Networks, Brokerage, and State-Led Technology Diffusion in Small Industry[1]

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The concept of "embedded autonomy" speaks to the importance of coordination and bidirectional information exchange between Weberian bureaucrats and their private sector interlocutors. It has proven influential in the sociology of development, where it originated, and in the broader discipline. But the prospects for bidirectional information exchange depend upon the structure and nature of the private sector, which has been all but overlooked by the literature on embedded autonomy. This article therefore encourages scholars to take private sector structure seriously by bringing existing network analytic methods to bear on the embedded autonomy debate. Specifically, I identify a tension between the requisites of information gathering, which is facilitated by nonredundant ties among actors, and information diffusion, which requires redundant ties; demonstrate how one Mexican agency has resolved this tension in assisting the upgrading of the artisanal ceramics sector; and conclude that the strategic filling of social network holes lies at the heart of effective bureacrats' efforts to promote development.

The concept of "embedded autonomy" (Evans 1995)—the idea that state bureaucracies work best when they are insulated and professional at the same time that they are deeply immersed in private sector networks—has been a

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major presence in scholarship on state-society relations and development. It has been cited thousands of times, been invoked to explain the success of the East Asian newly industrializing countries, to cast doubt upon the utilitarian notion that unfettered markets would drive national development, and to provide a broader framework for the study of state-society relations not only in sociology, where the concept originated, but in political science, planning, and economics as well.[2] The core insight of the framework is that a balance of Weberian autonomy and social embeddedness allows public officials to reconcile their own developmental goals with the incentives faced by private actors in different social and political contexts. Although Peter Evans developed the concept—and the corresponding framework—by examining the interactions of elite bureaucrats in pilot agencies and large firms in manufacturing industries (see also Johnson 1982; Amsden 1989, 2001; Wade 1990), his successors have challenged the importance of pilot agencies (Breznitz and Ornston 2012), identified cases of "multiple embeddedness" (O'Riain 2004), and discussed a "redistributive form of embedded autonomy" that prioritizes equity rather than growth (Heller 1999, p. 17). However, the actual features of the private sectors in which the officials are allegedly embedded remain underspecified. The best studies recognize the challenges of diffuse actors and interests and offer pessimistic, if vague, prognoses when the private sector is "less organized" (including Evans's own discussion of "encompassing embeddedness" [2010]); others simply ignore the private sector outright. More than a decade ago, therefore, Mark Granovetter identified the study of how state bureaucracies "become embedded with the business world, and how that can change over time," as the "logical next step" in the neo-Weberian research program (Krippner et al. 2004, p. 124). "How is business embedded within itself?" he asked. However, since then his question has hardly been broached, let alone answered, despite the widespread availability of network analytic tools and insights.

The purpose of this article is to begin to answer Granovetter's call by systematically examining how the nature of social relations shapes the manner in which bureaucrats are able to bridge what Nobel laureate Elinor Ostrom (1996) calls "the great divide" between the public and private sectors. In so

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[2] For example, it has been employed in areas as diverse as industrial policy (Rodrik 1997; Rodrik/World Bank 2008), globalization (Weiss 1998), European regionalism (Ansell 2000), public service provision (Ostrom 1996; Tendler 1997), taxation (Bernstein and Lü 2003), environmental sustainability (Frickel and Davidson 2004), petroleum extraction (Lewis 2009), and crime management (Lo 2009). Google Scholar reports over 5,500 citations of *Embedded Autonomy* (Evans 1995) alone, with hundreds more for related pieces.

doing, I argue that an understanding of embedded autonomy grounded in networks has critical and current implications for sustainable development and economic upgrading in poor countries. I propose that, given the uneven distribution of information among key stakeholders (Burt 2008), bureaucratic success may depend less upon the embeddedness of the bureaucrats themselves than upon the structure and nature of network ties among their private sector interlocutors. Specifically, if private enterprises have uneven ties between them and are geographically fragmented, bureaucrats face a tension between developing network relations that are useful for *gathering* information and those for *disseminating* information. Where government officials are able to develop communication with otherwise unconnected clusters of enterprises (what network analysts call "nonredundant" ties), they can maximize their capacity to gather varied (partially "nonsubstitutable") information about local conditions in order to understand the range of production issues policy should address. However, information is most efficiently diffused in situations where enterprises have multiple and overlapping ties to one another (so-called redundant ties). These insights draw upon ongoing debates about the benefits of network redundancy (Burt 2008; Podolny 2008; Reagans and Zuckerman 2008). More generally, I suggest that, in the context of fragmented private industry, it is possible to examine public-private ties systematically to determine where they exist, where they do not, and how that structure affects industrial behavior. Ultimately, rather than a definitive statement on state-society relations or innovation networks, this study is intended to encourage scholarship on development to take both the *structure* of the private sector and the conceptual and empirical *tools* sociologists use to study that structure more seriously.

To illustrate these points, I demonstrate how public sector efforts to disseminate a lead-free glaze in the Mexican ceramics sector have been shaped by the structure and nature of network ties in the private sector. This discrete developmental effort reveals the relative success of an autonomous state agency's ties to dense networks of private producers, contrasting that situation with the limits of dissemination where producers have fewer ties or where committed local contacts/brokers are not available; in the process I link the literature on embedded autonomy to earlier scholarship on the diffusion of innovations (e.g., Coleman, Katz, and Menzel 1957; Valente 1995) and to more recent scholarship on the dynamics of technology diffusion within industry clusters (e.g., Giuliani and Bell 2005; Giuliani 2007; Casanueva, Castro, and Galan 2013). In the following sections, I briefly review the role of public-private ties in industrial development and assert the importance of the shape and nature of private sector networks. I then introduce a least likely case for successful public-private coordination: the efforts of one autonomous government agency to diffuse a new productive technology in the unevenly organized Mexican ceramics industry. I use network data and

statistical models informed by ethnographic detail to both demonstrate the efficacy of private sector networks by assessing the effects of the program on producers who are networked to differing degrees with other producers in their communities and identify the relational work that underpins those structures. The final section offers conclusions and potential directions for further study.

DEVELOPMENT AND BIDIRECTIONAL INFORMATION BROKERAGE

Embedded autonomy is a concept synthesized by Evans (1995) from two disparate strands of literature: (1) Weber's work on the nature of bureaucracy and (2) the work of Gerschenkron (1962), Hirschman (1977), Johnson (1982), Amsden (1989), and Wade (1990) on late development in Europe and East Asia. From Weber, Evans draws the notion that bureaucrats and state agents should be autonomous or have a corporate identity that drives them to use their positions to pursue public goals rather than private goals motivated by other social relations. This corporate coherence implies insulation from and the capacity to resist the narrow interests of particular social groups. While retaining the idea of corporate coherence, Evans (1995) departs from the notion that complete bureaucratic insulation from society is ideal for transformative economic projects. Instead, to formulate effective and appropriate policies and strategies for economic advancement, bureaucrats should be "embedded" in civil society. This relationship allows for the bidirectional movement of information and coordination between bureaucracy and private actors. Gerschenkron (1962), Amsden (1989), and Wade (1990) stress that it is close public-private relations that allow for state interventions to be appropriately tailored to conditions in the private sector. Where autonomy is necessary for the state to be able to formulate developmental goals, the successful implementation of these goals is dependent upon embeddedness, which is the primary focus here.[3]

In spite of its influence, several issues have arisen with Evans's work and other early work on developmental states. Critically, much of it worked with the assumption that development policy was (1) directed by a central pilot agency that could (2) work with a coherent group of private industrialists, often operating in the same target sector. More recent thinking about the role of states in development has challenged the idea that state bureaucracy need be represented by such a pilot agency (Breznitz and Ornston 2012; see also O'Riain 2004; Breznitz 2007; Block 2008). In these scenarios, rather than a

[3] Following Wright (1996), I discuss embeddedness and autonomy as two independent conditions that are jointly necessary for transformative economic activity rather than discussing embedded autonomy as a compound condition that can be fitted along a single spectrum.

highly centralized Japanese MITI or a Korean Economic Planning Board, decentralized, self-directing agencies concern themselves with technological development projects. These decentralized developmental states—so-called developmental network states—are both functionally distinct and embedded in the private sector differently from the classical "developmental bureaucratic states" (O'Riain 2004). Where the latter undertook coordinated efforts in the interest of technological catching up and helping domestic firms compete in world markets they would not otherwise have entered, network states not only provide resources for the development of indigenous technologies but also broker and facilitate relationships among agencies, the private sector, and research institutions to that end (Block 2008). Regarding the relationship between the state and private sector in developmental network states, O'Riain refers to Irish state agencies as "multiply embedded" (2004, p. 149), referring to the fact that numerous state agencies maintain ties to private sector constituencies. The recognition that the state may not act through a single economic or technological development agency is important and fits with the notion that many states may have "pockets of effectiveness" (Roll 2014).

