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Jumping the Gun: Imperfections and Institutions Related to the Timing of Market Transactions

By ALVIN E. ROTH AND XIAOLIN XING*

This paper concerns the difficulties associated with establishing a time at which a market will operate. We first describe the experience of several dozen markets and submarkets, from entry-level professional labor markets in the United States, Canada, England, and Japan, to the (American) market for postseason college football bowls. The difficulties these markets have experienced in coordinating the timing of transactions have been decisive in determining how they are organized today. The paper develops a framework in which to address the timing of transactions and the tendency observed in many of these markets for transactions to become earlier and earlier. (JEL D40, C78, J44, N30)

The timing of transactions is a little-studied feature of markets, but one which plays a large role in their ability to function. Because transactions involve at least two parties, their timing involves coordination, and much of the benefit of a market has to do with bringing together many buyers and sellers at the same time, so that they can

consider a wide range of possible transactions. In many of the markets discussed in this paper, from markets for new lawyers and doctors to the market for postseason college football bowls, efforts to coordinate and control the timing of transactions have played a decisive role in shaping how each market is organized. In many cases, problems concerned with the timing of transactions led to potentially large losses of efficiency.¹

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Table 1 lists a selection of markets that have experienced, and in some cases continue to experience, serious problems associated with the timing of transactions. (These markets will each be discussed in more detail in the body of the paper, where Table 1's notations about "stages" will be explained.) In virtually all of these markets, the problems originate with the incentives that some market participants have to try to "jump the gun," and arrange transactions just a little earlier than their competitors. In most of these markets, substantial resources

¹In contrast to transactions, which involve *coordination* of timing, relatively more attention has been paid to the timing of investments, as in patent races (see e.g., the survey by Jennifer Reinganum [1989]), in which there are long-lasting benefits to being first. The establishment of retail outlets and new product introductions may sometimes fall into this category as well.

TABLE 1—A SELECTION OF MARKETS WITH TIMING PROBLEMS

Market	Organization	Stage
Postseason college football bowls	National Collegiate Athletic Association (NCAA)	1 and 3
Entry-level legal labor markets:		
Federal court clerkships	Judicial conferences	2, 1
American law firms	National Association for Law Placement (NALP)	1
Canadian articling positions	Articling Student Matching Program	
Toronto		4
Vancouver		3 or 4
Alberta (Calgary and Edmonton)		3
Entry-level business school markets		
New MBA's		1 (occasionally)
New marketing professors		1
Other entry-level labor markets:		
Japanese university graduates	Ministry of Labor; Nikkeiren	2
Clinical psychology internships	Association of Psychology Internship Centers	2
Dental residencies (three specialties and two general programs)	Postdoctoral Dental Matching Program	3
Optometry residencies	Optometric Residency Matching Services	1 and 3
Other two-sided matching:		
Fraternity rush		1
Sorority rush	National Panhellenic Conference	3
Entry-level medical labor markets:		
American first-year postgraduate (PGY1) positions	National Resident Matching Program (NRMP)	3
Canadian first-year positions	Canadian Intern and Resident Matching Service	3
U.K. regional markets for preregistration positions:	Regional health authorities	
Edinburgh		3
Cardiff		3
Birmingham		4, 1
Newcastle		4, 1
Sheffield		3 or 4, 1
Cambridge		3
London Hospital		3
American specialty residencies:		4
Neurosurgery	Neurological Surgery Matching Program	
Ophthalmology	Ophthalmology Matching Program	3
Otolaryngology	Otolaryngology Matching Program	3
Neurology	Neurology Matching Program	3
Urology	AUA Residency Matching Program	3
Radiation Oncology	Radiation Oncology Matching Program	1 and 3
Other specialties ^a	NRMP	3 and 4
Advanced speciality positions:		
12 (primarily surgical) specialties ^b	Specialties Matching Services	3
Three medical subspecialties ^c	Medical Specialties Matching Program	3
Four ophthalmology subspecialties	Ophthalmology Fellowship Match	3
Plastic surgery	Plastic Surgery Matching program	3

^aAnesthesiology, emergency medicine, orthopedics, physical medicine, psychiatry, and diagnostic radiology.

^bColon/rectal surgery, dermatology, emergency medicine, foot/ankle surgery, hand surgery, ophthalmic plastic and reconstructive surgery, pediatric emergency medicine, pediatric orthopedics, pediatric surgery, reproductive endocrinology, sports medicine, and vascular surgery.

^cCardiovascular disease, gastroenterology, and pulmonary disease.

have been devoted to control these timing problems. Many of the market organizations listed in Table 1 have been created solely for the purpose of controlling the timing of transactions (while in other cases this function has been undertaken by existing organizations).

Most of the markets mentioned in Table 1 are entry-level labor markets for professionals. Timing problems are particularly easy to identify in these markets, because while employment contracts can be signed at any time, employment itself typically begins only following the attainment of the necessary professional qualifications, such as graduation from medical, law, or business school, or university. In many of these markets, the date at which contracts were signed crept earlier and earlier from year to year, until in several cases contracts came to be signed as much as two years in advance of the date at which employment would begin. This unraveling of appointment dates often occurred despite the vigorous efforts of market participants to halt it due to the costs it imposed (costs of having to hire in anticipation of uncertain future need, costs of potential mismatches caused by the uncertainty of employees' qualifications before they had completed their training, and the increased costs of search and loss of liquidity as the variance in times of appointment increased). In many cases the process was halted or reversed only by the introduction of new procedures and forms of organization.

That similar phenomena can be observed in markets other than labor markets will be shown by examining the market for postseason college football bowl games. It is possible to focus clearly on questions about timing in this market also, because bowl games are played only following the conclusion of the regular college football season, but arrangements between teams and bowls may be made well before the end of the season. The costs of making arrangements long before the end of the season arise from the uncertainty concerning which will be the most highly regarded teams at the end of the season, and the consequent difficulty of arranging matches that will draw the largest television audiences by pitting against each

other teams with a claim to be the best. Yet the National Collegiate Athletic Association, despite the considerable enforcement power at its disposal, has been unable to enforce a date before which bowl bids may not be made. It recently gave up the attempt, prompting a significant reorganization of the market.

Because problems of timing may be easier to detect early in the history of markets, before they have been resolved, we also briefly examine the regulations governing medieval markets, typically weekly markets for ordinary commodities. The benefits that these markets provided depended to a large extent on the ability of buyers and sellers to coordinate on a time and a place for the market, and the laws governing the establishment and conduct of markets seem to reflect this. (In contrast to the markets in Table 1, we rely for descriptions of these and the other markets in Table 3 on secondary sources, and we observe only institutions in place, not the evolution of the market that led to their adoption.)

Indirectly, one of the larger themes of this paper is that markets may require a good deal of organization. This runs counter to the view implicit in much of the economic literature, which is that markets are largely self-organizing, in contrast to firms, whose more complex structure arises in response to market failures. The markets studied in this paper exhibit a good deal of complex structure themselves, which also arises in response to market failure.

That being the case, it is natural to ask why many markets—including many entry-level professional labor markets—appear *not* to experience the timing problems that are the subject of this paper, and why they manage to function well without any of the institutions which characterize the markets in Tables 1 and 3. Why does the entry-level market for new economics professors, for example, behave differently from the markets for American law-school graduates, or for graduates of elite Japanese universities? And why do some academic labor markets (e.g., in mathematics, chemistry, and biology) seem to be moving in the direction of later, rather than earlier appointments? This will be discussed in Section V.

The present paper builds on the work reported in Roth (1984, 1986), Roth (1990, 1991), and Susan Mongell and Roth (1991), which studied the centralized market-clearing mechanisms adopted in the market for first-year postgraduate positions for American doctors, in seven regional markets for British doctors, and in the recruitment process of American sororities, respectively. Only some of these centralized procedures succeeded in halting the unraveling of transaction dates. The analysis in these earlier papers focused on whether or not the outcome produced by the matching mechanism was *unstable* in the sense that some firm and worker who were not matched to each other would each prefer to be so matched. This analysis organized a lot of the observed market behavior, but because it employs static models it could address only indirectly the causes of unraveling over time.

The larger set of markets examined in the present paper, which includes additional markets that have adopted centralized procedures as well as markets that have not, allows a broader investigation of hypotheses about the causes, costs, and cures of unraveling transaction dates. We will propose formal models which for the first time directly address the causes of unraveling in environments in which timing decisions are explicit and when information may evolve over time. We will see that unraveling can occur in markets in which prices can adjust freely (such as the market for new associates in large law firms), as well as in those in which they cannot (such as the market for judicial clerkships in federal courts), and that associated with this unraveling is the potential for inefficient market outcomes.

In order to facilitate the description and comparison of the many markets in Table 1, Section I of this paper will describe common features observed in the evolution of these markets over time, divided into four stages. Section II will then provide the background to the present investigation, by briefly reviewing the American and British medical markets. Those observations demonstrate the importance of unstable matchings as a contributor to unraveling of transaction dates.

Section III will describe some of the particular features of each of the new markets considered in this paper. It is a long section, containing an unusual amount of descriptive material, which we feel is necessary to establish our claims that many markets experience the timing problems we describe. By looking carefully at a relatively large collection of markets, our intention is to establish that these timing problems play an important and persistent role in a wide variety of settings, and that they can usefully be organized around the four stages proposed in Section I. Section III concludes with a brief discussion of several markets whose histories we have not investigated, but which have also developed institutions related to timing. These include medieval markets, entry-level markets for professional athletes, marriage in a variety of cultures, and postdoctoral positions in academia. The descriptive material in Section III provides the motivation for the formal models in Section IV, which demonstrate that unraveling may have more than one cause. In addition to the static instabilities studied in Roth (1984, 1991), we show that the way information about agents evolves over time may be a cause of intertemporal instabilities which lead to unraveling, as may be the market power which accrues to agents as a result of the heterogeneity of the market. Section V concludes with a discussion, including a discussion of possible empirical tests of some of the predictions generated by the models.

I. Unraveling in a Prototypical Market

Each of the dozen nonmedical and several dozen or so medical markets and submarkets in Table 1² have evolved over time in ways that share many elements of a common pattern, with several fairly distinct stages. Despite the diversity among these markets, there are so many common ele-

²Precisely how many markets are represented in Table 1 depends on an assessment of how distinct the markets are in the different medical specialties, and for the different dental residencies. The relatively small overlap among these specialty markets is discussed in Subsection III-C.

ments in the timing problems they have encountered that it will greatly facilitate their description and comparison to begin with the somewhat idealized description of a four-stage process as experienced by a prototypical market. For convenience, we will refer to the participants in this prototypical market as if it were an entry-level professional labor market.

Stage 1 begins when the market comes into being (e.g., when a few hospitals begin offering internships, or when federal court clerkships are created by legislation) and the relatively few transactions are made without overt timing problems. By the middle of stage 1 the market has grown, and some appointments are being made rather early, with some participants finding that they do not have as wide a range of choices as they would like: students have to decide whether to accept early job offers or take a chance and wait for better jobs, and some employers find that not all of the students they are interested in are available by the time they get around to making offers. The trade journals start to be full of exhortations urging employers to wait until the traditional time to make offers, or at least not to make them any earlier next year than this year. Toward the end of stage 1, the rate of unraveling accelerates, until sometimes quite suddenly offers are being made so early that there are serious difficulties in distinguishing among the candidates. There is no uniform time for offers to be made nor is there a customary duration for them to be left open, so participants find themselves facing unnaturally thin markets, and on both sides of the market a variety of strategic behaviors emerge, many of which are regarded as unethical practices. Various organizations concerned with the market may have proposed guidelines intended to regulate it, without notable success. As stage 1 ends, influential market participants are engaged in a vigorous debate about what can and should be done. From beginning to end, stage 1 may have covered a period of more than 50 years, or fewer than 10.

In *stage 2*, either an existing market organization or a new one created for the purpose attempts to establish a uniform date before which offers should not be made,

and often an earlier date before which interviews should not be conducted, and a later date (or time) before which candidates who have received offers should not be required to respond. Sometimes this is hardly successful at all, with many market participants ignoring or circumventing the rules, and with those who obey them quickly finding that this puts them at a disadvantage. Even when uniform dates are successfully established and maintained, the market often experiences a great deal of congestion and chaotic behavior, as the deadline for accepting or rejecting offers grows near. A firm is eager to know whether its offers will be accepted, in time so that if it has unfilled positions it may approach its most preferred alternative candidates before they have had to accept any offers they have received; and candidates who have received offers, but not from their first-choice firm, are intent upon waiting until the last allowable moment before accepting any offer, in the hope of receiving a better one. Particularly if, as often seems to be the case, some fraction of candidates hold on to multiple offers as the final deadline approaches, this means that just before the deadline expires many transactions still remain to be made. Firms whose first-choice candidates reject them may now find that their next dozen candidates have already accepted offers, and candidates may receive preferred offers moments after making a verbal commitment to accept an earlier offer. In some markets such verbal commitments are virtually always honored, and in others they are sometimes reneged on. In either event, in the aftermath, many firms and candidates have just missed making connections they would have preferred. The result is that the following year witnesses a resurgence of strategic behaviors designed to avoid being caught short at the end of the market. Often new rules are formulated to prohibit the more brazen of these, and new adaptations are made. While some markets have persisted for many seasons in this fashion, systems of formalized dates are often abandoned, with the market either reverting to stage 1, or moving on to stage 3.

Stage 3 begins when centralized market-clearing procedures are instituted, either on a voluntary basis or with an attempt to

compel participation and prevent transactions from being made other than through the centralized procedures. Participants normally make initial contacts with each other and arrange interviews in a decentralized way but then participate in the centralized procedure instead of making offers to one another directly. In some markets the centralized procedure is scheduled to move back the date at which appointments are made (i.e., to reverse prior unraveling), while in other markets it serves simply to halt further unraveling. We observe at least three distinct classes of centralized procedures. The first class of procedures comprises the “matchmaker” mechanisms employed in many entry-level health-care labor markets and in the entry-level market for Canadian lawyers in Toronto, Vancouver, and Alberta. Under these procedures, firms submit rank-order lists of students, and students submit rank-order lists of firms; and the centralized mechanism then produces a matching of students with firms. The second class of procedures comprises the “draft” mechanisms employed in many entry-level labor markets for professional athletes (see Table 3). Under these procedures, teams take turns choosing students from a pool of eligible candidates, one student at a time, until every team has had a choice, after which the process begins again. Typically the rule for determining the order in which teams make choices is designed to promote balance among teams in the same league. The final class of procedures, of which we know in detail only the example of the market for college football bowls, is a system of overlapping contracts between and among teams and consortia of teams (conferences), on the one hand, and the business enterprises which promote the games (bowls) and, most recently, consortia of bowls on the other. Centralized mechanisms are not always successful, and so stage 3 sometimes ends with the abandonment of the mechanism and the reversion to stage 1. There are many examples of mechanisms which have proved quite long-lasting, however, and for many of these markets stage 3 may be the final stage in the market’s evolution. However some of these markets go on to stage 4.

In *stage 4*, with centralized procedures in place, unraveling begins (or continues) in the period before the mechanism is employed, as firms and students attempt to gather information about one another or gain advantage over their competitors before participating in the market-clearing procedure. The markets in which we have observed this kind of unraveling employ matchmaking mechanisms, and the unraveling has often taken the form of recruiting students for summer internships (or in the case of some medical specialties for “audition electives”), which amount to extensive interviewing opportunities in which the student spends a period of weeks or even months at the firm. Because of the length of time involved, students can interview in this way at only a very small number of firms (often only one), and firms can interview only a few students in this way. Because the percentage of new employees hired by each firm who were previously summer interns there sometimes becomes quite high, these internships can become a way of moving the recruiting process before the centralized matching mechanism, and the process of recruiting summer interns may start to resemble the stage-1 unraveling discussed above. (In some cases, these early recruiting activities may have predated the establishment of the centralized mechanism; i.e., they may be remnants of stage-1 unraveling that persist even after the establishment of centralized procedures.) However such unraveling prior to the central market-clearing mechanism does not eliminate all its benefits. A matchmaking mechanism still ensures, for example, that a desirable firm which ultimately wishes to fill five new positions can do so. This contrasts with the situation which existed in stage 1, when employment offers were made in a decentralized way, when it might have been that such a firm would have had to make ten offers to have a good chance of filling five positions, and it might have ended up in any given year with fewer than five new employees, or more.

Figure 1 summarizes this discussion and shows both the stages and the paths we have observed between them. Table 1 lists next to each market the most recently ob-

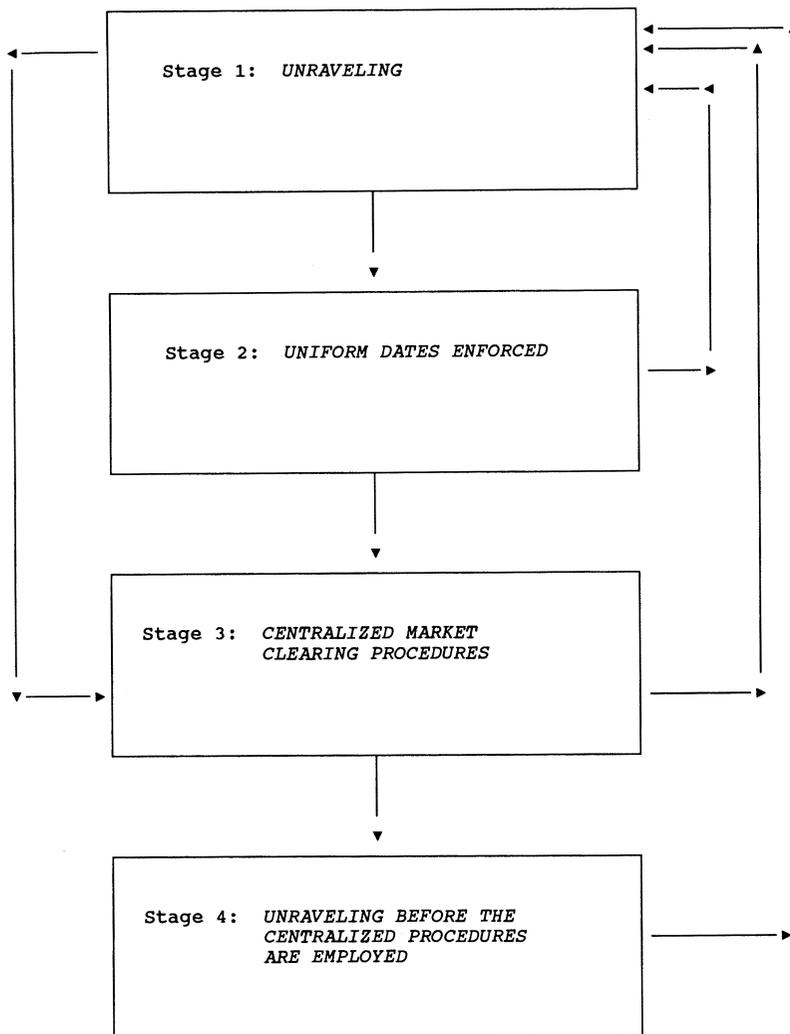


FIGURE 1. STAGES AND TRANSITIONS OBSERVED IN THE MARKETS OF TABLE 1

served stage, and if this stage has been reached from a higher stage, then that is shown also (e.g., the “2,1” next to Federal court clerkships indicates that a uniform offer date [stage 2] was tried and abandoned, and that the market has reverted to stage 1). Stages 1 and 2 are not always perfectly distinct, since the guidelines that are often formulated at the end of stage 1 can resemble more formal attempts to control dates of appointment, particularly when both are unsuccessful. Similarly, stages 3 and 4 are not always perfectly distinct.

We now turn to the description of the particular markets, beginning with an account of the medical markets studied in Roth (1984, 1991).

II. Background: American and British Doctors

A. First-Year Postgraduate Positions for American Doctors

The entry-level labor market for new American physicians is perhaps the classic case of transition from stage 1 to stage 2 to

stage 3. Since it has been described in Roth (1984), only a brief description is given here.

