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The Diffusion of the Legitimate and The Diffusion of Legitimacy*

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Abstract

This paper models the implications of *innovations* – concrete products and behaviors – being nested within *institutions* – abstract cognitive schema for evaluating the legitimacy of innovations. In effect, social actors assess the legitimacy of innovations vis-a-vis conformity to institutions such that a sufficiently legitimate innovation may be adopted without direct reference to the behavior of peers. However when innovations lack institutional legitimacy actors default to proximately peer-oriented heuristics like information cascades. Eventually if enough similarly aberrant innovations achieve widespread popularity, their conventions will become institutionalized as legitimate. Thus density creates legitimacy but this density can be at the level of the particular innovation or of the institution within which it is embedded.

1 Introduction

In understanding when and how people act, sociologists have tended to be especially interested in "situations where many actors behave in ways contingent on one another" (Granovetter, 1978, p. 1442). Indeed there is often a strong presumption that only such dynamic interdependence is truly social,

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as in the famous passage from Weber's essay on social action in which he suggests that "if at the beginning of a shower a number of people on the street put up their umbrellas at the same time, this would not ordinarily be a case of action mutually oriented to that of each other, but rather of all reacting in the same way to the like need of protection from the rain"(Weber, 1978, p. 23). Some readers have accepted the basic distinction but conceived of it as continuum rather than a discrete distinction, such that even in cases where we are mostly acting autonomously the behavior of others may still be a "marginal influence" (Granovetter, 1978, p. 1437). A much more radical critique of Weber's view rejects the premise entirely on the grounds that "it never occurred to him that umbrellas are only found in certain societies, and neither manufactured nor used in all" (Elias, 1978, p. 120). That is, sociologists from Weber through the present interested in how action might be social have mostly been thinking of whether action is *proximately* contingent on others; a tendency which has only increased with the recent interest in models based on networks, cascades, and other varieties of complexity. However what much of this research overlooks is that even behavior which is proximately indifferent to peer behavior may be *ultimately* social in that the actor's repertoire or toolkit is socially derived (Swidler, 1986; Tilly, 1983). We can thus usefully distinguish between different levels of abstraction in the nature of social action.

Paradoxically, there may well be a trade-off between proximately social and ultimately social action. A behavior which is completely congruent with social expectations may be performed immediately without reference to peers. In contrast, a dubious act will be performed more hesitantly, furtively looking to see whether others are acting likewise. For instance, applause is a thoroughly legitimate act and most audience members understand what aspects of a speech merit applause, so audience members tend to erupt into applause simultaneously as each member reacts directly to the applause lines, without waiting to see if peers are behaving similarly (Heritage and Greatbatch, 1986).[1] In contrast, booing is a boorish act and so audiences tend to gradually creep into booing, with each member waiting to see how many others have broached rudeness (Clayman, 1993). Likewise the paradigmatic case of density dependent behavior is the downright criminal behavior of ri-

[1]Note that this finding assumes an understanding that applause is restricted to immediately after a rhetorical unit or musical movement and that when such a unit has been completed is obvious. This is not especially complicated for oratory but is somewhat complicated for music. In some times (e.g., classical music prior to about 1900) and for some genres (e.g., jazz) this distinction does not hold and under these conditions applause is less focused and may well be more sensitive to peer influence (Ross, 2010).

oting (Granovetter, 1978). Ironically, it is the shared norms of rhetoric and applause that means we decide to applaud autonomously and the taboos against booing and rioting that make them contagious. There are two levels of social interaction determining an audience member's behavior, the generally institutionalized expectations of audience behavior and the actual behavior of the other people in the room. The aim of this paper is to synthesize diffusion and institutionalism so as to understand how behaviors like bursting into applause or opening an umbrella can be proximately atomistic but ultimately social.

2 The Diffusion of Innovation

The diffusion of innovation is a set of approaches seeking to understand when different actors in a social system will adopt an innovation (Rogers, 2003; Strang and Soule, 1998; Wejnert, 2002). In the typical "s-curve" model, the proportion of the system that has adopted the innovation over time starts out low, slowly builds to a critical mass where it achieves exponential growth, and finally levels off as it saturates the system. In other words, the hazard for adoption is a function of lagged adoptions (Bass, 1969; Mahajan and Peterson, 1985). The resulting cumulative adoption function is known as the s-curve because it resembles an italicized letter "s." The curve describes both the trivial and the essential, the ephemeral and the enduring, providing a good description of everything from how YouTube videos go viral over the space of a few weeks; to how hybrid seed corn became ubiquitous on Iowa farms over the course of two decades; to the spread of Christianity throughout the Roman Empire or the conversion of local populations to Islam under the Caliphate (Crane and Sornette, 2008; Ryan and Gross, 1943; Stark, 1996; Turchin, 2003).

A variety of mechanisms have been proposed for why some innovations diffuse via cumulative advantage. The most common assumption is contagion, whereby those who have adopted the innovation directly promote the innovation to those with whom they are in contact (Dawkins, 1976; Rogers, 2003; Ryan and Gross, 1943). A variant is structural equivalence contagion, wherein people imitate their rivals rather than their contacts (Burt, 1987). Threshold models do not necessarily rely on social networks but simply aggregate popularity (Granovetter, 1978). Among the most popular threshold models is the information cascade, where potential adopters use the number of prior adoptions as a heuristic of quality – a logic encapsulated in the album title *50,000,000 Elvis Fans Can't Be Wrong* (Banerjee, 1992; Bikhchandani et al., 1992; Salganik et al., 2006; Salganik and Watts, 2008). In all of these mechanisms the potential adopter is using prior adoption (by contacts, rivals, or the field as a whole) as a source of credible information about the innovation's desirability.[2] Note that many innovation studies find that potential adopters first learn about the innovation from the mass media or from a "change agent" (e.g., a salesman, missionary, or public health worker) but potential adopters view such sources of information as not credible because they are biased in favor of the innovation and/or are outsiders who don't understand how the innovation would apply in the local context. This is why exogenous sources like mass media and change agents usually drive *awareness* of the innovation but it often takes endogenous peer influence to drive *adoption* of the innovation (Rogers, 2003). This distinction between rapid awareness driven by outsiders and more gradual adoption driven by peers can be seen in two different roles performed by the same group of people – Moonie missionaries expected to convert Americans through street-preaching but actually only converted close friends and neighbors (Stark, 1996).

