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Mobilizing cookstoves for development: a dual adoption framework analysis of collaborative technology innovations in Western India

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Abstract. Domestic cookstoves in rural India have long been targeted by development programs dedicated to solving a diverse range of problems from deforestation and indoor air pollution to global warming and rural market inefficiencies. Theories on how technologies are mobilized in these design and diffusion innovation projects and what this presages for development outcomes can be improved by explicitly detailing the composition and structure of program governance frameworks. I develop a 'dual adoption analytic framework' to interrogate two technology innovation programs in Western India. This framework underscores the collaborative nature of technology mobilizations and, more specifically, how power is distributed across partnerships at different stages of the development process. Local partners are shown to function as influential mediating agents operating between extrinsic agencies and targeted village groups. They reinforce funding agency planning commitments while also activating economic contingencies and generating alternative development pathways. I also reveal how the structure of technology innovation projects—as either administratively heavy handed or committed to free market principles—influences intermediary behavior, intrapartnership structures of control and, ultimately, development outcomes for targeted artisan communities and households.

Introduction

Sitting in folding chairs at the back of a large classroom, Mr Mhagen and I watch as two dozen artisans from nearby villages enter the room and approach a display of assorted *chulha* (cookstove) models placed on the floor. As the men sit down around the display in preparation for their improved chulha marketing class, Mr Mhagen turns to me and comments that these stoves are all smokeless models. "They are marketed by agencies around Maharashtra to reduce harmful emissions in the cooking area." A few minutes later, as the course instructor enters the room and the classroom quietens, Mr Mhagen motions to a nearby window looking out on a small, forested area. "Not long ago these stoves were distributed by government agencies to reverse deforestation. Efficient burning of fuelwood was most important." He continues telling me about the history of chulha, noting how stoves have been the target of diverse development objectives.

> "Here, this course is paid for by agencies that want to reduce pollution and drudgery for women yes, but they also want to teach artisans how to think commercially. This stove program helps agencies test market approaches to distributing rural goods."

Mr Mhagen begins to whisper as the class gets under way, "And now, there is talk of replacing old stoves with new ones that don't contribute to climate change." He pauses for a moment before stating, "It is very funny, *chulha* are the solution to all the world's problems!"

Mr Mhagen's comment on chulha as the 'solution to all the world's problems' serves as a starting point for this paper, as it raises questions about how cooking technologies are mobilized and distributed in support of diverse development objectives. Bringing scholarship from development and technology studies into productive

dialogue, this paper advances theories on how cooking technology diffusion and innovation programs are accomplished within and between villages, laboratories, and institutions. Previous cookstove diffusion studies have primarily described cultural, technical, and administrative enablers and barriers to distribution (Aggarwal and Chandel, 2004; Hanbar and Karve, 2002; Pohekar et al, 2005; Smith, 1993). Within these discussions, cookstoves are treated largely as apolitical development objects, with little attention given to analyzing the actors and relationships shaping technology-based development. Borrowing core themes from actor-network theory, I take a more relational approach and set out to critically examine technology innovation projects in the context of the actions, characteristics, and interelationships between adopters, innovators, diffusion agencies, and the innovations themselves (Brown, 1981; Webber, 2006).

In Western Maharashtra cooking technologies are mobilized by external funding agencies in order to control the design and distribution innovation process and thereby advance institutional development objectives. Explicit attention to instrumentalist uses of technologies can bring into sharper relief the relationship between powerful institutions, supply chain economies, and chulha design and diffusion characteristics. And yet extrinsic agencies do not 'mobilize' alone as the state, much like other extralocal agencies, is notable for enforcing "management through alliances with locally powerful groups" (Robbins, 2000, page 127). That development programs proceed through a series of cross-scale and interagency alliances is not new (see, for example, Crewe and Harrison, 1999; Li, 1999; 2005; Mutersbaugh, 2002) and has been particularly well documented in the Indian context (Corbridge et al, 2005; Jeffrey, 2002; Kaushik, 2005; Krishna, 2003; Simon, 2009). Within these studies, development has been shown to involve the formation of shared commitments and governance responsibilities between exogenous actors and local groups (Agrawal, 2001; Dressler and Büscher, 2008; Selfa and Endter-Wada, 2008). What is less clear, however, is how control over technology design and distribution decisions is shared between partnership members at various stages of the development process—what I refer to as the 'collaborative technology mobilization process'. It has yet to be fully articulated how common and divergent development commitments are negotiated among participating actors operating at various scales and what these intrapartnership relationships presage for development outcomes.[1]

