

**THE COMPUTERIZATION MOVEMENT
IN THE US HOME MORTGAGE INDUSTRY, 1980-2004**

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February 2005

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Abstract

This paper reports on an empirical investigation of a particular computerization movement—the diffusion of automated underwriting in the US home mortgage industry—over a twenty-plus year timeframe. Building on and extending seminal work by Kling and Iacono (1988, 1995, 2001), this paper shows the influences of, and interplays among, technological action frames, institutional support, and technology performance, in the diffusion of automated underwriting and associated use practices.

Keywords: social movements theory, technology frames, technology organizing visions, innovation theorizing, institutionalism, technological development, technology use practices, diffusion of innovations, industry associations, automated underwriting, artificial intelligence, mortgage industry

1. INTRODUCTION

Kling and Iacono (Kling & Iacono, 1988, 1995) inquired “why do organizations adopt new computing technologies?” and challenged us to move beyond simple explanations based on the economics of need. They directed our attention instead to public discourse about computing (see also (Iacono & Kling, 2001) and to computerization movement advocates, such as professional associations, who provide arenas in which people develop technological action frames about what computing is good for and how it can fit into their organizations. They called for careful empirical studies of computerization movements that focus on the decline of computerization movements, value conflicts and counter-computerization movements, and alternative organizational practices of technology use (particularly those that differ from utopian visions).

In response to their call, this paper examines the changing technological action frames and organizational practices in a particular computerization movement as documented in the published discourse of a leading professional association over a twenty-plus year time period. Thus our study brings together the three related elements of Iacono and Kling’s (2001) analysis—frames, discourse, and practices. In addition, our study brings in two additional elements. One is institutional support. In addition to providing arenas in which frames can be constructed, professional associations and other institutions can provide powerful support in the form of legitimacy, education, financial resources, and investment in technology development,

which can contribute to the diffusion of computing innovations and their associated organizational practices (King et al., 1994). We also examine the course of technological development related to the innovation. As Kling and Iacono (1988) noted, the technology of artificial intelligence never lived up to the utopian visions of its proponents, a factor that undoubtedly shaped the AI use practices that eventually emerged. Setbacks and successes in the course of technology development, in our view, should be considered in the study of computerization movements, along with the more purely “social processes that drive computerization” (cf. Kling & Iacono, 1995)

Our study examines the diffusion of automated underwriting in the US home mortgage industry. This computerization movement is particularly relevant to the prior work of Kling and Iacono because it directly involves one of the general technologies they examined in 1988—artificial intelligence. In addition, because the electronic exchange of data is a key enabling technology for automated underwriting, our story also touches on the rise of the Internet, the focus of Iacono and Kling’s (2001) analysis.

In the next section of this paper we provide theoretical justification for our focus not only on frames, discourse, and practices, but also on institutional support and technology performance. Although it is easy enough to separate these elements conceptually, it is much more challenging to do so in the analysis of an actual computerization movement. Therefore, after we describe our data sources and analysis procedures and provide some background on the mortgage industry, we present our findings, not conceptual element by element, but rather in four thematically and chronologically organized sections. This presentation strategy highlights the interplay among the elements over time. Our discussion focuses on the multifaceted support activities of computerization movement activists, the influential effects of technology setbacks and successes, and the importance of social conflict in shaping the direction of computerization movements.

2. THEORETICAL BACKGROUND

In this section, we discuss three sets of elements that might contribute to the careers of computerization movements: technological action frames, institutional support, and technology performance. By “careers” we mean the diffusion of computer-based innovations and related work practices over time. We assume that computerization movements can exhibit highly

variable careers, some succeeding more or less as originally envisioned and fading into taken-for-grantedness, some failing through inability to mobilize supporters, some radically changing direction as a result of social or technical influences.

2.1 Technological Action Frames

Iacono and Kling define technological action frames as “multi-dimensional composite understandings—constituted and circulated in language—that legitimate high levels of investment for potential users, and form the core ideas about how a technology works and how a future based on its use should be envisioned” (Iacono & Kling, 2001). This conception derives from sociological theory on social movements and collective action frames. In that literature, participants in social movements are viewed as “actively engaged in the production and maintenance of meaning for constituents, antagonists, and bystanders or observers” (Benford & Snow, 2000), p. 613). This process of meaning construction is known as “framing.” The core tasks of framing are “*diagnostic* framing”—problem identification and causal attributions, “*prognostic* framing”—articulation of solutions and action plans and “*motivational* framing”—a “call to arms” or rationale for engaging in collective action to solve the problem, including the construction of *vocabularies of severity, urgency, efficacy, and propriety* (Benford & Snow, 2000). Frame construction occurs by means of three sets of overlapping processes: *discursive* processes in the form of talk and written communications, *strategic* processes in the form of rational analysis and goal-directed thinking, and *contested* processes in which responses to challenges are formulated (Benford & Snow, 2000).

Much recent research on social movement “frame-work” focuses on the *sources* of collective action frames. For example, action frames are said to arise in cultural conditions, political conditions, and organizational ideology (Reese & Newcombe, 2003) or in the mobilizing structure of the social movement or the larger political opportunity structure (Joachim, 2003). This research occasionally emphasizes the tendency of social movement activists or “entrepreneurs” to “seize opportunities” presented by external conditions and events (Joachim, 2003) to shape the content of their action frames.

The *consequences* of collective action frame-work are also interesting. In the social movements tradition, research has focused mainly on the “*intended* effects” and near-term consequences of

framing processes for the emergence and mobilization of social movements; much less work has addressed the longer-term outcomes and consequences of social movements (Giugni, 1998). In institutionalization theory, however, a concept closely related to that of frame-work—theorization—has been proposed as essential for the ultimate success of a certain type of social movement—the diffusion of innovations (Greenwood, Hinings, & Suddaby, 2002).

Greenwood et al. built upon work by (Strang & Meyer, 1993) and (Tolbert & Zucker, 1996) to argue that, in order for innovations to diffuse widely, they must first be “theorized”, a process in which industry associations can play a major role. According to (Tolbert & Zucker, 1996), *theorizing* involves two major steps—specification of a major organizational failing and justification of possible solutions to the problem. (These two steps are very similar to the diagnostic, prognostic, and motivational tasks of collective action framing of (Benford & Snow, 2000).) Perhaps the most intriguing observation made by (Greenwood et al., 2002) about theorizing (or framing) is that successful theorizing apparently requires the innovation to be framed as a *response to a problem* experienced by potential adopters, rather than as an *opportunity* of which they could avail themselves. This observation fits empirical data about the diffusion of administrative reforms, but whether it also applies to *technological innovations* is an open question. (Swanson & Ramiller, 1997) argued in support of the notion that a “business problematic” is an essential part of “organizing vision” of information systems innovations. (Like theorizing, the organizing vision concept seems nearly identical to that of technological action frames.)