While endogenous dynamics get most of the attention in the diffusion literature, many innovations see little or no proximate role for peer influence. In such circumstances potential adopters respond directly to exogenous forces and so the hazard of adoption is typically constant rather than increasing with prior peer adoptions.[3] This results in a convex cumulative adoption curve with immediate fast growth followed by slow growth. This pattern describes when doctors first prescribed tetracycline, when radio stations will begin playing a new pop song, when corporations designated an EEO/AA compliance officer, and when people learned about President Eisenhower's stroke or the September 11th terrorist attacks (Dobbin and Sutton, 1998; Rogers and Seidel, 2002; Rossman et al., 2008; Valente, 1993). Perhaps most notably, civil service reform spread exogenously among municipalities when

[2] Another class of threshold models is the "network externality" model which argues that the number of prior adoptions is not just a source of information, but raises the objective utility of adoption by facilitating direct or indirect coordination amongst those who have adopted the same innovation. For instance, harmonizing on an arbitrary technical standard allows the development of an open market for skilled labor familiar with the standard, thereby making conforming to the technical standard attractive to both firms and labor (David, 1985).

Also note that snob and fashion cycle models (e.g., Berger and LeMens, 2009; Leibenstein, 1950) do not assume monotonic effects of present popularity on the hazard for future adoptions and thus these models are beyond the scope of this paper.

[3] The usual model is to treat exogenous forces as constant but the model can be extended to accommodate time-varying data on the intensity of exogenous forces (van den Bulte and Lilien, 2001).

it was mandated by state governments but endogenously when the state government took no action (Tolbert and Zucker, 1983).[4] Figure 1 contrasts the endogenous and exogenous diffusion patterns.

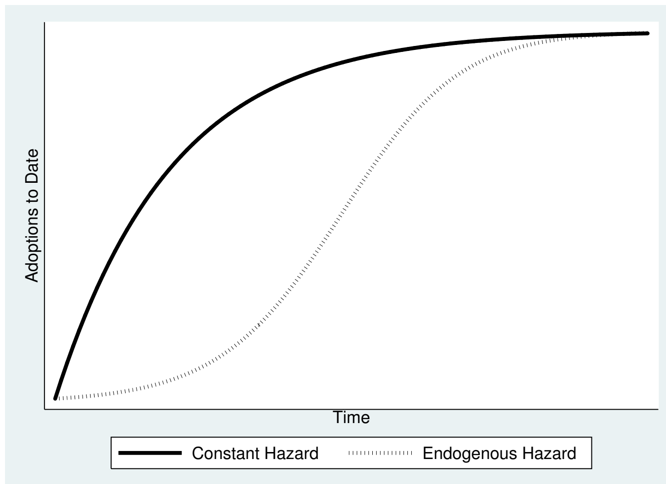

Figure 1: Ideal-Typical Innovation Diffusion Curves

Finally, many diffusion processes do not perfectly match the ideal-type of pure endogenous or exogenous diffusion but form a hybrid of the two. Such a model is often described as $f_t = (p + qF_t)(1 - F_t)$ where F_t is the proportion of potential adopters having already adopted; $f_t = \Delta F_t$; p is the exogenous rate; and qF_t is the endogenous rate at t.[5] Since the endogenous model is a special case of this model when p is zero and the exogenous model is a special case when q is zero, one can thus test for the relative importance of exogenous and endogenous dynamics by fitting the model and looking for the relative size of the constant (p) and increasing (q) components of the hazard function. Thus the shape of a cumulative adoption curve can have a theoretical interpretation where a mostly convex curve implies exogenous

[4]The present paper is similar to Tolbert and Zucker (1983) in many respects but different in others. The earlier work focuses on the actor's context (i.e., whether a city was in a reform state) whereas this paper focuses on the innovation's relationship to prior innovations. Furthermore, whereas that work shows the effect of macro on micro, this paper also shows how the macro is emergent from the micro.

[5]This nomenclature is from Bass (1969). A common alternate nomenclature for the same model uses a, b, and N instead of p, q, and F (Mahajan and Peterson, 1985; Rossman et al., 2008; Valente, 1993). Also note that alternative specifications like the Gompertz logarithmic risk pool function allow for issues like heterogeneous thresholds (Cleves et al., 2004; Mahajan and Peterson, 1985).

forces like advertising whereas an s-curve implies endogenous dynamics like word-of-mouth (Bass, 1969; Mahajan and Peterson, 1985; Rossman et al., 2008; Valente, 1993).[6]

When q is about two to ten times the size of p, early adoptions are mostly driven by exogenous sources but over time these forces are eclipsed by the exponential dynamics of endogenous diffusion. The hazard function thus includes both an endogenous and exogenous component. The "mixed influence" model originally dates back to a study of refrigerators, televisions, and other consumer appliances after the war (Bass, 1969). It has recently been revived as the "big seed" model that innovation is most effective when it starts broadly (Watts and Dodds, 2007), in contrast to the argument that network hubs are key to diffusion (Gladwell, 2000; Travers and Milgram, 1969).

The constant component of diffusion is usually explained as a function of the strength of exogenous influences, such as the volume of advertising aimed at consumers. This paper does not dispute these interpretations but develops the argument below that a necessary condition for highly exogenous diffusion is the perceived legitimacy of the proffered innovation. If an innovation does not resonate as legitimate, it will be prohibitively difficult for even strenuous external salesmanship to find many takers. Rather, potential adopters may become *aware* of a dubious new product or practice from these exogenous efforts, but actual *adoption* will be inspired by peers (van den Bulte and Lilien, 2010; Rogers, 2003; Ryan and Gross, 1943). Ironically then, an innovation can only diffuse "exogenously" to the extent that it is consonant with the local system. Innovations that are perceived as disruptive or imposed by outside actors will only be adopted by endogenous processes, or not at all. I further argue that one of the reasons that much of the diffusion literature finds strongly endogenous diffusion processes is that they often study innovations such as birth control that lack local legitimacy and thus they are conflating the diffusion of the particular innovation and the institution within which it is embedded.