Although the necessity of pilot agencies has been drawn into question, the assumption has largely remained that the private sector groups with whom they are embedded are themselves cohesive. While this may have been very clear in some cases—Korean Chaebol, for example (Amsden 1989)—even studies that examine less obviously unified private sectors either ignore their structure or implicitly treat them analytically as coherent groups. Hence, while the question of the structure of state agencies—either from a central pilot agency, experimental peripheral agencies, or multiple state agencies—has come under analysis, the nature of the private sector has generally not. The critical issue is that the efficacy of state contact with the private sector relies on relationships within the private sector: if good policy making requires effective brokering of information between public agents and private enterprises and between private enterprises themselves, then the structure and nature of the private sector becomes central. Concern has tended to focus on the question of how agencies are structured and how bureaucrats are held accountable, rather than on how the private sector is structured, let alone whether and how that structure shapes the prospects for productive state-society interaction.

This concern also arises in scholarship on networks within industrial clusters, which has demonstrated that industries cannot be assumed to be coherent or coordinated units or subject to uniform flows of information, even in the most auspicious of situations where the firms are homogenous and spatially agglomerated (see Huber [2012] for review; Kirkles and Duysters 2010). Flows of information in particular are dependent upon both the structure of relationships between firms and firm characteristics, not just shared location (Giuliani and Bell 2005; Giuliani 2007; Casanueva et al.

2013). Similarly, the nature of relations within business organizations is consequential for the movement of information; information does not circulate as Marshall suggested "in the air" (1920). With very few exceptions (e.g., McDermott, Corredoira, and Kruse 2009), however, private sector linkages to government agencies/bureaucrats and the consequences of those relations have remained unexamined.

If information flows are highly contingent, unevenly connected enterprises pose serious challenges to state agencies that seek bidirectional information exchange: How might state agents both receive and effectively impart information to them? Scholarship on network dynamics provides critical insight into this issue. Specifically, this problem is a manifestation of the tension between knowledge and power in network structures articulated by Reagans and Zuckerman (2008). They argue that in network structures marked by nonsubstitutable information there is a trade-off—rather than a compatibility (as in Burt 1992)—between ties that maximize power and those that maximize information. On one hand, nonredundant network ties are more effective for the gathering of information (Granovetter 1973; Burt 1992) as redundancy does not produce additional information per tie. Where clusters of the same industry are isolated from one another, for instance, the need for nonredundant ties becomes particularly clear: information does not spread between closed clusters, as they are separated by network holes, so information must be gathered independently from each. The information that circulates in each cluster is likely to be nonsubstitutable, reflecting local practices and market conditions. On the other hand, *within* those clusters, closed networks information and practice are "relatively homogenous," and multiple overlapping and redundant ties are most effective for spreading information (Burt 2008, p. 957; see also Burt 2010). Multiple channels increase the rate and efficiency of diffusion. Regarding this tension, Reagans and Zuckerman (2008, p. 906) find that "while nonsubstitutability in the resources available from alters is the basis both for superior knowledge-access and for power as a resource-provider, it simultaneously lowers ego's power as a resource-acquirer." In network terms, then, this is clearly a dilemma faced by public agents seeking to establish effective bidirectional ties to industries characterized by disconnected or loosely organized clusters of producers in the same industry. This trade-off lies at the heart of the policy maker's need to both efficiently receive and diffuse information to the private sector and thus at the heart of developmental efforts to promote technological upgrading.

Where development literature has generally conceived the role of public agents as being met by their position *within* a dense private network, they may also be met by a more distant bureaucrat's reliable ties *to key actors in dense private networks*. Note the difference: in the former conceptualization, the bureaucrat is a full-fledged member of the private network, whereas in the latter he or she is more distant and can operate by establishing contact

with key nodes in the network. By working through these key nodes across clusters (i.e., nonredundant ties to multiple closed networks), bureaucrats can develop a means to gather information from a broad swath of relatively isolated networks; by ensuring that these private sector contacts are tied into local networks (i.e., dense, highly redundant), they maximize the potential for information to be effectively disseminated. Thus, we see a practical solution for these cross-cutting network pressures faced by state agents, and it is effective development planners who are able to assess and fill holes in social networks. Finally, while the *structure* of industry networks is critical, the *nature* of the ties is also important: private sector brokers between the industry networks and public agencies, in particular, need to sympathize with the goals of the agency as well as be trusted members of local networks. In the empirical section that follows, I illustrate these points with a discrete policy intervention in the traditional ceramics production in Mexico, where the effects and limitations of ties to private sector networks are demonstrated by way of ethnographic data, network visualization, and statistical methods.

UPGRADING IN THE MEXICAN CERAMICS SECTOR

Case and Methods

The traditional ceramics industry in Mexico is characterized by very small enterprises that are unevenly organized, economically marginal, and reliant on outmoded technologies. The private sector focus of studies of state-society relations has been dominated by innovative sectors (e.g., Evans 1995; Breznitz 2007; Ornston 2012), large conglomerates (e.g., Amsden 1989), and highly organized business organizations (e.g., Silva 1997; Schneider 2004). However, most enterprises in less developed countries tend to be more similar to isolated clusters of ceramics workshops than to large corporations. Small enterprises provide most of the jobs in developing countries and play a critical role in maintaining welfare. For example, roughly 95% of enterprises in Latin America—and in developing regions more broadly—are small. In Mexico—one of the more industrialized countries in Latin America—roughly one-third of all workers are employed in family workshops (*talleres familiares*; Secretary of Economy 2012).

Small enterprises both face higher organizational barriers and are more challenging for public agents to engage than their larger counterparts. First, small enterprises face more intractable collective action problems not only because numerically larger groups are harder to organize than smaller ones (Olson 1965) but because they lack the financial resources that might otherwise be dedicated to organizing (Shadlen 2002, 2004). Their financial precariousness also means that they have lower incentives to participate in longer-term "exchanges for improving productivity" (Murrillo, Scartascini, and

Tommasi 2008, p. 21). Second, larger numbers of interested enterprises inherently raise the transaction costs of policy makers' efforts to communicate effectively with the private sector (Schneider 2015). In short, it is easier for states to develop a coordinated developmental relationship with a small number of relatively well-endowed actors than with a multitude of small firms. Scholars who have focused on large and leading industry have built their analyses upon cases most likely to be organized (or assumed to be), to be engaged by the state, and to have personnel moving between industry and the public sector. Industries characterized by very small enterprises represent less likely cases for successful public-private coordination and are a telling test of the mechanism of bidirectional exchange described in much of the scholarship on development. Their importance as employers and their role in equitable development (McCann 1996) makes generating cooperative relationships with small industries critical, and the rare success of bureaucracies that do form and maintain these relationships yields important lessons about the limits of state-society relations.[4]

Finally, small-scale ceramics production in Mexico not only typifies the organizational difficulties and barriers to innovation faced by small, low-tech enterprises and the challenges of state engagement (von Tunzelman and Acha 2005), but it is a case that is important in its own right in economic and human terms. Some 3.8 million Mexicans live in roughly 100 disparate communities that rely on small-scale ceramics production (Secretary of Health 2003). Many of these communities are rural, heavily indigenous, and economically depressed and have few sources of employment (Fonart 2010).[5] Compounding these disadvantages, the traditional use of lead oxide glaze in the industry has created a public health and environmental disaster by poisoning ceramics workers and their families and contaminating soil and water (Fonart 2009). Additionally, an estimated 30 million Mexicans regularly consume food prepared in and served upon lead-glazed ceramic products (Secretary of Health 2003). In recent years, the use of lead oxide has also eliminated any chance of accessing foreign markets, as rising quality standards disallow the import of lead-glazed ceramics. In short, the potential benefits (both private and public) of lead-free technologies are very high.