Greenwood et al. also noted that part of the theorizing process involves creating *moral or pragmatic legitimacy* for the innovation. This observation accords with Benford and Snow’s “vocabularies of severity, urgency, efficacy, and propriety”. In addition, it links the process of framing or theorizing with the management and IS literatures on organizational *legitimacy* (Suchman, 1995) and management *discourse* (Green Jr., 2004; Heracleous & Barrett, 2001; Ramiller & Swanson, 2003; Swanson & Ramiller, 1997). For example, Suchman (1995) discussed three types of legitimacy that organizations can claim for their actions—pragmatic legitimacy—resting on the self-interested calculations of stakeholders, moral legitimacy—employing “prosocial logic” about the public good or action as “the right thing to do”, and

cognitive legitimacy—arguments about necessity or inevitability of the action. Green (2004) theorized about the role of justifications in the diffusion of managerial practices and argued that justifications would fall off as diffusion increases and the innovation becomes taken for granted. He also discussed three types of justification—pathos (relating to emotions such as fear and greed), logos (relating to rational calculation), and ethos (relating to norms of appropriateness); he posited that a sequence of justifications starting with pathos, moving to logos, and ending with ethos would produce the most successful diffusion pattern. Heracleous and Barrett (2001) longitudinally analyzed discourse about the implementation of electronic trading in the London insurance market in terms of stakeholders’ “arguments-in-use”, which contain the framing or theorizing elements of goals, causal attributions, and justifications for actions. They concluded that, although often incomplete, arguments-in-use of conflicting stakeholders exhibit a deep structure that is relatively stable over time and guides stakeholders’ interpretations and actions, thus contributing to implementation success or failure. (Ramiller & Swanson, 2003; Swanson & Ramiller, 1997) analyzed discourse about (“organizing visions” of) information systems and technology innovations in terms of the claims’ interpretability, plausibility, importance, and discontinuity. (Again, these dimensions are reminiscent of Benford and Snow’s “vocabularies”).

In short, the framing or theorizing of IT innovations is believed to be a factor in their successful or unsuccessful diffusion. Framing or theorizing is a process that unfolds over time. It involves identifying problems; proposing solutions; creating causal arguments linking problems, solutions, and actions proposed to implement solutions; justifying solutions; and rhetorically countering arguments put forth by opponents. Justifications involve claims to various types of legitimacy and appeals to participants’ emotions; innovation entrepreneurs may frame their justifications around important contemporary external circumstances and events. The need for justifications is expected to decline as diffusion progresses; they may fade away altogether as an innovation comes to be taken for granted. Certain sequences or types of justifications may promote diffusion better than others.

2.2 Institutional Support

Kling and Iacono (1988) called attention to the role that computerization movement participants such as industry associations can play in the framing process, by providing contexts within which framing can take place. For example, in a longitudinal study of the Canadian accounting

profession, (Greenwood et al., 2002) concluded that both professional associations and the leading firms in the industry were instrumental in bringing about widespread diffusion of an organizational reform (the multi-disciplinary practice model of accounting firm structure). The practice was initiated by large accounting firms, and then legitimated and promoted through the actions of professional associations. In addition to their framing activities, associations “use committees and task forces that host intraprofessional discourses; official publications easily and comprehensively transmit ideas and scripts; and celebratory and developmental programs gather professionals and provide for interaction and discussion” (p. 74).

Recent work suggests that certain movement participants, including industry associations, can exert additional (and potentially more powerful) types of influences on the course of movements than framing or creating opportunities for framing. Frames or theorizations are usually manifested in “ideational statements”, but they may “also find expression in the *strategies and tactics* of their advocates” (Joachim, 2003) p. 250 added emphasis). Making a causal link between the “intended effects” of social movements, as reflected in their framing processes, and the actual consequences of social movements, such as diffusion of innovative practices, requires theoretical attention to the *actions* taken by social movement entrepreneurs to realize their goals (Giugni, 1998). In the case of social protests, relevant tactics of entrepreneurs include: making single-issue versus multiple issue demands, use or non-use of selective incentives, using violence and disruptive tactics versus peaceful ones, and setting up their organization with bureaucratic versus non-bureaucratic structures (Giugni, 1998). This focus on movement entrepreneurs’ actions is consistent with institutionalization theory’s emphasis, not just on the cognitive and normative structures that promote similarity among organizations, but also on regulatory structures by which some organizations employ coercive tactics with others (Teo, Wei, & Benbasat, 2003; Tingling & Parent, 2002).

Similarly, the management and IS literatures have drawn attention to the actions of industry associations and prominent firms as contributing to successful collective action and innovation diffusion through their actions. For example, (Astley & Fombrun, 1983) discussed how “agglomerate collectives”—clusters of similar organizations, such as the firms in an industry sector—can engage in successful collective action through the efforts of trade and industry

associations. “Because of the large number of organizations in agglomerate collectives, a centralized coordination and control mechanism is needed to monitor the execution of the collective strategy. Informal agreement and coordination become unworkable; collective action is *only possible* through more formalized arrangements such as cartels or trade and professional associations... . These centralized bodies are frequently capable of *imposing economic sanctions* over their members ...” (p. 582 added emphasis).

(King et al., 1994) explored the role of institutions such as government authorities, trade and industry associations, and trend-setting corporations in successful information technology innovation. They described in detail five “forms of institutional action” by which institutions can promote innovation. The five forms were: *knowledge building*—providing a base of scientific or technical knowledge, *knowledge deployment*—in the form of knowledgeable individuals and organizations or in the form of archives and libraries, *mobilization*—the encouragement of innovation through such activities as promotion and awareness campaigns and advertising, *standard setting*—a form of regulation to constrain organizational behavior in desired directions, and *innovation directive*—a command to produce innovations, through such actions as actually developing an innovation or providing resources (or subsidies) to other organizations to do so. (Damsgaard & Lyytinen, 2001) employed King et al.’s theoretical framework in the context of the diffusion of electronic data interchange and found that trade and industry associations were active users of all these tactics to varying degrees and with varying levels of success. They concluded that “trade and industry associations ... form significant players in the diffusion process [and they] are increasingly aware of their role in furthering [technology] diffusion” (p. 207). Damsgaard and Lyytinen also concluded that the role played by intermediating organizations changes with the stage of the innovation (discovery, implementation, institutionalization) and with the local context. Intermediating organizations were argued to play an *essential* role in the successful diffusion of *networked* information technologies, such as EDI.

