Intellectual Property and Standardization Committee Participation in the U.S. Modem Industry

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Abstract

We take a preliminary look at the interaction between patenting and standardization committee participation in the U.S. modem industry. Both involve a much wider set of firms than the downstream modem manufacturers themselves. Not surprisingly, the two activities are highly correlated across firms. Using five-year periods, Granger causality tests show that while patenting is predicted by participation in earlier standardization meetings, meetings participation is not predicted by earlier patenting. We interpret these results as reflecting the timing of standard setting relative to innovation.

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1. INTRODUCTION

The last two decades have witnessed a proliferation of high-tech consumer electronic products which exhibit network effects. Successful diffusion of these products is often contingent on a single product winning a battle of market standards or firms achieving compatibility among competing standards.[1] The benefit to consumers from purchasing a network good depends on the number of other consumers who eventually purchase the same network good, or a compatible one. This situation has two main implications for competition in network markets, with competing standards:

1. Consumers' expectations regarding the future size of a network are critical in the adoption decision. On the one hand, the expectation that one technology will become a standard may be self-fulfilling. On the other hand, fragmented expectations may lead to a battle with no winner. Postrel (1990) partly attributes the failure of quadraphonic sound in the 1970s to competing standards.
2. When network effects are relatively strong, long-term coexistence of competing incompatible standards is unlikely. A small initial advantage will likely influence consumer expectations about the adoption of a particular standard, which, in turn will lead to more consumers adopting the standard. Thus, an early lead can be transformed into an advantage that is difficult to overcome.

Thus, competition in network goods markets without a previously agreed-upon standard will often entail suboptimal demand and high risks for firms. Hence, firms may be willing to have a single standard set "outside" of the marketplace. Broadly speaking, there are three ways that can happen: First, national standards bodies, such as the U. S. Federal Communications Commission (FCC), can

[1] This section draws from Gandal (2002).

impose the standard on the market. Second, official accredited standard development organizations (SDOs)[2] can agree on which standards to set. An SDO must trace its accreditation to a governmental body, such as the American National Standards Institute (ANSI). In fact, ANSI accredits more than 270 public and private SDOs that follow ANSI policy in developing voluntary (consensus) standards and is the only U.S. representative to both the International Organization for Standardization and the International Electromagnetic Commission. The standards set by SDOs are non-proprietary. Third, industry trade groups, consortia, and other standard setting organizations (SSOs)[3] can jointly develop standards. As with standards set by SDOs, these standards are also typically non-proprietary.[4]

There is by now a large body of literature on the economics of compatibility and standardization.[5] Although the literature is primarily theoretical, there is a growing empirical literature as well. Despite the increasing importance of SDOs and SSOs in achieving standards, there is surprisingly little systematic economics research, either theoretical or empirical, on the topic.

Firms in oligopoly markets interact strategically in many different dimensions. In the case of industries where standardization and compatibility are important, firms meet in standardization organizations in addition to competing in both research and development and the product market. Indeed, firms have come to recognize the strategic importance of participating in standard setting

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[2] Examples of SDOs include the International Telecommunications Union (ITU), the oldest international standards body in the world, and the International Electrotechnical Commission. Given the importance of compatibility among international phone networks, the standards set by the ITU are done so by international consensus.

[3] SDOs are a subset of SSOs. See Caplan (2003).

[4] The DVD (digital video disc) industry provides an example of a jointly developed standard. Throughout the 1990s, video hardware and software manufacturers sought a digital format to replace videocassettes. In order to avoid another Beta/VHS format war, hardware manufacturers led by Sony, Toshiba, and Panasonic, and movie studios, led by Warner and Columbia (a division of Sony), worked together to establish a single standard. The result was the non-proprietary or "open" DVD standard.

[5] We will not provide a detailed survey here. See David and Greenstein (1990) for a comprehensive survey of previous work, and Farrell and Klemperer (forthcoming,) for a detailed survey of more recent work. Gilbert (1992), Katz and Shapiro (1994), Gandal (1995), and Matutes and Regibeau (1996) provide selective reviews of the literature. See Gandal (2002) for a discussion of policy issues and Stango (2004) for a survey of the literature on standards wars.

organizations and hence increasingly send senior decision makers in addition to technical staff to these meetings.[6]

There are several reasons why firms participate in standards meeting. As mentioned previously, in industries in which interoperability is important, competing incompatible standards may lead to the market failure of the technology itself. An additional reason to participate in standards meetings is that firms profit from getting their intellectual property into the standard. Most standards committees allow firms to earn "reasonable and non-discriminatory" royalties if their intellectual property is part of the standard. In many cases, this may be the best way for firms to earn revenues from intellectual property. Although economic models of standard setting typically envision two firms with complete and proprietary incompatible technologies, often many firms are involved, and no single one owns a full set of patents covering the essential components of the technology. In such cases, no single firm can credibly threaten to develop its own standard unilaterally.

Another reason for participating in standards committees is that that knowledge diffuses through the meeting process. Firms may gain key insights that will contribute to future intellectual property or help improve their competitive position in the product market.

