UCSD, mimeo (1987).

Diamond, P., A Search-Equilibrium Approach to the Foundations of Macroeconomics, Cambridge, MA: M.I.T. Press, 1984.

Farrell, J. "Cheap Talk, Coordination, and Entry," Rand Journal of Economics 18 (Spring 1987), 34-39.

Farrell, J. and G. Saloner, "Standardization, Compatibility, and Innovation," Rand Journal of Economics 16 (1985), 70-83.

__________________________, "Standardization and Variety," Economics Letters 20 (1986a), 71-74.

__________________________, "Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation", American Economic Review 76 (1986), 940-955.

Fudenberg, D., and J. Tirole, "A Theory of Exit in Duopoly," Econometrica 54, (1986) 943-960.

Gabel, H.L., Product Standardization and Competitive Strategy. Amsterdam: North-Holland, 1987a.

___________, "Open Standards in the European Computer Industry: The Case of X/OPEN," (1987b), in Gabel (1987a).

Hart, O., "Perfect Competition and Optimal Product Differentiation," Journal of Economic Theory 22 (1980), 279-312.

________, "Bargaining and Delay," mimeo, M.I.T. (1987).

Hendricks, K. and C. Wilson, "Equilibrium in Preemption Games with Complete Information," Working Papers in Economics E-86-72, Hoover Institution, 1986.

Katz, M.L. and C. Shapiro, "Network Externalities, Competition, and Compatibility," American Economic Review 75 (1985), 424-440.

__________________________, "Technology Adoption in the Presence of Network Externalities," Journal of Political Economy 94 (1986a), 822-41.

__________________________, "Product Compatibility Choice in a Market with Technological Progress," Oxford Economic Papers 38 (1986b), 146-165.

Matutes, C. and P. Regibeau, " 'Mix and Match': Product Compatibility Without Network Externalities," Sloan School of Management, MIT, mimeo (1987).

Rosenstein-Rodan, P., "Problems of Industrialization of Eastern and Southeastern Europe," Economic Journal (1943).

Rutkowski, A.M., Integrated Services Digital Networks, Dedham, MA: Artech House, 1985.

______________, "An Overview of the Forums for Standards and Regulations for Digital Networks," Telecommunications (North American Edition) 20 (1986), 84-96.

Sanders, T.R.B., The Aims and Principles of Standardization, International Organization for Standardization, 1972.

Simon, L., "Games of Timing," UC Berkeley, mimeo (1987).

Sullivan, M.T., and R.T. Zader, "The Role of Standards in Network Evolution," Computers and Standards 4 (1985), 33-53.

Verman, L.C., Standardization, A New Discipline, Hamden: Ardon Books, 1973.

FOOTNOTES

1. See Besen and Saloner (forthcoming) for details and further references.

2. Quote from Rutkowski (1986 p. 86). See Besen and Saloner (forthcoming) for more detail on these institutions and for further references.

3. See Farrell and Saloner (1985) for a treatment of how bandwagons can solve certain coordination problems, notably that of coordinating adoption of a new and superior technology as a standard. Farrell and Saloner (1985, 1986b) also discuss some limitations of the bandwagon process other than those described in the present paper.

4. See Besen and Johnson (1986) for more detail.

5. See e.g. Rutkowski (1986) and Sullivan and Zader (1985).

6. See Besen and Johnson (1986).

7. See Crane (1979).

8. See for instance Farrell and Saloner (1985, 1986b), Katz and Shapiro (1985, 1986a,b), and Matutes and Regibeau (1987). See Besen and Saloner (forthcoming) for an overview of this work and for a framework of the determinants of the standard-setting process.

9. This has occurred, for example, in modems, OSI, CD-ROM, railroads, and personal computers.

10. See Verman (1973) and Sanders (1972) for a discussion of the consensus principle.

11. For example, this occurred in the case of AM stereo and to a lesser extent in TV stereo.

12. "Product Standardization as a Competitive Strategy," INSEAD, June 9-10, 1986. The proceedings have been published in Gabel (1987a).

13. See e.g. Rutkowski (1985), p.9.

14. This is a primary focus of the Corporation for Open Systems.

15. See Sanders (1972) and Verman (1973), for example.

16. Even where the benefits to compatibility are large, this is not inevitable. Katz and Shapiro (1986b) show how firms' incentives to choose compatibility or incompatibility are affected by the dynamics of competition between them. And even if compatibility is preferable, the disadvantage of having to catch up on a rival's proprietary standard may be so large as to overcome that preference, so that compatibility may be impossible to reach unless a compromise is possible. For example, the European computer group X/OPEN chose UNIX as its standard operating system because no member was prepared to switch to another's previously proprietary standard. See Gabel (1987b) for details.

17. North American Presentation Level Protocol Syntax. See Besen and Johnson (1986) p. 80.

18. See Crane (1979) on the battle over color TV standards. A similar fight is proceeding on the new high-definition television (HDTV) front. European, especially French, government representatives at the International Radio Consultative Committee's plenary meeting in 1986 blocked the working committee's proposal to adopt NHK's system, which American and Japanese interests favored. (Broadcasting, May 19, 1986, p.70).

19. In this classic game of coordination, a man and a woman are choosing between the ballet and a prize fight. The main concern of each is to be in the company of the other (regardless of where they go), however he prefers the prize fight and she the ballet, or *vice versa*.