In short, industry associations and the leading firms in an industry can contribute to the diffusion of technical innovations, particularly networked information technologies, through a wide variety of actions, in addition to their contributions to the construction of technology action frames. These movement activists can develop technologies and standards; they can provide critical

resources such as knowledge and subsidies; they can publish written communications promoting the innovation; they can declare their commitment to the innovation; and they can sometimes impose sanctions to promote innovation adoption.

2.3 Innovation Performance

A third factor that could be consequential in the diffusion of technological innovations is the performance of the innovation itself. Much of vast literature on the diffusion of innovations is predicated on the empirical observation that some innovations diffuse faster than others. That observation spawned the "... central notion in the study of innovation ... that technologies possess attributes or characteristics and that these characteristics have systematic effects on diffusion ... " (Fichman, 2002), p. 111).

Many theorists have objected to technological characteristics as an explanation of innovation diffusion on the grounds that "choice-theoretic models are 'overrationalized,' treating the merits of an innovation as accessible to [potential adopters'] calculation" (Strang & Macy, 2001)p. 153). By contrast, many experts acknowledge that "... it is difficult for an organization to determine the reliability, capacity, and precision of a new technology, and whether a newer technology will soon appear to make it obsolete." (Tingling & Parent, 2002), p. 119). "Self-interested actors who might eventually use an innovation worry not only about the current performance of the innovation, but on the future change in performance. They want to know if the advantage gained by adoption can be sustained" (King et al., 1994)p. 144). Consequently, many organizations defer adoption until more information becomes available, and others may adopt early, not on the basis of rational calculations about the innovation's merits, but by imitating the decisions of early adopting peers (Tingling & Parent, 2002).

The problem with diffusion explanations based solely on social influences such as mimicry, fads, and fashions is that they are "'underrationalized.' They contend that managers pay close attention to what others do, while lacking interest in what happens when they do it. But business discourse focuses intently on performance ..., not popularity..." (Strang & Macy, 2001), p. 153). Therefore, *because* managers are unable to assess innovations confidently using rational calculation, they will "seek to learn from the coincidence of innovative strategies and subsequent outcomes" (p. 155). In other words, they are likely to base their adoption decision on "success

stories” that publish the results early adopters claim to have received from using the technology. Later, organizations that based their adoption decisions on other adopters’ success stories will abandon the technology, if it *disconfirms* their expectations. This process of adopting based on stories about technology performance and abandoning on the basis of direct experience is posited as an alternative explanation to mimicry for innovation fads and fashions (Strang & Macy, 2001).

The observation that the experience of disconfirming results can lead to diffusion failure also has echoes in the social movements literature. Social movements have limited ability to account for “discrepancies between ideology [or frames] and experience [of adopters]” (Babb, 1996)p. 1053). Therefore, “some collection action frames are ultimately disconfirmed empirically” (p. 1053). The implication is that “technologies at some points may constrain and obstruct the building of an organizing vision [or technological action frame]. In particular, turbulence, shifts, and setbacks in the core technology’s development may jeopardize an associated organizing vision” (Swanson & Ramiller, 1997)p. 467).

A related argument can be found in the literature on dominant technology designs—a single technology architecture that establishes dominance in a technology product class (Anderson & Tushman, 1990). The dominant design may arise from de facto competition in the marketplace; it may reflect the market power of a dominant technology producer (Anderson & Tushman, 1990). It might also emerge from standardization efforts by a national body or an industry association. There is no guarantee that the (rationally) best technology will emerge from these social and political processes. However, when it emerges, a dominant design ends the “period of ferment” in which technology producers try different solutions. Therefore, the emergence of a dominant design is often signaled by a shakeout among technology producers. Furthermore, the emergence of a dominant design ends potential adopters’ uncertainty about the merits of the technology and likelihood that it will be rendered obsolete by later technologies. Consequently, “the emergence of a standard [dominant design] is a prerequisite to mass adoption ... ” (Anderson & Tushman, 1990)p. 615).

The point here is that technological action frames, theorizations, or organizing visions are neither the same as, nor completely independent of, the technologies to which they relate. Information

about (un)successful technology development, the (non)emergence of a dominant design, and (un)gratifying results in practical experience are likely to influence adoption. In addition, when not already reflected in a technological action frame, this information is likely to be appropriated into the frame by movement entrepreneurs, as will information about external conditions and events (discussed earlier). Information about technology problems or setbacks or the non-emergence of a dominant design is likely to hinder diffusion, regardless of the attractiveness of the technology's action frame.

2.3 Recap

The foregoing discussion suggests that three interrelated factors influence the success of computerization movements, as indicated by the widespread diffusion of particular technologies and their associated use practices. The first is technological action frames, also called innovation theorizing or information systems organizing visions, which are reflected in discourse about the innovation. Frames may also be reflected in the actions of innovation entrepreneurs, also called institutions or intermediating organizations, such as industry associations and leading firms in an industry, but, independent of the frames, the actions may be influential, as in the case of industry associations investing in standardization efforts and technology development initiatives. A third factor is information about the performance of the technology, such as success stories that present the results achieved by earlier adopters, reports of technology setbacks or problems, or evidence of the emergence of a technology standard, also called a dominant design.

3. METHODS

We investigate the influences of, and interplays among, technology action frames, the actions of institutional supporters, and technology performance in the context of the diffusion of automated underwriting in the US home mortgage industry. This industry is particularly interesting for an analysis of computerization movements, because computerization began later in this industry than in many other "information-intensive" financial services such as consumer banking and credit card lending (Lebowitz, 2001). As a result, computerization movements in the mortgage lending industry are more easily accessible for examination than those that occurred a decade or more earlier. In addition, computerization movements in the US home mortgage industry are likely to be able to draw on ideologies (Kling & Iacono, 1988) and framing choices (Reese & Newcombe, 2003) that were already well developed in earlier computerization movements.

Automated underwriting is a particularly interesting innovation for our research purposes, because it diffused very rapidly (Jacobides, 2001b; Straka, 2000), suggesting the presence of a galvanizing action frame and the formation of widespread industry consensus.