[6]Like much of the literature, the canonical Rogers (2003) text allows for exogenous sources of diffusion but gives much more emphasis to endogenous processes. Specifically, he describes "innovators" (roughly the first 3% of adoptions) as being inspired by exogenous sources. However his illustrations show the cumulative adoption function as an "s-curve" and the first derivative as a normal distribution, which is only consistent with an essentially endogenous diffusion process.

3 Institutions and Legitimacy

Just as firms are nested within industries or fields, so are innovations nested within institutions (Strang and Meyer, 1993). For instance, particular artworks are nested within genres and particular deregulation policies are nested within the ideology of neoliberalism (DiMaggio, 1987; Henisz et al., 2005). When an actor decides whether to adopt an innovation, the implicit or explicit process is to first determine whether the innovation is a legitimate member of a category (commensuration) and then to compare the innovation to other members of that category (evaluation) (Espeland and Stevens, 1998; Hsu and Hannan, 2005; Phillips and Zuckerman, 2001). Thus innovations must conform to the conventions of a salient and appropriate category in order to even be considered for immediate adoption. This process can be promoted by the theorization of elites or the activism of social movements who articulate abstract rubrics for evaluating behavior (Green, 2004; Rao, 2009; Strang and Meyer, 1993; Swidler, 1986).

Diffusion can be rapid when the innovation is similar to incumbent practices and compares favorably along well-established criteria. The drug tetracycline was rapidly adopted by doctors, in large part because it was a member of a product category (antibiotics) that had been in widespread use since the war (Coleman et al., 1966). This meant that doctors understood what antibiotics were, why they were desirable, and how to evaluate the quality of a particular antibiotic against competitors. In short, while tetracycline was an innovation, it was well-situated within a legitimate institution. Physicians were able to understand almost immediately that tetracycline was both a member of a legitimate category and high quality by the standards of that category. As such they adopted it rapidly, with only a little regard to the behavior of rivals and it is telling that doctors who had significant experience with similar drugs were especially likely to start prescribing tetracycline immediately.[7]

Of course not all innovations that conform to incumbent institutions dif-

[7] The original report of tetracycline diffusion emphasized network contagion diffusion and it is still often cited as a case of either cohesion contagion or structural equivalence contagion (Coleman et al., 1966; Burt, 1987). However secondary analyses have established that while there may have been some contagion, it was a fairly small component as doctors adopted the drug too rapidly to have been much influenced by peers (Marsden and Podolny, 1990; Valente, 1993; Van den Bulte and Lilien, 2001). Some secondary analyses of the data still find some endogenous dynamics (Friedkin, 2010; Strang and Tuma, 1993). Whether one measures contagion effects in the tetracycline data is largely determined by such specification issues as city-level random intercepts and whether one assumes peer influence must be lagged or can be simultaneous.

fuse by the exogenous pattern. An actor might delay adoptions until after peer adoptions even if she considers an innovation to be thoroughly legitimate if there are issues of strong network externalities, limited availability (either from manufacturing constraints or intellectual property rights), high initial price, limited marginal improvement over a competing incumbent innovation, or strong complementarity with another innovation which is not itself widely extant.[8] Perhaps most importantly, if there is no exogenous force (such as a marketing campaign) creating awareness of the innovation, then only word-of-mouth can create awareness and so adoption would necessarily follow an increasing hazard even if every potential adopter finds the innovation to be so legitimate that she adopts immediately on being made aware of the innovation. The only claim is that for awareness and adoption of an innovation to be closely coupled, the innovation must derive legitimacy from institutional conformity. Therefore such institutional conformity is a necessary, but not sufficient, condition for an innovation to diffuse via a constant hazard.

Proposition 1: Only innovations that are nested within legitimate institutions may have a substantial constant hazard.

While innovations can diffuse rapidly when they are nested within already established institutions, in other cases innovations are truly novel and represent the first member of a category to which a population is exposed. In such cases the category has yet to achieve institutional legitimacy with the population. As such the innovation is not able to borrow the legitimacy of an incumbent institution but must make the much more ambitious case for both it's own worth and that of the category to which it belongs. These innovations are coterminous with the institutions they inhabit and so many "diffusion of innovation" studies are studying not only the diffusion of an innovation, but the diffusion of an institution.

For instance, the seminal "hybrid corn" study was studying not only the diffusion of a particular variety of maize, but coterminously the practice of purchasing seed corn rather than reserving a part of the previous year's har-

[8]While second or later generation products within a category benefit from legitimacy they suffer from substitutability with the existing stock of earlier generation products in the category (Pae and Lehmann, 2003). In 2007 and 2008 both Blu-Ray video players and the Windows Vista operating system had disappointing sales even though their basic product categories were thoroughly legitimate, indeed, nearly universal. The problem was that most potential adopters did not see them as sufficiently great improvements to warrant replacing perfectly functional DVD players or Windows XP installations. Furthermore, both innovations were only really useful if used with other innovations that at the time had low market penetration, respectively, televisions with 1080p resolution and computers with at least three gigabytes of memory.

vest (Rogers, 2003; Ryan and Gross, 1943). While hybrid seeds grow into high quality plants, they do not breed true so a farmer must purchase commercially produced seed every planting season. This new business model offered higher crop yields but had the downside of exposing farmers to more debt. The result was that the coterminous diffusion of the institution and the innovation was slow and involved great attention to peer behavior. The timing of adoption was consistent with an endogenous process and in retrospective interviews most farmers reported that they made the final decision to try the new seed only after seeing it work for neighbors. Likewise, much of the diffusion of innovation literature involves public health research in which women are encouraged to use family planning (Freedman and Takeshita, 1969; Placek, 1974; Rogers, 2003). This may involve not just diffusing technical innovations like the pill or IUDs, but the much more arduous coterminous diffusion of "family planning," a new institutional conception of gender relations and fertility in which women (rather than their husbands or fathers) are the locus of reproductive agency and children are not a blessing but a burden. The diffusion of IUDs among third world women in the 1960s is qualitatively different than the diffusion of the NuvaRing among American women in the last decade since to the latter the generic concept of scientific birth control is a thoroughly familiar, even taken-for-granted, concept.