Appointment dates unraveled from about the turn of the century until 1945, so that by 1944 medical students were arranging their postgraduate employment as interns two years in advance of graduation. Starting in 1945 a regime of uniform dates and times was introduced, and it was enforced with the help of an apparently successful refusal by medical schools to provide information about students prior to a specified date. This succeeded in reversing the unraveling, and appointment dates were first moved back into the junior year, and then into the senior year of medical school. However, in 1945 the period specified for offers to remain open was ten days, and this interval shrunk rapidly, so that by 1949 a 12-hour period was rejected as too long, and no minimum duration at all was specified. The congestion in the market, with its collateral missed opportunities and hasty agreements which were later sometimes not honored, led to the adoption, in 1952, of a (voluntary) centralized market-clearing procedure of the matchmaker variety. It was shown in Roth (1984) that this procedure is a stable matching mechanism, which is to say it always produces a matching that is stable with respect to the preference orderings submitted by the hospitals and students.³

³The question of whether the resulting matching is also stable with respect to the true preferences is more complicated. It is not a dominant strategy for all participants to state their true preferences, but equilibrium misrepresentation of preferences also yields matchings that are stable with respect to the true preferences, although there are unstable equilibria as well in markets with many-to-one matching (see Roth and Marilda Sotomayor, 1990 [theorems 4.4, 4.16, 5.14, and 5.18]). Ulrich Kamecke (1992) considers how an entry-level market organized in this way may interact with the market for senior physicians. The Canadian and American entry-level markets also interact, with Canadian students able to participate both in the U.S. market and in the Canadian Intern and Resident Matching Service, which is organized separately from, but coordinated with, the U.S. market.

With modifications to meet the changing market, this procedure remains in use today, and it serves to fill most of the approximately 20,000 first-year positions which become available each year. The recent evolution of the market, which has grown to include a variety of specialty residencies and positions for physicians beyond the first year after medical-school graduation, will be discussed later. First we turn to the similar experience of the entry-level markets in each region of Britain's National Health Service. Here too we will be brief, as these markets are studied in detail in Roth (1991).

B. *Regional Markets for Preregistration Positions in the United Kingdom*

Following graduation from medical school in the United Kingdom, a doctor must complete a year of preregistration experience before becoming fully eligible to practice. Each region of the National Health Service organizes its own market for preregistration house officers, with an average size of about 200 positions annually.

In the mid-1960's, dates of appointment in these markets had unraveled to well over a year before graduation from medical school. Uniform appointment dates had apparently been attempted in some regions, without success. A Royal Commission on Medical Education (1965–1968) studied the problem, noted that it had been solved by a centralized matchmaking mechanism in the United States, and recommended that regional markets establish their own matchmaking mechanisms (in which participation was compulsory). Because the details of the mechanism used in the United States were not then thought to be important (either in the United Kingdom or the United States), each of the regions was left to develop its own mechanism. Because some of the resulting matchmaking mechanisms failed to halt unraveling while others succeeded, the experience of these markets thus provides a natural experiment for examining the role of the mechanism itself.

Roth (1991) showed that the mechanisms adopted in two of the successful regions, Edinburgh and Cardiff, were stable match-

ing mechanisms.⁴ These mechanisms halted unraveling, and they are still in use. In contrast, matchmaker mechanisms implemented in Birmingham, Newcastle, and Sheffield (and in Edinburgh from 1967 to 1969) failed to halt unraveling and were subsequently abandoned. Because of the way in which they frequently produced unstable matchings, they gave participants the incentive to make under-the-table agreements well in advance of the formal procedure, which was subsequently used only in a pro forma way. By the time these mechanisms were abandoned, up to 80 percent of positions were prearranged (and formalized through the mechanism with submitted rank-order lists containing only a single, prearranged choice), which worked to the great disadvantage of those who participated without prearrangement (see Roth, 1991).

A final class of mechanisms, employed in the two smallest markets studied (for students at the Cambridge and London Hospital medical schools), each used linear-programming matchmaker mechanisms that may produce unstable matchings. However both of these mechanisms have controlled unraveling and are still in use. Roth (1991) speculated that the success of these potentially unstable mechanisms may be due in part to the fact that the participants in both of these small (approximately 100-position) markets have ongoing relationships with one another, and in part to the difficulty of using the linear-programming mechanisms in a pro forma way to effect a prearranged match. We will suggest another possibility in our discussion of Example 2 in Subsection IV-B.

We turn next to the new markets considered in this paper. Since these descriptions are necessarily selective, we will concentrate on providing good examples for each of

stages 1–4. These examples also suggest that unraveling may be due to causes other than instability. With this in mind, we pay particular attention to the way information about candidates' qualifications develops over time and to the way in which attempts to halt or reverse unraveling are sensitive to the degree of participation they elicit from key players.

III. A Selection of Markets with Timing Problems

In discussing the markets in Table 1, we will spend the most time in discussing those chosen as examples of stages 1 and 2. This is partly because stage-3 markets have been discussed at length in Roth (1984, 1990, 1991), but also because stages 1 and 2 exemplify the problems faced by all of these markets. All the markets have experienced stage 1, and the difficulties experienced by some of the markets in establishing uniform times (stage 2) also illuminate the difficulties of establishing and maintaining more centralized (stage-3) institutions.

A. *Examples of Stage 1: Unraveling*

To illustrate stage-1 unraveling, we will discuss two legal markets (the market for Federal court clerkships and the market for new associate positions in large law firms) as well as the market for postseason college football bowls. We will also briefly discuss the markets for new MBA graduates of American business schools and for new professors of marketing in business schools. We pay particular attention to the way information evolves over time in these markets, and this will play a big role in the formal models of Section IV.

Our discussion of both entry-level legal markets will concentrate on a period from the mid-1970's through the 1980's. To give some perspective on the size of the larger market of which these two submarkets are a part, note that the number of new graduates from ABA-accredited law schools grew in this period from just under 29,000 in 1974 to just over 36,000 by 1990 (National Association for Law Placement, 1988a, 1991).

⁴Questions of stability have to be reformulated in these markets in terms of preferences over pairs of positions because students require two positions, one in medicine and one in surgery.

1. *Federal Court Clerkships*.—Perhaps the most prestigious position that a new law-school graduate can take is as a law clerk for a distinguished federal judge. Obtaining such a position is a big step up on the career path of a young lawyer. And having a talented and compatible staff of clerks is a major component of judges' productivity. So it is not surprising that this market has exhibited fierce competition and generated a good deal of strategic behavior among the participants.⁵

The market for judicial clerkships dates from 1886, for Supreme Court Justices, but did not begin to approach its present size until Congress authorized the hiring of clerks for U.S. circuit (appeals) judges in 1930, and for U.S. district court judges in 1936. Presently Justices may hire four law clerks, circuit judges three, and district judges two (Alvin Rubin and Laura Bartell, 1989). The number of judges has grown over the years, and today there are about 2,200 clerkships for U.S. circuit and district court judges, in 13 federal circuit courts (the Federal, District of Columbia, and First through Eleventh circuits),⁶ and 94 district courts. It is the market for these positions that has experienced the most unraveling.⁷

Salary for these positions is fixed, and not subject to negotiation between judges and

candidates. However the desirability of and competition for particular clerkships vary. Circuit courts are generally regarded as more prestigious than district courts, and among the circuits, the District of Columbia circuit is widely regarded as the most prestigious. Also, individual judges on a given court have different reputations, concerning both how they work with their clerks and the degree to which they take an interest in a clerk's future career advancement (a special case being that some judges have a reputation as "feeders" of clerks to the Supreme Court).

Accounts of the market for clerkships from the 1950's indicate that it was a leisurely process in those days, with jobs being arranged at the end of the third year of law school, just as the student graduated and became available to occupy the position. Gradually the dates at which appointments were arranged became earlier, in a process that has accelerated over the last decade. In recent years, appointments have come to be made over a year in advance, to students in the middle of their second year of law school. Many judges make offers to second-year students in February and March, around the time that elections are held for the editorial boards of law reviews (which give a good early indicator of who are regarded as the most promising students); and some judges now make offers in January.

Aside from the unraveling of the appointment dates themselves, the process by which offers are actually made and received has also evolved, and (some) judges and (some) students have adopted what are regarded as "sharp" practices. On the judges' side the most notable of these are variations on "short fuse" or "exploding offers." (While the term "exploding offer" used to be applied to an offer which would be withdrawn if it were not accepted in some very short time, such as an hour, today the term seems to refer to offers in which no time at all is given, i.e., to offers which must be accepted during the telephone conversation in which they are delivered.) Some students play a form of "answering-machine tag" in which they try to buy time to contact other judges

⁵Alex Kozinski (1991 p. 1707) of the Ninth Circuit of the U.S. Court of Appeals writes:

This is the market that determines the career paths of some of the country's smartest and most promising young lawyers; it would be astounding if it were conducted with the gentility of a minuet. We are, after all, training courtroom gladiators not ballroom dancers.

⁶The circuit courts average about 12 judges each (with the largest being the Ninth Circuit in the West, the smallest the First Circuit in New England, and most other courts being very close to the average). Patricia Wald (1990 p. 152) writes that in the circuit courts "it is not unusual for a judge to receive 300–400 clerk applications, most from top-drawer candidates."

⁷The Supreme Court, which hires 37 clerks (four for each Justice plus one for the court itself) now largely draws from the pool of clerks of other Federal courts rather than from the pool of new graduates. There are also clerkships for other Federal courts than those we consider (e.g., Claims, Tax, International Trade, Military Appeals, Veterans Appeals) as well as some state and local courts.

to whom they have applied by making themselves unavailable to respond immediately to an offer.⁸

Both the unraveling of appointment dates and the spread of the associated strategic behavior have given rise to repeated attempts to reform the market. However these attempts have themselves generated some controversy. Judges on opposing sides of this issue have explained themselves (cf. Wald, 1990; Kozinski, 1991), which gives an unusual window on this market.⁹ Wald, in the D.C. circuit, has been an active proponent of reform of the market, while Kozinski, in the Ninth circuit, is an opponent of the plans that have so far been considered. However both agree on the costs which unraveling imposes. Kozinski (1991 p. 1710) summarizes these succinctly as follows:

To be sure, we would all prefer to know *precisely* how a particular student will do during the full six semesters he spends in law school. If a decision could magically be delayed until after graduation, we would have all of an applicant's grades as well as the potential input of a large battery of law school professors. Also, we could be better informed about the student's performance in various ex-

⁸In this market (unlike some we consider) it is apparently rare for a student who has accepted an exploding offer over the phone to renege subsequently when a preferred offer arrives. (It may be that the benefit of having even the most distinguished federal judge as a mentor is largely dissipated if there is another federal judge—with lifetime tenure—who will regard a young lawyer as dishonest or unethical.) However Kozinski (1991 p. 1728) writes "Incidents where law clerks wriggle out of commitments with judges are more common than one would guess. They are usually predicated on some changed circumstances but sometimes reflect merely a change of heart. Even under the best of circumstances, it is an extremely delicate matter and the judge's reaction might well turn on whether he relied on the clerk's commitment in turning away other qualified applications."

⁹This controversy has also generated a number of stories in the popular press, some of which have in turn raised concerns among judges about the public image of the judiciary (see e.g., David Margolick, 1989; Sandra Torrey, 1991).

tracurricular activities. Did she do an excellent job as a law review editor? Did she publish and, if so, what does the product look like? Did he compete in moot court and, if so, how high did he place?...All of these would be mighty helpful hints when picking clerks.

Motivated by such concerns, a number of unsuccessful attempts were made to control the unraveling of appointment dates. Wald (1990 p. 156) summarizes them as follows:

Since the early 1980s there have been sporadic attempts to establish ground rules. The Judicial Conference of the United States established an ad hoc committee in 1982 that recommended a schedule for beginning interviews in September of the candidates' third year but set no fixed, enforceable time within which to make offers. Many judges abided by the recommended guideline but a substantial number did not. Because of the consequent tensions, the effort was abandoned. In successive years, judges in several circuits agreed to deadlines on offers in April or July, but again, many judges were unwilling to accept these constraints.

Throughout the eighties there were, alternatively, open-season years (judges were free to make an offer at any time) and years in which many (but not all) judges in many (but not all) circuits agreed to hold to a specified deadline.

As the decade drew to a close, an attempt was made to establish more broadly uniform dates for offers to be made, and a uniform time that these offers should be left open. Wald (1990 pp. 157–58) summarizes these most recent attempts as follows:

In 1989... a group of judges, including several circuit chiefs, undertook a campaign to have the Judicial Councils, the governing bodies for the circuits, adopt deadlines for clerkship offers. Recognizing that it was unlikely such a directive could be enforced against an errant judge, it was still hoped that a policy directive from the

Councils would carry more weight than an informal agreement of judges. In the spring of 1989, the District of Columbia Judicial Council passed the following Resolution:

‘Commencing in 1990, the D.C. Circuit Council is committed to the practice that no job offers, tentative or final, shall be made to law clerk applicants before May 1st of the applicant’s second year.’

... In the end, the D.C., Federal, First, Second, Third, Fourth, Sixth, Eighth, Tenth, and a majority of judges on the Ninth adopted some form of limiting resolution. The Fifth, Seventh, and Eleventh declined. There were two variations in the resolutions: some, but not all, contained a provision that the offers remain open for twenty-four hours; some made compliance with the May 1st deadline contingent upon the concurrence of all other circuits; some agreed unilaterally.

As Mayday approached, complying judges grew increasingly anxious; efforts to get agreement on a twenty-four-hour waiting period for acceptances failed... By consensus, a one-hour waiting period was fixed.

Wald goes on to say (p. 159):

What actually happened on May 1? A few judges weakened at the end and made calls ahead of the deadline. This, in turn, provoked the students to call other judges they preferred before the noon deadline, so there was a destabilizing flurry of predeadline transactions. But the major complaint was the frenzy with which offers had to be made and accepted. Those judges who gave their choices time to reflect found themselves severely disadvantaged.... By 12:15 virtually all of the bidding in the D.C. Circuit was over. Between 12:00 and 12:15, judges were making offers on one line as calls came in on a second from frantic applicants trying to learn if they were to get an offer before they responded to the offer of another judge.

Wald and colleagues from the First, Second, and Third circuits subsequently conducted a survey of the U.S. circuit judges to better assess the outcome. Fifty-two of the 65 judges replying answered yes to the question “Prior to May 1 noon EDT, did any applicants that you sought for interviews already have a clerkship?” In a memo reporting the survey results to all U.S. District and Circuit Court judges, James Oakes et al. (1991) write that they are notifying the American Association of Law Schools that:

there are no guideposts in place for 1991...[and]...if they are concerned about the acceleration of the law clerk hiring process, they will have to do something about it themselves.

Wald concluded her 1990 article with a discussion of the “medical model.” After describing the centralized market-clearing mechanisms used in the market for first-year medical graduates, she suggested that a centralized procedure adapted to the specific needs of judges be considered as a solution to the problem of unraveling appointment dates in the law-clerk market.

Kozinski (1991 p. 1719), in discussing why he opposes any move toward either a centralized market-clearing system or a system of uniform dates, writes:

...not all clerkships are created equal. Geography plays a role. Judges on the east coast enjoy the advantage of proximity to many of the country’s best law schools. Prestige counts. Some circuits, the D.C. Circuit in particular, tend to draw a disproportionate share of the nation’s top applicants. Seniority matters. Judges with many years on the bench naturally have an advantage over upstarts like me who have to work hard at achieving a national reputation. The problem with many reform proposals is that they tend to reinforce these patterns by decreasing the means by which less-favored clerkships can compete for desirable applicants.

He goes on to note that a common feature of uniform-date procedures, whether

centralized or decentralized is that:

such plans eliminate a very important bargaining tool for judges competing for the most gifted clerkship candidates—the ability to make offers early and entice applicants into ending the anxiety and uncertainty by accepting early.

We will return to this point in Example 1 in Section IV.

In closing, we note that the unraveling of appointment dates has proved resistant to the efforts of the law schools as well as the judicial conferences. Kozinski (1991 p. 1725) notes, for example, that:

At some schools, the placement office insists on collecting the letters of recommendation so that all may be sent at a 'proper date.' Streetwise students avoid this pitfall by asking their recommenders to send letters directly to the judges.

The incentives for professors in accommodating students in this way, he notes, is that there is considerable value to professors (e.g., in attracting good research assistants) in maintaining a reputation of being a "feeder" to good clerkships.

Thus in the market for judicial clerkships, attempts to halt or reverse the unraveling of appointment dates by establishing a uniform date for appointments have so far failed. We turn next to the other "elite" market for new law-school graduates, the market for positions in the largest law firms. In contrast to the market for clerkships, in this market salaries play a large role.

2. *American Law Firms.*—The highest starting salaries paid to new law graduates are paid to those who enter the largest law firms (with over 250 attorneys), and the larger the law firm, the higher is the salary distribution. In 1990, about 12 percent of new law graduates whose first jobs were in law firms took positions in the largest firms, which for our purposes are those with over

250 attorneys.¹⁰ The very highest salaries of all are paid by the largest New York firms, which in 1990 paid a median starting salary to new graduates of \$83,000. The competitiveness of this market is reflected in the fact that the interquartile range (25th–75th percentiles) of these salaries was only \$1,000 (National Association for Law Placement, 1991 p. 52). This is a market that has also seen "salary wars" that resulted in large jumps from year to year: in 1968 the starting salaries at the largest Wall Street firms jumped 58 percent, from \$9,500 to \$15,000, and in 1986 25 percent, from an average of \$49,573 in 1985 to \$61,203 in 1986.¹¹

However, competition in this market has not been confined to wages. The market has also experienced serious unraveling, in many ways parallel to that experienced in the judicial clerkship market, but with important differences as well. In particular, much of the unraveling has come in the recruitment and hiring of students for summer positions as "summer associates." Because many firms fill the majority of their new hiring needs by hiring students who have been their summer associates, the competition to recruit and hire the most promising summer associates has become a proxy for

¹⁰The 1990 salary survey (National Association for Law Placement, 1991) classifies the largest firms in two categories: 251–500 attorneys and over 501 attorneys. However, the salary distributions for firms in these two categories are virtually identical. The survey reports (p. 16) that in 1990 the national median starting salary was \$30,000 for firms with no more than 10 attorneys, \$40,000 for those with 11–25 attorneys, \$45,000 for 26–50 attorneys, \$53,000 for 51–100, \$60,000 for 101–250, and \$70,000 for firms with 251 or more attorneys.

¹¹The figure of \$15,000 from 1968 (which is before the earliest National Association for Law Placement [NALP] salary survey) was the starting salary at Cravath, Swaine & Moore, which was quickly matched by other New York firms (see Sidney Zion, 1968). For the 1986 figure see NALP (1988 pp. xxii, 201). Note that the size of the largest firms has also changed in this period: in the 1986 salary survey, the largest category of firms is 100 or more attorneys. For a discussion of some determinants of legal salaries, see Richard Freeman (1975) and Ronald Ehrenberg (1989).

entry-level hiring.¹² And the hiring dates of both full-time and summer associates has unraveled.

Briefly, in the 1950's and 1960's relatively few law schools even had formal placement offices to arrange on-campus interviews, and law students largely found their own post-graduation employment, around the time of their graduation.¹³ By the early 1970's, on-campus recruitment was common, and summer associate positions for second-year students began to be common as well. By the late 1970's, even first-year students were being offered summer associate positions, and by the middle of the 1980's the unraveling of recruiting had proceeded to such an extent that some students were being offered summer associate positions before they had matriculated at law school.¹⁴ Thus a

¹²A survey of 1982 summer associates by the National Association for Law Placement found that 90 percent of those working at the largest (more than 100 attorneys) New York firms received offers of permanent employment, and that across the country such firms filled just over 60 percent of their new hiring with students who had been 1982 summer associates or had just completed judicial clerkships (Daniel Wise, 1983). (There is some ambiguity in these numbers, because some but not all of the students who had just completed judicial clerkships will have been summer associates at the firms which they join after their clerkships.) A 1987 survey (see Wise, 1987) reported on 32 New York firms of which 18 filled over 50 percent of their hiring with returning 1986 summer associates. (Again, the numbers are probably too low, since, for example the prestigious firm of Cravath, Swaine & Moore, which employed 44 summer associates, and made offers to all of them, had only 13 return the following year [29.5 percent], while 25 [57 percent] accepted judicial clerkships and may have returned after completing them.