Our research approach is an analysis of articles about computerization in *Mortgage Banking* magazine (<http://www.mortgagebankingmagazine.com>) from 1980 to today. *Mortgage Banking* is a publication of the Mortgage Bankers Association of America, the leading association for firms in that industry. The publication includes feature articles, company profiles, and a calendar of industry events, as well as news about legislation, economic changes, and technology. Thus, it is an excellent source of historical data on the concepts of interest in this study: automated underwriting theorizing frames, institutional supporting events, computerization performance, automated underwriting diffusion, and relevant external events and conditions. *Mortgage Banking* magazine is indexed in ABI Inform/Proquest from 1977, with full-text availability from 1987.

We first sought to obtain all articles in *Mortgage Banking* that deal substantively with topics related to general and specific computerization movements. The terms used to describe computerization have changed over time. “Automation” was the term commonly used in the 1980s; in the 1990s, the terms “technology” and “information technology” came into vogue. The specific technological innovation of interest in this paper can be referred to as automated underwriting, credit scoring, loan origination technology, among other ways. To make sure that we would capture all relevant articles, we conducted Proquest searches with twelve different search terms, which were selected on the basis of trial and error as likely to return the largest number of relevant articles. Eliminating duplicates left a corpus of 632 articles for the period 1982 to 2004. (There were no relevant articles in 1980 and 1981.)

Two researchers read all articles in the corpus relating to the specific technology described, if any, and to general themes related to the goals of this research. We then selected the articles related to automated underwriting and closely related concepts (e.g., credit scoring, mortgage scoring, risk-based pricing, underwriters, and enabling technologies such as EDI and standards) for finer analysis. In the second phase of coding, we independently coded each of the remaining 214 articles using the concepts outlined in the theoretical background section. (The article within

year was the unit of analysis.) Data analysis proceeded in several stages. As recommended by (Miles & Huberman, 1944), we constructed time-ordered matrices, with rows for each article in sequence by date and columns for each of the concepts. We analyzed first within concept to see how, for example, the computerization action frames changed over time. Then we compared across the columns to examine interdependencies among action frames, institutional interventions, technology performance, and diffusion outcomes.

4. FINDINGS

In this section, we first provide some relevant context, briefly describing the US home mortgage industry. In four subsequent sections, we trace the career of the automated underwriting innovation. The first section describes automated underwriting and its diffusion as framed by one important category of institutional actor. The second section shows the dependence of that vision on key enabling technologies and technology use practices. The third section describes the conflict those arrangements engendered among members of another key stakeholder group, their alternative framing and use of the technology, and the institutional support provided by their industry association. The last section traces the story through a major technological change in enabling technology—the introduction of the Internet.

4.1 Background on the Mortgage Industry

Historically, the entire mortgage lending process in the US —assessing borrowers’ credit worthiness, evaluating property value, collecting mortgage payments, etc.—was handled by one type of organization—local savings and loan banks. To increase the flow of funds available for mortgage lending, the US government chartered certain private corporations to buy and securitize mortgages. In conjunction with other environmental changes, the growth of two government-sponsored enterprises (GSEs)—FannieMae and FreddieMac—resulted in massive changes in US mortgage industry structure. Although some mortgage lenders continue to hold the mortgages they underwrite in their own portfolios, more than half of all mortgages are sold to investors (Van Order, 2000), thus splitting mortgage lending into two segments—“primary,” where borrowers obtain loans from originators, and “secondary,” where mortgages are sold by originators and bought by investors (Cummings & DiPasquale, 1997).

Today, the primary mortgage market (origination, the major focus of this study) is both vertically disintegrated (Jacobides, 2001a) and fragmented. There are many specialized organizational types, including mortgage bankers, mortgage brokers, credit reporting companies, mortgage insurers, title companies, escrow companies, and other service providers. Within each of these segments (except mortgage insurance, which is concentrated), there are many providers. However, there are signs of rapid consolidation: It is estimated that the top five lenders currently originate over 50% of residential mortgage loans and that the top ten firms service over 50% of such loans. There is also some evidence of reintegration, at least at the top end of the size spectrum (Van Order, 2000).

By contrast, the secondary market can, for most intents and purposes, be considered a duopoly. The GSEs, FannieMae and FreddieMac, have grown rapidly into dominant players: Roughly 50% of the \$6.3 trillion (2003 figure) in outstanding US mortgage debt for single family residences is either held in portfolio by the GSEs or is held by investors in the form of mortgage-backed securities guaranteed by the GSEs (Cummings & DiPasquale, 1997). Because they purchase such a large amount of the loan production of the primary market, they act as de facto regulators of the primary market. They can not only influence primary market underwriting behavior by publishing the guidelines by which they will assess loans for purchase, they can also, to some extent, influence primary market technology adoption by specifying the formats in which they will accept loan documentation.

Another key institutional player in the industry is the Mortgage Bankers Association of America (MBAA or MBA <http://www.mbaa.org/>). Founded in 1914, MBA is the leading industry association for companies in the real estate finance business, the largest segment of the US capital market. Its approximately 2,800 members cover all industry segments, including mortgage lenders, mortgage brokers, thrifts, insurance companies, etc. MBA represents the industry's legislative and regulatory interests and conducts educational activities and research for its members. As will be discussed more fully below, the MBA, working closely with the GSEs, has been a major force in computerization movements in the mortgage lending industry.

4.2 Credit Where It's Due: The Diffusion of Automated Mortgage Underwriting

Mortgage lending was historically viewed as less readily automated than other types of credit decisions. Until the mid-1990s, the mortgage process was largely manual and decentralized: tens of thousands of underwriters employed by thousands of mortgage lenders subjectively reviewed borrowers' credit reports and voluminous documentation against their own underwriting guidelines as well as those of conduits and investors (such as the GSEs) (Straka, 2000).

Following serious problems with mortgage defaults in the 1980s, the GSEs and mortgage insurance companies sought to increase their ability to predict defaults and to make automated underwriting decisions based on their predictions. Empirical research in the late 1980s and the early 1990s suggested that borrowers' negative equity (owing more than the property was worth) was the greatest risk of default, and the importance of a borrowers' credit history was poorly understood. Part of the problem lay in the lack of availability of sufficient credit data, which was distributed across many sources and reported in nonstandard ways: In the early 1990s, "virtually no institution was storing credit records on mortgage loans in an easily accessible medium" (Straka 2000, p. 213). Motivated by the success of credit scoring techniques in predicting default in other financial services (e.g., credit cards), the GSEs and mortgage insurers began exploring the applicability of that technique in mortgage lending. In 1992, Freddie Mac completed a study using generic credit scores (FICO scores, after Fair, Isaac and Company) and concluded that they were a significant predictor of mortgage default and thus should be a component of mortgage scoring models.