In this paper, we focus on modems. Network effects arise in modem markets because compatible modems are required to transfer data between the sending and receiving parties, for example, between consumers and Internet service providers (ISPs). Consumers benefit from a modem standard because this enables them to change their ISP without having to change modems. Additionally, a standard enables consumers to travel to other geographic areas and connect to the Internet through the local ISPs.

technology—33 kbs per second.[7] The incompatibility in the market led to confusion among consumers and reduced sales. As one industry analyst wrote somewhat colorfully, "Back in 1996, for example, there was the heated, worldwide standards battle involving 56 kbs analog modem technology that dragged on for a couple of years. Consumer confusion soared, modem sales declined dramatically, and the modem industry in general received a strong punch in the stomach."[8] The standards war featured efforts by both sides to influence the expectations of adopters, with exaggerated claims of dominance. However, the consensus is that, rather than tip the market, the standards war instead caused confusion among consumers and ISPs, which delayed modem adoption.

Here, we empirically examine the interaction between intellectual property and participation in standardization committee meetings. We employ "meeting" data from the Telecommunications Industry Association, the SDO responsible for developing voluntary (consensus) standards in the analog modem market in the United States. We first conclude this section with a literature review. In Section 2, we discuss the modem market; we chose this market because the product is well defined. In Sections 3 and 4, we present our data on patents and on participation at standardization committee meetings, respectively. We report basic correlations and Granger causality tests in Section 5. Our major finding is that while participation in standards meetings predicts future intellectual property (both unweighted and citation weighted patents), the reverse is not true: patents and citations are not good predictors of future meeting attendance. We interpret these results primarily as reflecting the timing of standard setting relative to innovation, although we also consider the effects of knowledge diffusion at the meetings. In Section 6, we conclude and provide a direction for further research.

1.1 Literature

In Farrell and Saloner's (1988) seminal theoretical paper about the economics of standards committees, the authors find that standards committees have desirable properties. In their study, each firm has a

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[7] See Ageureau, Greenstein, and Rysman (2003).
[8] See Garen (2004).

proprietary (incompatible) standard. There are network effects, so both firms prefer to use the same standard, but each prefers its own standard to that of the rival firm. Farrell and Saloner then examine the incentives for these firms to achieve coordination via standardization committees and they compare committees to (1) to a pure market process in which there is no communication among firms and firms can make unilateral standardization choices and (2) a hybrid committee/market process in which firms meet in committees and yet can also make unilateral standardization decisions. They find that committees can better set standards in the sense that committees are more likely than market processes to achieve coordination, that is, standardization (which is efficient in their model). Nevertheless, there is a trade-off here since the committee process will typically take longer than it would if standardization choices were left to the market. Perhaps, not surprisingly, the hybrid process outperforms the other two mechanisms.

Several recent empirical papers are a welcome addition to a small, primarily case study literature. Lemley (2002) examines the intellectual property policies of standardization organizations. Augeureau, Greenstein, and Rysman (2003) examine the modem standards war of 1996 through1998; they claim that the failure to reach standardization in the market was due to ISPs' incentives to differentiate their product. Simcoe (2004) examines the standard-setting process of the Internet Engineering Task Force and finds that increased levels of commercial participation are associated with an increase in the time to reach agreements on standards. Meidan (2004) examines a "standard setting race" between two SSOs—an official SDO and a commercial SSO—for the case of cable modems. Using event study methodology and stock market returns, she finds that the commercial consortium's standardization decisions created increased competition in the retail market.

2. *MODEMS*

Modems were invented in the 1950s. In 1977, Dennis Hayes invented the first modem for personal computers (PCs). In 1978, he founded Hayes Associates, Inc, and in 1979, he shipped the first PC modem. Hayes became the industry standard, achieving a 60% of the world's modem market in 1985.[9] Hence many competing vendors marketed their modems as Hayes-compatible. The PC modem changed the industry from one that worked via leased lines to one that worked via dial-up connections.

Early modem speeds were very slow by today’s standards. In 1981, modems ran at speeds of 1.200 kbs. In 1983, Hayes released the Smartcom II, which ran at modem speeds of 2.400 kbs. By 1996, the maximum speed had increased to 56 kbs (see Table 1).

Early modems were prohibitively expensive as well. In 1981, the average price of a (1.200 kbs) modem was approximately $1500, that is more than a dollar for each bit per second. By 1997, the price of an (analog) modem with a speed of 56 kbs had fallen to less than $300, or $0.005 for each bit per second.[10] That translates into a more than 30% decline in speed-adjusted prices per year for the fifteen-year period from 1981 to 1996.[11] The International Telecommunications Union (ITU) standards shown in Table 1 typically were developed before competition developed in the market.[12] Nevertheless, there was a standards war in this industry over the 56K standard. In September 1996, U.S. Robotics (3COM) submitted the first V.90 56K proposed standard to the ITU. In November 1996, Lucent and Rockwell, agreed to make their chipsets interoperable by using the so-called Kflex standard. However, the Kflex and U.S. Robotics standards were incompatible. Because of the incompatibility, sales to consumers and

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[9] See http://gtalumni.org/StayInformed/magazine/win99/high.html.
[10] Prices in Table 1 come from Bob Kenas (1997).
[11] In comparison, quality-adjusted computer prices fell by about 15% in the 1980s and early 1990s and only reached rates of decline of about 30% in the second half of the 1990s. See Gordon (2000) and Oliner and Sichel (1994).
[12] There often were precursor modems from individual vendors before the ITU standards, but their numbers were low.