[4] Mexico itself is an unlikely case to see effective development policy, having largely forsaken active industrial policy in the 1980s. The claim here is not that the effective dynamic is government-wide but rather a single pocket of efficiency. This is not inconsistent with other studies that identify the potential benefits of these pockets and the imperfections of bureaucratic structures even in the most successful developmental states (see Evans 1998). Moreover, there is a sustained interest in the capacity of such pockets to produce positive developmental outcomes (e.g., Roll 2014).

[5] The presence of similar communities in which small industries are clustered and engaged in producing very similar goods is quite common in the developing world (Giuliani, Pietrobelli, and Rabelotti 2005).

Just as they are challenging for agents of the state, however, enterprises of this kind are difficult subjects of study. Because of the challenges associated with establishing reliable relationships with respondents (Gottlieb 2006), more than a year of fieldwork was necessary for this project, and a great deal of qualitative data inform the analysis. This includes (1) observation of production in several dozen workshops across several central Mexican states; (2) observation of formal producers' group meetings and interviews with members and group leaders; (3) observation of government-led training sessions in two states and interviews with trainers; (4) interviews with officials in the federal agencies, as well as elected officials and bureaucrats in several states; and (5) semistructured interviews with roughly 50 ceramics workshop heads.[6]

Moreover, a survey based on interviews and observation was administered to some 200 ceramics-producing workshops in the village of Capula, Michoacán, in an effort to systematically study the networks of producers and the dynamics of adoption. An estimated 75% of the village population of several thousand is economically reliant on the production of ceramics (Covarrubias, personal interview 2011). According to the National Fund for the Development of Artisan Goods (Fonart), Capula is a village that has made early progress toward becoming compliant with workplace lead restrictions (about 20% of producers, as compared with roughly 10% nationally) and may thus (optimistically) represent the future of similar villages (Covarrubias, personal interview 2011). These surveys inquired about workshop characteristics and production practices and if and when adoption of the new technology had occurred, as well as asking workshop heads to identify other workshops with which they had contact (i.e., their "ego network"; Wasserman and Faust 1994). The survey was undertaken on a door-to-door basis in an attempt to incorporate as nearly as possible the entire population of ceramics producers in the village. Officials familiar with the village estimated that the nearly 200 surveys represent over three-quarters of the active workshops in the village.[7]

[6] These efforts were concentrated in the central Mexican states of Michoacán and Puebla.

[7] Gathering data on the full network was not possible given that the population of producers itself was unknown (many operate informally). Instead data were gathered on personal "ego networks," in which respondents were asked to identify other workshop heads with whom they had contact. Data gathered for ego networks obviously make the generation of a complete social network problematic; for this reason while I present visualizations of all of the workshops and their self-identified formal and informal ties, I do not make a more formal quantitative analysis of the full network of producers. This manner of constructing networks assumes that personal networks have remained unchanged over the decade since producers have been adopting lead-free glaze. While this assumption is always cause for concern in studies that are time sensitive, in a small village setting, where population and location tend to be quite stable, kinship and friendship relations are likely to change less than in other settings. That said, the assumption is also motivated by the difficulty of collecting reliable time-series data on personal contacts over the past decade through a survey.

Barriers to Upgrading

The government motives for regulating and promoting upgrading in the Mexican ceramics sector include the detoxification of working conditions as well as consumer safety and prospective access to foreign markets. In spite of the benefits to producers—both opportunities for economic advancement and improved labor conditions—the process of eliminating lead oxide glaze is complex; this is largely a consequence of the nature of small production in family workshops and the typical manner in which ceramics are marketed, both of which impede upgrading not only in the Mexican ceramics industry but in small-scale industries in developing countries more generally.

Impediments to upgrading stem in part from the nature of learning in small businesses and family workshops and are often informational. In such workshops, research and development activities are minimal, if they exist at all, inhibiting the formation and adoption of new technologies and techniques and making experimentation unlikely (von Tunzelmann and Acha 2005). Traditional practices in Mexican ceramics production further discourage experimentation because firing occurs in large batches, leaving no low-risk means of experimentation. Moreover, as finances for families and the "business" are generally not kept separate in family workshops, obligations to the family typically are put before reinvestment in the business (Whyte 1996). The larger and more immediate the short-term family costs are relative to the income earned from the business, the less likely workshop heads are to make long-term investments (Peréz-Lizaur 1997). Finally, teaching in the family workshop occurs in the typical craft manner, with the rising generation trained in the production methods by older, expert workers. Learning occurs "vertically" within closed families, rather than "horizontally" across the community. This condition is further exacerbated by the belief held by many ceramics workshop heads that the competition between workshops is so keen that specific information about production must be protected. Thus, family workshops and their workers are isolated in terms of information about production practices and tend to perpetuate practices that have traditionally been used within the family, and the sector as a whole is very slow to adopt newly available technologies.

The structure of the market for ceramic goods also acts as an informational hurdle to adoption of new technologies.[8] Even for producers who know how to adopt the new technology, informational uncertainties still surround its adoption, which stem largely from the producers' weak market position (Dietz et al.

[8] Consistent with the short time horizons for small enterprises (Murrillo et al. 2008), "improvement" here has an immediate economic connotation: their goods can be produced more efficiently or for less and sold more broadly or at higher prices.

1991).[9] Most workshops sell in bulk to *acaparadores* (literally, "monopolists" or "hoarders"), who resell the products in markets around the country. Under this oligopsony, the workshops have little capacity to negotiate the price for their goods and are highly risk averse. In short, the structure of production and market for these goods perpetuate uncertainty about the upgrading and have obstructed the indigenous development or adoption of new technologies in ceramics-producing clusters, including a substitute for lead oxide glaze. While the details are particular to the ceramics industry, the barriers are broadly typical of the kinds of informational obstacles facing small enterprises more generally (von Tunzelmann and Acha 2005).

State Development Goals

Beginning in the 1990s, the Mexican government took an interest in ending the widespread and long-standing use of lead oxide as a fluxing agent in ceramic glaze, a task whose design and implementation fell to a small but autonomous agency (in Weberian terms) within the Secretary of Social Development. Coinciding with tightening international norms on lead exposure, the government published legal norms prohibiting the sale of lead oxide for use in the ceramics sector and the sale of ceramics glazed with lead. Although geared toward harmonizing written law with international organizations and trade partners, whether or not concerned agencies actually enforced those de jure restrictions was another matter; and, if they did attempt to enforce, the tools with which they were to approach enforcement were unspecified.[10] Cofepris (Federal Commission for the Protection against Health Risks) is the agency within the Ministry of Health charged with legal enforcement of lead restrictions. In weighing options for enforcement, Cofepris officials consulted Fonart, an agency broadly concerned with the economic and social well-being of artisans. Fonart officials made it clear that no apparent alternative technology was within the reach of the mostly poor, low-tech workshops and that, although punitive enforcement alone was unlikely to be effective, nonenforcement was damaging to the health and economic prospects of the workshops. Based on these concerns, Cofepris elected a "tutelary" approach to encouraging compliance, rather than either strictly punitive enforcement or nonenforcement (Schrank and Piore 2007), and asked Fonart to establish a Lead

[9] This is consistent with the notion that the solution to one barrier may simply reveal another sticking point and that, consequently, a sequential or experimentalist approach may be the most appropriate means of pursuing development (see Rodrik 2004; Sabel 2004; Sabel and Reddy 2007).