This issue is much discussed in the diffusion of innovation literature where it is mostly known not as legitimacy or institutions, but as "compatibility" which is "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" Rogers (2003, p. 240).[9] A review of compatibility studies (mostly qualitative studies of failed public health and development campaigns) leads Rogers to "Generalization 6-2: The compatibility of an innovation, as perceived by members of a social system, is positively related to its rate of adoption" (2003, p. 249). Rogers does not decompose "rate" into a constant and increasing component, but in all of his examples he implies that compatibility will make the target audience more receptive to the entreaties of "change agents" such as salesmen or public health workers. Since such change agents are exogenous to the system, their efforts will not be an increasing function of local adoptions

[9]Note that "compatibility" is in many ways a less nuanced concept than "institution." Compatibility is understood in relation to a culture in its totality and is usually invoked regarding attempts to spread technologies and practices from more to less technologically advanced societies. In contrast, institutionalism is congruent with the toolkit conception of culture and is readily applicable to both more and less advanced societies (Swidler, 1986). Furthermore, institutionalism has a well-articulated understanding for the role of elites (DiMaggio and Powell, 1983; Strang and Meyer, 1993).

(Bass, 1969). Thus we can extrapolate that innovations that are compatible with incumbent institutions will diffuse with a constant hazard. In contrast, when innovations lack institutional legitimacy they can only be legitimated by direct observations of peer behavior.

Proposition 2: Innovations that deviate from extant institutions will either diffuse via increasing hazards or not at all.

Of course the stock of institutions itself is not static but can derive from experience. As the field gains successful experience with aberrant innovations, their common properties are institutionalized and future innovations along these lines benefit from legitimacy. As a category becomes more popular it becomes more familiar and cognitively accessible such that future innovations along similar lines benefit by analogy with the extant innovation. For instance a few decades after hybrid corn seed conquered the corn belt, hybrid sorghum seed was introduced to Kansas. On strictly technical grounds, farmers in arid Southwest Kansas would have benefited tremendously from adopting the new seed but they did so slowly because they lacked experience with the concept of purchasing hybrid seed and thus to them hybrid sorghum lacked legitimacy. In contrast, the seed was not especially useful in temperate Northeast Kansas, but farmers there had experience with the analogous hybrid corn seed, and so in the first season they planted 27% of their sorghum acreage with the new seed and would have planted it more but they exhausted the seed company's inventory (Brandner and Strauss, 1959). Moreover, institutionalization can be conceived of as practices not only spreading, but taking root by developing a legitimating rhetoric and being integrated into social structure (Colyvas and Jonsson, 2010; Green, 2004). So while affirmative action began as a response to state demands that often consisted of just filing reports with government auditors, over time companies developed an elaborate "diversity management" ideology advocated by an array of consultants and internal stakeholders within firms who promoted the perpetuation of affirmative action long after demands from the state abated (Dobbin and Sutton, 1998; Kelly and Dobbin, 1998). These dynamics are the mechanisms through which institutionalization occurs and are more powerful as the related innovations become more prevalent. Hence the relationship can be approximated as density dependence (Hannan and Carroll, 1992; Hsu and Hannan, 2005).[10] Firms in nascent industries suffer from a lack of legitimacy for their product category such that capital

[10]Note that in organizational ecology, "density" is simply frequency rather than a ratio of frequency to some broader set. This paper follows that literature in using "density" to mean a count, as distinct from the related concept of "saturation" to mean the count as a fraction of the total population or ratio to carrying capacity.

is hesitant to invest in the field and potential customers don't understand why the product is desirable, a pattern not only understood by the scholarly literature but the business press which has noted that the paradox of innovative product launches is that to be successful new product categories require both cognitive accessibility and ancillary services but these conditions tend to exist only for mature product categories (Moore, 1999). Regardless of mechanism, the more popular innovations within a category are the more institutionalized the category becomes. For instance, within broad categories of policy earlier initiatives seem to legitimate subsequent initiatives such that the category as a whole, rather than just specific initiatives, seems to tip at a certain point.[11]

Proposition 3: Successful past experience can institutionalize the conventions of heretofore aberrant innovations.

Above I have reviewed the literature on diffusion of innovations and the nesting of innovations within institutions and the related issue of "compatibility" with local culture. From this I derived three theoretical propositions. First, only innovations that are sufficiently legitimated by conformity to institutions can diffuse via "exogenous" patterns. Second, less legitimate innovations will diffuse endogenously or not at all. Third, successful innovations can institutionalize their product categories. In the next section I will formalize these propositions in a simulation.

4 Simulation

While the literature reviewed above has tackled the issue of how legitimacy can affect diffusion, it has done so with the implicit or explicit assumption that the role of legitimacy is to catalyze more rapid endogenous diffusion. However, this assumption is only valid for relatively small legitimation effects. As shown in the following simulation, it is a corollary of the threshold model of diffusion that large legitimation effects imply proximately exogenous diffusion patterns.

Threshold models treat each actor as having a threshold for adoption drawn from a distribution. When the innovation's popularity (with network alters and/or the field as a whole) exceeds the actor's threshold, the actor adopts (Abrahamson and Rosenkopf, 1997; DiMaggio and Garip, 2010; Gra-

[11]Studies of hate crimes legislation across American states and neoliberal reforms across countries both show that specific policies within these policy categories all tend to tip at the same time, around 1986 and 1993 respectively (Grattet et al., 1998; Henisz et al., 2005).

novetter, 1978). The actor in this model can be seen as analogous to a nerve cell, which fires when incoming synapses meet the cell's particular threshold. Likewise, thresholds can be thought of as analogous to reservation prices in price theory, except adoption is not triggered by low price but high popularity. The model is flexible enough that we can imagine that intrinsically appealing innovations (e.g., facially plausible ideas) may require less peer influence to be adopted than intrinsically unappealing innovations (e.g., facially bizarre ideas) (Centola et al., 2005). For instance, state legislatures may pass laws immediately when they are simple and salient to voters (such as "three strikes" for repeat criminal offenders), but wait to see how other states handle the proposal when the law is less obviously a political winner by virtue of its complexity and obscurity (such as "individual development account" tax sheltered savings accounts for poor people) (Nicholson-Crotty, 2009). In the simulation below I model actors' thresholds as being sensitive to popularity of both the innovation itself and the category to which the innovation belongs. When the categorical density is high, the adoption curve at the innovation level becomes exogenous.