ISPs were lower than expected. Hence, the industry appealed to standardization agencies to establish a standard.

In April 1997, the ITU set up a special committee to determine a 56K (V.90) standard.[13] In February 1998 the V.90 standard was approved by the ITU. The relatively short time between the first submission and the setting of the standard was apparently a record for the ITU. Following the introduction of the standard, all new Kflex and U.S. Robotics modems were produced according to the V.90 standard and hence were interoperable. Hence, even when a standards war broke out, the standard was eventually resolved through a committee process.

3. PATENT DATA

We obtained all 604 patents issued between 1976 and 1999 with the word *modem* in the title.[14] We then matched the patent numbers using the National Bureau of Economics Research patent data, which is publicly available at http://www.nber.org/patents/. From the Web site, we obtained data on the grant year, the assignee, and the number of citations to each patent. Figure 1 shows that until 1982 there were less than 10 patents issued per year with the word *modem* in the title. For 1982–1999, the number of modem patents per year increased steadily, reaching 80 in 1999.

One hundred ninety-four firms received patents with the word *modem* in the title during the 1976–1999 time period. In Table 2, we show the number of modem patents and citations to these patents by firm for 1976–1999, as well as for the sub-periods 1976–1989 and 1990–1999. (The citations are dated by the year of the receiving patent.) Motorola, the leader in cable modems from its introduction in

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[13] Since the Telecommunications Industry Association (TIA) TR-30 committee was the U.S. technical advisory group to the ITU during this period, it was also actively involved in the process. Indeed, Les Brown, the chairman of the TIA TR-30.1 subcommittee at the time, was listed on the ITU press release announcing the standard. See http://www.itu.int/newsarchive/press_releases/1998/04.html.

[14] Nearly half (44.5%) of these patents are to be found in the three-digit patent class 375 "Pulse or Digital Communications"). Another 18.5% are in 379 ("Telephonic Communications"), and another 12% in 370 ("Multiplex Communications"). The remaining 25% are to be found in more than thirty other classes.

1997 on, had the most patents overall, as well as the largest number during 1990–1999. Hayes, the first and initially dominant firm in the industry, was ranked high during 1976–1989, but fell in the rankings during 1990–1999. U.S. Robotics, the current market leader in dial-up analog modems, was absent from the top fifteen during 1976–1989, and was ranked only twelfth during 1990–1999. The list of firms includes not only modem manufacturers, but producers of both modem inputs and complementary products as well, as the fourth column in the table indicates.

4. STANDARDIZATION MEETINGS

In the United States, the Telecommunications Industry Association (TIA) is the primary association that sets voluntary standards in this area. The TIA was formed as the result of a merger of the United States Telecommunications Suppliers Association and the Information and Telecommunications Technologies Group of the Electronic Industries Alliance in 1988.

The TIA is an SDO accredited by the ANSI to develop voluntary telecommunications standards. As such, TIA's intellectual property policy is consistent with that of ANSI: Namely, any essential patent in a U.S. standard must be licensed according to "reasonable and non-discriminatory" terms.

We focus on the TIA TR-30 committee, which is responsible for setting analog standards in data transmission systems and equipment. One of the key responsibilities of the TIA TR-30 committee is to set analog modem standards in the U.S.[15] The TIA TR-30 committee was also the U.S. technical advisory group to the ITU, the organization that sets international telecommunications standards. This committee has three subcommittees that address three subtopics:

- TR-30.1—Modems
- TR-30.2—Data termination equipment–data communication equipment interfaces and protocols

[15] There is a separate standards committee for digital modems, hosted by the Alliance for Telecommunications Industry Solutions.

- TR-30.3—Data communications equipment evaluation and network interfaces

The committee and the subcommittees meet on a regular basis, with approximately five to six meetings per year (see Table 3). The committee and subcommittee meetings are typically held jointly. Occasionally a subcommittee will hold an additional separate meeting.

Our data consists of participation records of the 56 TR-30 meetings that took place between 1990 and 1999.[16] The TR-30 subcommittees show that the committee is responsible for more than just modems. However, participation data for the subcommittees are not complete and only available for a few of the years. Nevertheless, the main committee meeting and the subcommittee meetings are held at the same time at the same location, and most participants who attend the main committee meetings attend the subcommittee meetings as well. Indeed, there is a very high correlation (0.92) between participation at TR-30 standardization meetings during the 1993–1999 period and participation at TR 30.1 committee meetings during the same period.[17] Hence, it is reasonable to use TR-30 participation data.