[10] As Levitsky and Murrillo (2009) point out, there is often a gulf between the de jure design of institutions and their enforcement. They identify numerous Mexican institutions that are stable but unenforced.

Substitution Program to (1) coordinate the development of the alternative technology for the industry—which it did by overseeing a working group of chemists, glaze producers, ceramics workshops, and social scientists—and (2) train workshops into compliance (Samford 2015).[11] The resulting alternative technology was difficult and time intensive for Fonart to develop but required no capital investment from workshops to adopt: a nontoxic glaze engineered to function in existing kilns, applied similarly, and having roughly the same cost basis. Its adoption, then, is largely a matter of knowledge, training, and practice. The approach to diffusion has emphasized coaxing producers into compliance through training sessions that address informational barriers and risks of adoption, rather than punishing noncompliant workshops.

While potentially untrue of Fonart as a whole, the Lead Substitution Program is sufficiently autonomous, professionalized, and insulated to withstand industry pressure from producers that would undermine the program's efforts. The program has been led by a *técnico*, who was involved in the program for over 15 years, through major political changes at the federal level, and staffed by experienced trainers. The Lead Substitution Program has been resistant to calls by artisans to relax the rule that only lead-free ceramics can be purchased and sold in Fonart stores throughout the country, an effort to reward those who are in compliance with the law. Moreover, because the agency has neither control over the norms for lead use nor the ultimate enforcement authority, there is little threat of abuse of their position by program agents, who largely serve in educational and coordinating roles. Finally, the perspective of Fonart agents has come to be that lead restrictions should include punitive measures, a much sterner line than they have been able to take because regulatory power rests with Cofepris. In short, in addition to the Lead Substitution Program acting with a relatively high degree of autonomy in designing an intervention, there is both a personal commitment to promoting the use of lead-free glaze among the professional staff and little opportunity to benefit personally from ties to individual artisans and producers' groups.[12]

[11] Since then, Fonart has been the primary actor and the Lead Substitution Program within it has been the primary diffuser of information about the toxicity of lead and the lead-free technology. Fonart agents report no coordinated cross-agency cooperation and even expressed frustration with the inactivity of other agencies (such as state-level organizations) that have the capacity to assist. There have been small efforts by nongovernmental organizations; these efforts have tended to be very focused (i.e., they affect very few workshops). In short, while it is impossible to rule out the possibility that ceramics producers have received relevant technical information from other sources, Fonart's Lead Substitution Program has operated independently and is treated as such here.

[12] To offer a contrast, the state of Michoacán's Center for Artisan Goods (Casart) is a state-level agency whose lack of autonomy has made it vulnerable to pressures from civil society that negatively affect the goal of eliminating lead use. For example, the director has bent to pressures from ceramics producers to continue selling lead oxide glaze in

Information Aggregation and Diffusion

Although Fonart's Lead Substitution Program is autonomous in the sense of being corporately coherent, not "captured" by the private interests of producers and not simply reactive to external pressures, this autonomy has clearly been insufficient for achieving the goal of curbing the use of lead oxide. Implementation has relied on the formation of brokering ties that allow for both the collection of information about communities of workshops and the ability to diffuse information to them. As Reagans and Zuckerman (2008) suggest, this bidirectional exchange has required navigating the network tension between redundancy and nonredundancy, particularly given that information is unevenly distributed and partially nonsubstitutable between clusters (Burt 2008). Specifically, as this section will demonstrate, the Lead Substitution Program's strategy has been to engage the discrete clusters of ceramics producers through the development of local contacts (i.e., nonredundant ties) and to use those contacts as the lynchpins of information diffusion *within* the clusters.

The Lead Substitution Program has no permanent presence in most producing communities, and coordination is consequently complicated by the network and physical isolation of the clusters.[13] In response, the agency has cultivated community-level contacts as a direct point of contact within each community. Many ceramics-producing communities have some form of producers' group; it is in these communities with preexisting, "visible" formal networks that the agency has sought to cultivate contacts, because of the regular meetings and established means of communication between group members. In the western state of Michoacán, for example, many villages have a local branch of the Michoacán State Artisans Union. For state agents who must gather and impart information about available technology or programs, recruiting local contacts structurally embedded in these dense networks efficiently multiplies their capacity to do so. In Reagans and Zuckerman's (2008) terms, they have attempted to develop nonredundant ties to individuals in communities that have dense redundant relations among their ceramics producers.

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ceramics-producing villages, at the same time that it is officially interested in eliminating its use. Casart's upper administration—political appointees—has been influenced by ceramics producers' claims that the cessation of subsidized provision of lead oxide will create unbearable economic hardship (Covarrubias, personal interview 2011). (See Tendler [2002] on the "devil's deal" between small firms and local politicians.)

[13] This is not to suggest that there are no operational state institutions in the parts of rural Mexico where most ceramics communities are located or to draw an artificially unambiguous distinction between state and society. That said, the "thinness" of the presence and operation of state institutions in much of Latin America and many other developing regions is a well-recognized condition (O'Donnell 2004). The capacity of bureaucrats to begin operating in previously unregulated and often very isolated rural communities is not at all given.

These contacts allow for the reciprocal movement of information from clusters of producers back to bureaucrats. From the inception of regulatory enforcement, workshops have shaped implementation. They helped clarify that there was no available lead oxide free glaze and, therefore, agitated against immediate punitive enforcement through Fonart, thus giving the agency an interest in assisting in the development of a nontoxic glaze. Moreover, workshops have often acted as field-testing sites for the development of the new glaze and reported on interactions between newly developed glaze and locally used pigments, a role that they continue to play as the community trainers gather and return information about the training sessions. Training sessions are used to discuss what barriers to lead-free adoption producers face, what particular interventions they feel are necessary, how frequent and where training courses should be held, and technical information about the glazes, which can be adjusted for local conditions. For example, one community in the state of Puebla felt that without lead-free certification, consumers seeking such products still faced uncertainty and early adopters would fail to benefit fully from upgrading. In response, Cofepris has worked to establish a certification program. Because conditions in the roughly 100 ceramics-producing communities are slightly different, it has been important to gather partially nonsubstitutable information from as many communities as possible.

Regarding diffusion *within* local networks, the spread of lead-free technology and know-how through guided training/practice sessions is at the heart of the efforts to encourage the adoption. These sessions are applied: multiple producers bring unfinished wares to glaze with supplies provided by the government. This allows producers to observe and experiment with small batches of their goods, with no glaze or fuel costs. Informational barriers and the financial risks of experimentation are thus mitigated and producers gain hands-on experience with the alternative technology. Critically, participants in these training sessions are recruited through the community-level networks by the local Fonart contacts, who lack the resources to communicate with all workshops. It is in this respect that the dense ties between workshops become critical for efficient diffusion.