The next challenge was to design automated mortgage scoring tools. Three approaches were tried. Fannie Mae and at least one mortgage insurer tried the "mentored expert systems" approach in which programmers captured the rules by which human underwriters made decisions.

"One problem is that an 'expert system' still leaves us with evaluations which depend somewhat on subjective judgments, regardless of how carefully these judgments are worked out by the underwriting experts' panels. The second and perhaps insurmountable problem is that the experts' models eventually become obsolete." (1989: 460¹)

¹ Numbers are authors' *Mortgage Banking* article identifiers.

A second approach tried, weighted variables models, was also found to be flawed, because “we have no basis for determining the relative weights to be assigned” (1989: 460). The third and ultimately successful approach was the discriminant model, which used statistical analysis to indicate “which are the most important case characteristics and the weights each should have. These weights and case values are multiplied and summed to obtain a rating or score for each case” (1989: 460). In 1994, Freddie Mac announced successful pilots of its automated underwriting (AU) system, Loan Prospector, which used the discriminant modeling approach. Shortly thereafter, Fannie Mae introduced its discriminant modeling system, called Desktop Underwriter.

In 1995, Freddie Mac issued an industry letter promoting the value of credit scoring techniques as a tool for reducing default risk (1996: 335). Adoption of credit scoring and AU systems was rapid. In 1996, a mortgage insurer reported that “the use of credit scores from the ... FICO scoring model skyrocketed” (1996: 335). In the same year, Freddie Mac partnered with the Federal Housing Administration to develop a special version of Loan Prospector to underwrite FHA loans (typically riskier than the loans the GSEs purchased at that time). By 1997, Fannie was running 1500 loans per day through Desktop Underwriter; Freddie was handling 1700 loans per day through Loan Prospector.

Research conducted by Fannie, Freddie, and independent entities began reporting substantial benefits to AU adopters around the year 2000. An independent study concluded:

“A large contributor to reducing costs has been the implementation of automated underwriting systems (AUS) and the associated process changes. ... Total underwriting costs were almost one-third lower for those companies that use AUS on more than 60 percent of the loans they originate.” (2000: 184)

A Freddie Mac report similarly hailed the successes of automated underwriting. “In a 1996 report, Freddie Mac made big claims for its nascent automated underwriting service It’s been five years and millions of mortgage originations later. Has Loan Prospector lived up to its billing?” Freddie concluded the answer was yes: Loan Prospector had increased accuracy, enabled faster processing, lowered costs, increased lending fairness, and expanded homeownership opportunities (2001: 141). And a survey conducted by Fannie Mae announced

that automated underwriting (in conjunction with seamless IT integration) was the most important factor contributing to the superior performance of top performing mortgage lenders (2002: 121).

In 2002, a freelance writer quipped: “If there is a wholesaler [lender] left on the planet not using Internet technology to lock loans or an automated underwriting system to deliver decisions in minutes, we didn’t find it” (2002: 99). Fannie’s Desktop Underwriter was referred to as an industry “standard” (2002: 109).

“The most firmly entrenched lending technology by far is AU. Today, AUS technology is virtually essential to the mortgage lending process.” (2003: 48)

The foregoing account shows the intricate interplay among, and influence of, framing processes (credit scoring and AU as tools for predicting and managing borrower default risk), institutional support (statements and technology offerings by the GSEs and mortgage insurers), and technology performance (failure of certain modeling techniques) in the diffusion of automated underwriting. Unfortunately, this version of events leaves out more than it reveals. The following sections describe the career of automated underwriting as a struggle among stakeholders, an ongoing battle with technology, and a collective action by mortgage bankers spearheaded by their industry association.

4.2 Automated Underwriting: An Incomplete Innovation

By 1991, Freddie Mae had progressed with the development of a statistical approach to AU to the point where the GSE was convinced that the technology could be used on a large scale. There was only one fly in the ointment. The technology required large amounts of credit data, and keying the data in was a serious bottleneck.

“After an 18-month pilot project, the corporation could get good results, *as long as it fed the program massive amounts of information*. But it was almost more expensive to take the massive underwriting files, extract that data and key it in and let the system underwrite it, than it was to have an underwriter do it...” (1991: 421, added emphasis)

The solution to the problem was clear (to the GSEs): For AU to work on a large scale, *mortgage lenders* would have to supply credit data electronically when they submitted their loans for underwriting.

Anticipating this requirement, the MBA had earlier begun working to introduce electronic data interchange standards into the loan origination process. In 1988, the MBA launched an initiative to streamline mortgage lending with standardized forms like the Uniform Residential Loan Application and to develop EDI standards for the exchange of credit data (1988: 880). This proactive move reflects the lenders' dissatisfaction with their already considerable experience of using EDI with the GSEs for delivering closed loan packages (the secondary market).

The GSEs had different data requirements and transmission standards, forcing lenders to maintain duplicate business processes and technology interfaces.

“... [W]hile both systems require much of the same data, a mortgage banker must do a significant amount of manual work before transmitting to either system. In addition, if a lender changes delivery agency, the work must be re-done *because the two systems are not uniform.*” (1988: 492 added emphasis)

Lenders were concerned that using EDI-enabled AU would involve extra work for them if the GSEs did not relax their information and documentation requirements (1990: 439).

Consequently, the lenders agreed that in order for the electronic exchange of loan origination data to be a success, the GSEs would have to agree to common EDI transmission and data standards:

“[MBA] conference participants agreed that ... if electronic data exchange was to be a success, ... the industry [read: lenders] must broadly support the idea of exchanging data. This broad level of support would only come from a universally recognized data transmission standard, a standard ... *that would not allow any competitive advantage to a vendor, organization [read: GSE] or company.*” (1988: 492 added emphasis)

Despite some progress toward standardization through MBA initiatives, the GSEs persisted in their proprietary technology development paths. On a “red letter day” in 1993, a highly publicized EDI transaction pilot—a request for payment of a mortgage insurance claim coupled with payment via an automated clearinghouse—was described as foretelling “a technological

revolution” (1993: 393). And, in 1994, when the GSEs announced the 1995 availability of their automated underwriting services, they also announced their fee-based offerings of value-added network (VAN) services for EDI transmission (1994: 374, 371).