When examining technology innovation programs, it is not enough to merely determine *that* such programs succeed and fail for certain targeted communities. Instead, I endeavor to trace patterns of uneven development to the relationship between participating actors and also to the overarching organizational and administrative structure of design and distribution projects. My first objective is therefore to underscore the collaborative nature of technology mobilizations and, more specifically, to highlight how power is distributed across partnerships at different stages of the development process. Doing so enables us to better understand why development succeeds and fails for particular targeted community groups. The second objective is to highlight the influential role of local intermediaries in the mobilization process. Despite the presence of top-down policy directives in each case study, the distribution and innovation of cooking technologies are achieved in a manner that at least partially reflects the interventions of local partnership members. Following my previous paper (Simon, 2009), I call attention to the crucial role of mediating agents who influence

[1] The term 'collaborative' is not meant to imply that all participants necessarily share similar project objectives or views on how best to achieve development. Within collaborative technology mobilizations, decisions and actions are rarely unified. Partnerships are collaborative insofar as all members agree to share resources and administrative duties.

development as it unfolds on the ground. Each short story highlights how local alliance members intercede technology supply chains in order to both reinforce funding agency objectives and chart new development trajectories within diverse economic fields. In this sense local partnership members are shown to serve as both conduits and sources of power. They stabilize hegemonic technology distribution economies and also activate alternative technology design and economic potentials (Gibson-Graham, 2006; Hickey and Mohan, 2004). My third objective is to differentiate between collaborative technology mobilizations under centrally planned and market distribution frameworks. Here, alliances in each setting are evaluated in order to assess how the behavior of local partnership members (and, by extension, control over key development decisions) varies under each distribution structure, and what this portends for technology innovation outcomes.

Dual adoption analytic framework

In order to effectively interrogate these issues I argue for the utilization of a 'dual adoption analytic framework' (see figure 1). This framework presents a useful investigative structure for examining how technologies are actively produced through oftentimes complex and multiscaled planning histories (Robbins, 2001). Numerous studies have described how technology-based development programs generate outcomes that fail for certain targeted rural communities while succeeding for others (eg Baker and Jewitt, 2007; Birkenholtz, 2008; Dubash, 2002; Jewitt and Baker, 2006; Patterson et al, 2007; Shriar, 2007). However, within these accounts very little attention has been given to evaluating how governance frameworks operating across temporal and geographic scales shape these outcomes. The dual adoption analytic framework distinguishes between three phases of the development process. First is the planning phase that occurs prior to the formal adoption of funding agency design and diffusion innovation protocols. This is followed by an implementation phase that occurs after protocol adoption and involves intervention by other organizations vying to shape development trajectories. Actors operating within each phase combine to influence the design and distribution characteristics of technologies that in turn

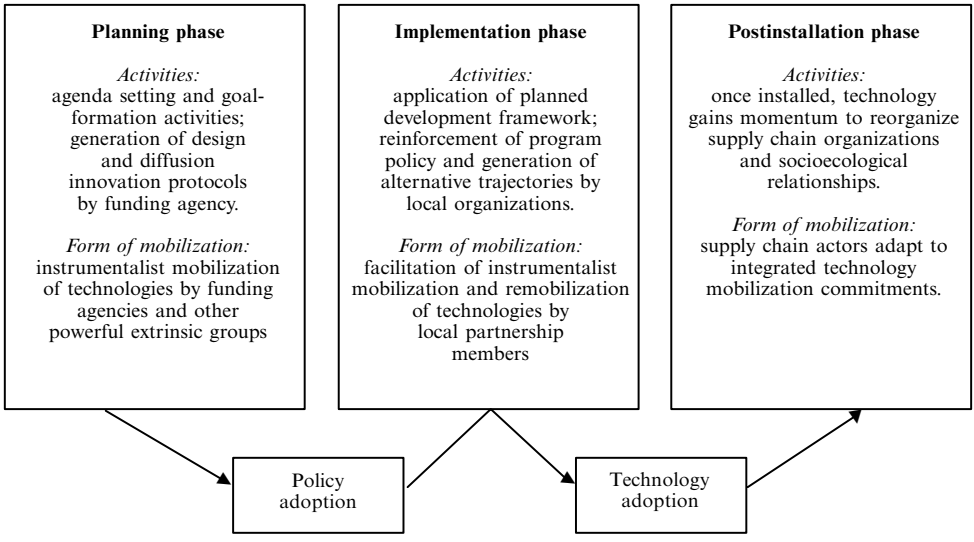

Figure 1. Dual adoption analytic framework for technology-based development.