Figure 2 shows the average attendance at TR-30 meetings over the 1990–1999 period. The figure shows a steady increase from approximately 35 participants per meeting in 1991 to 58 in 1993. Attendance remains relatively high, peaking in 1997 at 62 participants per meeting during the standards war over the 56K modem. Afterwards, for 1998–1999, attendance falls to slightly more than 40 per meeting, perhaps partially due to resolution of the standards war and the advent of the digital modems.

Overall, 177 firms participated in at least one TR-30 meeting during the 1990–1999 time period. In Table 4, we present the 1990–1999 participation data for the top 15 of those firms; we also include data for the sub–time periods of 1990–1994 and 1995–1999. Four firms — Motorola, AT&T, Rockwell, and General Datacomm —accounted for 25% of the meeting participants for 1990–1999, and the top 15 firms accounted for approximately 54% percent of total participants during that same time period.

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[16] We do not have attendance data for five of the meetings during 1990-1999, specifically, three meetings during 1990-1994 and two meetings during 1995-1999.

[17] The 1995 and 1998 participation data are missing for the TR-30.1 subcommittee. Hence, we use the equivalent data for the full TR-30 committee. This calculation is made for the forty-five firms that hold patents and attended meetings.

Not listed in Table 4 are the top 15 firms for each sub-period, which are obviously different than those from the entire 1990–1999 period. Our data show, however, that while the top 15 firms of 1990–1994 accounted for more than 66% percent of the participants, the top 15 firms of 1995–1999 accounted for just 51% percent of the participants. This suggests that an increasing number of firms believe that there are benefits from participating in the meetings.

5. PATENTING AND MEETING PARTICIPATION

Approximately 194 firms received patents with the word modem in the title during the 1976–1999 period. Similarly, 177 firms attended TR-30 standardization meetings during the 1990–1999 period. The Herfindahl index (HHI) for patents during the 1990–1994 period is 378 and 225 during the 1995–1999 period. Similarly, the HHI for standardization meetings is 448 for 1990–1994 and 262 for 1995–1999. Hence both intellectual property and standard meeting "competition" have become less concentrated over time. These concentration figures are extremely low relative to what the modem product market concentration figures are likely to be, but, as we saw, both meeting participants and patentees are drawn from a much wider set of firms. However, the modem patent HHI is not so much greater than the average three-digit patent class HHI of 314, which is striking considering that the average number of assignees in a three-digit class is almost 2400—an order of magnitude greater than our set of patent modems.[18]

When we merge the two data sets (by assignee number), we find that only 45 firms both attended TR-30 standardization meetings during the 1990–1999 period and held patents with the word modem in the title. (Thus, 326 firms either held at least one patent or attended at least one meeting.)

Nevertheless, (see Table 5a), these 45 firms accounted for more than 47% of the total patents issued and 41% of the citations for 1976–1999. In addition, 55% of the firms with patents attended

[18] The average three-digit HHI and number of assignees is calculated on the NBER data for 1976-1999 patents only.

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standardization committee meetings for 1995–1999, up from the 41% for 1990–1994. Also, (See Table 5b) 64% of the attendees at the TR-30 standardization meetings for 1990–1999 held relevant modem patents.

An interesting question is whether there are participants who regularly attend standard committee meetings but do not hold patents (or vice-versa). Of the 15 firms with the most participants (see Table 4), only three firms did not hold patents. Two of the three, Satchell Evaluations (67 participants) and

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5. EMPIRICAL ANALYSIS:

We now use the merged data set to conduct a more formal analysis. We first define the following variables at the firm level:

- Patents: Total number of patents issued during the 1976–1999 period
- Citations: Total number of citations during the 1976–1999 period
- Meetings: Total number of meeting participants for the 1990–1999 period
- Meetings1: Total number of meeting participants for period 1,1990—1994,
- Meetings2: Total number of meeting participants for period 2, 1995–1999
- Patents1: Total number of patents issued during period 1, 1990–1994
- Patents2: Total number of patents issued during period 2, 1995–1999
- Citations1: Total number of citations during period 1, 1990–1994
- Citations2: Total number of citations during period 2, 1995–1999

Descriptive statistics appear in the appendix. See Tables 6a and 6b for correlations for the following three variables: (1) total number of patents for the 1976–1999 period, (2) total number of citations for the 1976–1999 period, and (3) TR-30 meeting participation for the 1990–1999 period. We present the data are for all 326 firms that have at least one patent or attended at least one meeting in Table 6a; and we present the same summary data for the 45 firms that had patents and attended meetings in Table 6b.

These tables show that there is a very high degree of correlation between patents and citations. This, of course, is not surprising. The interesting result is the relatively high degree of correlation between patents and meetings. Also, the correlations are similar for both data sets. See Table 7a (full data set) and Table 7b (45 firms) for correlations using the period 1 and period 2 variables. We first compare

the correlations across periods 1 and 2 for the same variable. The correlation between Meeting1 and Meeting2 is 0.72 for all 326 firms, while it is 0.68 for the smaller data set.