The Stata code for the simulation is given in the appendix. Start by assuming a population with latent adoption thresholds drawn from a standard normal and with a small seed group already having adopted. Let the actors assess a dubious innovation, the ex ante appeal of which is so small as to only appeal to actors with extremely low thresholds, three standard deviations below the mean. However assume an endogenous effect arbitrarily set such that every 20% of the population that has adopted increases the appeal of adoption sufficient to meet the thresholds of another one standard deviation of actors. In any given period an actor adopts if a random variable centered on the actor's latent adoption threshold meets the appeal of the innovation, as adjusted for its current popularity.[12] Finally, we can assume that actors are not only sensitive to how many peers have adopted the particular innovation, but also other innovations in the same category. We can arbitrarily set this sensitivity to categorical density such that every twenty extant innovations in a category makes the new innovation one standard deviation more appealing.[13] We can then allow the simulation to run

[12]Setting the endogenous effect higher provides similar results but setting it lower implies that diffusion is always essentially exogenous. Similar results obtain if the simulation uses an additive instantaneous error term instead of centering an instantaneous random variable on the actor's latent tendency. Curious readers are invited to experiment with applying different parameters to the simulation program.

[13]I treat categorical density as the count of extant innovations for the sake of simplicity in this simulation. Substantially similar results obtain if categorical density is defined as

for twenty-five iterations for each innovation and up to sixty innovations in the category and see the pattern of diffusion.

The results are given as both a surface plot and a line plot in figure 2. In both plots the horizontal is time since the innovation's launch and height is the innovation's saturation at time. The density of the category of which the innovation is a member is shown as depth in the surface plot and (for selected densities) as separate lines in the line graph. The first innovation within a category (front-most in the surface graph or dots in the line graph) is s-shaped but shallow and only tips around the 13th iteration. This indicates an endogenous growth process, albeit a slow one. As the category accrues density, the diffusion of each innovation is more rapid but by the 20th category it still follows a distinct s-curve. However once categorical density reaches a critical mass, in this simulation about 30 or 40 extant innovations in the category, the curve for each new innovation changes qualitatively from an s-shaped curve to a convex curve, indicating a diffusion process that is indifferent to proximate peer behavior and is usually interpreted as "exogenous." By the 60th innovation (rear of the surface graph or solid line in the line graph) the graph is completely convex. Note that at what categorical density the innovation-level dynamic switches from endogenous to exogenous is of course a function of how sensitive actors are to categorical density and this parameter is assumed by the simulation. The point of the simulation is not to pinpoint exactly what the critical mass of categorical density is, but rather to show that if we assume actors to be sensitive to categorical density then at *some* point this implies qualitative changes for how innovations within that category diffuse. Once this occurs, we can meaningfully say that the category is institutionalized and innovations embedded within the category are ipso facto legitimate.

4.1 Implications of the Simulation's Assumptions

The above simulation deliberately uses parsimonious and clean assumptions because this allows for more tractable theory-building than complicated and nuanced assumptions (Kanazawa, 1998; Tilly, 2004). Nonetheless, social reality is messy and so having accomplished the theory-building synthesis it is worthwhile to discuss how sensitive it is to these assumptions and what the implications might be of changing them. Below I discuss implications of the following assumptions: the standard issues of the innovation-level Bass model, that categorical density has a direct and linear legitimation effect,

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the sum of innovation saturations.