¹³Harvard University was an exception and formed a placement office after World War II. John Ferrick (1984 p. 24) notes that "It handled arrangements for large Wall Street firms to conduct interviews with upper-class students." He further notes that in the next decade "a small handful of other institutions" began to help arrange on-campus interviews and that by 1984 every accredited law school had a placement service, with the bulk of these having been established in the early 1970's.

¹⁴We are indebted to Jaime Studley, then the Executive Director of the National Association for Law Placement, for this latter observation (pers. comm., 7

large part of the hiring of law students was based on recruiting that took place long before their law-school record was complete.

In an attempt to regulate the market, the National Association for Law Placement (NALP), formed in 1971, issued regulations to govern recruitment by law firms. The revisions these regulations underwent are illuminating, because they speak of the pressures the rules were under from law firms and law students prepared to obey the letter of the law while contravening its spirit. For example, in 1987 the NALP's Recruitment Practices Committee proposed revisions, which were adopted in 1988, of its "General Standards for the Timing of Offers and Acceptances." Figure 2 reproduces parts of the 1988 regulations (NALP, 1988b) as they appeared in a memo (LaNell D. Black and Jerrie Hawley, 1988), showing new additions underlined and deletions crossed out, in order to make the changes clear.

Black and Hawley (1988) provide some explanations of the proximate causes of these rule changes. They note that terms such as "should" and "may" have been replaced by "shall," to disabuse those who thought that these guidelines were intended only as suggestions. They note that paragraph 1 is a response to short-fuse and exploding offers.¹⁵ Regarding paragraph 2, they note that there is particular concern about the deepest unraveling (i.e., that connected with first-year students) but that this

September 1988). See also Mark Rust (1986) and the National Association for Law Placement's "General Standards for the Timing of Offers and Acceptances" discussed next. In some schools the schedule of on-campus recruiting had moved to before the start of the school year. For example, Rust (1986 p. 23) quotes an administrator at Columbia as follows: "We have four hundred employers here in the last week of August, and we schedule eleven thousand interviews. The overwhelming bulk of those interviews are over by the first day of class."

¹⁵"This provision was drafted so that no students would be pressured into 'on the spot' decisions—a common problem for first year students in particular" (Black and Hawley, 1988).

"12. All offers to law students ~~shall~~ should remain open for at least two weeks after the date made. This provision shall be construed for students covered by paragraphs 3 and 4 below so that the later response date is applied.

"23. Prospective employers ~~shall~~ should not initiate contact with, interview, or make offers to begin recruiting or schedule interviews with first semester first year students before ~~November 15 and should not make offers to such students until after~~ December 15. First semester first year students shall not initiate contact with prospective employers before December 1.

"31. Prospective employers offering positions prior to October 1 to second and third year students ~~prior to October 1 to students~~ employed by them during the preceding summer ~~shall~~ should leave those offers open until at least November 15, provided the student reaffirms his/her interest in the offer within 30 days of the date of the offer letter...

"4. Prospective employers offering positions in the fall to other students who were not employed by them during the preceding summer ~~shall~~ should leave their offers open until at least December 15, provided the student reaffirms his/her interest...

"65. ...After October 1, a law student ~~shall~~ may not hold open more than four offers of employment simultaneously, including offers received as a result of previous summer employment. For each offer received that places a student over the limit, the student ~~shall~~ must, within one week of receipt of the excess offer, reject an offer. It is recommended that employers provide copies of offer letters to the students' placement directors to assist them in monitoring this standard.

"87. Violations of these standards should be reported to the student's Placement Director.

"98. A law school may deny use of its placement facilities to students and employers who fail to adhere to these principles and standards for law placement and recruitment activities."

FIGURE 2. REVISIONS OF THE NALP "GENERAL STANDARDS FOR THE TIMING OF OFFERS AND ACCEPTANCES"

has proved difficult to control.¹⁶ Paragraph 6 responds to frequent employer complaints about “offer hoarding” by students (see e.g., Timothy Corcoran, 1986).

Regarding the enforcement of these regulations, which is relegated to the law schools in paragraphs 6, 8, and 9, Black and Hawley (1988) note that “It is recognized that not all law schools have adequate resources at this time to ensure total student compliance.” Indeed, the regulations seem to have proved difficult to enforce. For one thing, these regulations were met almost immediately with lawyerly changes in strategy. For example, some law firms began to give offers which met the letter of paragraphs 1, 3, and 4 by remaining open for the required period, but which structured the compensation so that the offer was competitive because it included a “signing bonus” which could only be collected if the offer was accepted much more promptly (Studley, pers. comm., 7 September 1988).

The recession of the early 1990’s has cast some of this unraveling in a new light. In 1991 there were firms which, at the last moment, withdrew offers which had been accepted more than a year in advance of when employment was to begin (Ken Myers, 1991). That is to say, they laid off associates

who had not yet reported for their first day of work. This underlines one of the costs of the unraveling of appointment dates. On the other hand, early indications are that the percentage of new hires in the largest firms who were former summer associates may be quite high for the class of 1991, and so the incentives for students to compete for these positions remains.

Thus in the market for new associates, particularly new associates in the largest law firms, attempts to halt the unraveling of recruiting and of appointment dates have been unsuccessful, as have attempts to establish uniform dates (however early) for recruiting and hiring. Thus the problems of unraveling are not confined to markets in which salaries cannot be easily adjusted to help clear the market.

We turn next to a very different sort of market which has experienced very similar problems, and for which the manner in which information develops over time is particularly clear.

3. *Postseason College Football Bowls.*—

The market for postseason college football games is one in which the evolution of information over time is both regular and public. Each week throughout the fall, college football teams play each other. Each Monday or Tuesday, newspapers all over the country publish widely followed polls distributed by the Associated Press (AP) and the United Press International (UPI), ranking the top 25 teams (out of just over a hundred “Division 1A” schools). (The AP polls sportswriters, while the UPI polls college coaches.) After the conclusion of the regular season, selected teams meet each other in postseason games, called bowls, which are played in late December and early January, with a concentration of the most lucrative bowls on New Year’s Day, a national holiday which offers access to a potentially large television audience.

The National Collegiate Athletic Association (NCAA) tried for a number of years to prevent unraveling of the dates at which bowls and teams finalized agreements about which teams would play in which bowls. However it gave up in failure following the

¹⁶“The questions surrounding recruiting of first year students engendered the most discussion and the widest divergence of opinion. There are many people who would like to remove first year students from the placement/recruitment process altogether but the reality is that most first year students do not want to be excluded and simply set out independently to find employment...and many employers would feel disadvantaged in this competitive environment if they were not allowed to pursue first year students....”

“Please note the additional sentence in this provision which sets forth the *earliest* date first semester first year students may contact employers...this should cut down on the amount of correspondence with first semester students (many of whom begin writing employers as early as August)...” (Black and Hawley, 1988).

An unrevised regulation, in the NALP’s accompanying “Principles of Law Schools” is that “Law Schools should not offer placement services to first semester students prior to November 1 (Black and Hawley, 1988). Recall in this context the similar experience of law schools in the judicial clerkship market.

1990–1991 football season. This in turn has prompted a rapid reorganization of the market. Consequently, we concentrate here on the period 1989 through the beginning of 1992, which covers three seasons.

The bowls themselves are independent businesses, each of which controls a stadium and makes contracts with a television network and possibly with a corporate sponsor. In the 1989–1990 season there were 18 postseason bowls, with a combined payout to participating teams of just under \$59 million (see Football Bowl Association, 1990). In the 1990–1991 season a new bowl, sponsored by the Blockbuster Video corporation, entered the market, making a total of 19 bowls.¹⁷ The most lucrative of these bowls is the Rose Bowl (which in 1989–1990 paid \$6.6 million to each team). However the Rose Bowl is a “closed” bowl: it has a long-term contract with the Big Ten and Pacific-10 football conferences, and each year the champions of those two conferences play each other in the Rose Bowl (and the conferences share the bowl revenues of their champions). Thus the Rose Bowl is not involved in the unraveling of transaction dates.

But none of the other bowls with payoffs per team of over \$1 million is in the same situation.¹⁸ In the 1989–1990 season the Fiesta Bowl was an “open” bowl, which is to say that it needed to find two teams to play on January 1. The other top bowls

¹⁷These are the All American Bowl, Blockbuster Bowl, California Raisin Bowl, Domino’s Pizza Copper Bowl, Eagle Aloha Bowl, Federal Express Orange Bowl, Florida Citrus Bowl, Freedom Bowl, Hall of Fame Bowl, John Hancock Bowl, Liberty Bowl, Mazda Gator Bowl, Mobil Cotton Bowl, Peach Bowl, Poulan/Weed Eater Independence Bowl, Rose Bowl, Sea World Holiday Bowl, Sunkist Fiesta Bowl, and USF&G Sugar Bowl.

¹⁸The other bowls with over \$1 million payoffs per team in the 1989–1990 season are the Orange (\$4.2 million per team), Sugar (\$3.3 million), Cotton (\$2.9 million), Fiesta (\$2.5 million), Citrus (\$1.2 million), Gator (\$1.2 million), and Holiday (\$1.0 million). Except for the Holiday Bowl, all of these play on January 1, as does the Hall of Fame Bowl (\$.94 million). (see Football Bowl Association [1990] for payoffs, and NCAA [1990] for dates.)

were all “semi-closed,” which means that they each had a contract with one football conference, whose champion would be one of the teams to play, and that the bowl would therefore need to find one additional team to play on New Year’s Day.¹⁹ The available pool from which these additional teams come consists of teams that are not in any football conferences (“independents”) or are in conferences but are not contractually tied to any bowl.

Because the attractiveness of the product—the bowl game—depends on the attractiveness of the teams, there is consequently great competition among the top bowls to sign up the most attractive teams. A big component of the attractiveness of a team is its ranking at the end of the regular season, and its potential, following the bowl games, to be regarded as the putative “national champion.”²⁰ Of course, the earlier in the regular season that semi-closed and open bowls reach agreement with particular teams in the available pool, the harder it is to predict what their ranking will be at the end of the season. On the other side of the

¹⁹The champion of the Big Eight conference plays in the Orange Bowl, the Southeastern conference champion plays in the Sugar Bowl, the Southwest Conference champion plays in the Cotton Bowl, and the Atlantic Coast Conference champion plays in the Citrus bowl (with some escape clauses in case the ACC champion is ranked highly enough in the UPI poll to be a contender for the “national championship”—about which, see footnote 20.

²⁰Following the bowl games, the AP (sportswriters’ poll) and UPI (coaches’ poll) publish final team rankings for the year, and a team which is ranked number 1 in both polls is widely regarded as the national champion. Although there is a very high correlation between the AP and UPI rankings throughout the year, the fact that the top-ranked team only rarely plays the second-ranked team in a postseason bowl makes the determination of the best team problematic. Factors other than rankings which also play a role in making teams attractive to bowls are the ticket-sales potential (which depends on the loyalty of the fans and their proximity to the bowl), television drawing power (which has to do with success in previous years as well as the current year) and the conference with which the team may be associated. For teams that do not have a shot at the national championship, these other factors are of increased importance. (The coaches’ poll is now sponsored by USA Today-CNN.)

market, the earlier a team signs with a semi-closed or open bowl, the harder it is to predict the ranking of its competition on New Year's Day.

For this and related reasons, the NCAA attempted to control the date at which bowl agreements were signed. It did this by specifying a date (colloquially called "Pick-Em Day") before which such agreements were forbidden. In particular, in the 1989–1990 and 1990–1991 seasons, the NCAA regulations specified that bowls may not offer and teams may not accept "a formal invitation" "from August 1 to:

- (a) The conclusion of [the team's] football game on the Saturday after the third Tuesday in November, or
- (b) Six P.M. local time on the same date, whichever is earlier." [NCAA, 1989 pp. 6–7; 1990 pp. 7–8]

That is, the NCAA attempted to delay agreements until a date that was itself well before the end of the regular season, since most teams would still have two games remaining after Pick-Em Day. Serious penalties were specified for violations of this rule, including a one-year suspension of postseason bowl eligibility for both bowls and teams. Despite the fact that the NCAA has enforced comparable penalties on teams for violations of player recruiting (see Subsection III-E), these penalties were not enforced in the matter of bowl agreements, and the regulations failed to stop the unraveling of transaction dates.

To get a sense of what was going on, consider the 1990–1991 season. (This was the straw that broke the camel's back, so to speak, since after this season the NCAA abandoned attempts to control the date of transactions.) Table 2 shows how the AP (writers' poll) rankings of teams evolved over time, for the teams which played in postseason bowls. (Houston, Florida, and Oklahoma, highly ranked teams—numbers 9, 11, and 20 at the end of the regular season—had been declared ineligible for postseason play by the NCAA, and are therefore not represented in the table.) The rankings are given for each Tuesday through

the season, as well as the postseason rankings which followed the completion of the bowl games. Note that the rankings may vary widely from the beginning of the season to the end, as in the case of Auburn, which was ranked as number 3 in September but had dropped out of the rankings by the end of the regular season.

Pick-Em Day in 1990 was Saturday, November 24, and the most widely publicized agreements reached before that time were reached at least 13 days earlier. Notre Dame, an independent (and always a television favorite), had begun the season as the number-1 ranked team and had recovered from an early loss to regain that position by early November. In the meantime, Colorado had overcome an early season loss and a draw to become the number 4 team in the AP rankings (and number 3 in the UPI ranking). When Colorado beat Oklahoma State to clinch the Big Eight championship, they were assured a berth in the Orange Bowl and a rise in the rankings to number 2. The next day, on Sunday November 11, 13 days before Pick-Em Day, an agreement was announced between the Orange Bowl and Notre Dame that was widely reported in the news (see e.g., Malcolm Moran, 1990). At the time the agreement was reported, this meant that the currently first- and second-ranked teams would meet in the Orange Bowl. Announced the same day was Virginia's acceptance of a bid from the Sugar Bowl to play the still to be determined Southeastern Conference champion.²¹ Following the Orange Bowl agreement, the University of Miami agreed to play in the Cotton Bowl against the still to be determined Southwest Conference champion. At this point, Notre Dame, Virginia, and Miami each still had four games remaining in the regular season.

²¹This came after Virginia decided to decline an offer from the Fiesta Bowl because of the controversy surrounding the failure of a referendum the previous Tuesday to make an Arizona state holiday in honor of Martin Luther King, Jr. (the Fiesta Bowl is played in Tempe, Arizona).

TABLE 2—1990 COLLEGE FOOTBALL BOWL GAMES: RATINGS

Bowl	Matches	Ratings (writers' poll)																							
		Postgame		11/27		11/20		11/13		11/6		10/30		10/23		10/16		10/9		10/2		9/25		9/18	
		Legal bid date (6:00 P.M. Saturday, November 24)		Notre Dame to Orange Bowl, Virginia to Sugar Bowl, Miami to Cotton Bowl																					
Rose	Washington (Pacific-10) Iowa (Big Ten)	5 18	8 17	9 18	9 13	10 13	10 13	6 6	7 13	7 15	7 22	7 25	17 25												
Orange	Notre Dame (Independent) Colorado (Big Eight)	6 1	5 1	7 1	7 1	1 2	1 4	1 9	2 10	3 10	3 14	3 14	8 14												
Sugar	Virginia (Atlantic Coast) Tennessee (Southeastern)	23 8	10 10	12 14	14 14	14 14	9 11	11 11	1 11	1 11	1 11	1 11	1 11	2 4											
Cotton	Miami (Independent) Texas (Southwest)	3 12	4 3	3 5	2 6	3 7	5 14	8 14	8 13	8 19	8 19	8 19	3 9												
Fiesta	Louisville (Independent) Alabama (Southeastern)	14 —	18 25	17 —	20 —	20 —	22 —	25 —	— —																
Citrus	Nebraska (Big Eight) Georgia Tech (Atlantic Coast)	24 2	19 2	19 2	10 3	11 4	13 7	13 16	3 16	4 16	4 11	4 18	7 18												
Gator	Michigan (Big Ten) Mississippi (Southeastern)	7 21	12 15	13 15	15 16	16 17																			
Hall of Fame	Clemson (Atlantic Coast) Illinois (Big Ten)	9 25	14 16	14 16	16 17	17 18	18 19																		
Holiday	Texas A&M (Southwest) Brigham Young (Western)	15 22	13 13	4 4	4 5	5 8	8 10																		

Ratings (writers' poll)

Bowl	Matches	Legal bid date											
		12/4	11/27	11/20	11/13	11/6	10/30	10/23	10/16	10/9	10/2	9/25	9/18
Liberty	Ohio State (Big Ten) Air Force (Western)	—	24	25	19	21	—	—	—	—	20	15	16
John Hancock	Southern California (Pacific-10) Michigan State (Big Ten)	20	21	18	19	23	21	21	15	16	15	18	5
Peach	Indiana (Big Ten) Auburn (Southeastern)	16	22	23	24	23	24	—	24	—	18	22	24
All-American	North Carolina State (Atlantic Coast) Southern Mississippi (Independent)	19	—	20	23	24	15	4	20	22	—	—	3
Aloha	Syracuse (Independent) Arizona (Pacific-10)	—	23	24	25	—	—	—	—	—	—	—	—
Copper	California (Pacific-10) Wyoming (Western)	—	—	—	—	—	23	23	—	21	25	16	18
Freedom	Oregon (Pacific-10) Colorado State (Western)	—	—	—	—	—	—	—	21	23	—	—	—
Independence	Maryland (Atlantic Coast) Louisiana Tech (Independent)	—	—	—	—	—	—	—	19	18	21	—	—
California	San Jose State (Big West) Central Michigan (Mid-American)	—	—	—	—	—	—	—	20	22	—	—	—
Blockbuster	Penn State (Independent) Florida State (Independent)	11	7	10	11	18	21	24	—	—	—	—	—
		4	6	8	8	9	12	12	7	10	2	2	2

These agreements were able to elude NCAA penalties because they were “unofficial” and “informal.” At the same time, although they were presumably legally unenforceable, the fact that the same bowls and teams are involved with one another year after year apparently makes it quite rare for such agreements to be broken.²²

Shortly after these agreements, Notre Dame lost a game and finished the regular season ranked number 5. Virginia, which had lost only one game prior to its agreement with the Sugar Bowl, lost two games subsequently, and finished the regular season unranked in the AP poll (and ranked number 23 in the UPI poll). By the end of the regular season it was clear that no bowl would have the number-1 and number-2 teams (Colorado and Georgia Tech, respectively), and indeed when the bowl games were over there was no consensus national champion: Colorado was ranked number 1 in the AP poll, and Georgia Tech was atop the UPI poll.²³

Faced with a persistent and public inability to enforce Pick-Em Day, the NCAA abandoned the attempt (and began to consider some kind of centralized matching procedure).²⁴ The Football Bowl Associa-

tion (FBA) responded with an attempt to enforce a Pick-Em Day of its own (to be November 17 in 1991) and voted to levy a fine of \$250,000 on any member who violated this understanding.²⁵

However the FBA was no more successful than the NCAA, and following the 1991–1992 season, *Sports Illustrated* summarized the situation as follows (William

of North Carolina) explained this decision in a letter (to Roth, 15 March 1991) as follows:

The decision was made to eliminate from the NCAA Bylaws legislation that prohibits an institution from tying into a bowl before a particular date because the particular piece of legislation was being largely ignored and, most importantly, could not be enforced. In recent years, the NCAA has worked toward eliminating rules that were unenforceable, and the membership overwhelmingly felt that this was one of those rules. The bowl association has on its own decided to implement its controls, and there will continue to be a selection date, although it will not be an NCAA violation if an institution does not adhere to that date.... Whether or not this will improve the situation, of course, remains to be seen. If this does not work, our committee is looking at the possibility of instituting a draft whereby teams would be ranked and given a drafting order, and the teams would be allowed to pick the bowl they would like to attend, or the bowls would be ranked in a particular drafting order and they would be allowed to draft teams into their bowl. Either of these would take place on a pre-determined date.