The correlations between patents across periods and between citations across periods are lower than the correlations across meeting attendance. The correlation between Patent1 and Patent2 is 0.35 for the full data set and 0.27 for the smaller data set. Similarly, in the case of citations, the correlation across the two periods is 0.30 for the full data set and 0.27 for the smaller data set.

When we look across different variables and different periods for the full data set, we find that the contemporaneous correlation between citations and meetings is higher in period two than it is in period one. Similarly, the correlation between patents and meetings is higher for period two. Perhaps the most striking result is the relatively high correlation between Citation2 and Meetings1 (0.60 for the full data set and 0.63 for the smaller data set.)

5.1 GRANGER CAUSALITY

The relatively high correlations in Tables 7a and 7b between intellectual property, which includes patents and citations, and meeting participation data begs the question of whether there is a causal relationship between these variables. That is, does increased participation in standard committee meetings lead to increases in intellectual property, or does increased intellectual property holdings lead to greater participation at standards meetings?

Given the limitations of our data, we can test for causality only in the narrow, technical sense formalized by Granger (1969) and Sims (1980).[19] In this interpretation, a variable *X* causes *Y* if lagged values of *X* are significant in explaining *Y* in a regression in which lagged values of *Y* are also explanatory variables. It is, of course, possible that causality can exist in both directions. This test is performed

[19] This section draws from Gandal, Greenstein, and Salant (1999), who conducted a similar type of analysis.

using vector autoregressions.   We are not estimating a structural model when performing these tests; nevertheless, we believe that this type of analysis is useful for an initial examination of these variables.

Since it typically takes an average of two to three years to receive a patent, it seems sensible to use two periods that correspond to periods for which we have data on standard committee participation: 1990–1994 and 1995–1999. Because there is there is only a single lag for the standard participation data we employ the following specification:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 X_{t-1}.$$

Formally, X causes Y if X_{t-1} is significant in explaining Y, after controlling for Y_{t-1}. We present results from vector autoregressions of intellectual property on meeting participation and vise-versa in Tables 8a and 8b.

In the case of all the full data set (326 firms), the first column of Table 8a shows that early patents predict later ones; every additional early patent is associated with about half of an additional later patent. Even controlling for this effect, early participation in standards meeting predicts later patents. An additional participant at each of the twenty-nine meetings in the first half of the 1990s would predict an additional 1.7 patents in the second half. The second column of Table 8a similarly shows that early citations predict later citations. Likewise, after controlling for the lagged dependant variable, early participation in standards meetings explains the later citations as well.

In Table 8b, we present results for the smaller data set, namely, for the 45 firms that both patented and attended at least one meeting. Now, the lagged dependent variable has no predictive power in either of the first two columns. Yet participation in the early standards meetings still predicts the late patents and citations.

The obvious explanation for our finding is that firms with pending but not yet granted patents attend the committee to have the standard incorporate their intellectual property. However, as there is typically a lag of only two to three years between patents applications and patent grants, it is possible that

firms lobby to introduce innovations for which they have not yet applied for a patent—although there are obvious risks in doing so. Another possible explanation is that the information garnered at these meetings help advance firms' intellectual property portfolio. Another type of knowledge diffusion may be relevant to the effect of early meetings on citations; firms may cite patents of other firms attending standard meetings. We hope to discriminate among these various explanations in further research.

The third and fourth columns of Tables 8a and 8b show that past participation in early standardization meetings is a good predictor of participation in later ones. With our limited data, we cannot hope to discriminate between a heterogeneity explanation for this correlation, and a state-based explanation, that is, that firms that participate in standardization meetings realize the benefits from doing so and continue to participate in the future. More interesting is the finding that neither early patents nor early citations predict participation in the later standardization meetings. This finding indicates that only recent innovations are the subject matter of these meetings. Innovations covered by patents that are four to five years old must either no longer be technology relevant or have had their standardization decision already made—they are either already in or out of the standard.

6. CONCLUSION

We empirically examined the interaction between patenting and participation in standardization committee meetings. We showed that while many firms obtained modem patents and many firms participated in standardization meetings, only a small subset of firms (45 of 326) both obtained patents and participated in the standardization meetings. These firms accounted for a significant percentage of the patents received and the total number of meeting attendees. For these 45 firms, we find a fairly high correlation among the intellectual property (measured by both patents and citations) and meeting participation data. Using Granger-causality tests, we also find that although participation in standards meetings predicts future intellectual property, early patents or citations do not predict later participation in

the meetings. We interpret these results primarily as reflecting the timing of standard setting relative to innovation, although we also consider the effects of knowledge diffusion at the meetings.

Missing from this analysis is a formal consideration of the firms' importance in the product market. This third element is difficult to add not only because there are various modem product markets (dial-up, faxes, etc.), but also because both meeting participants and patentees often are not modem producers at all, but input suppliers or users. Furthermore, market share data are difficult to obtain. Nevertheless, understanding the three-way interaction of meeting participation, patenting, and product market competition is surely essential to a full understanding of the role of standardization committees in the modem market, and in markets more generally. We hope to address this issue in further research.