continue, during the third phase, to reorganize supply chain social relations of production and domestic cooking practices.[2]

Fundamental to this framework is recognition that funding agencies and local groups share responsibilities (ie collaborate) during the technology mobilization process. A dual adoption framework is therefore useful for challenging assertions that science and the policy paradigms it produces are like a carefully tended garden that "tends to grow in directions that are consistent with the goals of political and economic elites" (Hess, 2007, page 22). This line of reasoning suggests that powerful agencies are able to concretize, or 'lock in', ideological agendas during the planning phase of development through preemptive objective-setting behavior (Demeritt, 1998; 2001; Latour, 1987). As a consequence, technology design and distribution protocols are adopted containing policies that reflect the prescribed management objectives of extrinsic agencies. As Birkenholtz (2009, page 123) notes, once installed, technologies then gain "momentum in shaping social and political institutions and ecologies" through the disciplining of technology designers, fabricators, distributors, and users. There is indeed evidence from Maharashtra that forms of 'reverse adaptation' are widespread as various supply chain actors have adapted social relations of production to meet modified technology design, production, and distribution requirements. These requirements in turn influence the form and spatial distribution of indoor ecological change across various villages and households. Indeed, the ability of technologies to actively construct the world around them postinstallation is crucial for understanding the recursive relationship between technologies, social institutions, and ecological change (Latour, 2004).

I am, however, careful to diverge from characterizations of technology-based programs that reduce the development process to preinstallation and postinstallation stages. Such a perspective tends to treat powerful agencies and targeted user groups as discreet and inherently oppositional. Under this lens one group of powerful actors sets the parameters of technology innovation while recipient groups adopt (and adapt to) those technologies with varying levels of willingness and success (Winner, 1986). If, as Hess (2007) suggests, technology innovation trajectories typically follow the goals of political and economic elites, then other organizations will be left to search unsuccessfully for alternative technology development outcomes.

Instead, with this paper I embrace a relational approach to understanding the bidirectionality of interactions between social–technological–ecological actors that is customary of work within the field of actor-network theory. Evidence from Maharashtra suggests that analysis of preinstallation phases should differentiate between periods of policy planning and program implementation. Drawing this distinction highlights the propensity for planning and implementing agencies to share responsibilities and control over the technology design and diffusion process. This approach distinguishes between 'adoption' as a policy and material practice. The former refers to the moment when design and diffusion characteristics are 'adopted' within development policy, while the latter refers to the occasion when technologies are installed and put into working function. A dual adoption approach demonstrates how, once installed, technologies reflect and reinforce the integrated commitments of agenda-setting funding agencies,

[2] It is important to note that all technology-based development programs operate differently and this model is in no way meant to reflect variations in programs implemented in different geographies and between unique assemblages of interest groups. In some cases the funding agency may have very little role in determining program objectives. In other cases local actors may have a greater influence during planning phases of development. This model is, however, useful as a heuristic for conceptualizing technology innovation programs as composed of diverse groups interacting across various temporal and geographic scales.

and also of intermediary organizations and village-level interest groups who enter the development process once innovation frameworks are being implemented.

The remainder of this paper is divided into four sections. In the following two sections I describe two important chapters in the history of improved cookstove intervention in Maharashtra, India that each highlight (a) how and why technologies and their supply chains are mobilized by development partnerships, (b) how power is distributed across partnerships and in particular the influential mediating role of local partner members, (c) the influence of state and market distribution structures on the collaborative mobilization process, and (d) what these technology design and diffusion governance characteristics mean for recipient households and supply-chain artisans. In the discussion section I revisit core objectives of the paper in order to advance theories on the collaborative technology mobilization process and the role of local intermediaries as agents capable of both stabilizing development mandates and activating alternative development pathways. A short conclusion summarizes my main findings.