Based on the workshop survey discussed above, figure 1 depicts a visualization of the networks—both public-private and private—in the major ceramics cluster in Capula, Michoacán. The square nodes at the top of the figure represent two Fonart employees (the national director of the Lead Substitution Program and the Fonart director for the state of Michoacán). The bottommost, shaded square node represents the agency's village-level contact, who is a ceramics producer recruited as a contact by Fonart. Each of the round nodes represents a single workshop whose head participated in the survey. The community contact sits in the structural hole that separates Fonart's bureaucratic network from the network of workshops in the community, with formal ties up to Fonart agents and down to three leaders of community producers

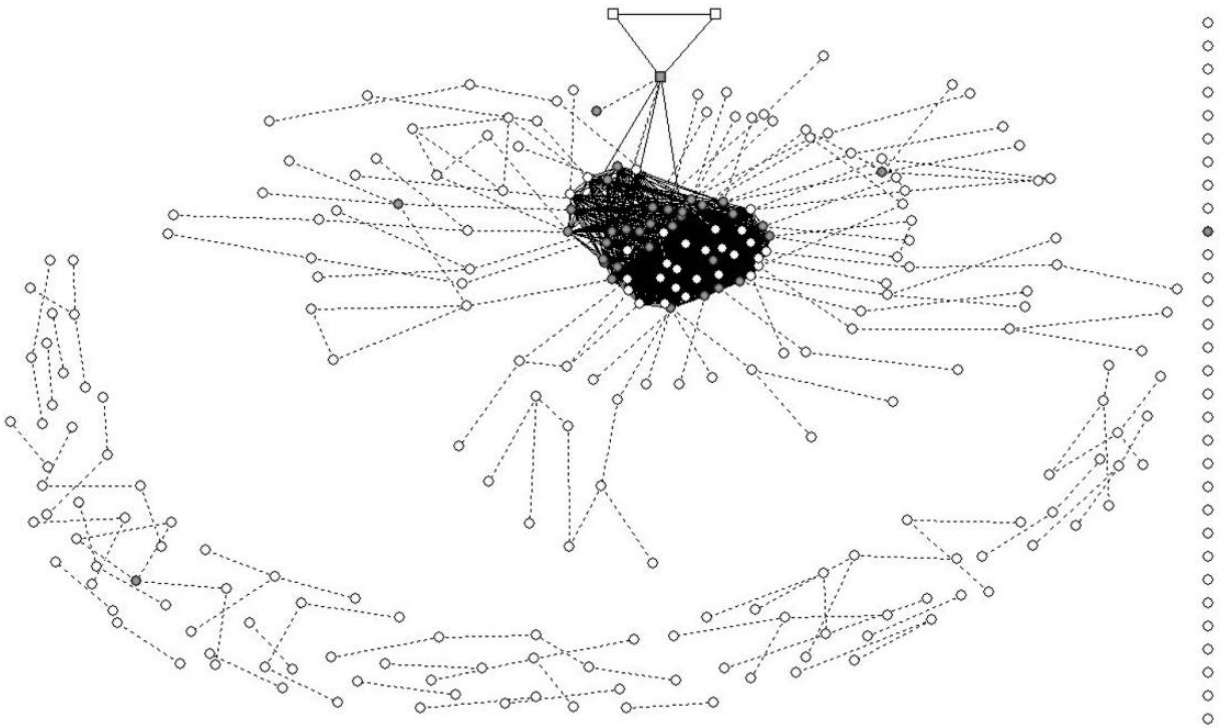

FIG. 1.—Government workshop network (Capula, Michoacán); open square node = government agent; closed square node = community contact; open circle = untrained workshop; closed circle = trained workshop; unbroken line = formal tie; broken line = informal tie.

groups (along with several informal ties to other workshops).[14] Solid lines are indicative of the formal ties that link workshop heads through shared membership in the producers groups, both the village group of the state artisans union and the Fonart-supported cooperatives; these workshops are clustered near the center of the figure. Dotted lines indicate nondirectional informal ties to other workshop heads (typically friends, neighbors, or kin); these are ties that workshop heads reported when queried about their contacts with other ceramics producers in the community and represent the potential for the movement of information through less formal channels.[15]

Understanding that each of the ties in the figure represents the potential for the flow of information, the most consequential relationships are (1) those between the community contact and the state and federal Fonart agents and (2) between members of the formal producers' groups. Through this first relationship, information about lead substitution programs is distributed to the disparate communities: a new technology exists and law requires its adoption, free training courses are available, and government-sponsored training courses will be offered. Rather than communicate directly with producers in town individually, the agency's community contacts ask formal group leaders to spread the word about training sessions. Through the second relationship—the local formal networks—this information is disseminated among ceramics producers in the cluster, and information is aggregated by leaders of producers groups and passed to the government agents through the community contact. While this is an efficient manner for an understaffed and underfunded public agency to diffuse and gather private sector information, it means that those who are tied to a formal group are much more likely to be recipients than those isolated from formal organizations. A frequent complaint from unaffiliated producers is that they are simply uninformed about programs, speaking to the weakness of this method of spreading information.

Insofar as this public-private brokerage stems from a tie to key actors embedded in the community, the network visualization offers insight into that relationship. First, it emphasizes the importance of the community contact, who is both an independent producer and contracted by Fonart to fill the structural hole between local networks of producers and the government agency. Remove this node from the network, and the result is two independent subgroups: public bureaucracy and private producers group. Second,

[14] There is a larger bureaucratic network attached to the state Fonart representative and the national director of the Lead Substitution Program. Nodes for other bureaucrats are not included as systematic surveying of the bureaucracy was not undertaken because, as discussed above, there is no apparent cross-agency coordination.

[15] Included in the group of isolates on right-hand side of the figure are both those workshop heads who reported no specific ties (roughly three-quarters), and those who refused to respond to the survey question about informal ties (roughly one-quarter).

it demonstrates the fact that this mode of communication is relatively efficient for the Lead Substitution Program: a single embedded village contact can serve as both spreader and aggregator of specific cluster information without the necessity of bureaucrats being directly tied into the redundant network ties in the village. At the same time, however, it clearly depicts the fact that many workshop heads lack the social contacts necessary to either access information issued by the Lead Substitution Program and intended for producers in general or to have their particular concerns and ideas aggregated for presentation to the agency. For example, those workshop heads who have been trained are shaded and appear, for the most part, among the dense formal connections at the center of the network. The structure of relations between workshops, then, affects the extent to which information exchange is achievable: Lead Substitution Program agents have little apparent capacity to communicate with the isolated producers (i.e., isolates) that occupy the periphery of the cluster and very limited capacity to push them to join formal groups. In short, the effectiveness of coordinated action depends in very large part on the redundancy of ties between producers in the cluster (for local diffusion) and the ability to develop nonredundant ties to multiple clusters (for broad information collection).

Quantitative analysis of data gathered in the workshop surveys confirms the centrality of the Lead Substitution Program's use of formal networks as points of contact; it is almost exclusively members of producers' groups that receive the direct training that government provides, even though trainings are technically open and unaffiliated workshops express interest in them. Figure 2 confirms a very strong relationship between membership in a formal network of producers and receiving training: almost none of the workshops that do not belong to one of the formal producers groups have been trained, while roughly half of the networked workshops have been. In interviews, a common complaint from unaffiliated workshop heads is that they are not "invited" to the training sessions. Not all who receive the subsidized training do become compliant (see fig. 3), but the survey results indicate that proportionally those who have received training are much more likely to become compliant than those who have not.[16] Together with figure 1, these results illustrate that formal producers' groups have been crucial to Fonart agents' efforts: not to embed themselves among the producers, but to use producer networks as tools to broker information about the use of lead-free glaze and to mitigate the costs of adoption for workshops.

[16] Figures 3 and 4 report *n*'s of 136/137. Although 175 workshops were surveyed, some 40 of these reported producing unglazed or high-temperature ceramics, making them technically compliant with restrictions on lead oxide, although not because they upgraded to the new technology; they were therefore excluded.

		Formal Group Membership (%)	
		No	Yes
Recipient of Training (%)	No	83.0 ($n = 88$)	17.0 ($n = 18$)
	Yes	12.9 ($n = 4$)	87.1 ($n = 27$)

FIG. 2.—Membership in formal producers network as a predictor of training. Pearson $\chi^2 = 53.5$, $P < .001$, $N = 137$ (workshops using glaze).