²⁵Steven Hatchell, chair of the executive committee of the Football Bowl Association (and Executive Director of the Orange Bowl) wrote about the situation in a letter (to Roth, 25 February 1991) as follows:

There have been obvious violations of the selection date process in recent years. While many of the bowls do not issue the “formal” invitation until that Saturday in late November, they have informally put the entire deal together. The earliest date many bowls have made agreements was in late October. This past year, many of the bowl pairings were known by the first weekend in November.

While all bowls have been accused of moving too early in this process, the problem seems to have increased with the recent influx of new bowl games. There are currently 19 postseason bowls, which has forced many of the smaller bowls to choose matchups as early as possible to avoid being left completely out of the picture....

[At the NCAA Convention last month] the Football Bowl Association decided that some action must be taken. We voted unanimously to maintain the selection date at its current time frame in late November and impose a \$250,000 fine to any bowl that violates the deadline. It was our belief that the combination of the bowls’ trust in each other and the public embarrassment that a fine would bring to the bowl and its title sponsor would be enough to withstand the temptation.

²²Because of the substantial penalties for breaking NCAA rules, there are no public accounts of the details of these informal agreements. However in confidential discussions with participants in this market, great confidence was expressed in the reliability of such agreements, once made. This is not to say that these agreements are never broken, and we heard of at least one occasion in which a university broke an unofficial agreement with a major bowl and was ostracized by the bowl (and perhaps by some other bowls, although this is less clear) for several years thereafter.

²³The best matchup turned out to be in the Cotton Bowl, which at the end of the regular season had the number 3 and 4 teams in both polls. The fact that many teams had made early arrangements worked to the advantage of the new Blockbuster Bowl, which had not been in a position to attract highly ranked teams early in the year. It hosted Florida State and Penn State, each of which had lost two games early in the season and were not highly ranked in early November, but which were the number 6 and 7 teams at the end of the regular season.

²⁴John Swofford, chair of the Postseason Football Subcommittee (and Athletic director at the University

Reed, 1991 p. 128):

Although the Football Bowl Association did a lot of blustering, saying that bowls that committed to teams prematurely could be fined as much as \$250,000, the feeling now is that so many bowls broke the agreement, the FBA would make itself even more of a joke—if that's possible—by launching an investigation.

The 1991–1992 bowls also failed to produce a matchup of the top two teams and again ended without producing a consensus national champion (the AP chose Miami, while the UPI chose Washington).

Aside from the size of the television audiences which matchups of top-ranked teams would draw, the FBA has reason to be concerned that the failure to produce a national champion is an invitation for entry into their market. In 1992 the Home Shopping Network proposed to the NCAA a \$33 million package for a bowl to be held January 18, between the two top-ranked teams. Although this proposal has not advanced, the threat is clear.

In the meantime, teams and bowls were reorganizing themselves to meet the evolving market conditions. A new football conference, the Big East, was formed (including Miami as its most prominent team).²⁶ This new conference, together with four other conferences (Atlantic Coast, Big Eight, Southeastern, and Southwest) and Notre Dame joined in a consortium with the Orange, Sugar, Cotton, and Fiesta bowls, whose object is to reverse the unraveling of transaction dates and to increase the chance of a bowl game between the two highest-ranked teams.²⁷ To this end, the consortium

²⁶The Big East teams are Boston University, Miami, Pittsburgh, Rutgers, Syracuse, Temple, Virginia Tech, and West Virginia.

²⁷The goals and form of the consortium evolved out of complex multilateral negotiations, with the initial impetus being the desire of the new Big East conference to assure its champion of a postseason bowl. The Big East and ACC together approached the Orange, Sugar, and Cotton Bowls, and Notre Dame and the Fiesta Bowl became involved in the course of the negotiations.

agreement specifies a somewhat complicated procedure by which teams will be matched to bowls, based on their rankings at the end of the regular season.²⁸ Before the agreement was concluded, the Blockbuster Bowl weighed in with an offer to become a closed bowl with the champions of the Big East and ACC, but this was rejected. After the consortium agreement was made, and long before the start of the 1992–1993 season, the Blockbuster Bowl announced (on May 20, 1992) an agreement that Penn State (one of the few remaining independent teams, but due to join the Big Ten Conference in 1993) would play in its game on January 1, 1993. The Blockbuster's chair, Charlie Frankel, was quoted in *The New York Times* (21 May 1992, p. B7) "We've just set a new precedent for pick-'em day."²⁹

This market is thus in considerable flux. Having failed in repeated attempts to enforce a uniform date for transactions, large parts of the market are moving to increasingly centralized procedures (i.e., involving more teams and bowls), while other parts of the market are unraveling further.

4. *Business-School Markets: New MBA's and Marketing Professors.*—We conclude the examples of unraveling with a brief mention

²⁸If the top two teams are from the Big East, ACC, or Notre Dame, they will play each other in the Fiesta Bowl. Otherwise the bowl whose host team (under the preexisting semi-closed bowl agreements) is the highest ranked will get the highest ranked of the Big East, ACC, or Notre Dame teams, and the remaining teams will be allocated in order of rankings. As of this writing some details (such as the current status of the semi-closed bowl agreements) seem still to be under discussion.

²⁹At the end of the 1992–1993 regular season, the consortium did indeed produce a match between the number-1 and number-2 ranked teams (Miami and Alabama, respectively) in the Sugar Bowl, and the victor, Alabama, was subsequently ranked number 1 in both the writers' and coaches' polls. The Blockbuster Bowl did not fare as well as in the previous year, however: although Penn State was considered a contender for the national championship when it accepted the Blockbuster offer before the season began, it entered the Blockbuster Bowl ranked number 21 at the end of the season, where it played (and lost to) 13th-ranked Stanford.

of two markets which depart from the pattern of the markets discussed above in that the unraveling they have experienced seems to be regarded as being of manageable proportions. Therefore, in these markets, no market-wide efforts have been made to reverse it. Our point in concluding the discussion of stage-1 unraveling with these markets is to avoid giving the impression that unraveling necessarily leads to market reorganization.

The top MBA graduates from the most prestigious business schools have for some years been regarded as attractive recruits for a variety of businesses. The most aggressive firms (e.g., consulting firms in the 1970's, and investment banking firms in the 1980's) have periodically engaged in early offers with short fuses. (Margaret Neale and Max Bazerman [1991 p. 123] also describe a variation on exploding offers in which the offered salary goes down for every day that the candidate delays accepting.) Although we are not aware of any attempt to organize a market-wide response to such practices, the deans of particular business schools whose students are the subjects of such offers have sometimes responded with threats to deny the offending firms easy access to their graduates, typically by denying them on-campus recruiting facilities. There seems to be little evidence or consensus on how effective such sanctions have proved to be.

The situation in marketing is that the major job market for new business-school professors of marketing is organized around the summer meetings of the American Marketing Association. The market thus occurs a little over a year in advance of the date for which the positions are to be filled. This was not always the case: in the 1950's the American Marketing Association still held its market-oriented meeting at the Allied Social Sciences meetings between Christmas and New Year's Day. The change to the earlier meeting means that graduate students are often interviewed and hired before having begun their dissertation work (and there is a consequent problem when the time comes for tenure evaluation). The marketing historian Stanley Hollander summarizes the situation in a letter (to Roth, 8 April 1991) as follows:

When I received my doctorate in February of 1954, the schools at which I interviewed wanted to read my dissertation. Today, most of us are hiring new entrants at the ABD level. Our practice here [at Michigan State University's Graduate School of Business] is to make appointments at the visiting assistant level until the degree is obtained, in good part to avoid the start of the tenure clock.

Thus the unraveling in this market has involved not only the time at which new marketing professors are recruited, but also the point in their careers at which they assume their new responsibilities. However, as in the MBA market, we are not aware of any market-wide response to the unraveling of the market.

Having now looked at markets whose unraveling has promoted active attempts to control it and at markets whose unraveling has been regarded much more casually, we turn to markets which have enjoyed at least a measure of success at controlling the unraveling of appointment dates.

B. *Examples of Stage 2: Enforcement of Uniform Dates*

We have already seen some of the difficulties encountered by markets that attempt to halt unraveling by enforcing a regime of uniform dates—in the markets for Federal Court clerkships and postseason college football bowls. In both of those markets, the attempts to enforce uniform dates never really met with any success at all and were abandoned. In this section, we consider two markets in which systems of uniform dates and times have been employed for many years.

The first of these is the market for new humanities and social-science graduates of elite Japanese universities.³⁰ Repeated at-

³⁰Preeminent among these elite universities is the University of Tokyo, but the group of universities whose graduates are the targets of the competitive recruiting practices to be described also probably includes, to different degrees, Hitotsubashi, Hokkaido, Keio, Kobe, Kyoto, Kyushu, Nagoya, Osaka, Tohoku, Tokyo Insti-

tempts have been made to enforce uniform dates before which positions should not be advertised, students should not be recommended, applicants should not be interviewed, and offers should not be made. Periodically, these attempts have broken down. However the formalities of observing at least some of these dates have often been observed, with the breakdowns coming in a variety of informal arrangements, including some unusual strategic behavior unique to this market (as far as we know).

The second market to be considered in this section is the market for clinical psychology interns in the United States. That market has employed a system of uniform dates and times since the early 1970's, although it has faced continuous problems.

1. *Japanese University Graduates.*—We will concentrate on the years 1970 through 1990, a period for which we have contemporaneous accounts.³¹ However, the unraveling of the market, and even attempts to halt the unraveling through the establishment of uniform times for recruiting, apparently go back much further.³²

The 1970's were marked by a series of agreements between firms (through various employers' federations such as Nikkeiren [The Japan Federation of Employers' Associations]), university organizations (such as the Association of National Universities),

and government ministries (including the Ministry of Education, and later the Labor Ministry) concerning dates at which various recruiting activities could be undertaken. These agreements failed in two ways. First, some of their clauses, such as those which prohibited firms from giving employment exams or from having students make visits to companies before certain dates, were largely ignored. Others, such as those which prohibited firms from making formal offers of employment before a certain date, were circumvented through informal guarantees of employment, known as *naitei*. As a result, employment decisions for university graduates unraveled despite these agreements. The popular name for this unraveling is *aota-gai*, which translates as "harvesting rice while it is still green." In what follows, keep in mind that the Japanese academic year begins in April and ends in March.

In 1970, amidst concern that the universities might be disrupted in June in connection with the renewal of the U.S.–Japan security treaty, *Asahi Shimbun* (22 April 1970, morning edition, p. 14) reported that *aota-gai* was being replaced by *sanae-gai*—"harvesting rice while it is newly planted." Despite an agreement that companies would not begin recruiting before June 1 (for technical graduates, and July 1 for others), the story reported that large banks had already held their employment exams, and the chairman of the employment committee of the Union of Private Universities was quoted as saying that there were cases of *naitei* to juniors in the middle of February. The situation was apparently not improved by an adjustment of the dates in 1972 which prohibited the beginning of recruitment only until May 1 of the junior year.

In 1975, a new attempt to reverse unraveling was initiated, in which companies were to invite students for on-site interviews only after October 1 of the senior year, and were not to hold employment exams until November 1. When this too failed to halt the unraveling, a 1979 agreement specified that a committee including the Labor Ministry would monitor compliance, and firms which violated the agreement would, after a

tute of Technology, and Waseda. (Engineering graduates are apparently hired in a somewhat different way, which appears to involve long-term relationships between some companies and some professors.)

³¹Our published sources are from the *Japan Economic Journal* and the *Japan Times*, which are both in English, and from *Asahi Shimbun* and *Nihon Keizai Shimbun*. We are grateful to Ms Hiromi Tojima of the University of Tokyo for translations of these latter accounts from Japanese into English.

³²A retrospective story in the *Nihon Keizai Shimbun* (12 October 1984, evening edition, p. 3) says "The history of the agreement goes back to 1953. It was a time of job shortages, and students came to start their job-hunting activities early. At a meeting for solving the problem, seven universities, 28 business organizations, and some ministries concerned agreed that universities should not begin to recommend seniors to companies until October 1."

warning, be publicly named. This had the effect of increasingly driving the recruiting “underground” (so that company visits were arranged informally, through the “old boy” network of alumni from a given university), but it did not halt the unraveling. In 1981 the Labor Ministry announced that starting in 1982 it would no longer monitor the agreement, since it had no effective way of enforcing it.³³

Throughout the 1980’s, attempts were made first to maintain the “ten-eleven” (October-November) dates and, after 1986, an earlier schedule that allowed contacts in August and offers in October. These attempts were without notable success. The offering of *naitai* continued, particularly as the disadvantages of trying to abide by the official dates while others did not became apparent.³⁴ There were increasing reports that companies would essentially try to kidnap those applicants to whom they had offered *naitai*, to prevent them from interviewing at other companies. (Notice the close strategic relationship of this tactic to the exploding offers observed in the markets for American lawyers.) In 1988 the Nikkeiren established a telephone line to which students could appeal if they found themselves in this situation.³⁵ Summarizing

³³The *Nihon Keizai Shimbun* (27 November 1981, morning edition, p. 1) has a story covering the Labor Ministry announcement and reviewing the history of the various failed “gentlemen’s agreements” about recruiting. Note the parallel between the Labor Ministry’s decision and the decision of the NCAA no longer to try to enforce a date for college bowl transactions.

³⁴The *Japan Economic Journal* (5 October 1985, p. 4) summarizes the situation by saying “no parties to the agreement are keeping their word,” and notes that “*Aota-gai* is a situation in which the honest are made fools of.”

³⁵The following description (in a year when first contacts were prohibited before August 20) is from the *Japan Times* (8 July 1989):

Many companies, after offering *naitai*, also resort to “*kosoku*,” or physical restraint, in order to prevent the students from having contact with other companies. . . . In order to help these students, Nikkeiren last year established a telephone line at its Employment and Education Policy Department to listen to their complaints. Nikkeiren had to issue warnings to some of the companies to “release” the students. They received 530 calls from students and 157 companies were re-

the history of these “gentlemen’s agreements,” the *Japan Economic Journal* wrote (17 March 1990, p. 1) “there is an even greater shortage of gentlemen corporate recruiters than university graduates.”

Thus, over a period of more than 20 years, attempts to set dates for the recruiting of new university graduates and for the signing of formal contracts has not effectively controlled the dates at which de facto recruiting, through informal channels, takes place.

We turn next to a market in which the control of transaction dates has been more successful, although certainly not without many problems.

2. *Clinical Psychology Internships*.—Clinical psychologists are employed as interns prior to completing their doctoral training. The first internships seem to have been established in the early part of this century and to have become a regular part of professional development in the 1930’s and 1940’s.³⁶ In recent years the market has involved just over 2,000 internships each year, offered at about 500 sites (Philip Laughlin and John Worley, 1991 p. 434; Carl Zimet, pers. comm. [letter to Roth, 21 June 1991]) (see also Bernhard Blom et al., 1990a p. 20).

The timing problems experienced by this market were a sufficient cause of concern by the 1960’s that a new organization, the As-

ported to have resorted to detaining students. . . . This year, the hotline was set up on April 17, about 10 weeks earlier than last year. Nikkeiren Chairman Eiji Suzuki said last week that it has already received 108 calls.

In some of the cases, students were told to report to companies on July 1 and July 2. “July 2 is the day for the state examination for public officials” [a Nikkeiren] spokesman said. “It is quite possible that companies were trying to prevent the students from taking that exam.” . . .

Nikkeiren’s 1984 survey, which covers most major companies, shows that 88.4 percent of them think the agreement on recruiting graduates should be continued, although 87.7 percent admitted that they did not abide by it.

³⁶Philip Laughlin and John Worley (1991) identify what may have been the first internship, in 1908, and discuss the emergence of an accreditation process in the 1930’s and 1940’s.

sociation of Psychology Internship Centers (APIC) was founded in 1968 specifically to combat it. James Stedman (1989) reports that, in 1972, APIC proposed a system of uniform dates of appointment which was adopted for the 1973 recruiting season. Subject to many modifications and periodic reevaluations, the system remains in use today.³⁷ Starting in the 1970's, APIC began to distribute a newsletter, which provides a record of the virtually continuous difficulties which the system of uniform dates and times has experienced, and of the modifications considered (and occasionally adopted) to ameliorate these.

One set of modifications involved the period for which offers were required to remain open. In 1976 this period was reduced from five days to three, and in 1978 from three days to one. The Uniform Notification Plan for most of the 1980's specified that offers are to be made no earlier than 8:00 A.M. Central Standard Time of the second Monday in February, and that offers must be accepted or rejected by noon the next day.³⁸

³⁷About the early, undocumented history of this organization, Stedman (1989 p. 35) remarks: "All three of these founding fathers [of APIC] were very clear about one historical fact, namely that APIC was organized primarily to deal with a lack of regularity in the intern selection process. Ivan Mensh said students of the late '60s complained about deals being made between internship sites and certain select students."

Ronald Fox (1990) recalls that "Obtaining agreement for a Uniform Notification date was difficult, but most people agreed that some order needed to be brought to the chaos created by every program setting dates as it pleased.... Some of our major problems with a uniform date were in large cities with several internship programs which competed with each other for students. Each was afraid to agree to an honor system which might leave them 'holding the bag' when notification date arrived."

In 1992 APIC changed its name to the Association of Psychology Postdoctoral and Internship Centers (APPIC), reflecting the growth of postdoctoral as well as predoctoral internships. To avoid confusion we will refer to the organization as APIC, the name it operated under throughout the period we discuss.

³⁸The formal rules of the present Uniform Notification Procedure were first adopted for the 1979-1980 season (although, as will be discussed, some modifications were adopted in 1988, and subsequently dis-

This system of uniform times has generated complaints about several kinds of behavior. The first of these concerns simple violations of the rules, involving offers made before the legal time or demands for a response before the legal time. For example, surveys conducted by Michael Carifio et al. (1987) and Carifio and William Grace (1992a,b) find that between 10 percent and 25 percent of applicants surveyed report being made an offer before uniform selection day. (One attempt to deal with this was made in 1988, when under an "Early Acceptance" plan, offers before the second Monday in February were legalized under the condition that replies not be demanded until the usual time, but this plan was abandoned after one year.) A related complaint is that applicants are subjected to a great deal of informal pressure both to indicate in advance whether they will accept an offer and to reply before the deadline.³⁹

Still a third class of complaints concerns congestion in the final hours of the system. Some of this simply involves the difficulty of transacting a good deal of business in a

carded). The relevant rules read as follows (Stedman, 1989 pp. 37-38):

2. Accepted applicants are to be notified no earlier than 8:00 A.M. Central Standard time (CST) of the second Monday in February. Those applicants must respond no later than 12:00 CST the following day.
3. Alternate applicants accepted between 8:00 A.M. Monday and 12:00 noon on Tuesday may be asked to respond by Tuesday noon CST but not earlier.
4. Applicants accepted after Tuesday noon should be prepared to make a relatively quick decision, on the assumption that they have already considered any earlier offers....
6. Applicants who are being thought of as alternates for the center's first choices may be notified of their alternate status but not before 8:00 A.M. CST on the second Monday in February.
7. Once a center's positions are filled, all remaining applicants should be so notified.

In 1991 these rules were again modified. Among other changes, the interval specified in rules 2-4 was reduced from 16 hours to 7 hours. See Roth and Xing (1994) for a discussion of the implications of changes in the time during which offers remain open.