Research for this project was conducted over a six-month period in 2005 – 06. Field research involved open-ended interviews, surveys, and participant observation in the Kolhapur, Satara, and Sangli districts of Southwestern Maharasthra. Village-wide surveys were conducted with all females in charge of household cooking in four villages (up to several hundred per village), and semistructured interviews and follow-up surveys were carried out with forty females from the initial survey population. Participant observation and open-ended interviews were conducted with eleven nongovernmental organization (NGO) employees closely involved with chulha distribution activities in my study area, including four program managers and seven field officers. These extended interviews were conducted during a period of nearly four months shadowing NGO employees during training classes, village demonstrations, and visits with artisans in the study area. Open-ended interviews and survey questions were also used to examine the experiences of fifteen artisans producing, marketing, and installing improved cookstoves in one or more of the four districts. These areas lie within the Pune division of Maharashtra and contain some of the most productive agricultural lands in the region. These districts were selected because they were targets of both state-subsidized and internationally financed, market-based interventions.

Story 1: mobilizing cooking technology supply chains for conservation

In 1983 the Government of India introduced its most far-reaching and influential cookstove program. Under the jurisdiction of the Department of Nonconventional Energy Sources (later assuming a ministerial designation), the National Program on Improved Cookstoves (NPIC) set out to install efficient and cleaner burning cookstoves in rural homes throughout India. From 1984 to 2002, and as a result of the NPIC program, cookstoves were modified in over 32 million rural households. In the state of Maharashtra, alone, approximately 2 million improved stoves were distributed (NCAER, 2002; World Bank, 2002a).[3] Constructed through local artisan networks and designed with the aid of village-level field demonstrations, improved chulha in Southwestern Maharashtra were designed to meet goals associated with the appropriate technology model of rural development—a framework promoting local employment generation and the production of ecologically, culturally, and financially suitable technologies for households. The Appropriate Rural Technologies Institute (ARTI) began promoting this vision during the early 1980s by engaging in the

[3] The 2 million stove estimation for the state of Maharashtra was calculated using the following data: 1.1 million stoves distributed in 1983 – 93 (NCAER, 2002) and 790 000 stoves distributed in 1995 – 2000. The years 1994 and 2001 are omitted from this total due to lack of reliable data.

"development, through laboratory and field trials, of improved stove models suitable for the eating and cooking habits of the region in operation" (Hanbar and Karve, 2002, page 50) and by emphasizing stove fabrication and distribution "as a vehicle of income generation in rural areas" (page 51). Like traditional chulha, improved varieties require only locally available resource inputs and are intended to be simple to operate and inexpensive to fabricate.

Under the NPIC, authority over stove fabrication and artisan training courses was handed down to ARTI, which served as the regional nongovernmental technical back-up support unit (TBSU). Despite efforts by the NPIC to partner with ARTI and decentralize improved cookstove design and diffusion tasks, certain performance standards and technical stove specifications remained influenced by policy objectives radiating from Ministry of Nonrenewable Energy Sources (MNES) offices in New Delhi. Centralized control was asserted four times a year when representatives from ARTI and other stove-producing NGOs met with the Ministry's Chulha Approval Committee (CAC). Here, scientists and engineers consulted with high-level officials from the MNES to ensure that new designs met program goals and contained construction dimensions that would ensure proper performance standards (Rehman and Malhotra, 2004).

During the 1980s and early 1990s CAC advisers argued that improved chulha should play a central role in efforts to thwart deforestation by containing baseline specification promoting fuel efficiency. Efficient burning stoves were designed primarily to lower levels of wood consumption amidst fears of an emerging 'fuelwood crisis' threatening the livelihood of rural communities throughout India (Agarwal, 1986; Nagothu, 2001). The effect for many forest-dependent communities and women in particular, it was argued, was a significant decrease in access to forest resources including wood fuel for cooking and heating (Pandey, 2002; Sinha, 2001).

The shaping of conservation policy around engrained environmental management orthodoxies and institutionally dominant beliefs concerning ecological change are well documented (eg Forsyth, 1996; Neumann, 2002). Indeed, in Western Maharashtra the design and fabrication of appropriate cooking devices remained consistent with state performance mandates and conformed to MNES anti-deforestation policy goals throughout the 1980s and early 1990s.[4] Predominantly male scientific officers and craftsmen at ARTI supported MNES officers and CAC members by performing lab-based and field-based tests in order to generate stoves capable of reducing wood fuel consumption.