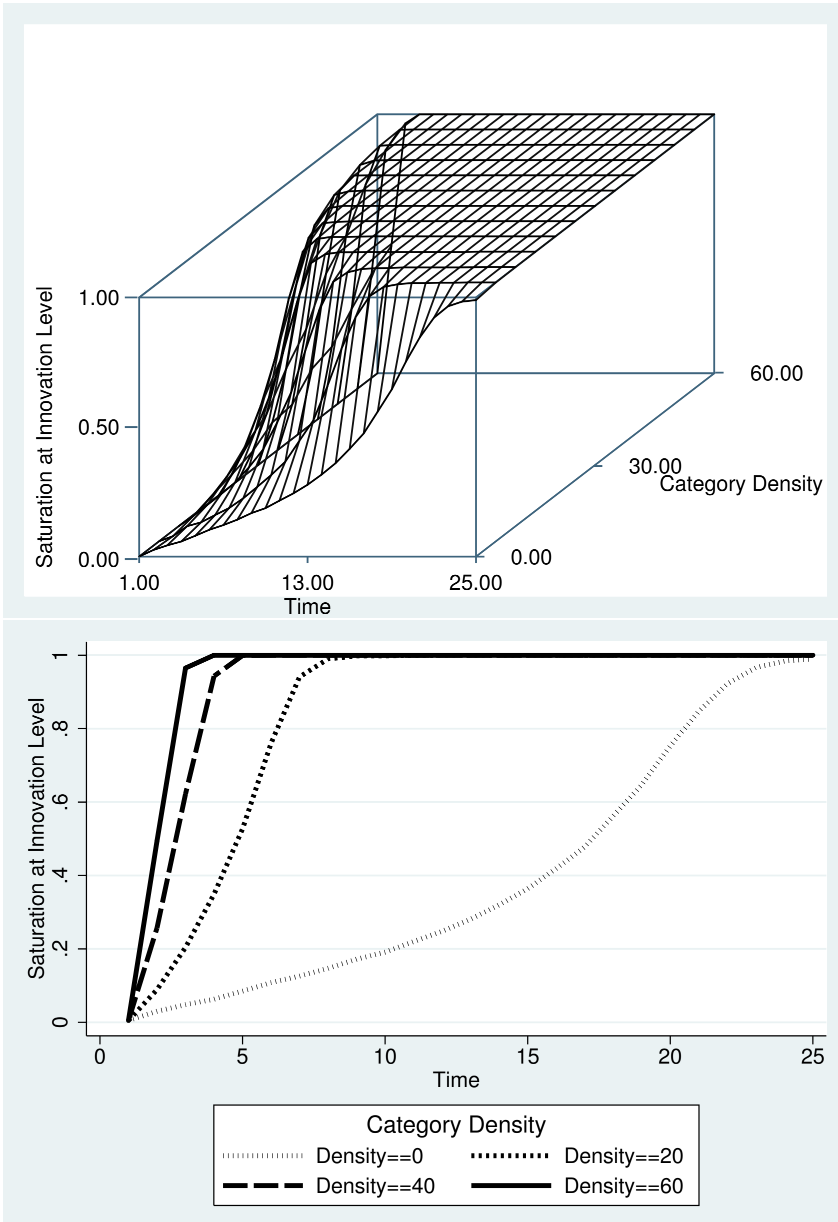

Figure 2: Simulated Innovation Diffusion by Category Density

that innovations fall neatly into discrete categories, and that categorical legitimacy effects are homogeneous across all actors.

First, this paper adopts several assumptions at the innovation level from the Bass (1969) model, all of which are most relevant to the endogenous aspect of diffusion. The Bass model assumes that an actor's adoption of an innovation is discrete, irreversible, and perpetually contagious. This assumption is realistic for many innovations over the short to medium term but in other cases a more elaborate model like the SIR (susceptible-infectious-recovered) model in epidemiology is appropriate. Another simplifying assumption is the idea that endogenous diffusion occurs at the field-level rather than through physical space, across a social gradient, or through network structure. This is a realistic assumption if we assume that actors are less attentive to local adoptions than to field-level summaries of behavior (e.g., bestseller lists or retail inventories that prefer bestsellers) (Anderson, 2006; Salganik et al., 2006; Sorensen, 2007). Even if diffusion does occur through network structure, the process is closely approximated by a non-spatial model if the social network has a low to moderate degree of segregation (Turchin, 2003; DiMaggio and Garip, 2010). So for the most part the simulation should be robust to the simplifying decision to specify generalized endogenous effects rather than contagion through an adjacency matrix. However there is one important way in which a network structure might affect the simulation of categorical density effects. Intrinsically unappealing innovations can only spread when networks are highly clustered and have few random graph elements whereas intrinsically appealing innovations spread much more rapidly with the addition of random graph elements (Centola, 2009; Centola and Macy, 2007; Centola et al., 2005; Hedstrom et al., 2000). Since in the simulation innovations with low categorical density have little appeal, this implies that early in the development of a category, innovations will spread most rapidly through highly clustered network structures. Hence we might expect insular cliques to be especially fecund in birthing novel innovations but once categories mature new innovations within these categories will come from more integrated parts of the social system.

At the categorical level, the simulation assumes that density directly translates into legitimation. This is partly based on the assumption that increased categorical density makes the category more cognitively accessible to the actor but also that structural aspects of institutionalization are a function of categorical density. If we relax this assumption and make institutionalization loosely coupled to categorical density we can allow more room for the agency of stakeholders, activists, institutional entrepreneurs, gurus, theorists, etc. (Briscoe and Safford, 2008; Colyvas and Jonsson, 2010;

Dobbin and Sutton, 1998; Green, 2004; Rao, 2009; Strang and Meyer, 1993). Specifying imperfect mediation into the simulation would preserve its general implications but would make the shift from "endogenous" to "exogenous" innovation-level diffusion even more abrupt.[14] Thus elaborating the mechanism through which categorical density is related to diffusion may make the dynamic more complex and subtle but preserve the broad outline of the relationship that autonomy presupposes legitimacy and legitimacy is usually related to categorical density.

A more complex issue is the treatment of categories as clear and discrete. This paper assumes that an innovation is clearly nested within a single category (which may or may not be legitimate) and categories are nominally distinguished, lacking adjacency, hierarchy, or confusion vis-a-vis other categories. In fact, many market objects and actors are simultaneously within several categories, which implies such issues as focused or unfocused identities and niche width (Hsu, 2006; Hsu and Hannan, 2005; Zuckerman, 1999). Likewise, new product categories do not come ex nihilo but are usually understood as offshoots or hybrids of existing forms (Kennedy, 2008). This implies that the issue which here is called simply "categorical density" is not just how dense the category is, but how plausible is the innovation's claim to the category, with the issue compounded if the innovation straddles several categories. Furthermore, literature on the problem of unfocused identities suggests that combining categorical identities can not be reduced to anything as simple as the average legitimacy of all the categories to which the innovation is attached (Hsu, 2006; Zuckerman, 1999). Exploring the implications of categories in the plural is beyond the scope of this paper, but it is interesting to note that it implies that there is not necessarily a natural zero for categorical density since almost any new category will not be completely novel but can make some kind of claims on earlier categories. This implies that successful institutionalization rhetoric should emphasize continuity with extant categories early on and then a distinct identity as the category matures (Kennedy, 2008).

A related assumption is that categorical density has homogeneous effects throughout the field. This assumption is somewhat unrealistic if we assume that categorical density works through mechanisms at or close to the actor-level *and* that actors have substantial variance in their exposure to extant members of the category. So for instance we could array individual consumers

[14]For instance, the mediation mechanism suggested by Green (2004) can be operationalized in the simulation by modeling discourse as a random quadratic function of categorical density.

on a continuum from technophobes to gadget geeks based on their individual familiarity with the product category of consumer electronics. Once the category of consumer electronics matures, such a scenario is likely to result in something like the Bass mixed influence curve with the gadget geeks adopting any new gadget immediately followed by endogenous diffusion promoting the new gadget to broader populations for whom the category is not as institutionalized. Alternately we can imagine that heterogeneity in exposure to a category is highly clustered at the group level. For instance, early Christianity was a synthesis of Judaism and Hellenism and the resonance the new religion had with these systems of thought was more legitimating for Jews and Greeks than for Latins (Stark, 1996).[15] In the extreme case we can imagine isolated populations of actors and so categorical density is effectively categorical density for that population. A relaxed version of this scenario would be to imagine a situation where groups are especially attentive to their own group but also sensitive to trends within other groups, such as consumers who are aware that a product while new to them was a big hit in the neighboring country (Dekimpe et al., 2000). Either the isolated or cosmopolitan scenario is compatible with the model presented in this paper so long as categorical density is specified relative to the salient population.