While the upper left quadrant of figure 3—which shows the majority of workshops without formal training in lead-free technology—may be troubling, it is relatively easy to understand: the lack of access to training is a function of workshops' locations in the network of producers. However, the group that has been more frustrating for Lead Substitution Program agents is represented by the upper right quadrant of figure 3: the large proportion of workshops that have been formally trained but remain noncompliant with restrictions on the use of lead. Through interviews and the survey, almost all producers in this quadrant indicated that a lack of market certainty or information was a reason for their continued nonadoption; roughly a third of them also mentioned a need for further training, and only one named the need for further training as the sole reason for nonadoption.[17] It is this group that underlines the importance of reliable market information that assures producers new technology represents an improvement over the old—along with the government's potential limitations on providing market information.

In interviews, without exception, those producers who have adopted the lead-free glaze identified their motive as economic (rather than health or environmental concerns). In open-ended interviews, many adopters also indicated that they had committed to upgrading after seeing someone close to them make the transition successfully, helping them overcome the uncertainty stemming from market conditions. As discussed below, the majority of workshop heads reported little sharing of detailed production information between workshops; instead informal ties allow producers to monitor

[17] For some of these producers there is likely a tangled relationship between seeking more training and seeing market opportunity; nevertheless market uncertainty plays a central, if not exclusive, role in keeping trained workshops from compliance. In contrast, the experiences of those who became compliant without the training courses are more varied: some report being able to experiment by themselves or with friends or family members, even though these kinds of interactions are relatively rare.

Compliant with Lead Regulation (%)		Training (%) No	Training (%) Yes
	No	85.7 ($n = 96$)	14.3 ($n = 16$)
	Yes	41.7 ($n = 10$)	58.3 ($n = 14$)

FIG. 3.—Training as a predictor of compliance with workplace lead regulations. Pearson $\chi^2 = 22.3$, $P < .001$, $N = 136$ (workshops using glaze).

the general behaviors of the workshops to which they have closer relationship (whether they have upgraded, if their goods seem to be selling, if their fortunes have changed visibly, etc.). As such, informal ties between producers seem to act as important conduits of information about the commercial viability of lead-free production, transmitting the knowledge that the lead-free glaze represents an improvement over historical methods.

The workshop survey also gathered data on other factors that might shape the decision to upgrade. These data include the number of workers regularly employed in the workshop and the amount of production, based on the amount of clay used on a monthly basis. Typically, levels of experience and education (i.e., measures of human capital) would be expected to correlate positively with the capacity to upgrade or adopt innovations. Finally, in order to gauge the effects of informal networks, workshop heads were asked to identify specific workshops with which they had contact. A "personal network exposure" (PNE) figure was calculated for each workshop head based on the "alters" they identified and the workshop heads that identified them (Valente 1995). The PNE consists of the proportion of each workshop head's identified contacts that had adopted lead-free glaze prior to or in the same year as the respondant. The PNE, in other words, is an effort to capture the degree to which individual workshops are exposed through their informal networks to other workshops that had successfully upgraded. Initial results from the community survey bear out the importance of personal networks. Producers who have adopted the technology have much higher mean PNE (.37) than those who have failed to upgrade (.04; $P < .01$). A similar relationship holds if only the producers who have been formally trained are considered (see fig. 3, right-hand column): the mean PNE of those who went on to adopt is .38 and .11 for those who have not ($P < .05$).

Incorporating a broader array of the characteristics of the workshop and workshop head, table 1 reports the results of a series of Cox proportional

TABLE 1
Adoption of Lead-Free Technology over Time

	Hazard Ratio	
	Model 1	Model 2
Recipient of training	4.15**	
	(2.09)	
Member of formal group		2.88*
		(1.56)
Number of workers	.98	1.04
	(.22)	(.22)
Amount of production	.95*	.96*
	(.02)	(.02)
Years of experience	.98	.99
	(.02)	(.02)
Education level	1.27	1.31
	(.46)	(.54)
Informal tie to prior adopter (proportion)	11.84**	11.56**
	(7.58)	(7.70)
Likelihood ratio χ^2	44.7**	40.6**

Note.—Cox proportional hazards model with Breslow method for ties. Dependent Variable/"Failure" = glaze adoption. $N = 134$. Nos. in parentheses are SEs.
** $P < .01$.
* $P < .05$.

hazard models that assess the rate of adoption of lead-free glaze in the years since it was introduced.[18] The model includes the measures of human capital, production size in employees and clay inputs, and informational indicators: training, formal group membership, and exposure to prior adopters. Most workshop characteristics—with the exception of amount of raw material consumed—have no significant effect on the workshop head's decision to adopt the lead-free glaze. Production size is likely to be negatively associated with adoption because those whose strategy is to focus on smaller but higher-quality firings are more likely to experience direct market pressure from exporters or foreign buyers than those who produce in bulk primarily for the domestic market. Those factors that do positively affect the likelihood of adoption are participation in a training course, formal group membership, and higher rates of exposure to previous adopters through informal personal networks.

[18] See the appendix for definitions of variables used in the Cox regression and descriptive statistics. The regression results are effectively the same whether the Breslow or Efron methods for resolving tied failures are used. Moreover, the findings are broadly consistent with different model specifications, such as cross-sectional logistic and probabilistic regression, giving confidence in the robustness of the findings.

The regression results underline the importance of formal producers' networks (and the opportunity to receive training) as well as informal relations in a network of ceramics-producing neighbors, friends, and extended family that contains early adopters (and the consequent ability to monitor their market activity).[19] Even among extended family and friends, little information about production explicitly flows between the workshops, so rather than the kind of technical information that is disseminated through the training courses, the informal networks allow monitoring of slightly more public information. Have other workshop heads one knows adopted lead-free glaze, and, if so, do they seem to be successfully marketing it? This firsthand information about the viability of the glaze may not be technical, but as long as the technology is only being slowly picked up by early adopters, it may be more difficult to obtain and no less important.[20]

The consequences of both training and informal ties with prior adopters on the likelihood of adoption over time are presented visually in figure 4, a plot of the survival functions of different combinations of these conditions over the 12 years since the technology began to be introduced to the village.[21] Time alone has a very small effect on the likelihood of adoption in the absence of either membership in a formal organization (and the consequent possibility of training) or contact with prior adopters: it is clearly not enough

[19] Two questions about self-selection arise from this analysis: First, is the relationship between training and adoption a spurious consequence of some preexisting motivation to train and upgrade? Interviews and survey data suggest that the relationship is not spurious. In the first place, most interviewees (including unaffiliated producers, as mentioned above) indicated curiosity about learning the new technology and the potential to earn higher income rather than approaching the trainings with a preexisting inclination to alter production methods. Survey evidence demonstrates a sizable gap between those who have been trained and those who later adopted (only about half of trainees; see fig. 3), similarly suggesting that those who receive training are not necessarily committed to adoption of the new glaze when they attend training sessions. The second question is what factors might raise the likelihood of being trained. Logistic regression (not reported here) indicates that levels of experience and education, workshop size, and informal ties with prior adopters are unrelated to who is trained; membership in a formal organization is the only reliable predictor of training.

[20] Diffusion of innovations often follow an S-curve in which rates of adoption are slow at early stages, then increase, and then decease again as the last holdouts adopt (Valente 1995). In Mexico, where an estimated 10% of ceramicists have transitioned away from lead oxide glaze, those who have are very much "early adopters." Even a village like Capula, Michoacán, where almost 20% have adopted the diffusion is still very much in the early stages, although anecdotal information suggests that the rate of adoption may be increasing in such villages.

[21] For these survivor functions, the amount of production is set at the mean. Formal group membership is dichotomous, taking a value of one for affiliated workshops and zero for others. For informal networks, the proportion for "un-networked" workshops takes a value of zero, and that for "networked" workshops takes a PNE value of .5 (the mean of nonzero responses).