Technical advertisements from the MNES directed at designing fuel-efficient stoves were supported by a punitive enforcement system. Noncompliance through the sustained distribution of nonstandardized stoves was met with swift penalties that included revoking artisan accreditation and removing TBSU employees from management posts. As one artisan noted, "when the CAC issued its orders for stove design, I did not question them. Why would I risk my business?" Other artisans, however, indicated that their cooperation with the MNES was far from coerced. Program managers at ARTI described forming partnerships with MNES officers and following stove fabrication protocols in order to maintain a supervisory position in the production of state-sanctioned stoves:

[4] Despite its remarkable influence at the policy level, by the mid-1990s most local agencies and policy makers alike rejected the notion that wood collection for domestic purposes was a major driver of deforestation and widespread woodfuel shortages (Nagothu, 2001; Pandey, 2002; United Nations, 2000).

"At the time, we were always competing with other agencies to earn government support. If we wanted to keep our influence in nearby communities, then we followed the rules. Working with the government gives us opportunities to help villages now and in the future."

Maintaining strong ties with NPIC officials therefore provided ARTI with a clear advantage over other NGOs and science institutes in the region seeking to develop working relationships with powerful government functionaries.

And yet officers at ARTI and its partner NGOs worked equally hard to comply with the needs and development objectives of local entrepreneurial classes. Employees at ARTI recruited artisans and incorporated their enterprises into a network of subcontracted chulha producers. They also worked alongside NPIC program officers as local advisers assisting in the distribution of material cost offsets to entrepreneurs. As a field officer at the Sahyadri Cooperative put it,

"The officials in Delhi wanted to create jobs, that was their goal. But how could they? They were not here. And artisans did not know about the NPIC subsidies. We looked after the workers. We trained them. We helped them earn accreditation and transfer financial resources so their enterprise would grow."

By positioning themselves between artisans and the state, local NGOs served as crucial catalysts for the distribution of subsidies to technology fabricators and distributors. As cost subsidies were distributed within nearby artisan communities, savings were passed down to consumers resulting in affordable stove prices for even the poorest households.

The fuel-efficient chulha: implications for households

The material construction and performance specifications of standardized improved cookstoves were not merely a benign byproduct of policy prescriptions and organizational goals. Quite the contrary, stove characteristics shaped their compatibility (or incompatibility, as the case may be) with household needs throughout their area of distribution. The prominent Bhagylaxmi improved 'efficient' stove model (figure 2) was first developed and disseminated under the NPIC in the early 1980s. It was designed first and foremost to reduce the amount of woodfuel required to achieve and sustain boiling water (Tilak et al, 1990). Promoting fuel-use efficiency meant improving heat transfer from flame to cooking pot per unit weight of woodfuel consumed. This common stove was designed to burn only fuelwood because it was assumed (we now know incorrectly) that fuelwood was the primary fuel consumed (Hanbar and Karve, 2002). As a result they were ill equipped to burn other commonly used forms of biomass such as dung and crop.

By the mid-1990s, however, the primary objectives of cookstove programs were radically altered. Cleaning the indoor environment and serving the health needs of female stove users became the dominant policy objectives (Hanbar and Karve, 2002).

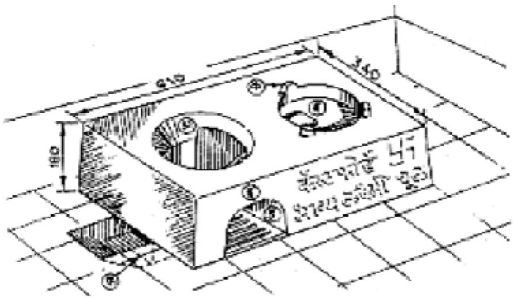

Figure 2. Bhagylaxmi stove (source: Appropriate Rural Technologies Institute).

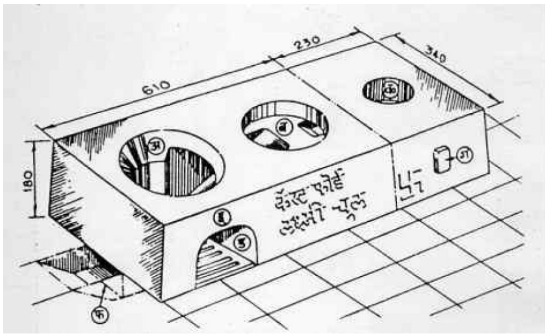

Figure 3. Laxmi stove (source: Appropriate Rural Technologies Institute).