References

Augeureau, A., S. Greenstein, and M. Rysman. 2003 Coordination vs. Differentiation in a Standards War: 56K Modems,Northwestern Mimeo.

Caplan, P. 2003. Patents and Open Standards, National Information Standards Organization, available at http://www.niso.org/press/whitepapers/Patents_Caplan.pdf.

Cargill, C. 2004. Standardization, the Necessary Luxury, available at http://www.geoplace.com/gw/2004/0403/0403ogc1.asp

David, P. and S. Greenstein. 1990. The Economics of Compatibility Standards: An Introduction to Recent Research, *Economics-of-Innovation-and-New-Technology* 1 3–41.

Farrell, J. and P. Klemperer. Forthcoming. *Handbook of Industrial Organization*, *Volume 3*.

Farrell, J. and G. Saloner. 1988. Coordination through Committees and Markets, *Rand Journal –of Economics* 19 (2): 235–52.

Gandal, N. 1995. A Selective Survey of the Literature on Indirect Network Externalities, *Research in Law and Economics,* 17: 23–31.

———. 2002. Compatibility, Standardization, and Network Effects: Some Policy Implications, *Oxford Review of Economic Policy* 18: 80–91.

———, Greenstein, S., and Salant, D. 1999. Adoptions and Orphans in the Early Microcomputer Market, *Journal of Industrial Economics*47: 87–105.

Garen, C. 2000. Analog Modems Take Center Stage: Industry Trend or Event, *Electronic News* August 7, 2000. http://www.findarticles.com/cf_dls/m0EKF/32_46/65023364/p1/article.jhtml, (accessed April 8, 2004).

Gilbert, R. 1992., Symposium on Compatibility: Incentives and Market Structure, *Journal of Industrial Economics* 40: 1–8.

Gordon, R. 2000. Does the New Economy Measure Up to the Great Inventions of the Past, *Journal of Economic Perspectives* 14: 49–74.

Granger, C., 1969, Investigating Causal Relations by Econometric Models and Cross-Spectral Methods, *Econometrica*,
37: 424-438.

Hill, Karen, High Tech Hub, http://gtalumni.org/StayInformed/magazine/win99/high.html.

International Telecommunication Union, 1998. Agreement reached on 56K Modem standard, available at http://www.itu.int/newsarchive/press_releases/1998/04.html.

Katz, M. and C. Shapiro, 1994, “Systems Competition and Network Effects,” *Journal of Economic Perspectives,* 8: 93-115.

Kenas, B. 1997. The document is available at http://www.nric.org/fg/fg2/sc1/fg2-sc1-modems-final.doc. Original sources include the Information Technology Industry Council and the Data Analysis Group.

Lemley, M. 2002. Intellectual Property Rights and Standard-Setting Organizations, *California Law Review* 90: 1889.

Matutes, C. and P. Regibeau. 1996. A Selective Review of the Economics of Standardization: Entry Deterrence, Technological Progress, and International Competition, *European Journal of Political Economy* 12: 183–206

Meidan, M. 2004. The Effects of the Standardization Process on Competition: An Event Study of the Standardization Process in the US Cable Modem Market, Mimeo, Stanford University, Stanford, CA.

Merges, R. 1998. Institutions for Intellectual Property Transactions: The Case of Patent Pools, Mimeo, University of California-Berkeley, Berkeley, CA.

Oliner, S. D. and D. E. Sichel. 1994. Computes and Output Growth Revisited: How Big is the Puzzle? *Brookings Papers on Economic Activity* VOLUME #?(2): 273–317. (AU: IS THIS A JOURNAL?)

Postrel, S., 1990, “Competing Networks and Proprietary Standards: The Case of Quadraphonic Sounds,” *Journal of Industrial Economics,* 39: 169-185.

Simcoe, T. 2004. Committees and the Creation of Technical Standards, Mimeo, University of California-Berkeley, Berkeley, CA.

Sims, C., 1980, Macroeconomics and Reality, *Econometrica*, 48: 1-48.
Stango, V. 2004. The Economics of Standards Wars, *Review of Network Economics* 3: 1–19.

APPENDIX

Table A1: Descriptive Statistics: Full data set, N = 326

Variable	Mean	Std. Dev.	Minimum	Maximum
Meetings	7.22	21.48	0	209
Patents	1.76	3.63	0	27
Citations	14.03	37.00	0	334
Meetings1	3.48	12.87	0	136
Meetings2	3.74	10.30	0	88
Patents1	0.37	1.07	0	8
Patents2	0.87	2.14	0	18
Citations1	4.22	14.61	0	148
Citations2	2.45	10.06	0	132

Table A2: Descriptive Statistics: Firms with at least one patent and attending at least one meeting, N = 45

Variable	Mean	Std. Dev.	Minimum	Maximum
Meetings	33.76	46.83	1	209
Patents	6.24	6.98	1	27
Citations	45.04	70.64	0	334
Meetings1	16.11	29.72	0	136
Meetings2	17.64	21.19	0	88
Patents1	1.24	1.93	0	8
Patents2	3.56	4.32	0	18
Citations1	15.27	27.45	0	148
Citations2	11.31	24.24	0	132