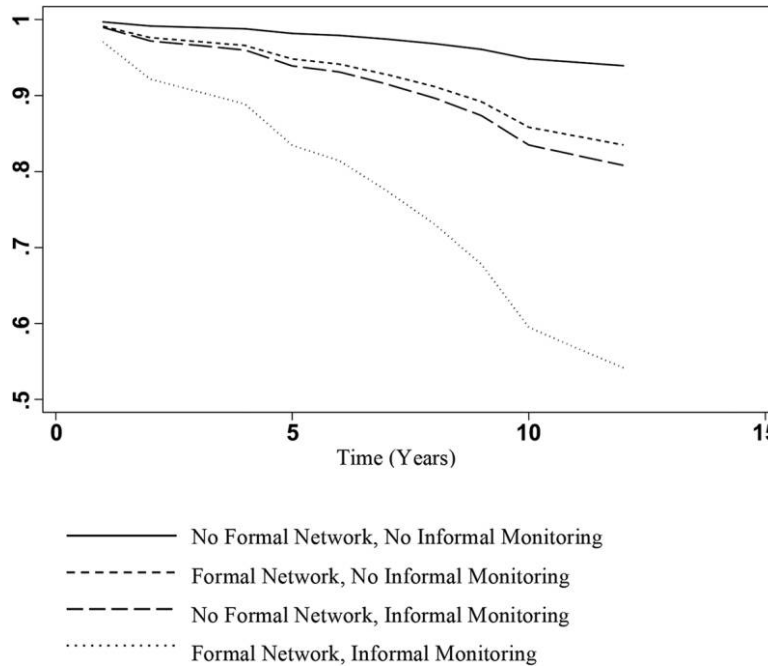

FIG. 4.—Survival functions for adoptions (Capula, Michoacán)

to be located within a community where technical and market information is present. Informal exposure to prior adopters and membership in a formal organization independently decrease the rate at which workshops continue to use the traditional technology by roughly 15%–20% over time. The largest effects over time are among those workshops that are tied both to previous adopters and to formal producers group. Among this group, for whom technical and market informational gaps have been addressed, the likelihood of adopting during the period in question approaches 50%.

Beyond Network Structure

While the results above demonstrate the critical role of network structure, they tell little about the content of the relationships between producers and the personal characteristics of the community contacts. Looking beyond their position or "network embeddedness" to the nature of the relationships between them, or what Zelizer (2012; also Bandelj 2012; Block 2012) calls the "relational work" done between the nodes, the nature of (1) the community contacts to the bureaucracy as well as to the community and (2) the social relations between the producers are themselves consequential. Ethnographic

data gathered to understand these relationships do not belie the findings reported above about network structure, but they do suggest that the task of government in generating bidirectional coordination with fragmented sectors is not as simple as identifying auspicious network conditions and maximizing nonredundant ties to dense community networks. In this case, the structure of the network is largely shaped by the relational work that is done between the nodes.

Because the role of the local contacts is instrumental and because they are effectively placed in positions of informational privilege, their willingness to act effectively and in good faith is critical; several factors underpin this disposition. First, aside from having ties to formal networks of producers, interviews with contacts revealed an ideological interest in the adoption of the new technology, either for the health of the community or for the continued viability of community's economic well-being. In some communities, Lead Substitution Program agents have had difficulty finding someone ideologically committed to the project, hobbling the agency's efforts (Covarrubias, personal interview 2011).[22] Second, the local contacts display pride in their own efforts to aid their communities' development, a finding consistent with other studies of locally recruited public operatives (Tendler 1997). Third, although it seems unlikely that this is the sole motivation, the contacts are compensated for leading training courses, which provides pecuniary benefits or offsets the loss of income from ceramics production. Finally, the Lead Substitution Program director has demonstrated a capacity to easily communicate electronically and telephonically with the local contacts, making their activities relatively easy to monitor in a general sense, although, given their dispersion and the lack of agency resources, there are obvious problems with rigorous monitoring of the effectiveness of these community trainers. In short, while an admittedly imperfect system, the manner in which these local contacts are recruited seems to rely on a personal interest paralleling that of the agency.

Regarding the relations between producers, what is perhaps most notable is a tension between a keen sense of atomistic competitiveness between the workshops and a corporate identity and willingness to cooperate to obtain collective benefits, such as locations in markets to sell their products. State agents, nongovernmental organizations observers, and producers themselves

[22] In some communities the Lead Substitution Program has been unable to recruit effective contacts, leading to variation in adoption *across* clusters. Several trainers indicated the reticence of some rural and closed communities—often indigenous—and the difficulty of gaining access in order to establish a local contact. Some communities may have numerous willing trainers, while others may have none; while the knowledge that there is no alternative trainer might raise the specter of "capture" by a privileged contact, the strong sense that genuine interest drives contacts' actions likely mitigates that threat.

report jealous guarding of the specifics of production methods from other producers, including extended family members (also Dietz et al. 1991). One producer reported using the kiln in his father's home workshop, for example, but only in the father's absence in order to protect the details of his productive methods. Moreover, there is typically little economic exchange between the workshops (nodes) as they each work primary materials into finished products; as a consequence there is little supply chain information exchange, and producers compete for buyers. In part because of this competitiveness, the producers tend to be keen observers of those they are in close contact with, reporting being able to identify who has adopted lead-free glaze, who is doing comparatively well based on visible consumption, and so on without trading specific production details. As these contacts are often friends, extended family, and respected neighbors, observation of their behaviors is influential.

Moreover, social relations also partially underlie membership in the formal organizations. For example, extended familial relationships were occasionally cited as reasons for belonging to the formal producers' groups, as producers were encouraged to join or vouched for by associates or extended family members. It is unlikely that these otherwise competitive enterprises would cohere without these noneconomic ties. This has major implications for the role of the community contact: this person must at the same time form a bureaucratic relationship with the government agents and work to retain a position of respect and belonging in the community. A Nahuatl-speaking Fonart contact in the state of Puebla, for example, reported her linguistic skills to be key not only to her being able to communicate with the community but as an indicator of her belonging to the largely indigenous community. Beyond the simple recruitment of well-placed contacts, those contacts must manage this tension between remaining a part of the local community and introducing policies outside of the norm.

The work that is done in the networks identified in the previous section is critical to the capacity of Fonart agents to develop and sustain the kinds of relations that allow them to maximize nonredundant ties to dense and redundant networks. In other words, overcoming the collection/diffusion tension (Reagans and Zuckerman 2008) that is inherent to bidirectional exchange with unevenly networked industries is contingent upon the ability to recruit like-minded and responsive but locally connected and trusted community contacts.

CONCLUSION

To reiterate briefly, for the Mexican government the decision to eliminate the use of lead oxide glaze was motivated by social and economic development concerns. The substantial role that Fonart's Lead Substitution Program has played in assisting the generation and diffusion of alternative

technology has exhibited a surprisingly high degree of bureaucratic flexibility and responsiveness. Given the barriers faced by the workshops, a strictly punitive approach to the enforcement of restrictions on the use of lead glaze would have resulted in short-run job loss in many remote and marginalized communities; yet government inaction would have allowed persistent health problems among artisanal ceramics producers and their customers, not to mention foregone opportunities to enter foreign markets. Efforts have nonetheless begun to yield fruit where the relatively autonomous Lead Substitution Program agents have been able to (1) engage trusted, motivated contacts embedded in preexisting producer networks—allowing for bidirectional brokerage of information between clusters and government agents—and to (2) use those existing producers' networks for improved diffusion among local workshops. Rather than maintaining close relations to the private sector, therefore, the parameters of the success of this developmental program are defined by the structure of relations between producers and the ability of state agents to recruit committed contacts within those existing networks underpinned by interpersonal relationships.