“Firms need to establish EDI connections *before implementing automated underwriting*, so that information from credit bureaus, mortgage insurance companies, and others can be fed into the electronic underwriting system.” (1994: 374 added emphasis)

The lenders expressed numerous concerns about the proposed arrangements. First, EDI standards were not fully developed, leading to fears about having to maintain thousands of different interfaces with brokers and other service providers (1994: 374). EDI was further problematic because of its high connect-time charges that put it out of the reach of many small players (1995: 369). For example, although many lenders were able to *request* credit reports from reporting agencies electronically, they usually *received* credit reports via fax. Similarly, fax was used by “more sophisticated” lenders (the ones that did not rely on mail and courier) to communicate with their brokers. Thus, unless the lenders were to underwrite the costs of operating EDI links and reengineering “the whole process” themselves (1994: 374), *they* might be faced with the prospect of having to rekey vast amounts of data to comply with the GSEs’ requirements. Furthermore, industry participants worried about a “growing ‘sophistication gap’ in the application of technology between thrifts and mortgage banks and between small competitors and large” (1993: 769).

The GSEs tried to allay these concerns in various ways. First, they waived “reps and warranties” for lenders who used their automated underwriting systems. This promise reduced requirements for paper documentation and, in effect, guaranteed lenders that they would not be required to repurchase the loans from the GSEs in the case of underwriting errors. Second, the GSEs assured lenders that they would not make their AU systems available for use by brokers or real estate agents, but they allowed the *lenders* to do so. This provision enabled lenders to capture data at the point of sale (the interface between the borrower and the broker or real estate agent) and also enabled the *underwriting decision to be made at the point of sale*. (The implications of this opportunity are discussed below.) Third, the GSEs never required the lenders to use their VANs (with the attendant fees) to submit loans for underwriting.

“Interestingly, Freddie Mac currently supports direct-dial capabilities for its pilot automated underwriting system, set to debut nationwide early in 1995. The use of GoldWorks—its VAN—is not required.” (1995: 369)

Despite the GSEs’ protestations that AU would benefit borrowers and “empower” lenders (1994: 374), lenders were slow to adopt AU, and EDI use never became widespread in the industry. In 1995, the MBA proclaimed the “adoption and *real production use* of the established X12 standards [its] top priority in 1996” (1994: 374 added emphasis). The MBA was confident that EDI transmission standards would put “such interfacing nightmares ... to rest ... regardless of the disparity with their internal data structures [in other words, regardless of the GSEs’ differing data formats”. Despite the MBA’s efforts, less than a quarter of all lender submissions to the GSEs used AU in 1997, two years after the introduction of AU. Furthermore, most brokers and other service providers continued to rely on fax or dial-up for several more years (1996: 325, 2000: 173).

The GSEs’ insistence on proprietary data formats reflects a framing of AU as a weapon in their fierce duopolistic competition. As framed by the GSEs, the AU system (together with electronic data interchange) was an *electronic hierarchy* that would tie lenders and their sources of supply more tightly to the GSEs, thus locking the lenders in. One GSE would triumph over its foe by amassing a larger dedicated supply base, locked in through its AU system. Unfortunately for the GSEs, EDI technology did not fully cooperate, and the Internet later changed the rules of the game, enabling the lenders to fight back.

Every Lender’s Dream: AU as a Tool for Lenders

Lenders framed AU differently than the GSEs did. Lenders’ experimentation with automated underwriting dates back as far as that of the mortgage insurers and the GSEs. In 1986, AU was described as a tool to help mortgage *lenders* reduce delinquencies. Lenders that embraced AU were expected to weather the coming shakeout in the mortgage industry, unlike non-adopters (1986: 045). A mortgage lender reported in 1997 the successful development and use of an AU system based on an analysis of the GSEs’ published underwriting guidelines and a statistical sample of the lender’s loan data (1987: 59). In 1992, the large lender Countrywide announced its rollout of an AI-based automated underwriting system and its discussions with the GSEs about electronic data transmission and potential GSE acceptance of Countrywide’s automated lending

decisions. In 1993, a group of west coast lenders collaborated with vendors to develop a commercial AU system for lenders “on a budget” (1993: 388).

Lenders’ development and use of automated underwriting systems was a logical step from several points of view. First, some lenders retained some or all of the loans they made in their own portfolios (not selling them to the GSEs) or sold loans directly to investors (without using the GSEs as conduits). There would be little point in paying the GSEs fees for underwriting these loans. Second, until the late 1990s, the GSEs only purchased conventional conforming loans—loans less than a certain dollar amount which met stringent underwriting criteria. Many lenders sought to serve borrowers with low documentation, impaired credit, or borrowing needs exceeding GSE guidelines. Early on, the GSEs’ systems could not handle such loans. Therefore, some lenders saw the need for their own automated underwriting tools.

By 1997, however, the GSEs’ systems (first widely available in 1995) had evolved to the point where they were able to underwrite government loans, subprime loans, and jumbo loans.

“Manual guideline underwriting worked around univariate “knockout rules” (such as no loans above a 36 percent debt ratio). Exceptions and risk layering (e.g., poor credit plus debt higher than 36 percent) were allowed (case-by-case or in policy) with little or no risk quantification and feedback. In contrast, scoring tools and AU have allowed the tradeoffs between risk factors to be more precisely quantified, giving the industry greater confidence in “pushing the envelope” of acceptable expected default rates... .” (Straka, 2000)p. 217)

It was this “pushing of the envelope” that allowed the GSEs to extend into new loan categories, which some lenders undoubtedly perceived as strategic encroachment.

Through the use of multivariate analysis, the GSEs’ AU systems became “black boxes”, and it was no longer possible for the GSEs to publish their lending guidelines in entirety (1997: 672, 2001: 76). This opacity reduced the ability of lenders to estimate whether and at what price one GSE would purchase a loan without running the loan through that GSE’s AU system. In combination with strong incentives to use the GSEs’ systems (waived “reps and warranties”), fees charged for using the GSEs’ systems, and the GSEs’ refusal to accept automated decisions from other AU engines, the lack of transparency in the GSEs’ AU systems reduced the lenders’

traditional ability to play the GSEs off against each other in search of the best deal (1997: 302). Since the advent of automated underwriting, if a lender wanted to compare the agencies' pricing *before* deciding where to sell the loan, the lender had to use both AU engines, incurring higher costs that could amount to several million dollars a year (1997: 302).