³⁹Just as the discussion of legal markets by lawyers often focuses on the precise wording of rules, clinical psychologists frequently discuss the *affective* responses to these practices, such as how stressful and anxiety-provoking they are.

short time and in accordance with the guidelines.⁴⁰ However there are also numerous reports of particular behavior which concentrates transactions very late in the specified period. This includes the holding of multiple offers by candidates (rather than the prompt rejection of all but one) and the practice of internship centers telling many candidates that they are highly ranked alternates (with the consequence that they do not accept offers already received until the last moments before noon on Tuesday).⁴¹

An interesting feature of the history of this market is that, motivated by the success of the centralized market-clearing system used by medical graduates, there have been proposals virtually throughout the history of the uniform notification plan that the psychologists too should move to a centralized matching mechanism (see e.g., Ivan Mensh and Orgel, 1978; Association of Psychology Internship Centers, 1981, 1985; Briggs, 1984).⁴² None of these proposals got beyond the proposal stage until the 1990–1991 recruiting season, when a trial run of a centralized matching procedure was conducted, for information purposes, alongside the usual procedure, by which transactions were actually made (see Blom and Sanford Pederson (1988, 1989; Blom et al., 1989, 1990a, b). However, following problems in the way this trial run was conducted, the computerized system was rejected by the

APIC membership. Thus, with all its troubles, the Uniform Notification Procedure remains in place.

We turn next to some markets which have adopted centralized market-clearing procedures.

C. *Examples of Stage 3: Centralized Market-Clearing Procedures*

Just as familiarity with the American medical market permitted regional markets in Britain to move (in some cases directly) from unraveling to centralized market-clearing, the medical model was familiar in other health-care professions as well. We next consider two nonmedical health-care markets that turned to the medical model of centralized matching to solve their timing problems.

1. *Other Health-Care Markets: Dentistry and Optometry.*—A 1984 survey of residency program directors in the dental specialty of oral and maxillofacial surgery (OMS) revealed that just over 70 percent of them “had experienced the late withdrawal of an applicant who had initially accepted a firm offer” (John Kelly, 1985a p. 1). This was after unsuccessful attempts had been made to adopt a system of uniform dates.⁴³ Shortly thereafter, a decision was made to adopt a centralized market-clearing process, and National Matching Services Inc., the firm which runs the medical match for the National Resident Matching Program, was commissioned to run a similarly organized dental match.

⁴⁰For example David Briggs (1984 p. 11) reports that filling four positions from 44 applications involved more than 100 completed phone calls and another 100 attempted calls.

⁴¹Guidelines to encourage students to formulate their preferences ahead of time and quickly reject all but the most preferred offer have been proposed from time to time without notable success (see e.g., Cynthia Belar and Sidney Orgel, 1980 p. 674; Grace, 1985 p. 480). It is obviously to the advantage of an internship center to have as many as possible of its acceptable candidates available until the last minute, in case it should be rejected by its more preferred candidates.

⁴²The Association of Psychology Internship Centers (1985) reference involved the solicitation of detailed cost estimates from Elliott Peranson, currently of National Matching Services Inc., which operates the medical match on behalf of the National Resident Matching Program.

⁴³Responses were received from 70 of the 99 non-military residency programs, covering 140 out of a possible 195 positions (with the largest program offering four positions). A parallel survey of residents elicited responses from 190 of the residents. An interesting difference between the two surveys is that only three program directors reported making offers before November 3, but 39 residents reported *receiving* offers before November 3. Kelly (1985b p. 3) remarks “This discrepancy in reporting points graphically to the problem or deficiency of our present system [of uniform dates], that of a major breach of ethical, honest behavior.”

This match, which is now called the Post-doctoral Dental Matching Program, was sufficiently successful so that it has grown in the ensuing years to include other dental specialties. In addition to OMS the match for 1992–1993 included pediatric and periodontal residencies, as well as residencies in general practice (mostly in hospitals), and advanced education in general dentistry (mostly in dental schools). Together these made for a market of 1,204 positions. However, although the match is organized so that applicants may apply to any combination of programs, the submarkets are largely distinct: of 1,837 applicants for 1992–1993 positions, 1,527 (83 percent) applied to only one kind of program. Of the 993 applicants who ranked one of the three specialty programs, only 70 (7 percent) had ranked another kind of program first (National Matching Services, 1992).

In optometry,⁴⁴ the success of centralized matching is not yet clear. Residencies in optometry first became available in the mid-1970's, to provide opportunities for specialty training, and as part of a movement for optometrists to become more involved in primary care (instead of merely diagnosis and vision correction). Only a small number of residency positions are available, and most of these are affiliated with Department of Veterans Affairs (VA) health-care facilities (where a one-year residency gives two years of seniority for those who obtain a position at a VA facility). In 1990 the American Optometric Association accredited 40 residency programs at VA facilities and another dozen at schools of optometry and other sites.

The National Association of VA Optometrists (NAVAO) organized and operated a centralized match in 1986. However, while the majority of VA programs participate in the NAVAO match, by 1990 it had attracted only one school-based residency program to participate, so that a substantial portion of the market continues to operate

in a decentralized way. This places some participating programs at a disadvantage in competing with nonparticipating programs. The rates of participation thus appear to be in flux, and it is too early to predict the outcome. (We will see a similar situation when we discuss the market for radiation oncology residencies, and the effect of participation rates will be discussed in Section V in connection with Examples 4 and 5 and Theorem 2.) In 1991 NAVAO handed over control of the matching service to an independent organization newly created for the purpose, Optometric Residency Matching Services, Inc., in an effort to encourage the inclusion of the non-VA residency programs (but as of 1992 only two such programs had chosen to participate). Another problem facing this match is that students have sometimes reneged on their match agreement and taken a nonresidency position (rather than a different residency).

We turn next to some centralized matching procedures which have halted further unraveling in the markets in which they operate, but which are scheduled so that the matches that are made through them still occur quite early by the historical standards of those markets.

2. *Fraternities and Sororities.*—Fraternities and sororities are social organizations for undergraduate men and women widely found on the campuses of American colleges and universities. In the 1800's, only seniors were admitted to membership, but competition for desirable members caused an unraveling of dates at which members were recruited. (This unraveling, or "rushing," entered the language as the name still used for fraternity and sorority membership drives today.) By the turn of the century, recruitment dates had unraveled through the four years of college, and (at least in some regions of the country) into the preparatory schools from which particular colleges traditionally drew their students. In 1928 the National Panhellenic Conference, the umbrella organization of sororities, adopted a centralized matching procedure, called the Preferential Bidding System, which effectively deferred recruiting until

⁴⁴This description is primarily based on conversation and correspondence with Tim Messer.

students had actually arrived on campus as freshmen. However no similar centralized system was adopted by fraternities (see Mongell and Roth [1991] and the references quoted there).

In the intervening years, the demographic makeup and geographic mobility of college students has changed sufficiently so that recruitment before college admission has become increasingly impractical. Today both sorority and fraternity recruitment begin at roughly the same time—as soon as students arrive on campus—even though only the sororities use a centralized mechanism. Thus this is a case in which the continued use of a centralized mechanism no longer appears to have a major impact on the time at which recruitment takes place. Note however that the benefits of sorority and fraternity membership can also begin as soon as students are admitted to membership, since today it is common for sororities and fraternities to own houses in which their members live, and membership becomes a focus of social life throughout the four years of college.

Thus, unlike the professional labor markets we consider, the early recruiting of contemporary fraternities and sororities does not involve agreeing to transactions long before they will be consummated.⁴⁵ We turn next to consider some medical labor markets in which centralized mechanisms are used to make transactions long before the start of employment.

3. *Medical Specialties.*—As medical practice has become more specialized, entry-level positions have also, and first-year generalist internships have been replaced by more specialized first-year residencies.⁴⁶

⁴⁵In this regard, an interesting account of various of the institutions that have been used to allocate housing to Harvard undergraduates is given by Susan Collins and Kala Krishna (1993).

⁴⁶Reflecting this change, the matching program for first-year medical graduates was called the National Intern Matching Program prior to 1968 when it was renamed the National Intern and Resident Matching Program, and in 1978 it took its current name, the National Resident Matching Program, following the demise of the first-year rotating internship.

However, medical specialization requires clinical experience considerably past the first postgraduate year, and while the unraveling in appointment dates for first-year postgraduate (PGY1) positions had been successfully reversed by the introduction of centralized matching, unraveling for more advanced residencies continued. To deal with this unraveling, beginning in 1978 and gathering steam throughout the 1980's, many specialties successfully introduced centralized matching for their advanced residencies and fellowships (i.e., for positions which begin 2–6 years after graduation from medical school). Unlike the centralized match for PGY1 positions, the matches for these more advanced positions often take place substantially in advance of the beginning of employment. In fact, a number of matches for PGY2 and PGY3 positions take place before the match for PGY1 positions.

In 1978, a centralized match was introduced for second-year postgraduate positions in ophthalmology.⁴⁷ This match is independent of and takes place before the National Resident Matching Program (NRMP) match for PGY1 positions. Since then, other matches which operate independently and take place before the NRMP

⁴⁷August Colenbrander, who organized that match, writes (letter to Roth, 19 February 1991): "For twelve years before that, the desirability of a match had been discussed, but people did not dare enter into one for fear that some program directors would not 'play by the rules.' The running joke was: 'Father you need to get me into Medical School, I was just offered an Ophthalmology residency.'" Colenbrander has subsequently become the coordinator for the PGY2 and three matches in neurological surgery, otolaryngology, and neurology, for the PGY4–6 matches in plastic surgery, and fellowships in four ophthalmology subspecialties (retina, cornea, glaucoma, and pediatrics). Based on the publicly available description of the matching algorithm used in these matches, it appears to be a stable matching mechanism, at least for uncomplicated matches. Because of the complexity of these markets, and the occurrence of special cases (e.g., the matching of married couples [see Roth, 1984]), we are not in a position to assert that the algorithms always produce stable matchings. However, for the purposes of this paper, it seems justified to count both these matching algorithms, and the NRMP specialty matches (to be described shortly) as stable mechanisms.

have been established for PGY2 positions in neurological surgery, for PGY2 and PGY3 positions in otolaryngology, and for PGY3 positions in urology. In these matches, medical-school seniors obtain their second- and third-year employment from 18 to 30 months before they will begin work, and also *before* they will be matched to their PGY1 positions.

Part of the reason for this may have to do with the fact that students need particular preparation to take different advanced positions, and advanced knowledge of admission to a specialty with limited entry can guide this preparation. But the timing also seems to reflect competition among specialties. For example, dermatologists initially attempted to schedule an independent match for advanced positions during the PGY1 year instead of during the senior year of medical school but had to abandon this initial attempt in view of the timing of other matches (Colenbrander, pers. comm. [letter to Roth, 24 March 1991]).⁴⁸ In contrast, the somewhat less competitive specialty of neurology (cf. Colenbrander, 1989) runs a two-tier match, with only some PGY2 positions being filled by medical-school seniors 18 months in advance, and the rest being filled by first-year residents, only six months in advance.

In the 1980's, the NRMP also began to include PGY2 positions in its match, so that medical-school seniors could match *simultaneously* to their PGY1 and their PGY2 positions.⁴⁹ The specialties offering a substantial percentage of their PGY2 positions through the NRMP are anesthesiology, emergency medicine, orthopedics, physical medicine, psychiatry, and diagnostic radiology (see National Resident Matching Service, 1990; Allen Lichter, 1992). While these specialty submarkets allow students to apply to more than one specialty, in practice this seems to be rare: in 1990, 82 percent of seniors participating in the match applied to only one

kind of specialty program (National Resident Matching Program, 1990 p. 9).⁵⁰ Similarly, the NRMP has sponsored separate matches by a dozen advanced specialties, under its Specialties Matching Services, and a common match for three advanced medical subspecialties under the Medical Specialties Matching Program.⁵¹ Despite their common match (in which applicants can apply to more than one kind of program), even the markets for the three medical subspecialties are quite distinct: out of 2,029 applicants in the 1991 match, 1,933 (95 percent) applied to programs in only one subspecialty (National Resident Matching Program, 1991b table 5). Part of the reason for how separate these specialty markets are may have to do with the process of preparing for each match, which in some cases begins long before the match itself. We will speak about aspects of this shortly, when we discuss examples of stage-4 unraveling.

It should be noted that not all specialty matches were successful on their first attempt. In the 1960's, independent specialty matches were attempted and subsequently abandoned in psychiatry, radiology, orthopedic surgery, and pediatrics (see Lichter, 1992 p. 1148). It is illuminating therefore to consider the case of radiation oncology, which is currently in the process of trying to organize a match.

⁵⁰Arrangements can also be made for students who wish to participate in more than one of the four PGY2 specialty matches run by Colenbrander (letter to Roth, 5 March 1991), although here too this seems to be the exception.

⁵¹The specialty matches run separately under the Specialties Matching Services are colon/rectal surgery, dermatology, emergency medicine, foot/ankle surgery, hand surgery, ophthalmic plastic and reconstructive surgery, pediatric emergency medicine, pediatric orthopedics, pediatric surgery, reproductive endocrinology, sports medicine, and vascular surgery (see National Residents Matching Program, 1991a). The internal-medicine subspecialties run under the Medical Specialties Matching Program are cardiovascular disease, gastroenterology, and pulmonary disease (see National Resident Matching Program, 1991b). The exact make-up of these programs changes from year to year.

⁴⁸Dermatology now runs such a match as part of the Specialties Matching Service of the NRMP.

⁴⁹For each PGY2 position, a student may submit a supplemental preference list of PGY1 positions.

Lichter (1992) reports that, in 1989, the first year of the radiation-oncology match, out of approximately 150 positions, only 120 were included in the match (and apparently some of the most competitive positions were not), and “a significant number of candidates withdrew to occupy the 30–35 residency slots that were offered outside the match” (p. 1151).⁵² He notes that additional programs withdrew in the second year of the match and that a larger number of candidates withdrew after entering the match to accept these positions. As Lichter notes (p. 1149):

When there are far more applicants than there are training positions, the temptation for an applicant to take a residency position offered outside the match is nearly overwhelming. Since non-match programs are not bound by a uniform acceptance date, such programs often preempt the match process by making offers days or weeks in advance of the match deadline. If sufficient numbers of applicants are removed from the match process due to this unfair competition, the specialty match inevitably collapses. This threatens to happen currently in Radiation Oncology.

Thus in radiation oncology, as in optometry, participation in the match is still in flux.⁵³ In Section V we will consider why the percentage of participants may be so important.

With the proliferation of advanced positions, medicine starts to give us a picture of unraveling not only in entry-level labor markets, but throughout the initial decade of increasingly specialized career paths. The many medical specialty markets exhibit sur-

prisingly little overlap, in terms of how many applicants for one kind of specialty also apply for positions in other specialties that may be available through the same match. The process of unraveling that has brought the different submarkets to the point where they wish to participate in a centralized match has occurred fairly separately as well, with different specialties joining at different times, often after experimenting with attempts at a uniform appointment date.^{54,55}

However, as we have begun to note, the establishment of centralized matching mechanisms—even stable mechanisms—does not necessarily end such unraveling. We turn now to consider this phenomenon in more detail.

D. *Examples of Stage 4: Unraveling Before a Centralized Mechanism*

It would be surprising, given the intensity of strategic behavior that we have observed in markets in stage 1 or stage 2, if all efforts to gain competitive advantage ended when markets established centralized market-clearing procedures, even if the mechanisms involved are stable. Some of the most widely reported practices, such as the efforts of employers to extract from students pledges to rank them first, may or may not involve an actual unraveling of the dates at which

⁵⁴That is not to say, of course, that there is not interaction between different specialty markets, particularly for the relatively junior (PGY2 and PGY3) positions. A medical-school senior who participates in one of the pre-NRMP matches (e.g., in ophthalmology) and fails to obtain a position goes on to pursue another specialty through the NRMP. However, many of the other most competitive specialties are already foreclosed to such a student. An interesting question which is far beyond the scope of the present study is how the relative timing of entry into different specialties—and the early timing of all of the most competitive of them—influences the pattern of physician choice of specialties, including primary-care specialties.

⁵²The match was held in December 1989. Prior to 1989, offers had customarily been extended to medical-school seniors in October and November (see Lichter, 1991 p. 1150). Compare this to the January and February match dates for the other specialties.

⁵³For the 1993 match, radiation oncology participated in the NRMP match, with six programs offering 10 first-year positions and 60 programs offering 129 second-year positions.

⁵⁵For some of the earliest discussions about matching in the different specialties, which shed light on their history and prehistory, see José Barchilon and Ward Darley (1968), Philip Calcagno (1968), Frederick Malkinson (1969), Sherman Coleman and Darley (1971), John Tucker et al. (1978), and Ferris Hall (1981).

decisions are made. We will concentrate here on practices which clearly do, and in which substantial resources are expended well in advance of the start of the centralized match.

Because of the long and varied experience that medical markets have had with stable matching mechanisms, they are a natural source of examples, and we will also consider the market for new graduates of Canadian law schools.

1. *Medical Markets.*—The Association of American Medical Colleges (AAMC) gathers information through an annual Graduation Questionnaire to which around 75 percent of graduating medical-school seniors reply (see e.g., Association of American Medical Colleges, 1990a). They also conduct an annual forum on problems in the transition from medical school to residency (see e.g., Association of American Medical Colleges, 1991b), which provides input from program directors as well. These sources provide evidence of some unraveling before the centralized match for both the least competitive and the most competitive positions.

At the least competitive end, the most common kind of PGY1 positions are in internal medicine, and these medical residents perform much of hospitals' day-to-day work, so it is a matter of concern to those hospitals that fail to fill all of their positions. Hospitals that fail to fill their positions in the match are left to try to fill them after the match with unmatched students, who are often graduates of foreign medical schools.⁵⁶ It appears that some of the hospitals that regularly fail to fill all their positions have begun to recruit foreign medical graduates *before* the match.⁵⁷

⁵⁶In 1990 and 1991, for example, just under 7 percent of U.S. students, but approximately 40 percent of graduates of foreign medical schools, were unmatched by the NRMP (National Resident Matching Program, 1991a).

⁵⁷Because some foreign students who make arrangements before the match presumably do not enter the match at all, it has so far proved difficult to estimate the magnitude of this phenomenon. But see Association

of American Medical Colleges (1991b p. 8) for a brief discussion of the withdrawal of foreign students *after* the match. See also the discussion of the apparently growing use of financial incentives in this connection (Association of American Medical Colleges, 1991b pp. 10–11).

At the most competitive end of the market, several specialties (orthopedic surgery and neurosurgery prominent among them) have begun to suggest to applicants that they must take part in *audition electives* if they wish to be seriously considered as candidates for residencies. An audition elective, typically taken early in the senior year of medical school, before the centralized match, is an on-site clinical experience of several weeks' duration. Thus it is not feasible for a student to audition at more than a very few programs away from his own institution. Nevertheless, in the 1991 survey, 36 percent of students planning to take a residency in orthopedic surgery, and 28 percent of students planning to take one in neurosurgery reported that they had taken *two or more* electives in that specialty at an institution *other* than their own (Association of American Medical Colleges, 1991a table 5). Over 80 percent of the students interested in those two specialties reported that they had been told by one or more programs that they were more likely to be selected if they took an audition elective in the specialty at that institution (Association of American Medical Colleges, 1991a table 4). These figures represent an increase for both specialties over the previous year (Association of American Medical Colleges, 1990b).

Note that, to the extent that programs indeed favor students who have had successful audition electives with them over students with whom they are acquainted only through ordinary interviews, the increase in audition electives means that the matching decisions are being made well before the match. Because students can take very few audition electives, their choices among certain specialties, and among programs in those specialties, are also being made increasingly early. At the same time, programs can use audition electives to inter-

tion of American Medical Colleges (1991b p. 8) for a brief discussion of the withdrawal of foreign students *after* the match. See also the discussion of the apparently growing use of financial incentives in this connection (Association of American Medical Colleges, 1991b pp. 10–11).

view only relatively few students, and these must be chosen even earlier during medical school than the schedule of the match would suggest. Thus, programs are faced with selecting which students to accept for audition electives on the basis of even less information than would be available at the time of the match.

A similar unraveling is at work in the market for Canadian lawyers, which we consider next.

2. *Canadian Lawyers.*—Canadian lawyers must serve an “articling” year following their graduation from law school, before admission to the bar. As in many of the markets we have discussed, where a lawyer serves his articling position has an important effect on his subsequent career, particularly as a very high percentage of articling positions at the most prestigious firms result in offers of permanent employment at the same firm.⁵⁸ The center of the market for Ontario lawyers is in Toronto, while the market in British Columbia centers on Vancouver. We will concentrate on the larger, Toronto market.