Figure 1: Patents with the word *modem* in the title: 1976–1999

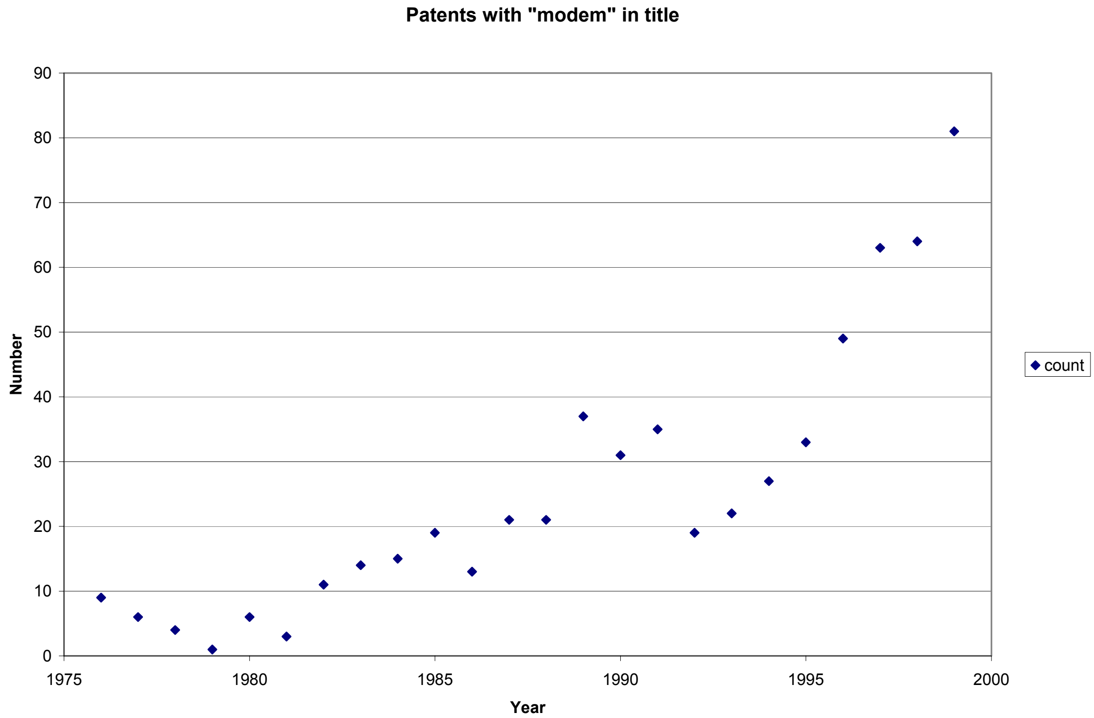

Figure 2: Average Attendance Per TR-30 Meeting: 1990-1999

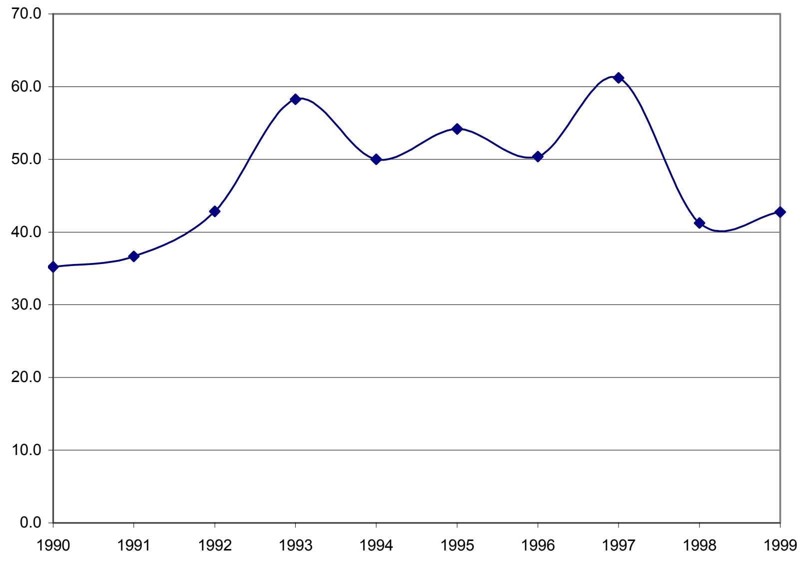

Table 1: Analog Modem Timeline

Maximum Speed (in kbs)	Year	Average Price	ITU Standard
9.6	1984	1,167	V.32
14.4	1991	653	V.32bis
33.6	1994	505	V.34, V.34+
56 .0	1996	350	V.90