Under these circumstances, use of an "independent" AU system "as a prescreening tool in conjunction with the agencies' automated systems" began to seem like a good idea even for lenders that had not already developed their own underwriting systems (1997: 302). The downside was, however, that using multiple systems "further complicate[d] the efficiency problem by layering on the additional cost of using multiple automated underwriting systems in different phases of the origination process" (1997: 302).

The efficiency problem stemmed from lenders' desire to deploy AU at "the point of sale", where a borrower interfaced with the broker or a lender's retail loan officer. The traditional lending process involved a borrower "prequalification" step; prequalification decisions occasionally had to be changed as a result of a GSE's subsequent underwriting decision, leading to borrower dissatisfaction. If lenders could shift the GSE decision to the point of sale, they could improve customer satisfaction, reap significant efficiency benefits from business process reengineering, and possibly gain competitive advantage relative to less sophisticated peers. In the lenders' ideal world, they would be able to run a loan simultaneously through *several* AU systems (including their own) and pay the GSEs underwriting fees *only* for the loans the GSEs actually purchased (1997: 302). In this way, lenders could hope to regain some of the pricing leverage over the GSEs they lost because of AU's lack of transparency. Understandably, the GSEs were not amenable to this suggestion. Nevertheless, the issue did not go away, but resurfaced in 2004.

In this environment of conflict over the GSEs' AU policies, lenders' adoption of AU lagged. In 1997, despite the GSEs having emerged as "dominant providers" of AU services, only twenty to twenty-five percent of eligible loans went through the GSEs' AU systems (1997: 302). Most lender participants in an annual mortgage production survey reported that they did not make full use of AU systems (i.e., use AU at the point of sale) owing in part to lack of integration with back-end systems (1997: 293) (promoted by the GSEs' ongoing refusal to accept common data standards—a condition that endured until 2001). Lenders' concerns about AU and their

dissatisfaction with GSE policies led to the formation in 1996 of an MBA task force on automated underwriting and in 1997 of an MBA task force to promote interagency cooperation (1997: 302, 304).

Despite these MBA initiatives, the GSEs persisted in their technology-based competition. They continued to enhance and offer fee-based technology services to industry participants. For example, the GSEs provided access to their AU systems through the Internet. (Freddie did, however, waive connection fees for this service.) In 1997, Fannie introduced an EDI-based network to connect lenders with providers of services such as property appraisals (1997: 313).

By 1999, it was apparent to some observers that Freddie had lost its technology race with Fannie. Freddie quietly began purchasing loans that had been underwritten with Fannie's system. And, "in a landmark agreement", Freddie agreed to purchase mortgages underwritten by lender Norwest's AU system (Marlin, 1999). Under the deal, Norwest began selling nearly all its loan production to Freddie. A short time later, BankAmerica made a similar deal with Freddie, and Countrywide announced a similar deal with Fannie. (Recall that Countrywide had first initiated talks about such an arrangement in 1992.) Interestingly, despite the "hierarchical" nature of these arrangements, which appear to lock the lenders in to a single large customer, they were hailed as a victory for *lenders*.

"The deal between Freddie Mac and Norwest is a very important deal because it may force Fannie to lower its fees, or shift its business model to compete for business with Freddie Mac.

"To other mortgage participants, it's an important deal because it returns to the lender control over the origination event, and may usher in a period of reduced fees for those using [GSEs'] automated underwriting. But it's also an agreement that spotlights the acute dissatisfaction with automated underwriting." (Hochstein, 1999).

Mortgage lenders believed that, like the rest of the technology industry at that time, the GSEs should "give their technology away in order to increase their volumes ... attracting as many users to automated underwriting as possible" (Hochstein, 1999).

Whether or not these deals represented a victory for lenders, they may have helped fuel lenders' adoption of automated underwriting (independent or GSE systems). From use for less than 25% of the loans sold to GSEs in 1997, automated underwriting progressed rapidly to use for 100% percent of some lenders' loan production in 1999, to use "deeply embedded into the business environment" in 2001 (Jacobides, 2001a) to use by nearly 100% of all lenders by 2003 (2003: 45). The deals between GSEs and large lenders certainly did not discourage lenders from investing in independent AU systems, either via the installation of commercial packages or via new custom development. Even smaller lenders and Internet startups began developing their own AU engines. For example, Impac, a medium-sized "alt A" lender (prime credit borrowers who don't supply loan documentation and whose loans were not heavily purchased by the GSEs at that time) decided to develop its own AU system after reviewing the custom software developed by IndyMac, its much larger competitor. In 2001, Impac automatically decisioned 100% of its loans through its AU system, which cost the company \$1.5 million to build (Grant, 2001). Internet-only DeepGreen Bank of Cleveland developed a "lights-out" (fully automated, no human intervention) Internet-based mortgage lending operation with integrated AU decisioning (Grant, 2003). These and many other examples show that, whether they used an independent AU system alone or in conjunction with the GSEs' systems, mortgage lenders were making AU technology their own.

Enter the Internet: AU at the Point of Sale

Quietly at first, but with rapidly growing insistence, the Internet became integral to the mortgage lending business. The first mentioned successful uses of automated underwriting at the Internet point of sale occurred in 1999—Finet's iQualify.com (1999: 247) and Mortgage.com (1999: 244), later purchased by ABN AMRO. Just one month later, *Mortgage Banking's* editor-in-chief opined that "lenders must regard the Internet as a new medium for originating [loans], not just an advertising or information medium" (1999: 242). In other words, the point of sale was starting to shift toward the Internet, and AU had to be there.

Although brokers were by now accustomed to using AU systems, few submitted their information to lenders electronically for automated entry into AU; they used fax instead. When at the height of the 1999 refi boom, Fannie began offering its AU system to brokers as a service to the industry (reneging on its 1995 promise to the lenders) there was little response from

brokers at first. Then Fannie embedded Desk Originator into a loan origination system many lenders were using (2000: 173), and brokers' direct use of AU began to increase sharply. Lenders became concerned that:

“... the brokers would be able to shop around among different wholesalers for the best rate. *GSEs have been aggressively lobbied by the mortgage banking industry to not provide their AU directly to brokers*, potentially disintermediating mortgage banks in the process.” (Jacobides, 2001b) added emphasis

Moody's opined that “the mortgage banking industry is in a phase of substantial transformation as a result of the combined impact of technology and the GSEs (2000: 170).