20. See Hendricks and Wilson (1986) and Fudenberg and Tirole (1986).

21. This game is discussed, for example, in Fudenberg and Tirole (1986). It was first proposed by Richard Gilbert.

22. A simple non-binding straw vote would establish if the opposite were true. Since the obvious focal outcome if the straw votes agree is for the firms to adopt the agreed-upon standard, neither has an incentive to lie about its preferences. For to do so could only encourage the other firm to adopt the first firm's less preferred standard.

23. In contrast to models in which a deadline gives one player a strategic incentive to wait (as in Hart (1987)), there is no such incentive for our players.

24. This is not always so. Since we are considering nascent technologies, new information may arrive, and delay may be valuable.

25. The minor modification is that the uncoordinated outcomes have unequal payoffs.

26. Another apparently appealing representation of the outcome of no coordination would be that each player adopt his preferred system: 1 adopts A and 2 adopts B. But this would not be an equilibrium: either player unilaterally would prefer to change his choice.

27. Because the committee proceedings are cheap talk and there is no private information, the only effect of committee proceedings is to make one outcome focal. When one player concedes and the other holds firm, we interpret this as an "agreement" on the latter's preferred technology, and we believe that following such a self-enforcing agreement is focal.

28. A more generous assumption would raise the payoff from both players conceding in the committee game. It is intuitive, and we will prove in Proposition 3, that this would make the committee game more attractive overall. This would merely strengthen our main result.

29. Simon (1987) has shown the value of studying games of timing in continuous time by taking limits of finite-horizon games.

30. For plenary sessions, the period can be several years. For example, the plenary session of the CCIR in May 1986 failed to reach agreement on a standard for high-definition television, so that the next possible date will be in 1990. (See Besen and Johnson (1986)). If the committee period is much longer than the corresponding period for the bandwagon, our result could of course be reversed; we discuss this further in the Conclusion.

31. Proposition 3 does not apply if $w > c$; but in that case we know that $V(n) > c > W(n)$.

32. As before, the results only become stronger if we make a more generous assumption about what happens if both concede.

33. See Farrell (1987).

34. See Diamond (1984) and Roberts (1986) for examples in which coordination difficulties can cause aggregate unemployment.

35. See for instance Rosenstein-Rodan (1943).

36. See Hart (1980).

37. Elephant seals, for example.

38. Coordination without sunk costs has been studied recently by Crawford and Haller (1987).

Jan-88

RECENT ISSUES OF THE WORKING PAPER SERIES
OF THE DEPARTMENT OF ECONOMICS
UNIVERSITY OF CALIFORNIA, BERKELEY

Copies may be obtained from the Institute of Business and Economic Research. See the inside cover for further details.

8751 Barry Eichengreen
DID INTERNATIONAL ECONOMIC FORCES CAUSE THE GREAT DEPRESSION?

Sep-87.

8752 Jeffrey A. Frankel
MONETARY AND PORTFOLIO-BALANCE MODELS OF EXCHANGE RATE DETERMINATION

Sep-87.

8753 Albert Fishlow
MARKET FORCES OR GROUP INTERESTS: INCONVERTIBLE CURRENCY IN PRE-1914 LATIN AMERICA
Sep-87.

8754 Albert Fishlow
SOME REFLECTIONS ON COMPARATIVE LATIN AMERICAN ECONOMIC PERFORMANCE AND POLICY
Sep-87.

8755 Barry Eichengreen
REAL EXCHANGE RATE BEHAVIOR UNDER ALTERNATIVE INTERNATIONAL MONETARY REGIMES: INTERWAR EVIDENCE
Sep-87.

8756 Leo K. Simon and William R. Zame
DISCONTINUOUS GAMES AND ENDOGENOUS SHARING RULES

Oct-87.

8757 Leo K. Simon
A MULTISTAGE DUEL IN CONTINUOUS TIME

Oct-87.

Jan-88

RECENT ISSUES OF THE WORKING PAPER SERIES
OF THE DEPARTMENT OF ECONOMICS
UNIVERSITY OF CALIFORNIA, BERKELEY

Copies may be obtained from the Institute of Business and Economic Research. See the inside cover for further details.

8758 Joseph Farrell and Carl Shapiro
OPTIMAL CONTRACTS WITH LOCK-IN

Oct-87.

8759 Joseph Farrell and Eric Maskin
RENEGOTIATION IN REPEATED GAMES

Oct-87.

8760 Joseph Farrell and Nancy T. Gallini
SECOND-SOURCING AS A COMMITMENT: MONOPOLY INCENTIVES TO ATTRACT COMPETITION

Oct-87.

8761 Pranab Bardhan
ALTERNATIVE APPROACHES TO THE THEORY OF INSTITUTIONS
IN ECONOMIC DEVELOPMENT
Nov-87.

8762 Jeffrey A. Frankel and Alan T. MacArthur
POLITICAL VS. CURRENCY PREMIA IN INTERNATIONAL REAL INTEREST DIFFERENTIALS:
A STUDY OF FORWARD RATES FOR 24 COUNTRIES
Dec-87.

8863 Joseph Farrell and Robert Gibbons
CHEAP TALK CAN MATTER IN BARGAINING

Jan-88.

8864 Joseph Farrell and Garth Saloner
COORDINATION THROUGH COMMITTEES AND MARKETS

Jan-88.

8865 Joseph Farrell and Carl Shapiro
DYNAMIC COMPETITION AND SWITCHING COSTS

Jan-88.