During the mid-to-late 1990s the link between fuelwood collection and large-scale deforestation was challenged and concerns over indoor air pollution increasingly captured the interest of development agencies. As a consequence, improved 'smokeless' Laxmi stoves became more widely issued. Smokeless improved cookstoves are designed to reduce harmful emissions, and emphasize ventilation through the use of hoods and chimneys (Karve, 2007). The updated, smokeless Laxmi chulha (figure 3) increases the flow of oxygen into the burning chamber, which improves fuel combustion efficiency for a diverse set of fuel types and enables biomass to burn in a more complete manner without emitting partially combusted carbon, commonly referred to as 'soot'. It also contains a pipe fitting on its right side that can be affixed to a mud or cement chimney to remove smoke almost entirely from the cooking environment (Karve, 2007).

The pollution-reduction benefits brought about by transitioning from efficient to smokeless chulha were higher than initially thought. According to studies by scientists and engineers who tested these stoves, fuel-efficient varieties did not necessarily reduce pollution levels (Smith, 2000). Moreover, these studies showed that in many cases "the improvement in overall efficiency of a stove... is generally at the expense of he fuel combustion efficiency" (Hanbar and Karve, 2002, page 53), leading harmful emissions to be higher in improved 'efficient' stoves than in many traditional varieties (IPCC, 2007, page 729). The Bhagylaxmi and early Laxmi models, designed to increase fuel efficiency, actually had lower fuel combustion efficiency than a traditional stove—that is, burning wood efficiently also generated more soot (Zhang et al, 1999). Even early Laxmi stoves equipped with chimney pipes to remove smoke were installed in ways that emphasized fuel efficiency at the expense of smoke output. When field tests by TBSU employees found that shorter stove pipes increased fuel efficiency by reducing the velocity of flue gases, it was recommended by members of the CAC that Laxmi stoves should be delivered with chimneys of only 3 feet tall. In most cases this was not even high enough to reach the roof, let alone protrude through it (Tilak et al, 1986).

Story 2: mobilizing cooking technologies for commercialization

Indicative of postmodern development state programs (Das, 1998; Gupta, 1998; Li, 2005), the NPIC utilized a social-welfare-oriented model of intervention that issued guaranteed sales payments to artisans and subsidy provisions to households. Both of these conditions brought program benefits to members of scheduled castes, tribes, and other backward classes (NCAER, 2002). The mid-1990s, however, brought about a dramatic shift in the institutional and economic landscape of cookstove production.

During this period the World Bank's Energy Sector Management Assistance Program (ESMAP) began advising a number of household-energy-related programs in India. Officials within ESMAP criticized the NPIC for being an unwieldy public enterprise incapable of generating substantive household demand (Hanbar and Karve, 2002; Kishore and Ramana, 2002; Rehman and Malhotra, 2004). ESMAP therefore suggested a more limited role for the government, and advocated for increased market incentives and business opportunities for firms in the private sector to deliver household energy services. After nearly eighteen years of operation, India's central government phased out the NPIC in mid-2002.

A few months after the NPIC closed, ESMAP released an 'Agenda for Action' with the goal of alleviating health risks associated with indoor air pollution for rural poor while simultaneously enabling economic growth:

> "To ensure a sustained effect of mitigation measures, there is a need to promote market mechanisms for distribution of improved stoves and commercial fuels. Programs that disseminate improved stoves on a commercial basis enjoy greater financial sustainability and respond better to user demand, including the production of more durable stoves. Similarly, a liberalized market for commercial fuels with a level playing field for all operators with proper regulations would lower the costs and increase the quality and availability of services to consumers" (World Bank, 2002b, page 5).

Beginning in early 2003, and following a series of structural adjustment directives from ESMAP, the Shell Foundation—a corporate foundation of the Royal Dutch and Shell Group of Companies—began investing in sustainable markets and disseminating scalable business practices for the purpose of increasing the regional distribution of improved cookstoves. The state of Maharashtra was used as a test site for their Commercialization of Biomass Fuel and Cooking Devices (CBFCD) program (Shell Foundation, 2005).