Although the simulation does not explicitly integrate the assumptions discussed here they provide the opportunity for further theoretical elaboration. As discussed, relaxing most of these assumptions would complicate the model without changing its essence: that legitimate innovations can diffuse by constant hazard functions, that illegitimate innovations will diffuse by increasing hazard functions, and that as density in a category rises future members of the category shift from the illegitimate to the legitimate pattern. In the final section I will discuss some implications of these inferences for the broader literatures on diffusion and institutionalism.

5 Conclusion

This paper has argued that if an innovation is situated within a highly legitimate institution, the innovation can diffuse rapidly without the s-curve characteristic of cascades and contagion. Although actors may often be in-

[15]Not only did Christianity reach thoroughly Hellenized regions like Asia Minor much earlier than Latin regions like North Africa, but even in the city of Rome the early church mostly served Greek-speaking minorities. The church did not begin to develop a Latin liturgy or literature until the papacy of Victor I (189-199) and it was only in the late 4th century that the church in the West became characterized by such Latin speakers as Ambrose, Jerome, and Augustine.

fluenced by one another's behavior, drawing information from peers may be superfluous if the innovation is sufficiently compelling by virtue of its membership in an institutionalized category. When actors internalize shared expectations they can each apply these rules directly, which creates a proximately atomistic pattern of behavior that is nonetheless collective through the mechanism of the shared expectations.

Consider the example of a religious service. Most religions do not expect the congregation to sit passively like bored undergraduates in a lecture, but to engage in fairly elaborate choreography of kneeling, standing, sitting, bowing, chanting, reciting creeds, making various hand gestures, etc.. Devout congregants will anticipate the rhythm of the service such that a congregation composed entirely of such devout worshipers will see the onset of a ritual behavior follow an exogenous pattern as each worshiper responds directly to cues in the service. In contrast, infrequent worshipers will not be so practiced and so a congregation composed mostly of infrequent worshipers will see the contagious onset of behavior as they do not necessarily attach any significance to the rabbi opening the ark or the reader placing the gospels on the lectern but do notice that more and more people in the front pews have started standing and probably ought to be imitated. That is, the infrequent worshipers are more attentive to each other's prayer behavior than are the frequent worshipers. Hence, a naive view of "social action" would lead us to the conclusion that the devout congregation at the weekday mass or the morning minyan is *less* social than the merely annual attendees at an Easter or Yom Kippur service – a bizarre inference when one considers that it is the weak religious attachment of the holiday worshipers that leads them to imitate each other as they lack the strong socialization into religious observance necessary to follow the service directly.

That is, "exogenous" behavior is really social in that the participants have such a strong set of shared expectations that peer behavior can be anticipated rather than waited for and observed. This can be the case even for behavior that is, in a theoretical (but not predictive) sense density dependent. "Coordination games" are situations where it is important that the actors converge on a common behavior, for instance if several manufacturers hope to benefit from network externalities by agreeing on an industrial standard. These issues are density dependent in the sense that the pay-off is a function of density, and may in fact be density dependent in the sense of endogenous diffusion. However actors can solve a coordination game simultaneously if they have sufficiently strong shared expectations so as to anticipate each others behavior even without communicating (Schelling, 1960). Many diffusion problems can be conceived of us as protracted coordination games that can be most rapidly resolved through shared expectations. For instance, most people would feel embarrassed to be the only one applauding a speech, but they can still do so without waiting for others since the institutional structure of rhetoric lets them converge on anticipated peer behavior (Heritage and Greatbatch, 1986). Going from a scale of seconds to a scale of months, many innovations are most useful if they are adopted widely, and so format wars tend to be resolved endogenously unless and until a trade group certifies a standard and thereby lets all actors anticipate one another's future behavior (Augereau et al., 2006; Dranove and Gandal, 2003). Institutions can serve to promote coordination without communication by providing a cognitive context through which innovations diffuse (Strang and Meyer, 1993). Understanding how innovations are nested within institutions can provide a means of bridging cultural and structural approaches, making the former tractable and the latter realistic.

Note that since few innovations are thoroughly idiosyncratic, this suggests that many innovations would diffuse via constant hazard functions which in turn raises the question of why the literature pays so much less attention to these patterns than to various endogenous processes. First, it may actually be the case that constant hazard functions are rare. The model presented in this paper assumes certain auxiliary scope conditions, most notably that awareness be immediately universal. Adoption can never outpace awareness and so a constant hazard for adoption presupposes an exogenous force (such as a marketing campaign or a decree from the central state) creating awareness. Another scope condition is effectively unlimited reproducibility, a condition that can be failed by manufacturing constraints, proprietary contracting, or intellectual property rights. Manufacturing constraints seem to have been a limit to what would have otherwise been almost immediate adoption of hybrid sorghum in the temperate regions of Kansas (Brandner and Strauss, 1959). The Apple iPhone provides a good example of legal barriers to diffusion, being exclusively contracted to AT&T in the United States and with Apple suing HTC and Palm for offering similar products. Thus even if this paper's theoretical model is valid, its results could fail to generalize if such scope conditions as immediate universal awareness and immediate universal availability do not prevail. In other words, institutionalization may be a *necessary* but not sufficient condition for rapid diffusion of an innovation. However there are cases where the scope conditions are essentially unproblematic, especially circumstances where a powerful actor has ensured widespread awareness but imposes no limitations on adoption. The tetracycline case is a good example because Pfizer went to great lengths to ensure that all physicians were aware of tetracycline and sent large stocks of it to pharmacies that would honor any doctors' prescriptions (Coleman et al., 1966). Likewise, the spread of pop singles among radio stations meets these scope conditions since there is a standard mechanical royalty and record labels heavily market songs to stations (Rossman et al., 2008). We might expect similar fulfillment of the scope conditions in any field with an active trade press and either open architectures or nonexclusive licensing.