The value added of wholesalers is suffering as a result of the democratization of technology. The fact that a broker can now get a mortgage preapproved by Fannie Mae and Freddie Mac is an example of this process at work and represents a major evolution.” (2000: 170)

As one article put it, in an IT-related context: “Some lenders are squawking, ‘when GSEs compete, we lose’” (Kersnar, 2002).

Another example of the same process was that smaller lenders without sophisticated underwriting systems could use the GSEs' systems to price their loans appropriately, hence competing effectively with larger lenders (Jacobides, 2001b). “As a result, pricing competition between mortgage banks has increased” (2000: 170). Ironically, the lenders' earlier concerns (1994 timeframe) that smaller “technology have-not” lenders would suffer from automation were also laid to rest (2003: 43).

Large lenders struck back in two ways. First, they aggressively developed and promoted their own “electronic partner networks,” putting their AU capabilities at the point of sale interface between the borrower and the Internet:

“No other area of technology creates the stir that automated underwriting (AU) does ... [M]uch more important is the way automated underwriting puts investors [read: the GSEs] ahead of wholesale lenders in the mortgage food chain and in direct contact with brokers for the first time. ... Most brokers currently use [either of the GSEs' AU systems offline] as part of their origination routines—consequently, many lenders feel a loss of

control over the process. In response, the newest AU options available to brokers are a result of *lenders deciding they need to get back in between the broker and the investor*. These options—almost all private wholesale [lender] Web sites where brokers can submit loans for AU, and in some cases lock the loans as well—include Countrywide’s CWBC, InterFirst’ MOAI and Indy Mac’s e-MITS.” (2000: 173, added emphasis)

By 2002, Interfirst’s MOAI system was “capable of underwriting, locking, closing and funding [loans] online in less than four hours, from start to finish” (2002: 67). Through efforts such as these, the lenders reflected their belief that, although there would always be a place for brokers in mortgage lending, arming brokers with technology “misses the boat completely.” The new goal was to put technology in the hands of the *borrowers* (2001: 139). This was not a game the GSEs could play. They were prohibited by federal charter from originating loans.

The second way in which the lenders fought back was by renewing their push for standards. After the MBA’s major EDI thrusts of the late 1988s through mid-1990s, the standardization effort seemed to lose direction, and the GSEs continued to hold to their proprietary data formatting requirements. In 1999, the mortgage industry turned to the promise of XML to bring seamless integration between the primary (origination) and secondary (securitization and sale) sides of the mortgage market. Co-opting other EDI and XML standards development groups, the MBA secured the active participation of the GSEs in a data standardization effort, called MISMO (Mortgage Industry Standards Maintenance Organizations). In what a MISMO spokesperson later referred to as MISMO’s greatest achievement to date, the GSEs agreed in 2001 to accept common data standards for underwriting. (Recall that industry participants had been calling for such standards since 1988.)

Not content in that victory, the mortgage lenders, took the high ground and appealed to moral legitimacy (borrower benefit) to renew their unsuccessful 1997 demand for single-fee access to both GSE’s AU systems.

“For the benefit of the consumer, I think it’s important that we allow multiple AUSes to review each and every loan. From a technology standpoint, this is an easy accomplishment, and existing technology can more than handle such a feat. ... There are some potential hurdles, of course. The developers of the AUSes must be willing to work in an openly competitive environment. They must also accept industry standards such as

those developed by MISMO. ... For this to occur, the industry would need to rally together to advocate for such a solution.” (2004: 3)

The outcome of this battle remains to be seen.

5. CONCLUDING REMARKS

Our abbreviated version of the career of automated underwriting necessarily leaves out many interesting issues concerning the framing of AU systems. Among them are the potential consequences of AU for housing discrimination (or fairness), for the employment, skill, and job quality of human underwriters, for market instability owing to the expansion of mortgage lending to higher risk borrowers, and for the ability to personalize mortgage products, rates, and conditions to each individual borrower. Also not discussed were the prospects for a fully electronic mortgage lending process. In addition, although AU now seems to be taken for granted in this industry, its framing and use practices are still evolving, as the last section shows.

Despite these limitations, our long historical view does suggest some answers to Kling and Iacono’s (1995) question: “why do organizations adopt new computing technologies?” Although clearly a factor in the diffusion of automated underwriting, the economics of need, in the form of the drive to reduce mortgage defaults, were far from the only factor. Technology action frames clearly played a significant role. Regardless of who created them, technology action frames, such as “AU as tool for reducing defaults”, “AU as incomplete.” “AU as tool for lenders”, “AU at the point-of-sale”, helped mobilize support in the form of technological innovation, adopters, and support by powerful actors. These technology action frames encapsulated problems, solutions, casual arguments, justifications, and counter-arguments. Frames were sometimes couched in terms of opportunities, other times of problems. Framing justifications changed over time, variously appealing to self-interest, arguing about inevitability, and referring to the good of small lenders or the ultimate customers—the borrowers. By at the end of the study period, justifications of the innovation itself had all but faded away as it became a taken-for-granted feature of life in the industry. The framing of that innovation and its organizational use practices continued, however, to be hotly contested.

Our story also reveals the importance in the diffusion of automated underwriting of the supportive actions of institutional actors. The role of industry associations like the MBA is

clearly not limited to the provision of arenas in which framing can occur. The MBA actively lobbied its members around certain courses of action, most notably gaining the GSEs' acceptance of common underwriting data standards. They also created standardization initiatives and even set up its own telecommunications network for members in 1995, later spun off as an independent venture. The GSEs also played highly influential roles, not just as framers, but also as technology developers and vendors and as wielders of incentives and coercive sanctions.

Finally, the career of automated underwriting owes not a little to technology itself. Had the mentored expert system approach proved workable, AU practices might look very different today. Had EDI been less expensive, early opposition to the use of AU might not have materialized, and along with it the various alternative AU use practices instituted by lenders. The advent of underwriting data standards may yet enable new practices that are currently unforeseen. The changing fortunes of technology helped shaped both the actions as well as the frames of various players.

Kling and Iacono's groundbreaking work reminds us not to privilege economic accounts of the diffusion of new technologies over social ones. Our study reinforces Law's (Law, 1987) contention that we should also consider technological influences, along with the economic and social.

6. ACKNOWLEDGEMENTS

This research was funded in part by the National Science Foundation's Digital Society and Technology Program (Award Numbers: 0233634, 0231584, and 0323961).

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