Appointment dates began to unravel in the 1970’s, eventually moving back before the completion of the second year of law school. The Ontario Law Society proposed guidelines for a system of uniform dates for offers and acceptances, but this proved less than satisfactory, and in 1986 in Toronto (and in 1987 in Vancouver) a centralized matching procedure was introduced.⁵⁹

However, in recent years, there has also been a growth among major firms of pro-

grams to employ students in the summer following their second year of law school. Barry McGee at the Toronto law firm of Blake, Cassels & Graydon writes (letter to Roth, 25 March 1991) that “the vast majority of summer students return to the same firm to article,” and that

Students now feel virtually compelled to obtain a summer job in Toronto after their second year in law school and as a result, a substantial portion of the articling hiring process has now been placed on the shoulders of the summer program. Students are being hired for summer positions halfway through their second year in law school.... Everyone recognizes that this is a back-door method of obtaining an articling position.

Thus this market has come to resemble the American law-firm market, even though a centralized matching system is in place. The centralized match nevertheless continues to offer substantial advantages, even to firms that arrange much of their articling hiring in advance through summer studentships. McGee goes on to say:

The major advantage [the matching system] has for law firms is that the firm can be assured that it will not end up hiring more students than it wanted to hire. Prior to implementation of the match, that was often a problem. Our firm generally made twice as many offers as we had positions available, and there was always a prospect that we would end up with many more [articling] students than we wished to hire.

Thus we see a tendency toward unraveling even in markets which have instituted predominantly stable matching procedures.^{60,61}

⁵⁸In one major Toronto firm the “hire back” rate has been in the range of 60–70 percent.

⁵⁹In both cases, the technical support for the match is provided by National Matching Services, Inc., the firm which supports the medical matches run by the NRMP, and the basic design of the match is a stable matching mechanism. The Vancouver and Toronto markets are largely separate. In 1991, there were 691 students applying for 556 positions in Toronto, and 237 students applying for 150 positions in Vancouver, with only 23 students who applied for positions in both cities (National Matching Services, 1991a,b). In 1993 Alberta (Calgary and Edmonton) implemented an articling student matching program, with a match to take place in July (Elliott Peranson, pers. comm. [letter to Roth, 13 January 1993]).

⁶⁰However the unraveling seems to be less severe than the stage-1 unraveling observed in the American law-firm market. In the Canadian market, only the larger firms have summer programs, and the number of summer positions is typically no more than half of the number of articling positions which are ultimately filled (Peranson, pers. comm. [14 August 1992]).

⁶¹In the legal recession of the early 1990’s, when firms are hiring fewer students and many students are

Before concluding the descriptive portion of this paper, and to further place the phenomena we describe in context, we consider several other markets in which timing seems to be important, including some academic labor markets in which the trend is toward later, rather than earlier, appointment dates.

E. *Other Markets with Institutions Related to Timing*

1. *Athletes and Osteopaths.*—Table 3 lists several markets with institutions having to do with market timing. The most closely connected to the markets already studied are the markets for athletes. Athletes are highly trained professionals whose talents are uncertain when they are young and are revealed more fully as they grow older. For athletes, physical age as well as professional training may play a large role in the resolution of uncertainty, since athletes in many sports are recruited before they have reached their physical maturity in terms of size, speed, and strength. In several American professional sports, teams acquire the services of new professional athletes through centralized drafts. However, the age at which athletes are predominantly drafted varies, with hockey and baseball drafting substantial numbers of players as they graduate from high school (and then continuing to train them in minor leagues), while basketball and football draft primarily college athletes (with college athletic teams serving

as substitutes for minor-league training). While college teams do not participate in any centralized market-clearing mechanisms, there are uniform dates before which agreements with high-school athletes cannot be finalized, with fairly strict enforcement by the NCAA.⁶²

Of course athletic drafts serve other functions than control of timing, since they are also used to create the possibility of balance among teams which compete with each other. Nonetheless, the age and educational status at which athletes are eligible to enter a draft are issues that come under periodic challenge, which suggests that timing issues are of considerable importance.⁶³

One aspect of athletic drafts worth mentioning is that they do not produce stable outcomes, nor do they need to, since the rules under which leagues operate do not allow a team to hire a player drafted by another team. (However, in the case of athletes who can play a second sport, or who

⁶²Nearly all Division 1A schools have agreed to abide by the rules associated with what is called the National Letter of Intent. Each year there is a date (typically in the first two weeks of February) and time (specified to the minute) before which high-school athletes cannot commit to attend a given school, by signing a National Letter of Intent. Because the letter is signed before a student's grades and standardized exam scores may be available, the school (which also signs the letter) commits itself to offer an athletic scholarship contingent on the student being eligible for academic admission. The penalty for failing to honor the commitment is that the student loses a year of eligibility to play college sports.

⁶³In 1992, Major League Baseball instituted a change in its draft rules which, if it survives challenges in arbitration and the courts, will increase the percentage of players who become professionals directly out of high school. Under prior rules, a team which drafted a high-school player lost its rights to him if he went to college instead of turning pro, and he had to be re-drafted when he graduated from college. High-school players who did not receive attractive offers after being drafted could thus get a second chance, four years later, by going to college. College players are more mature: in the 1992 draft, all but seven of the 28 first-round draft choices were college players (see Bill Koening and Deron Snyder, 1992). Under the recently changed rules, however (see e.g., Murray Chass, 1992), a team which drafts a high-school player retains the rights to his services for five years.

having trouble finding positions, the Toronto market is beginning to experience a limited amount of both earlier and later unraveling. Some firms are opting out of the match to make early offers to good students, and in response their competitors feel pressure to make early offers also. (This seems to have happened with firms engaging primarily in family law and in criminal litigation.) At the same time, a few small firms which have been unsuccessful in competing for the best students have decided to do their recruiting six or seven months *after* the match, so that they can avoid the expense of interviewing students who are not very interested in them, and so that they interview at a time when they will also have more information about how many articling students they will need.

TABLE 3—OTHER MARKETS WITH INSTITUTIONS
RELATED TO TIMING

Market	Institution
American professional sports	
Basketball	draft
Football	draft
Hockey	draft plus minor leagues
Baseball	draft plus minor leagues
College sports	uniform signing dates
Osteopathic internships	matchmaker mechanism
Marriage	minimum legal age laws, matchmaking, "bespoke" institutions
Academic job markets in mathematics, biology, chemistry	postdoctoral positions
Medieval and modern commodity markets	uniform timing (e.g., laws against "forestalling")

have been drafted out of high school and have the option of going to college, instabilities are sometimes resolved by the threat to do so.)

A similar measure of compulsory power seems to be available in the match which places osteopathic interns. In that market, the match is conducted by the same organization that accredits schools and practitioners. The algorithm used is both unstable and easy to manipulate, but the level of control in that market seems adequate to prevent a breakdown of the matching procedures.⁶⁴

2. *Marriage*.—A class of transactions in which unraveling is not at all uncommon is

⁶⁴See Helen Baker and Janice Wachtler (1991 table 2) for the low incidence of match violations. Osteopaths use a priority matching algorithm which first seeks to make 1-A matches, then 2-A, then 1-B, and so forth (where students rank programs 1, 2, 3... and programs rank students A, B, C...). This procedure obviously makes students very sensitive about listing a second choice, which they might be matched to (as a 2-A match) and thus miss a chance at their first choice (as a 1-B match). In response to this, the rules of the match specify that "Students are not permitted to list any...programs...more than once, or to leave intervening blank lines (i.e., listing programs only on the first and third lines) in an attempt to subvert the matching algorithm" (American Osteopathic Association, 1992 p. 5).

in the arrangement of marriages. While in many modern societies the age at marriage seems to be getting later (see e.g., Ted Bergstrom and Mark Bagnoli, 1993), in developing countries it is not so unusual to find marriages arranged quite early, particularly for women. In some countries (India is one), minimum-age laws have proved difficult to enforce (see e.g., Geeta Ramasathan, 1992), and at various times and places formal and informal matchmaking arrangements have emerged. In searching for a striking example of unraveling, we considered places where child marriages occur, and even primitive societies in which unborn children may be betrothed (contingent on their gender). However, the most striking example we have encountered involves a stone-age aboriginal people of Australia, the Arunta. Because the Arunta are polygynous, there is a relative shortage of women. Baldwin Spencer and F. J. Gillen (1927) describe "the most usual method of obtaining a wife" (p. 469) among the Arunta with the following example:

A ... man and a ... woman ... had a daughter.... About the same time a ... man and a ... woman had a son born.... The two fathers consulted, and the result was that the little girl was made *Tualcha mura* to the infant boy. The latter is the prospective husband of the prospective daughter of *the ... girl*" (p. 471 [final emphasis added]).

That is, the infant girl is to be the *mother-in-law* of the infant boy. The arrangements for marriage are made by the father of the infant boy on behalf of his son, with the father of the infant girl on behalf of one of his granddaughters by his infant daughter. Thus in this society marriages are transacted more than a generation in advance of when they can be consummated.

We turn next to a collection of markets in which the time of transactions seems to be getting later, rather than earlier.

3. *Academic Markets for Mathematicians, Biologists, and Chemists*.—Rather than occupying conventional academic appoint-

ments upon completing the Ph.D., in many scientific fields it is becoming common for graduates first to obtain postdoctoral appointments—sometimes more than one—before being considered for assistant-professor positions, particularly at the most competitive universities. The National Science Foundation conducts surveys of new Ph.D.'s which contain data on the numbers going directly into conventional academic positions versus those going into postdoctoral appointments. Because the survey does not distinguish between academic appointments at research universities and others, the figures give only an imprecise picture, but they reflect a general trend that is quite clear in mathematics, biology, and chemistry. In each case, the ratio of postdoctoral positions to academic positions has climbed from 1970 to 1990. In mathematics, the ratio of postdoctoral appointments to academic appointments grew in that period from 0.08 to 0.5, in chemistry from 2.08 to 9.16, and in biology from 1.51 to 8.85 (tabulations made from table 15 of National Science Foundation [1991]).⁶⁵

In biology and chemistry, postdocs in large labs play a role rather similar to medical interns and residents (in that they are essential for the running of the lab). There is some possibility that unraveling in these markets is beginning to go in both directions: on the one hand, more years as a postdoc are required to be competitive for tenure-track positions at top schools, while on the other hand, initial postdoctoral appointments may be made earlier and earlier in the graduate-student career.

Needless to say, it is easier to evaluate the academic promise of a new Ph.D. with two additional years as a postdoc than of a new Ph.D. In the concluding discussion, we will suggest that this tendency toward later appointment dates is a reflection of the same forces that, under different conditions

of supply and demand, cause unraveling to earlier appointment dates.⁶⁶

For our final examples, we look to markets which operate periodically (e.g., every day or every week). In these markets timing is also important, even though it becomes harder to specify precisely what is meant by making a transaction early (since any transaction made when the market is closed is earlier than the next market but later than the previous market).

4. *Medieval and Modern Commodity Markets.*—Although we have so far concentrated on labor markets, similar phenomena may occur in markets generally, and in commodity markets in particular. One opportunity to look for evidence is before markets become well established and, as always, in the rules and regulations which govern markets. For example, reporting on various markets from the 13th to 16th centuries in England, Louis Salzman (1931 p. 75) reports that town bylaws often “contained clauses against ‘forestalling,’ that is to say, intercepting goods before they reach the open market.” He goes on to say (p. 76):

Thus at Norwich no one might forestall provisions by buying, or paying ‘earnest money’ for them before the Cathedral bell had rung for the mass of the Blessed Virgin; at Berwick-on-Tweed no one was to buy salmon between sunset and sunrise, or wool and hides except at the market-cross between 9 and 12; and at Salisbury persons bringing victuals into the city were not to sell them before broad day.

What is at issue here seems to be the market itself, which attracts buyers and sellers only insofar as there is a reasonable prospect that there will be a good supply of both at

⁶⁵See Ehrenberg (1991) for a much fuller discussion of these data, and the difficulties in interpreting them. He notes (table 7.9) that the majority of U.S. citizens and permanent residents who take postdocs go on to academic appointments.

⁶⁶Transactions also have a tendency to occur quite late in environments in which negotiations about terms are conducted under a deadline (see Roth et al., 1988), but it seems likely that the causes of this phenomenon are different than those studied here.

the appointed time and place.⁶⁷ In particular, the appropriate time for a market is when many buyers and sellers are gathered, and if many trades are transacted early, the market may become so diffuse as to no longer attract many participants.^{68,69}

Of course the ability of market organizers to restrict the timing of transactions depends on the legal environment. In 1906 the Chicago Board of Trade instituted a regulation prohibiting members from transacting for grain in transit, after the close of the market, at any price other than the closing market bid. (That is, they did not prohibit transactions, but prohibited new bids in private transactions after the market close.) In 1913 the District Court for the Northern District of Illinois found this to be an illegal

practice, in violation of the Sherman Act. However in 1918 the Supreme Court reversed this decision, holding that the regulation was a legitimate measure to establish an orderly market.⁷⁰

A more contemporary example may be the situation which followed the collapse of the command economy in the former Soviet Union. In 1990, as the restructuring of the economy opened up new avenues of trade, there were widespread reports that shops were empty and that consumers were obtaining goods through privileged channels (e.g., at work, before goods reached shops). For example, *The New York Times* (24 November 1991, section 3, p. 1) reports that Polaroid's joint venture in the Soviet Union

has had to hire a person just to make deals with collective farms for eggs, meat, and other essentials for its workers. Otherwise, many employees would have to skip work to forage for such things.

The more such early private deals are done, the less there is in the shops, and the longer shoppers who need to go to the shops must stand in line, and the more incentive there is for firms to try to make deals directly with suppliers. Thus, there was a tendency to unravel along the distribution chain.

IV. A Modeling Framework

We have seen considerable variety in the behavior of markets which experience unraveling of transaction times. This section seeks to place this variety into a common framework. However, we will not be proposing that all unraveling results from exactly the same cause. Instead, we consider several reasons why some participants have an incentive to try to change the timing of transactions. Since there are only two direc-

⁶⁷In Pittsburgh until a few years ago, the farmers' market which runs on Tuesday and Thursday afternoons in Highland Park used to begin only after the firing of a starter's gun, but this practice was discontinued because it was felt that some of the customers objected to guns. However, the farmers maintain pressure on each other not to begin selling before the appointed time.

⁶⁸Unraveling of a market of this fashion can take place in space as well in time. For example, Salzman also reports (1931 p. 132) that under medieval laws markets could be prevented from being established too near to an existing market, and also, for markets on rivers, nearer to the sea:

Besides injury through mere proximity, and anticipation in time, there might be damage due to interception of traffic. . . . Such interception was more usual in the case of water-borne traffic. In 1233 Eve de Braose complained that Richard Fitz-Stephen had raised a market at Dartmouth to the injury of hers at Totnes, as ships which ought to come to Totnes were stopped at Dartmouth and paid customs there. No decision was reached, and eight years later Eve's husband, William de Cantelupe, brought a similar suit against Richard's son Gilbert. The latter pleaded that his market was on Wednesday and that at Totnes on Saturday; but the jury said that the market at Dartmouth was to the injury of Totnes, because Dartmouth lies between it and the sea, so that ships touched there and paid toll instead of going to Totnes; and also that cattle and sheep which used to be taken to Totnes market were now sold at Dartmouth; the market at Dartmouth was therefore disallowed.

⁶⁹In suggesting that laws controlling the timing of transactions contributed to the growth of exchange and commerce, we are following in a tradition of explaining other medieval legal and economic institutions in this way, as in the work of Douglass North (1990) and Avner Greif (1993), for example.

⁷⁰*Board of Trade of City of Chicago v. United States*, Supreme Court of the United States, 1918, 246 U.S. 231, 38 S. Ct. 242, 62 L. Ed. 683 (see also Richard Posner and Frank Easterbrook, 1981 pp. 172-77). We are indebted to an anonymous referee for this citation.

tions (earlier and later) in which the time of transactions can be changed, different reasons sometimes change the timing in the same direction. The essential condition for unraveling is that some firms have an incentive to make early offers to workers who have an incentive to accept them.

The models we will explore are descendants of the “marriage model” proposed by David Gale and Lloyd Shapley (1962), and the “assignment model” proposed by Shapley and Martin Shubik (1972), which differ in that money may be transferred freely in the latter, but not in the former. Both of these models are “two-sided” matching models in the sense of Roth and Sotomayor (1990), in that every agent belongs to one of two disjoint sets representing, for example, firms and workers, or buyers and sellers.⁷¹ However, where those models are static, we will consider situations in which choices are made over time; and where those models are deterministic, here we allow for uncertainty which resolves itself over time.

For simplicity, we consider situations in which there may be some “final” period T (e.g., the end of the regular college football season, or law-school graduation) after which uncertainty can no longer be resolved before transactions must be made. It is also possible to make transactions at earlier times, $T-1$, $T-2$, and so forth. At these earlier times, agents on both sides of the market may have only probabilistic informa-

tion about the state that will prevail at time T . In the examples we look at here, we keep things simple by supposing that the uncertainty is only about the qualifications and relative standings of the workers (e.g., the law students, or the college teams) and that the properties of the firms are known throughout. Both the preferences of firms for workers and the preferences of workers for firms may depend on how the uncertainty is resolved (e.g., not only may firms prefer to employ certain kinds of workers, but a student’s preferences over firms will depend on his own characteristics and qualifications at time T). Thus, in signing contracts before time T for employment after time T , both firms and workers face uncertainty (e.g., a firm may not know how it will evaluate a particular student in comparison to others before final semester grades are in, and a law student may not know if he will wish to pursue a career as a litigator until after he has participated in moot court).

In this context, there is a potential for transaction times to unravel whenever it is not an equilibrium for all contracts (for employment following time T) to be signed at time T . We will discuss three related reasons—all involving pairwise instabilities—why transactions may have a tendency to move from time T to $T-1$ (or from any time t to $t-1$).

The first of these has to do with instabilities at time T . Suppose that the institutional arrangements at time T are such that, if all parties wait to make their transactions at that time, an unstable matching will result (i.e., if there will be pairs of agents, not matched to each other, who would prefer to be so matched). If the uncertainty at time $T-1$ is sufficiently small compared to the cost of being mismatched, then such agents have an incentive to make their transactions early to avoid the unstable institutions at time T (e.g., the congestion in the last moments of a uniform timing regime, or an unstable centralized market-clearing mechanism). Unraveling of this sort was observed clearly in Roth (1991).

A different reason for unraveling, which exists even if there are institutional arrange-

⁷¹Two-sidedness is natural when we consider labor markets—see Vincent Crawford (1991) for a clear discussion of some of the modeling issues. It is a little less natural when we consider the market for college football bowls, since in that market transactions involve *three* sides: two teams and the bowl. But except for the Fiesta Bowl, the most competitive bowls are of the semi-closed variety, so in the short term this market is two-sided in the period we consider, since each semi-closed bowl needs to attract only one team. Similarly, commodity markets need not be two-sided in the long term, since a buyer may turn into a seller, but it is not a bad approximation for the short term, particularly for medieval markets since many transactions by middlemen were made illegal (by laws against “regrating” and “engrossing” [see e.g., Robert Palgrave, 1910]), so that participants were either buyers or sellers of a given commodity, but not both.

ments which will lead to a *stable* matching at time T , is that some participants may prefer to arrange their transactions before some uncertainties are resolved. By moving early, they may force other participants to move early also. The result of this process can be *ex ante* as well as *ex post* Pareto inefficient.

A third reason for unraveling has to do with the attraction of being on the market when the competition for one's services will be stiff. Even if there are institutional arrangements which will lead to a stable matching at time T , it may be that the expected success of worker w in obtaining a position if everyone waits until time T depends on the competition for his services that will exist then. So if certain firms are planning to fill their positions before time T , even if these are firms that would not normally succeed in hiring worker w at time T , it may be in w 's interest to accept an earlier offer.