Second, there may be a case selection problem. Most diffusion studies in sociology are less interested in the diffusion of a particular innovation than they are in the diffusion of institutions and they tend to use innovations as indicators of institutions, which themselves are latent. That is to say that sociologists tend to select cases in which a new innovation and a new institution are diffusing coterminously and thus the category has no density from which the innovation can borrow legitimacy. Thus it is not surprising that hybrid maize, IUDs, and central bank independence all follow a roughly s-shaped diffusion curve as each was *deliberately* chosen by its researchers as a leading innovation within the institutions of, respectively, agricultural extension service technologies, scientific birth control, and neoliberalism (Polillo and Guillen, 2005; Rogers, 2003; Ryan and Gross, 1943). If we imagine a counterfactual research tradition in which researchers purposely select cases that are firmly situated within established institutions we might expect to see more cases where these innovations diffused via constant hazards. Compared to sociology, marketing is less interested in large social and cultural shifts and more interested in the spread of particular products and thus one testable implication of this speculation is that a meta-analysis comparing diffusion models in sociology to those in marketing would show more constant hazard functions in our sister discipline.

Third, publication bias and emphases in theoretical framing may be suppressing or downplaying findings of constant hazards. Endogenous processes — whether locally through networks or generally by means of cascades or externalities — are a distinctly and obviously *social* class of phenomena. As such the idea that fads are emergent from micro-interactions is exciting to a discipline that constructs its self-identity in opposition to methodological individualism. Given such an orientation, imagine the researcher who discovers (or the peer reviewer who reads) that a particular innovation diffuses such that in every period proportion h of holdouts adopt and h is not a function of whether ego's peers have adopted. Given that the inevitable question "is it sociological" answers itself when asked of endogenous processes, such a finding of diffusion by constant hazard must not seem like a positive finding but a disappointing *failure* to find contagion.

Probably the best example of this is the seminal tetracycline diffusion study (Coleman et al., 1966). To a first approximation, doctors had an essentially constant hazard function for adopting the drug with the raw number of adoptions per month starting high and declining as the risk set became saturated. However the tetracycline study is famous for being one of the first attempts to rigorously synthesize social network data and diffusion data and both the original authors and many secondary analyses have emphasized the comparatively minor extent to which endogenous processes (i.e., cohesive contagion, structural equivalence contagion, and generalized cascades) can be found in the data and largely bracket the more substantial exogenous effects of the drug company's marketing efforts and medical journal articles about clinical trials (Burt, 1987; Friedkin, 2010; Strang and Tuma, 1993; van den Bulte and Lilien, 2001). The contagion findings in the data are real, but it is telling that in the original report and most secondary analyses they are given more emphasis than the much larger baseline constant hazard. The general sense seems to be that a good finding is social and findings that appear to show individuals acting autonomously are more suited for the desk drawer, or at best a footnote in a paper highlighting appropriately social findings. Indeed, the standard definition of diffusion "excludes atomistic decision-making processes where actor choices are uninformed by the activities or choices of others" (Strang and Meyer, 1993, p. 488). Bracketing the issue of whether our data have an obligation to us to be "social," the argument of this paper is that what appears to be autonomous or exogenous may in fact be radically social and hence provides a justification and a road map for bringing the social back in, even to seemingly autonomous behavior.

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Appendix: Stata Script for Simulation

```
*graph requires surface.ado, ‘‘ssc install surface’’
clear all
capture program drop simdiffuse
program define simdiffuse
  local endo=1/‘1’ /*innovation endogenous effect*/
  local endomacro=1/‘2’ /*category endogenous effect*/
  local appeal=‘3’ /*ex ante appeal of the innovation */
  local ninnov=‘4’ /*number of innovations in category*/
  *seed
  disp "endo=‘1’ appeal=‘appeal’ endomacro=‘3’ ninnov=‘ninnov’"
  clear
  tempname simresults
  tempfile simresultsfile
  postfile ‘simresults’ endo endomacro appeal t adopt catdensity using "‘simresultsfile’"
  quietly set obs 1000
  quietly gen x0=rnormal()
  quietly gen adopt=0
  quietly replace adopt=1 in 1/5
  *iterations
  forvalues catdensity=0/‘ninnov’ {
    quietly replace adopt=0
    quietly replace adopt=1 in 1/5
    forvalues t=1/25 {
      quietly sum adopt
      post ‘simresults’ (‘1’) (‘2’) (‘appeal’) (‘t’) (‘r(mean)’) (‘catdensity’)
      quietly replace adopt=1 if ‘appeal’+(‘r(mean)’*‘endo’)+(‘catdensity’*‘endomacro’) > rnormal(x0)
    }
  }
  postclose ‘simresults’
  use ‘simresultsfile’, clear
end
simdiffuse .2 20 -3 60
twoway (line adopt t if catdensity==0, lcolor(black) lwidth(thick) lpattern(dot)) /*
  */ (line adopt t if catdensity==20, lcolor(black) lwidth(thick) lpattern(vshortdash)) /*
  */ (line adopt t if catdensity==40, lcolor(black) lwidth(thick) lpattern(longdash)) /*
  */ (line adopt t if catdensity==60, lcolor(black) lwidth(thick) lpattern(solid)) , /*
  */ legend(subtitle("Category Density") order(1 "Density==0" /*
  */ 2 "Density==20" 3 "Density==40" 4 "Density==60")) /*
  */ xtitle(Time) ytitle(Saturation at Innovation Level)
graph export figure2_lines.eps, replace
drop if mod(catdensity,5)>0 /*keep only every fifth density, makes for cleaner graph*/
surface t catdensity adopt, ztitle(Saturation at Innovation Level) /*
  */ ytitle(Category Density) xtitle(Time)

graph export figure2_surface.eps, replace
```