As the state disinvested in cookstove distribution programs, the region witnessed the emergence of flexible governance opportunities for community-level groups (Carney and Farrington, 1998; Larner, 2003; Smith, 2004; Swyngedouw, 2005). ARTI was chosen by the Shell Foundation to serve as a local partner because of its extensive experience managing chulha innovation and distribution programs in the region. By partnering with the Shell Foundation, ARTI further bolstered its legitimacy within local, national, and international development circles (Sundberg, 2003). Moreover, this partnership has brought about financial benefits for ARTI as development provisions have engendered relationships organized around acts of remuneration (Harriss-White, 2004). As ARTI issues development assistance, it in turn becomes a recipient of financial and political capital in local development affairs.

Serving as local partners under the CBFCD program involves working closely with local artisans to ensure that stove models are compatible with household needs while also collaborating with the Shell Foundation to oversee the implementation of their commercialization template. As one program manager at ARTI put it,

> "there is a whole business model we have to meet for the Shell Foundation. But you see, we know these villages best. We are the social-minded people. We develop our professionalism with an ear to the ground."

As it strives to meet Shell Foundation demands while also keeping 'an ear to the ground', ARTI has repositioned itself as an influential intermediary capable of concretizing policy protocols and also engendering unplanned technology innovation and distribution outcomes.

The chulha commercialization template: implications for households and artisans

Market-based development intervention has led to fabrication of stove technologies that are more likely to meet the needs of targeted households by reducing indoor air pollution and addressing regionally differentiated household fuel requirements. This is due in part to the removal of CAC design mandates and also the ability of artisans, with financial assistance from partner NGOs, to establish a customizable production framework capable of meeting diverse household technology requirements. And yet commercialization has also resulted in increased commodity prices that reduce local access to goods and services for poorer households. To begin with, under the NPIC indirect subsidies of up to 50% were issued to all targeted households. Market distribution, on the other hand, relies on marketing campaigns—newspaper, radio, public demonstrations—rather than on subsidized prices to attract customers. Without subsidies the cost of improved chulha immediately doubled for all households. The price indices for improved cookstoves have increased by another 50% as a result of changing upstream market conditions that affect chulha production costs for artisans. Of the fifteen artisans interviewed in this study, all reported raising their chulha price from between R180 – 220 per chulha to approximately R400 per chulha within two years of the NPICs closing (see table 1).[(5)] Such price increases occur through processes described by Tsing (2009) as "supply-chain capitalism" where the forces of structural economic change generate a set of market contingencies that are internalized and ultimately reworked by supply-chain operatives.

Table 1. Cookstove price and subsidy structure in Maharashtra.

Price (R)	Type of stove			
	Shell Foundation (2005)		National Program on Improved Cookstoves (2001)	
	one pot cement	two pot cement	one pot cement	two pot cement
Unit stove cost	400	400	220	220
Central subsidy	0	0	100	110
Cost to consumer (%)[a]	400 (100)[b]	400 (100)[b]	120 (55)[a]	110 (50)[a]

[a] Members of scheduled caste/tribe and other backward classes paid only R10 – 20 due to additional state-level subsidies.

[b] Some stove users receive subsidies from village-level sources, depending upon affiliation with self-help groups, village *Panchayat* allocation of state funding for health and education, or the assistance of outside agencies.

According to artisans, market-based production and distribution structures precipitate three influential production contingencies that alter the price index of improved chulha. First, because artisans no longer receive a list of targeted households from block development officers at the beginning of the year, they navigate the open market independently, actively seeking households through costly and time-intensive marketing campaigns. As one artisan noted, he is "unsure month on month what the future will bring. Under the NPIC" he went on, "artisans had a sure market—bulk money and orders ... equaled assurance." The outcome during initial years of commercialization has been lower sales volumes and higher marketing expenditures, leading artisans to

[(5)] For comparative purposes, surveys and extended interviews with fifteen artisans in the region targeted entrepreneurs participating in both NPIC and Shell Foundation distribution frameworks. Collection of data occurred during numerous extended multiday visits with artisans including periods of active chulha construction and dissemination.