Table 2: Patents with the word *modem* in title

Patents granted 1976–1999			Products[*]	Patents granted 1976–1989			Patents granted 1990–1999		
Firm	*Patents*	*Citations*		*Firm*	*Patents*	*Citations*	*Firm*	*Patents*	*Citations*
Motorola	27	122	D,U	Paradyne	13	156	Motorola	21	86
Paradyne	24	180	D	Hayes	10	186	IBM	18	74
IBM	23	119	U,I	Univ. Data	9	171	Intel	15	43
Hayes	18	334	D	Codex	8	131	Multi-Tech	13	101
Univ. Data	16	220	D	Racal Milgo	8	122	Fujitsu	13	63
Codex	15	262	D	Hycom	6	103	AT&T	12	166
AT&T	15	199	C	Motorola	6	36	Compaq	12	74
Fujitsu	15	78	C	IBM	5	45	NEC	11	42

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1915.9( )2( )6711(779( )2( )31.5EC 2684.8(Txas)52684.5(I))6.6n9( )2sF. 63

Table 3: Summary of meetings data: TR-30 and the subcommittees

	TR-30	TR-30.1	TR-30.2	TR-30.3
Meetings 1990–1999	56	57	55	60
Meetings 1990–1994	29	26	27	29
Meetings 1995–1999	27	31	28	31

Table 4: Participation at TR-30 Meetings

Firm	*Attendees, 1990–1999*	*Attendees, 1990–1994*	*Attendees, 1995–1999*	*Products*[*]
Motorola	209	122	87	D,U
AT&T	190	136	54	C
Rockwell Semiconductor	141	53	88	U
General Datacomm	106	71	35	I
U.S. Robotics	74	37	37	D
Intel	69	39	30	U
Satchell Evaluations	67	44	23	O
Hayes	66	40	26	D
3COM	58	0	58	D,U
Telecom Analysis Systems	55	33	22	O
Racal Milgo	54	38	16	D
Db Consulting	47	25	22	O
Texas Ins.	46	7	39	U,I
IBM	44	15	29	U,C
National Semiconductor	40	24	16	U
Participation, top 15 (1990–1999)	1266	682	584	
Total participation	2355	1136	1219	

[*] Firms products' are coded as follows: "downstream" modem (D), upstream inputs into modems (U), infrastructure for modems (I), complementary products (C), or other (O)

Table 5a: Patent and citation data summary by meeting participation

	Patents				Citations
	Total	*1976–1989*	*1990–1994*	*1995–1999*	
Attended meetings	281	65	56	160	2027
Did not attend meetings	324	115	78	130	2868
Total	604	180	134	290	4895

Table 5b: Meeting summary data by patents

	Attendees		
	Total	*1990–1994*	*1995–1999*
Have patents	1519	725	794
Do not have patents	836	411	425
Total	2355	1136	1219

Table 6a: Correlation among variables: All 326 firms

	Patents	Meetings	Citations
Patents	1.00		
Meetings	0.52	1.00	
Citations	0.80	0.39	1.00

Table 6b: Correlation among variables: The 45 firms attending meetings and holding patents

	Patents	Meetings	Citations
Patents	1.00		
Meetings	0.55	1.00	
Citations	0.75	0.45	1.00

Table 7a: Correlations among patents and meetings

Full Data Set (326 Firms)					
	Meetings1	Meetings2	Patents1	Patents2	Citations1
Meetings1	1.00				
Meetings2	0.72	1.00			
Patents1	0.36	0.28	1.00		
Patents2	0.42	0.56	0.35	1.00	
Citations1	0.33	0.27	0.89	0.35	1.00
Citations2	0.60	0.45	0.31	0.60	0.30

Table 7b: Correlations among citations and meetings: Smaller data set

The 45 Firms Attending Meetings and Holding Patents					
	Meetings1	Meetings2	Patents1	Patents2	Citations1
Meetings1	1.00				
Meetings2	0.68	1.00			
Patents1	0.46	0.27	1.00		
Patents2	0.39	0.55	0.27	1.00	
Citations1	0.39	0.25	0.90	0.25	1.00
Citations2	0.63	0.41	0.25	0.54	

Table 8a: Granger causality analysis: All firms (*t*-statistics in parentheses).

Full Data Set	*Dependent Variable*			
N = 326	Patents2	Citations2	Meetings2	Meetings2
Independent Variables				
Constant	0.50	0.27	1.68	1.66
	(4.45)	(1.23)	(3.93)	(3.95)
Patents1	0.45		0.24	
	(4.32)		(0.59)	
Citations1		0.08		0.027
		(2.50)		(0.94)
Meetings1	0.057	0.44	0.57	0.56
	(6.48)	(12.02)	(16.99)	(17.12)
Adjusted R-squared	0.22	0.37	0.51	0.51

Table 8b: Granger/Sims causality tests: All 45 firms (*t*-statistics in parentheses)

Small Data Set (45 Firms)	*Dependent Variable*			
N = 45	Patents2	Citations2	Meetings2	Meetings2
Independent Variables				
Constant	2.44	3.37	10.28	9.96
	(3.11)	(0.34)	(3.56)	(3.51)
Patents1	0.26		–0.64	
	(0.73)		(–0.46)	
Citations1		–0.03		–0.02
		(–0.26)		(–0.19)
Meetings1	0.05	0.52	0.51	0.49
	(2.11)	(4.90)	(5.63)	(5.67)
Adjusted R-squared	0.12	0.36	0.45	0.44