Although only a first step toward systematically incorporating the structure of the private sector into studies of state-society relations, the implications of this argument are far-reaching. In terms of scholarship on the development of poor countries under contemporary conditions, it underlines a manner of overcoming the tensions between gathering and diffusing information in unevenly organized sectors, an issue as yet unaddressed in the scholarship drawing upon the notion of embedded autonomy. This analysis raises the salience of private sector networks, and, as they are central to the effectiveness of coordination, suggests the utility of drawing on producers' networks. Beyond structure, it underlines the importance of local contacts who are both relationally committed to public sector goals and trusted within local private networks. In this case, the structure of the networks depends upon the relations of trust among ceramics producers in the community. While the precise relationships in other industries and in other countries will differ, the focus on Mexican ceramics reveals a great deal about the challenges of state-sponsored upgrading in unevenly organized industries. Existing development literature has typically focused upon the coordinating ties that link public and private sectors, taking for granted that public sector networks are structured in a manner that allows for the movement of information among firms. In industries like ceramics production in Mexico, this deeply embedded relationship is clearly unlikely to occur; conditions like large numbers of impoverished firms, unevenness of industry organizations, and geographic dispersion complicate the ability of public agents to engage in effective bidirectional exchange. The assumption of relatively coordinated industry actors has offered a biased view of brokerage of information between bureaucrats and private sector. Even in studies that question the im-

portance of a single centralized pilot agency for technology development (O'Riain 2004; Breznitz 2007; Breznitz and Ornston 2012), the private sector interlocutors are presumed to be relatively coherent, if their structure is questioned at all. This condition is simply not true in many industries, laying bare a critical problem: how a limited set of bureaucrats can be effective at both gathering necessary input from dispersed enterprises and diffusing information.

In Reagans and Zuckerman's (2008) terms, the question is how egos can maximize both power and knowledge, when those imply different network strategies (redundancy and nonredundancy), a tension that is heightened when information is nonsubstitutable and unevenly distributed (Burt 2008). This is critical to the effective bidirectional information exchange that makes policy more likely to achieve local development goals, such as, but not limited to, technological upgrading. The case reveals a practical—if imperfect—network solution: bureaucratic ties to embedded local contacts who act in good faith are potentially functionally equivalent to the bidirectional informational exchange inherent in embeddedness itself. If as Reagans and Zuckerman and Burt (2008) suggest, the network tensions are great, the outlook for many national policy makers in developing countries is quite pessimistic. As the network visualizations and quantitative data presented here emphasize, the strategy behind the use of formally organized groups as points of articulation with the community allows for the bridging of the structural holes between agencies and networks in the private sector. The consequent utility of using community contacts or liaisons to broker with existing networks of producers is clear, whatever the nature of those formal groups may be (union, cooperative, etc.). While excluding unaffiliated workshops or firms, this approach may be one of the few methods available to motivated and autonomous state agents limited by budgets and a lack of existing institutional ties to producers to develop effective information brokering ties to the industry they seek to affect.[23] The boundaries of these local networks—where the ties of formal affiliation end—are also the limits of communication and, thus, roughly the limits of upgrading. As long as existing networks of producers remain the primary means by which the bureaucrats link to the private sector to gather and diffuse information about production, this in-group/out-group division will likely continue to pose challenges for sector-wide upgrading as structural holes will continue to limit the information available to unaffiliated producers.

Beyond a practical means of dealing with the tensions between gathering and disseminating information to geographically disparate and unevenly

[23] The kinds of agencies for which these findings have clear implications are potentially quite broad. Beyond industrial development agencies, labor inspectorates and agricultural extension agents are clear examples.

organized industries, there is a more general lesson for bureaucrats in development agencies. If the role of bureaucrats in effective development projects has been recognized as participating in bidirectional exchange with the private sector, this study opens the question of *how* that is made possible by identifying a common circumstance in which auspicious network conditions do not exist. Effective development agents do not passively accept existing network conditions but rather *actively assess and fill critical network holes* that prevent necessary information exchange. Under some conditions—where firms in targeted industries are densely networked, for example—this adaptive building of networks may seem pedestrian; under others (see below), it may not be fully possible and some gaps may be beyond their capacity. Nonetheless, this active network generative role lies at the heart of their effectiveness.

As much as this case may suggest that there is hope for active state agencies seeking to improve the production, working conditions, and products of low-tech producers, it demonstrates limits as well. Although they are commonly geographically clustered and socially networked (Giuliani et al. 2007), for those that are isolated, there is little hope: individual small workshops in countries with underfunded and overburdened bureaucracies—even when those are efficient—are unlikely to be the objects of assistance. Even when there are dense community networks, the capacity to recruit a local contact that shares the commitment to upgrading is not a given. For example, in Mexico, indigenous communities characterized by high degrees of network closure—underpinned by tight intercommunity relations and external distrust—have proven particularly difficult for Lead Substitution Program agents to access in this respect (Burt 2010; Samford 2012). A variety of conditions beyond ethnolinguistic difference may result in the same problem: general thinness of the state (O'Donnell 2004), strong local allegiances or customs (Scott 1985), shared suspicion of the motives of state agents, and so forth. In short, although they may be low-capacity enterprises, the information diffusing and gathering capacity of the redundant ties in their networks constitute an critical input for successful developmental programs, the private sector contribution to what Ostrom (1996) calls "coproduction" of public goods. As scholars of industrial clusters and economic geographers have increasingly acknowledged, ideas and innovations do not simply move "in the air" (Marshall 1920); instead, their movements are highly dependent upon the structure and nature of private enterprise networks. The focus on cluster dynamics, however, typically excludes the consideration of how those networks might be used purposively for the intended—rather than merely de facto—diffusion of productive ideas. For the ceramics industry, these local networks may be thought of as a collective input: they are not homogenous or wholly inclusive, but without them, the state would have very little capacity to diffuse technology at all.

Finally, methodologically speaking, when brokerage and the role of specific network ties are brought to the forefront, even readily available meth-

ods of social network analysis can shed light on the coordinating ties between state agents and firms and within the private sector. These methods allow for the systematic observation of where those ties exist (or do not), a step that is critical in beginning to address Granovetter's concerns with the manner in which in which bureaucrats become embedded and how business is "embedded within itself" (Krippner et al. 2004, p. 124). A central concern facing the application of the notion of embedded autonomy has been the difficulty of demonstrating where embeddedness exists, where it does not, and where it may exist to a limited degree and linking those conditions to falsifiable claims about the effects of embedded autonomy. Network analytic methods offer the potential to overcome that pathology by concretely identifying where structural holes exist, where bridges are able to affect the brokerage of information between public and private actors, the nature and extent of ties between private actors, where key players are (or could fruitfully be) located in the network, and so forth. The methodological approach is likely to be especially beneficial in the developing world where contacts between the state agencies and the private sector and between firms are often not systematically documented. In short, bringing these methods to bear on a central developmental concept is an important first step toward pushing development scholars to take seriously not only the structure and nature of the private sector but also the use of existing methods that make systematic sectoral analysis possible.

APPENDIX

TABLE A1
Variables Used in Cox Regression

Variable	Definition	Coding	Descriptive Statistics
DV ("failure"): Adopter	Workshop produces any glazed ceramics without lead oxide glaze	0 = no 1 = yes	Min: 0 Max: 1 Mean: .18 SD: .38 *N*: 136
Training	Workshop has received external training in the use of lead-free glaze	0 = no 1 = yes	Min: 0 Max: 1 Mean: .19 SD: .39 *N*: 175
Number of workers	Number of workers in the workshop	Number given	Min: 1 Max: 7 Mean: 2.34 SD: 1.14 *N*: 175

TABLE A1 (*Continued*)

Variable	Definition	Coding	Descriptive Statistics
Size of production	Number of bags of clay used in production on a monthly basis	Number given	Min: 1 Max: 120 Mean: 24.76 SD: 23.63 *N*: 172
Experience	Number of years of experience as ceramicist reported by workshop head	Number given	Min: 1 Max: 70 Mean: 33.20 SD: 14.04 *N*: 175
Education	Level of education achieved by workshop head	0 = None 1 = Primary 2 = Secondary 3 ≥ Secondary	Min: 0 Max: 3 Mean: 1.05 SD: .54 *N*: 175
Personal network exposure (PNE)	Ratio of other workshop heads in ego network that adopted lead-free glaze prior or in the same year as workshop head	0–1	Min: 0 Max: 1 Mean: .07 SD: .21 *N*: 175

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