In contrast to the models in Roth (1984, 1991) and Mongell and Roth (1991), it is not our goal here to model in detail the strategic choices facing agents in one of the particular markets. Instead, we hope to help explain the common phenomena observed in many markets (with different detailed strategic environments). Consequently we focus on simple examples. Since unraveling due to instability at time T is a phenomenon identified in Roth (1984, 1991), we concentrate on the two new potential causes of unraveling identified here: the evolving uncertainty and the exercise of market power.

A. *Dynamic Models with Fixed Wages and Negotiated Wages*

1. *The Marriage and Assignment Models.*—We begin by introducing the static matching models on which we will build. The basic marriage model consists of two disjoint sets of players (e.g., firms and workers) $F = (f_1, f_2, \dots, f_n)$ and $W = (w_1, w_2, \dots, w_m)$. An outcome is a matching between firms and workers (which may leave some firms and workers unmatched). Agents have preferences over agents on the other side of the

market (and over the possibility of being unmatched), and they prefer one matching to another if and only if they are matched to a preferred partner. (The wages associated with each job description may be thought of as fixed, and reflected in the preferences of the workers.) A matching is unstable if some agent would prefer to remain single (unmatched) rather than be matched to his partner at that matching, or if some pair of agents, not matched to each other, would each prefer the other to the partners they are matched with.

Formally, a *matching* is a one-to-one correspondence μ from the set $F \cup W$ onto itself of order two [i.e., $\mu^2(x) = x$] such that if $\mu(f) \neq f$ then $\mu(f)$ is in W and if $\mu(w) \neq w$ then $\mu(w)$ is in F . The interpretation is that, if for any agent a $\mu(a) = a$, then a is unmatched; otherwise a is matched to $\mu(a)$, who must be an agent on the other side of the market (i.e., firms are matched to workers, and vice versa). Each firm f has preferences which can be represented by an expected utility function u_f defined on $W \cup \{f\}$, and each worker w has an expected utility v_w defined on $F \cup \{w\}$. A matching μ is *unstable* if some agent a prefers a to $\mu(a)$, or if for some pair (f, w) , f prefers w to $\mu(f)$ and w prefers f to $\mu(w)$. A matching is *stable* if it is not unstable. Gale and Shapley (1962) showed that the set of stable matchings is always nonempty. Furthermore, when no agent is indifferent between any two mates, there exists for each side of the market (F and W) a stable matching that is optimal for that side, in the sense that no agent on that side of the market prefers any other stable matching.

The basic assignment model also consists of two disjoint sets of players $F = (f_1, f_2, \dots, f_n)$ and $W = (w_1, w_2, \dots, w_m)$, and (in addition) an $n \times m$ matrix $Y = \{Y_{ij}\}$ for $i = 1, \dots, n$ and $j = 1, \dots, m$, where $Y_{ij} \geq 0$ is firm f_i 's income from employing worker w_j . A matching μ (as above) yields a total income, $Y(\mu)$, equal to the sum over all matched firms f_i of the quantities Y_{ij} such that $\mu(f_i) = w_j$. An outcome of the model consists of a matching μ together with a nonnegative $n + m$ vector of payoffs (π, s)

$= (\pi_1, \dots, \pi_n; s_1, \dots, s_m)$ such that $\pi_1 + \dots + \pi_n + s_1 + \dots + s_m = Y(\mu)$. The interpretation is that workers can take only one job, firms have only one position, and unmatched firms and workers produce zero. Workers and firms are risk-neutral income maximizers, so that their utilities over outcomes $[\mu, (\pi, s)]$ are the same as their payoffs at those outcomes.

An outcome $[\mu, (\pi, s)]$ is *stable* if for all firms f_i and workers w_j , $\pi_i + s_j \geq Y_{ij}$. (If this constraint were not satisfied for some i and j , then the outcome would be unstable with respect to f_i and w_j , since f_i could afford to offer w_j a salary $t > s_j$ such that $Y_{ij} - t > \pi_i$, so both f_i and w_j would prefer to be matched to each other at salary t than to accept the terms of the outcome $[\mu, (\pi, s)]$.) If $[\mu, (\pi, s)]$ is a stable outcome, we will refer to μ as a stable matching and to (π, s) as a stable payoff vector, and say (π, s) is compatible with μ . Note that at a stable outcome, if $\mu(f_i) = w_j$, then $\pi_i + s_j = Y_{ij}$, so although sidepayments between agents not matched to each other are feasible, they do not occur at stable outcomes.

Shapley and Shubik (1972) showed that the set of stable outcomes is always nonempty and that a stable matching must be an "optimal assignment" that maximizes the sum of the payoffs to the firms and workers over the set of all matchings. They further showed that every optimal assignment is a stable matching, and every stable payoff vector is compatible with every optimal assignment. Thus the payoff vector is what distinguishes different stable outcomes (as far as the utility of the players is concerned). For almost every assignment matrix the stable matching is unique.⁷² Shapley and Shubik showed that there always exists a firm-optimal stable payoff vector at which every firm's profit is as high as at any other stable outcome, and every worker's salary is as low as at any other stable outcome. (There is also a worker-optimal stable pay-

off vector, and when this is different from the firm-optimal stable payoff vector there is a continuum of stable outcomes.)

When institutional arrangements produce matches that are unstable with respect to some pair or pairs of agents, then those agents have an incentive to transact with one another early, to avoid the instability. This is the kind of unraveling that was observed by Roth (1991) in Birmingham and Newcastle. However this kind of unraveling does not explain the transitions from stable market-clearing mechanisms to the stage-4 unraveling observed in markets such as those for Canadian lawyers or neurosurgeons, nor does it explain the failure of stable stage-3 mechanisms to displace unraveling in various markets, particularly in those markets that have unsuccessfully attempted to adopt stable mechanisms. In what follows, we show that instability is neither necessary nor sufficient to cause unraveling.

2. *The Multiperiod Models.*—Agents may become matched to one another at times T or $T - 1$. At time $T - 1$ there may be uncertainty about the attributes that each worker will have at time T . The most convenient way to model this uncertainty will be to say that a worker w at time T is an agent with certain attributes, but that at time $T - 1$, before the attributes are known, the workers can be identified only as members of the set of agents $A = \{a_1, \dots, a_m\}$, and that associated with each agent a_j is a probability distribution \mathbf{P}_j over possible attributes. It will be sufficient for our purposes here to suppose that the attributes are something like class rank at time T , and that the probability distributions \mathbf{P}_j are probability vectors $\mathbf{P}_j = (p_{j1}, \dots, p_{jm})$ with p_{jk} being the probability that agent a_j will become worker w_k at time T . (So the matrix $\mathbf{P} = \{p_{ij}\}$ specifies the uncertain transition from the set A of time- $(T - 1)$ agents to the set W of time- T agents.)

In the fixed-wage model (based on the marriage model), the utility of firm f who matches with agent a_j at time $T - 1$ is the expected utility $u_f(a_j) = p_{j1}u_f(w_1) + \dots + p_{jm}u_f(w_m)$. Similarly, the expected utility (for employment after time T) of

⁷²That is, when we view an assignment matrix as a point in Euclidean $n \times m$ space, the set at which the optimal assignment is not unique has measure zero.

agent a_j who matches with firm f at time $T-1$ may depend on the resolution of the uncertainty. One extreme case is when agent a_j 's utility does not depend at all on his attributes, so that his expected utility function is the same at time $T-1$ and T . Another extreme case is when agent a_j 's utility depends entirely on his attributes, that is, when his utility is a simple expected utility $v_j = p_{j1}v_1(f) + \dots + p_{jm}v_m(f)$.

In the negotiated-wage model (based on the assignment model), if at time $T-1$ firm f_i offers a salary s to worker a_j and the offer is accepted, then a_j receives a utility of s for certain, while firm f_i 's expected utility is the expected value $p_{j1}(Y_{i1} - s) + \dots + p_{jm}(Y_{im} - s)$.

At time $T-1$, each firm may either choose to wait until period T or offer to match to any one worker. (An offer in the fixed-wage model consists of the choice of some agent a_j , while in the negotiated-wage model it consists of an agent a_j and a salary s .) Each firm makes this decision without knowing the decision of other firms, and any offers are delivered simultaneously. Any worker who has not received an offer has no actions to take at time $T-1$, while any worker who has received offers may accept at most one. A worker who accepts an offer and the firm f whose offer is accepted leave the market at time $T-1$ and are matched to one another. All other workers and firms remain on the market.

For our present purpose we may model, without loss of generality, the matching at time T as a revelation mechanism. In the fixed-wage model, firms still on the market at the beginning of time T know only that any offer they made at $T-1$ was rejected, and workers still on the market know only which firms approached them at time $T-1$ and were rejected. Based on this information (and the parameters \mathbf{M} , which become common knowledge at time T when the uncertainty about workers is resolved), each agent who was not matched at time $T-1$ submits an ordinal preference list of acceptable partners to the revelation mechanism, which produces a match. For any marriage model \mathbf{M} , this defines a two-stage strategic game, $\mathbf{G} = G(\mathbf{M}, \mathbf{P}; T, T-1)$, and the one-

stage game $\mathbf{G}' = G'(\mathbf{M}; T)$ which would occur if no firms made proposals at time $T-1$.

In the negotiated-wage model, firms and workers still on the market at time T are also matched by a revelation mechanism. Any firm f_i still on the market (knowing only that any offer it made at $T-1$ was rejected) must state a vector (Y_{i1}, \dots, Y_{im}) of incomes for each worker. In addition, it will be convenient to assume that a firm will not make an offer at time T to a worker who has rejected its offer at $T-1$.⁷³ We model this by supposing that, if f_i has made an offer to agent a_j and was rejected at $T-1$, and a_j is now worker w_k , the revelation mechanism will compute the time- T match with $Y_{ik} = -1$ (so that w_k is unacceptable to f_i , who would prefer to remain unmatched and receive 0). The revelation mechanism matches the firms and workers remaining at time T according to the firm-optimal stable outcome for the agents still on the market, according to the stated matrix \mathbf{Y}' as modified to take into account offers made at $T-1$. In the one-period game played by those remaining at time T , the workers have no strategic choices, and it is a dominant strategy for the firms to state their true values (see Roth and Sotomayor, 1990 theorem 8.16).

B. Uncertainty and Transaction Times

THEOREM 1: *Both in the fixed and negotiated wage models, instability of the outcome at time T is neither a necessary nor a suffi-*

⁷³This has the effect of "perfecting" the equilibrium we examine. There are other, more complicated ways to model this without altering the rules of the game, for example, by putting into the model a small amount of incomplete information that would not change any agent's actions at equilibrium but would cause a firm to update unfavorably its priors about a worker who deviated from equilibrium by rejecting an equilibrium offer at time $T-1$, so that after such a rejection the firm would prefer not to be matched to that worker. The reason perfection is an issue is that there is always a trivial, imperfect equilibrium at which every worker plans to reject any early offer and no firm makes any early offers.

cient condition for unraveling to occur at a perfect equilibrium.

We will prove Theorem 1 for the fixed-wage model; for the negotiated-wage model nonnecessity will follow from Theorem 3, and the proof of nonsufficiency is similar to the proof given via Example 2. To prove that instability at time T is not necessary for there to be unraveling we will suppose that the game G' produces stable matchings at all of its equilibria in undominated strategies,⁷⁴ and we will show that there may nevertheless be no equilibria of G at which all agents wait until time T to be matched.

Example 1: Unraveling Despite Stability at time T .— Let the set of firms be $F = \{f_1, f_2, f_3\}$ and the set of workers at time T be $W = \{w_1, w_2, w_3\}$. All firms have the same preferences, given by $u_{f_1} = u_{f_2} = u_{f_3} = u$ such that the utility of being unmatched is 0, and

$$u(w_1) = 4 \quad u(w_2) = 2 \quad u(w_3) = 1.$$

All workers have the same preferences, given by $v_{w_1} = v_{w_2} = v_{w_3} = v$ such that the utility of being unmatched is 0, and

$$v(f_1) = 10 \quad v(f_2) = 9 \quad v(f_3) = 1.$$

In the marriage market M which arises if no agents are yet matched at time T , there is a unique stable matching μ which matches firm i to worker i , that is, $\mu = [(f_1, w_1), (f_2, w_2), (f_3, w_3)]$.

Agents who are not matched before time T will participate in the stable matching mechanism G' which produces the firm-optimal stable match in terms of the stated preferences. Because there is a unique stable matching at time T , all equilibria in undominated strategies of the game $G'(M, T)$ produce the outcome μ (since it is a dominant strategy in this case for all agents to state their true preferences [see Roth and Sotomayor, 1990 theorem 4.7]).

⁷⁴The mechanisms which produce the optimal stable matching for one side of the market have this property; see theorem 4.16 in Roth and Sotomayor (1990).

At time $T - 1$ the agents are identified as $\{a_1, a_2, a_3\}$, and the probabilities p_{jk} that a_j will become w_k at time T are given by

$$\begin{aligned} p_{11} &= \frac{2}{3} & p_{12} &= \frac{1}{6} & p_{13} &= \frac{1}{6} \\ p_{21} &= \frac{1}{6} & p_{22} &= \frac{2}{3} & p_{23} &= \frac{1}{6} \\ p_{31} &= \frac{1}{6} & p_{32} &= \frac{1}{6} & p_{33} &= \frac{2}{3}. \end{aligned}$$

This defines the two-stage game $G = G(M, P; T, T - 1)$, about which we can say the following.

PROPOSITION 1: *Instability at time T is not a necessary condition for unraveling. In the game G of Example 1, there is no perfect equilibrium at which all agents are matched at time T . There is a perfect equilibrium at which all agents are matched at time $T - 1$.*

PROOF:

Let σ be an $(n + m)$ -tuple of strategies at which no matches occur at time $T - 1$, and suppose that σ is a perfect equilibrium. Then the players must use undominated strategies at time T , and so σ produces the unique stable matching μ , which gives f_2 an expected utility of 2. Therefore, f_2 would prefer to match with worker a_1 (or even a_2) at time $T - 1$, since his expected utility from matching to a_1 at $T - 1$ is $(\frac{2}{3})4 + (\frac{1}{6})2 + (\frac{1}{6})1 = 19/6 > 2$. Worker a_1 would have a higher expected utility if matched to f_2 at $T - 1$, since then he would lock in a utility of 9, instead of an expected utility of $(\frac{2}{3})10 + (\frac{1}{6})9 + (\frac{1}{6})1 = 50/6 < 9$. Thus, the assumption that σ is an equilibrium means that a_1 does not receive an offer from f_2 (or f_1) at $T - 1$. But the assumption that σ is perfect implies that a_1 cannot plan to reject the offer if f_2 deviates from σ by making an offer to a_1 at $T - 1$. So σ cannot be a perfect equilibrium.

For the last statement in the proposition, consider the strategy $(n + m)$ -tuple at which each f_i makes an offer to a_i at $T - 1$, each a_j accepts the best offer (i.e., offer from the lowest-indexed firm) he receives from f_i with $i \leq j$, and every player plans to submit his true preferences at time T in case he is

still in the market. This is a perfect equilibrium at which all matches are made at time $T-1$.⁷⁵ This concludes the proof of the proposition.

Note that we can interpret Example 1 along the lines of Kozinski's concern that uniform appointment dates would "eliminate a very important bargaining tool for judges competing for the most gifted clerkship candidates..." Suppose f_2 is a judge with a clerkship that is a little less desirable than that offered by f_1 , but substantially more desirable than others that may be available. Then the example shows why f_2 may be unwilling to wait until law students have been in school long enough so that their records may be confidently compared, since by doing so he will always lose the best candidate to f_1 . Clearly, judges f_1 and f_2 have different interests in the matter; and even though f_1 would prefer that all judges hire their clerks at time T , if f_2 goes early, f_1 prefers to go early also.⁷⁶

We next show that unraveling need not occur even if matchings at time T will be unstable.

Example 2: No Unraveling Despite Instability at Time T.—Let everything be as in Example 1, except that $u_{f_1}(w_2) = 11/3$, and the matching mechanism G' will produce the matching $\mu' = [(f_1, w_2), (f_2, w_1), (f_3, w_3)]$ if all agents remain unmatched at time T . (All other utilities, and the probability matrix P remain as in Example 1.) That is, G' is a

⁷⁵The argument that the equilibrium is perfect needs to establish that there is a set of vanishingly small mistakes ("trembles") for which it is optimal for the least desirable firm's offer to be accepted at time $T-1$. If the chance that f_3 will mistakenly leave agent a_3 off its list of acceptable matches at time T is larger than the probability that one of the other agents will mistakenly fail to offer or accept a match at time $T-1$, then it is optimal for a_3 to accept f_3 's offer at $T-1$.

⁷⁶If f_2 hires student a_1 at time $T-1$, then if f_1 nevertheless waits until time T his expected utility is no more than $(\frac{1}{3})4 + (\frac{2}{3})2 = \frac{16}{6}$, but if he makes an offer to a_1 himself at time $T-1$, a_1 will accept, and f_1 's expected utility would be $\frac{19}{6}$.

matching mechanism that ignores the stated preferences of the players but matches workers to firms on the basis of workers' identifiable attributes. Thus the strategies of the players in the two-stage game involve only their choices at time $T-1$. Note that the matching μ' is unstable with respect to firm f_1 and worker w_1 , both of whom would prefer to be matched to each other at time T .

Despite this, f_1 has no incentive to approach agent a_1 at time $T-1$ (even though a_1 would respond positively), since his expected utility from matching with a_1 at $T-1$ is only $(\frac{2}{3})4 + (\frac{1}{6})(\frac{11}{3}) + (\frac{1}{6})1 = 3.4$, which is less than the utility of $\frac{11}{3}$ that f_1 obtains by waiting until time T . Of course, f_2 has no incentive to go early if no one else does (since he matches with w_1 by waiting until T), and although f_3 would like to go early, no worker will accept his offer at $T-1$ (even if he could credibly commit to be unavailable at time T) since even worker a_3 , with the poorest prospects, would prefer to wait and take the chance that he will be the first- or second-ranked worker at time T . Thus, even though waiting until time T produces an unstable matching, it is a (perfect) equilibrium for all agents to match at time T .

Recalling our earlier discussion of the centralized market-clearing procedures used in the Cambridge and London Hospital medical schools, Example 2 suggests an additional factor which could contribute to the survival of these unstable mechanisms. Given the potential costs of unraveling, even the unstable centralized procedures employed in those two markets, which prevent unraveling, may be preferable to the decentralized procedures they replaced, which did not. The next result shows that the costs of unraveling may be borne by all of the agents.

THEOREM 2: *Unraveling may be ex ante as well as ex post inefficient, in both the fixed-wage and negotiated-wage models.*

For the negotiated-wage model, the result follows from Theorem 3. The proof for the fixed-wage model is given in the Appendix,

by considering Example A1. The essential feature of that example is that workers' utilities for different firms depend on their type at time T (e.g., how students feel about litigation firms depends on how good they turn out to be at litigation), so early matches have a chance of being mismatches.

We turn next to a different cause of unraveling.

C. Market Power and Transaction Times

In the two-period game $G = G(F, W, Y, P)$, if P is positive (i.e., if $p_{jk} > 0$ for all j and k) then (except on a set of measure zero) there is a positive "social cost" in arranging matches at time $T - 1$, which can be measured by the difference between the expected total income of the participants at the optimal assignment and at the match which occurs. Nevertheless, we will see that, even if a stable (and efficient) match is assured if all agents wait until time T , there is a strong tendency toward unraveling.

To see why, let $[\mu, (\pi, \underline{s})]$ be the firm-optimal stable outcome of the one-period (time- T) assignment game (F, W, Y) (i.e., \underline{s} is the lowest vector of salaries compatible with a stable outcome. The reason the salary $\underline{s}_j > 0$ of a worker w_j matched to firm f_i cannot be lower without producing instability is that there is some other firm f_k who would prefer to be matched to w_j if \underline{s}_j were any lower (i.e., $\pi_k + \underline{s}_j = Y_{kj}$. If exactly one such firm f_k supports w_j 's salary at the firm-optimal stable outcome, call f_k the *principal competitor* of firm f_i . (If the reason \underline{s}_j cannot be lowered is that it equals 0, or if there are two other firms who would prefer w_j at any salary lower than \underline{s}_j , then f_i does not have a principal competitor. A principal competitor has to be a single firm which is keeping up the price of some worker.)⁷⁷

⁷⁷Note that the set of matrices Y for which there is at least one principal competitor is a set of positive measure, since there is an open set around such a matrix (viewed as a point in Euclidean $n \times m$ space) in which principal competitors are preserved. However the set of matrices for which there are no principal

For any probability matrix P , we will say that the uncertainty is less than ϵ if for every agent a_j there is some k for which $1 - p_{jk} < \epsilon$. If the uncertainty about workers' attributes resolves itself in a continuous way, we may expect that the uncertainty can be made arbitrarily small by making the periods short (i.e., by making time $T - 1$ close to time T). However, if uncertainty resolves itself in a discrete way (e.g., when exams are taken), this may not be possible. Although in Theorem 3 we speak of "sufficiently small" uncertainty, examples can be constructed in which the results go through when the uncertainty is quite large.

THEOREM 3: *Let (F, W, Y) be an assignment game in which time- T matches are made at the firm-optimal stable outcome, and in which at least one firm f_k is a principal competitor. Then there exists an $\epsilon > 0$ such that for all positive P with uncertainty less than ϵ , there is no perfect equilibrium of the game $G = G(F, W, Y, P)$ at which all matches are made at time T .*

PROOF:

Let $[\mu, (\pi, \underline{s})]$ be the firm-optimal stable outcome of the assignment game (F, W, Y) , with $\mu(f_i) = w_j$, and f_k the principal competitor of f_i . Let σ be an $(n + m)$ -tuple of strategies such that no matches are made until time T . If σ is an equilibrium then it must be that no offers were made at time $T - 1$ and rejected, because any firm f_i which makes a rejected offer at $T - 1$ could have done better by withholding the offer and preserving the possibility of being

competitors also has positive measure (although it is not open). Consider, for example, a square matrix in which the diagonal elements are all strictly greater than 1, and the off-diagonal elements are all strictly less than 1. The firm-optimal stable outcome has each f_i matched to w_i , at a salary of 0, and there is an open set around this matrix at which this is also true. Thus, no firm has a principal competitor, on a set of positive measure. Xing (1992) considers a class of games in which firms are strictly ordered by their efficiency, and every firm except the most efficient firm is the principal competitor of the next most efficient firm.

matched to any worker at time T . Therefore, no early offers are made at σ , which implies that if, contrary to the theorem, σ is a perfect equilibrium, then the outcome at time T must be $[\mu(\pi, \underline{s})]$.

It will be simplest to continue the argument for the case of no uncertainty (i.e., the case such that for every agent a_j there is some k for which $p_{jk} = 1$), and then observe that the argument goes through for positive matrices \mathbf{P} when the uncertainty is sufficiently small. To this end, suppose now that f_k were to deviate from σ by making an offer to w_j at $T-1$ (since there is no uncertainty, w_j can be identified at time $T-1$), and suppose that w_j were to reject this offer. Then at time T the matrix of incomes \mathbf{Y}' would differ from \mathbf{Y} in that $Y'_{kj} < Y_{kj}$. The matching μ would continue to be an optimal assignment for the new matrix (since $\mu(f_k) \neq w_j$), so the only difference for w_j would be that $s'_j < s_j$, because f_k was the principal competitor determining the value of s_j . Thus for any salary t with $s'_j < t < s_j$, $Y_{kj} - t > \pi_k$. If σ is a perfect equilibrium, w_j cannot plan to reject such an offer of t from f_k at time $T-1$, and it would therefore be profitable for f_k to make such an offer. Therefore, σ is not a perfect equilibrium, and there is no perfect equilibrium at which all matches are made at time T . To see that the argument goes through when \mathbf{P} is a positive probability matrix with sufficiently small uncertainty, note that all inequalities in the argument are strict and would be preserved for sufficiently small uncertainty. All that would change is that, at time $T-1$, f_k would make the early offer to that agent a_q such that p_{qj} was near 1. This completes the proof.

Theorem 3 shows that unraveling is not an isolated phenomenon. It also underlines the manner in which this kind of unraveling is related to the heterogeneity of the market, since if firms and workers are largely homogeneous, there will not in general be any principal competitors. Thus we might expect to see this kind of unraveling in high-end professional labor markets rather than in markets in which labor is a commodity. As noted above, perfect equilibrium

matching under the conditions of Theorem 3 is inefficient. That is, we can state the following corollary.

COROLLARY: *For games as in Theorem 3, in which there is at least one principal competitor, if the probability matrix \mathbf{P} is positive, perfect equilibria are ex ante inefficient (except on a set of measure zero) if the uncertainty is sufficiently small.*

V. Discussion

Having seen how unraveling occurs in a number of markets, and having considered some models which suggest explanations for that unraveling, it may help put things in perspective to consider why some markets do *not* unravel. Consider the market for new assistant professors of economics at research universities. Like many of the markets discussed in Sections II and III, this is an entry-level market for professionals. But in this market, most transactions are not completed until students have made substantial progress on their Ph.D. dissertations and have good prospects of completing the Ph.D. before beginning their employment in the next academic year. Why don't academic departments of economics "jump the gun" and hire their new assistant professors several years before they complete their Ph.D.'s?⁷⁸

The models we have considered suggest that unraveling may be impeded if the uncertainty associated with hiring early is relatively large compared to the possible bene-

⁷⁸Richard Carson and Peter Navarro (1988) provide a nice description of the recent job market for beginning academic economists and note that a relatively small amount of unraveling occurs in what they call the "preemptive market." This largely occurs in the semester before the job-market meetings at the end of the calendar year. In the late 1960's, when new Ph.D.'s in economics were in relatively short supply, there were also schools which made exploding offers. For example, in January 1970, Ohio State University was authorized to fill six positions, and it made offers to 11 candidates, saying that the offer would remain open only until the first six acceptances were received (Howard Marvel and Don Parsons, pers. comm., 1 October 1992).

fits. If it is very difficult to evaluate the research potential of an economics graduate student before a substantial part of the dissertation has been completed, as seems to be the case, the risk of hiring a poor student (as in Example 2) may prevent economics departments from attempting to make very early hires.

Note that, at research universities, the entry-level job markets in different disciplines frequently share many features (e.g., letters of reference, large professional meetings, and on-campus interviews). If these institutions tend to produce stable matchings, the reason new marketing assistant professors are today recruited well before they complete the Ph.D., while new economics assistant professors are recruited around the time at which they complete the Ph.D. and new mathematics assistant professors are recruited after postdoctoral positions, may have to do with the different balance of supply and demand in those markets.⁷⁹ However, the empirical investigation of this hypothesis may involve more than a straightforward comparison of the ratio of new Ph.D.'s to academic positions to see whether this is lowest for marketing and highest for mathematics, since not all students may have a high likelihood of being eligible for jobs in research departments, and since there are markets other than academia for new Ph.D.'s.

Another factor which may contribute to the relatively limited unraveling of the beginning market for academic economists (and even academic marketers) is that in academic markets, unlike many of the nonacademic markets considered here, it is practical to hire late as well as early. That is, a department which finds that it cannot get the new Ph.D.'s it wants can try to enter the market later instead of earlier, and hire

at the associate or full-professor level. However, for most of the markets in which we have observed unraveling, this is not a practical alternative.

This is clearest when a perishable commodity like postseason college football bowl games is involved, but it is also the case in many of the professional labor markets discussed. For some of these markets, like the market for medical interns or federal court clerks, the nature of the position makes it attractive to the best junior candidates, but unattractive to candidates of similar quality later in their careers. In the market for new graduates of Japanese universities, the firms most involved in the unraveling of the market appear to be those that primarily offer lifetime employment, and so they also have little opportunity to hire senior candidates away from their competitors. For law firms, the problem of adverse selection presents itself: because the quality of an associate lawyer's work may be largely invisible outside of his firm, a firm that attempts to hire associates away from a competitor is faced with the likelihood that the competitor firm would make attractive counteroffers only to the best of its associates, so that the raiding firm would attract only the worst.⁸⁰ (In contrast, adverse selection is much less of a problem when raiding a competing academic department's associate professors, since the quality of their work can be judged from their published articles.) It may be possible to develop quantitative tests of the effect of the availability of senior candidates on unraveling in the market for junior candidates by considering markets for professional athletes such as baseball players, in which changes in the rules of free-agency have changed the availability of senior candidates.⁸¹

⁷⁹For example, in a market with a fixed number n of firms and a variable number m of workers, it is easy to construct models with the following property: as m increases, the ability to identify with sufficiently high probability which will be the n most desirable workers decreases. Then sufficiently large m will cause recruiting to occur at time T .

⁸⁰This problem of adverse selection is modeled by Xing (1992).

⁸¹If the availability of established players as free agents has influenced the costs that teams are willing to bear in competing for very young athletes, it might be possible to detect this both in the age at which the average ballplayer becomes professional and in the expenditures on minor-league teams.

The fact that unraveling may be quite inefficient suggests one reason why so much effort has been expended to halt or reverse it in the markets discussed in Sections II and III. In that context, it is worth considering what advice we can tentatively offer at this point. To date we have not observed any markets that have adopted a centralized market-clearing procedure that produces stable outcomes and then subsequently abandoned it after achieving high levels of initial participation. While the models explored in this paper suggest that this is a possibility that may yet be observed, the success of stable mechanisms where they have been adopted suggests that the stress on the market produced by the various kinds of instabilities may be cumulative, so that removing one kind of instability may go a long way to help coordinate transaction times. However, the argument used to prove Theorem 3 suggests why, in a market in which transaction times have already unraveled, it may not be a simple matter to reverse the unraveling by instituting a stable matching mechanism at some later time T .

The fact that workers have incentives to be matched when there is substantial competition for their services means that, as long as a substantial percentage of firms do not wait until time T , there will be incentives for workers to enter the market early also. Thus in markets such as radiation oncology and optometry, in which initial rates of participation in a stable mechanism are not high, the ultimate success of even a stable mechanism may be in doubt. Both the models and the experience of the many markets that have attempted to halt unraveling suggest that a cautious plan of attack would be to attempt to introduce a stable matching mechanism initially at an early time, when a substantial percentage of transactions are already taking place, and then to move the time at which the mechanism operates later only after it has attracted a high rate of participation. For markets in which a stable mechanism offers the possibility of an equilibrium at which transactions are made relatively late, this kind of gradual approach may increase the

likelihood of a successful transition from an inefficient early equilibrium to a more efficient late one. Of course, as shown by Example 1, there may be markets for which even a stable mechanism is insufficient to produce a late equilibrium.

In conclusion, the evolution of unraveling in the markets studied by Roth (1984, 1991) and Mongell and Roth (1991) was associated with the existence of worker-firm pairs which created instability in the final matchings. The present paper seeks to make two contributions. The first is to establish empirically, by considering a wider selection of markets, that unraveling of transaction times is a much more general phenomenon than had previously been evident. The second is to identify additional causes of unraveling (and of changes in the timing of transactions in either direction). We do not claim that these are the only causes of unraveling. On the contrary, unraveling seems to occur in a sufficiently wide range of markets so that it is likely that there are many causes. The additional causes we have identified have also involved pairwise instabilities (i.e., they can be studied at the level of specific worker-firm pairs), and this "pairwiseness" provides the common theoretical thread between the intertemporal instabilities introduced in this paper and the static instabilities of the classical two-sided matching models. We have also shown that unraveling may result in inefficiency. Whether the unraveling observed in any particular market is inefficient is of course a difficult empirical question. Indeed, one of the main contributions of this paper should be that it raises a host of empirical questions related to the timing of transactions.

At the most general level, this paper is about the organization and evolution of market institutions related to the timing of transactions. There is a sense in which the existence of an orderly market is a public good, and given the difficulties inherent in providing public goods, it should therefore not be so surprising that establishing a uniform time for a market may often present difficulties. For many of the markets discussed, the difficulties associated with coor-

dinating the timing of transactions have been decisive in determining how the markets have come to be organized.

APPENDIX

Example A1: Inefficient Outcomes Caused by Early Appointments.—For simplicity in this example, we will incorporate into the rules of the game the commonly observed behavioral phenomenon that a firm which has made an offer to a particular student and been rejected will not subsequently make an offer to the same student (recall footnote 73).

Let the set of firms be $F = \{f_1, f_2, f_3\}$ and the set of workers (graduating students) at time T be $W = \{w_1, w_2, w_3\}$. Firms' utilities u_f and workers' utilities v_w are given by

$$\begin{aligned} u_{f_1}(w_1) &= 10 & u_{f_1}(w_2) &= 5 & u_{f_1}(w_3) &= 2 \\ u_{f_2}(w_1) &= 10 & u_{f_2}(w_2) &= 7 & u_{f_2}(w_3) &= 2 \\ u_{f_3}(w_1) &= 2 & u_{f_3}(w_2) &= 10 & u_{f_3}(w_3) &= 7 \\ v_{w_1}(f_1) &= 10.5 & v_{w_1}(f_2) &= 10 & v_{w_1}(f_3) &= 9 \\ v_{w_2}(f_1) &= 10.5 & v_{w_2}(f_2) &= 10 & v_{w_2}(f_3) &= 8 \\ v_{w_3}(f_1) &= 8 & v_{w_3}(f_2) &= 9.4 & v_{w_3}(f_3) &= 9. \end{aligned}$$

An unmatched player's utility is zero.

In the marriage market M which arises if no agents have made offers before time T , there is a unique stable matching μ which matches firm i to worker i , that is, $\mu = [(f_1, w_1), (f_2, w_2), (f_3, w_3)]$. The payoffs at time T are:

$$u_{f_1}(w_1) = 10 \quad u_{f_2}(w_2) = 7 \quad u_{f_3}(w_3) = 7$$

and

$$v_{w_1}(f_1) = 10.5 \quad v_{w_2}(f_2) = 10 \quad v_{w_3}(f_3) = 9.$$

As in Example 1, agents who are not matched before time T will participate in the stable matching mechanism G' which produces the firm-optimal stable match in terms of the stated preferences. Because there is a unique stable matching at time T ,

all equilibria in undominated strategies of the game $G'(M, T)$ produce the outcome μ . Recall however that if a firm has been rejected by a student at time $T - 1$ it may not be matched to that student at time T : this can be modeled by supposing that in this case the mechanism treats the firm's utility for being matched with that student as -1 .

At time $T - 1$ the students are identified as $A = \{a_1, a_2, a_3\}$, and the probabilities p_{jk} that a_j will become w_k at time T are given by

$$\begin{aligned} p_{11} &= 0.6 & p_{12} &= 0.2 & p_{13} &= 0.2 \\ p_{21} &= 0.2 & p_{22} &= 0.6 & p_{23} &= 0.2 \\ p_{31} &= 0.2 & p_{32} &= 0.2 & p_{33} &= 0.6. \end{aligned}$$

If firm f_i matches with student a_j at time $T - 1$, then their utilities are their expected utilities at time T , which in both cases involve the uncertainty about a_j 's attributes at time T . In the case of the firm, this uncertainty is about which w_k will turn out to have been hired, while in the case of the student, the uncertainty is about what his preferences will be at time T (e.g., a student knows that if his qualifications turn out to be those which make him w_3 then he has little chance of promotion at firm f_1). So, for example, the expected utility of firm f_1 when matched to student a_1 at time $T - 1$ is

$$\begin{aligned} Eu_{f_1}(a_1) &= p_{11}u_{f_1}(w_1) + p_{12}u_{f_1}(w_2) + p_{13}u_{f_1}(w_3) \\ &= 0.6(10) + 0.2(5) + 0.2(2) = 7.4 \end{aligned}$$

and the expected utility of student a_1 when matched to firm f_1 at $T - 1$ is

$$\begin{aligned} Ev_{a_1}(f_1) &= p_{11}v_{w_1}(f_1) + p_{12}v_{w_2}(f_1) + p_{13}v_{w_3}(f_1) \\ &= 0.6(10.5) + 0.2(10.5) + 0.2(8) = 10. \end{aligned}$$

If no offers are made at time $T - 1$, then at a perfect equilibrium the outcome will be $\mu = [(f_1, w_1), (f_2, w_2), (f_3, w_2)]$ at time T ,

and the expected utility of the agents at time $T-1$ will be $Eu_{f_i}(\boldsymbol{\mu}) = u_{f_i}(\boldsymbol{\mu}(f_i)) = u_{f_i}(w_i)$, and $Ev_{a_j}(\boldsymbol{\mu}) = p_{j1}v_{w_1}(f_1) + p_{j2}v_{w_2}(f_2) + p_{j3}v_{w_3}(f_3)$, so the expected-utility vector for the firms is $E\mathbf{u}_F(\boldsymbol{\mu}) = (10, 7, 7)$ and for the students $E\mathbf{v}_A(\boldsymbol{\mu}) = (10.1, 9.9, 9.5)$.

We can now say the following about the two-stage game $\mathbf{G} = G(\mathbf{M}, \mathbf{P}; T, T-1)$.

PROPOSITION A1: *Unraveling may be Pareto inefficient. In the game \mathbf{G} of Example A1, there is no perfect equilibrium at which all agents are matched at time T . There is a perfect equilibrium at which all agents are matched at time $T-1$, and this equilibrium is ex ante Pareto inefficient: all agents would prefer that all matches be delayed until time T .*

PROOF:

Let σ be an equilibrium $(n+m)$ -tuple of strategies at which no matches occur at time $T-1$. Then at σ no firm has made an offer at time $T-1$ (since a firm which had made a rejected offer would have done better to preserve all its options until time T). If (in contradiction to the second statement of the proposition) σ is a perfect equilibrium, then the players must use undominated strategies at time T , and so σ produces the unique stable matching $\boldsymbol{\mu}$, which gives f_2 an expected utility of 7. Therefore, f_2 would prefer to match with worker a_1 at time $T-1$, since $Eu_{f_2}(a_1) = 7.8$.

Suppose f_2 deviates from σ by making an offer to a_1 at $T-1$ but a_1 rejects it. Then, by assumption, at time T student a_1 cannot match with f_2 . So a_1 's expected utility after rejecting f_2 's offer is $p_{11}v_{w_1}(f_1) + p_{12}v_{w_2}(f_3) + p_{13}v_{w_3}(f_3) = 0.6(10.5) + 0.2(8) + 0.2(9) = 9.7$, which is less than $Ev_{a_1}(f_2) = 9.88$. Since σ is a perfect equilibrium, this implies that a_1 would have accepted f_2 's offer if it had been made, which in turn implies that σ is not an equilibrium (since f_2 would have done better by making an offer to a_1).

For the last statement in the proposition, consider the strategy $(n+m)$ -tuple $\boldsymbol{\tau}$ at which each f_i makes an offer to a_i at $T-1$,

each a_j accepts the best offer (i.e., the offer from the lowest-indexed firm) he receives from f_i with $i \leq j$, and every player plans to submit his true preferences at time T in case he is still on the market. It is easy to verify that this is a perfect equilibrium at which all matches are made at time $T-1$, and each f_i is matched to a_i . Thus the expected utilities for the firms at this equilibrium are given by $Eu_{f_i}(\boldsymbol{\tau}) = Eu_{f_i}(a_i)$, so the vector of firms' expected utilities is $E\mathbf{u}_F(\boldsymbol{\tau}) = (7.4, 6.6, 6.6)$. The expected utilities for the students are given by $Ev_{a_j}(\boldsymbol{\tau}) = Ev_{a_j}(f_j)$, so the vector of students' expected utilities is $E\mathbf{v}_A(\boldsymbol{\tau}) = (10, 9.88, 8.8)$. Since $E\mathbf{u}_F(\boldsymbol{\tau}) < E\mathbf{u}_F(\boldsymbol{\mu})$ and $E\mathbf{v}_A(\boldsymbol{\tau}) < E\mathbf{v}_A(\boldsymbol{\mu})$, all firms and workers would be better off if no offers were made at time $T-1$, and instead the matching $\boldsymbol{\mu}$ were made at time T .

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