raise stove prices. Second, without NPIC-facilitated bulk orders, artisans buy raw materials such as cement and metal parts in smaller quantities so as to respond to unpredictable household orders.[6] With smaller production economies of scale, the cost of fabrication and average stove prices have increased. Third, artisans openly admit to performing acts of opportunism. Without federally mandated price points, many artisans bypass poorer households and seek out wealthier clientele willing to pay more for stoves. In the villages of Parandwadi and Ganesh Nagar, which contain a high number of poorer households, the elimination of subsidies and increased production costs for artisans have resulted in stove prices that prohibit many households from purchasing and experiencing the health benefits of improved chulha. Only 35% of households in Pharandwadi and no homes in Ganesh Nagar made purchases.[7] Opening up the cookstove production and distribution process to private investors has fundamentally altered artisan supply chains and the price and distribution structure of improved cookstoves.

The ripple effect of targeted international investments in market infrastructure has not only contravened core affordability objectives of the appropriate technology program espoused in ESMAP's Agenda for Action, but has also undermined efforts to maintain high rates of job creation. Development projects in India are frequently marked by acts of corruption and favoritism, which tend to funnel development benefits to a select group of well-connected individuals (Corbridge and Kumar, 2002; Harriss-White, 1999; 2004; Jeffrey, 2002; Jeffrey and Lerche, 2000). The infusion of financial capital into market infrastructure has only fueled such outcomes and offset social safeguarding activities aimed at promoting local employment generation. For example, a small number of artisans in Southwestern Maharashtra have outperformed their competitors by receiving disproportionate levels of Shell Foundation seed money. Field officers at ARTI and its partner NGOs intentionally issue development benefits to artisans who are capable of returning favors through political and financial reparations. One field officer with access to Shell Foundation money captured this behavior by mentioning sarcastically that "you work to help all fabricators and distributors of *chulha* but not all of them are capable of returning the favor." These acts of corruption and favoritism have led many formerly profitable rural artisans to fail in the commercial marketplace as a result of being crowded out by larger, more lucrative artisan enterprises. According to a long-time artisan and fabricator of chulha chimney pipes,

> "If you outworked your competitors, your business would grow. That's how it was under the NPIC. Now it matters who you know. Who can give you special deals and privileges?"

[6] The cost of raw materials for artisans has increased due to smaller and intermittent purchase orders. Many regional wholesalers have experienced significant revenue increases as a consequence of increasing their profit margins per unit of raw material sold. The financial benefits received by a few regional wholesalers from the commercialization of cookstoves at the expense of dozens of artisan enterprises does not satisfy the employment-generation objectives of appropriate technology programs and in fact signifies the reallocation of wealth away from many towards a few.

[7] Surveys were distributed to all households in order to determine why each village had such low acquisition rates. In order to pinpoint how higher unsubsidized cookstove prices might influence household decision making, semistructured interviews were conducted with forty households who indicated in initial surveys that they operated without a functioning improved cookstove yet held a strong desire to purchase one. Out of thirty households in the villages of Parandwadi and Ganesh Nagar, twenty six (fourteen and twelve, respectively) specifically described finding unsubsidized chulha too expensive and not worth the purchase price. These numbers should not come as a surprise to officials familiar with stove distribution in India. In 2002, near the end of the NPIC, a similar study by the NCAER found that 92% of beneficiary households would not have chosen to purchase an improved chulha had subsidies been eliminated.

In another notable example, a relative of a Shell Foundation program surrogate used familial connections and direct access to foreign investments to open a large warehouse for the production and sale of improved cookstoves. Other artisans in the region expressed concerns about operating against such a formidable competitor holding numerous competitive advantages. "This money", one artisan mentioned in reference to Shell Foundation investments, "is supposed to support the whole *chulha* market, not just one or two artisans." As a result of these and other similar acts of collusion, patronage, and nepotism, the region has witnessed a slowly deepening artisan class structure and the emergence of a petty bourgeoisie community composed of large-scale chulha producers with more employees, higher storage space availability, and higher volume of sales. This is an important distinction as the artisan community class system has transitioned from flat to highly uneven. Coupled with a decrease in strict procedural mandates, this has led to increased diversity within the artisan economy and the possibility for multiple economic positions and development pathways.

Discussion

Domestic cookstoves in rural India have long been targeted as low-hanging-fruit technologies for addressing a diverse range of problems from deforestation and indoor air pollution to global warming and rural market inefficiencies. Theories on how technologies are mobilized in these design and diffusion innovation projects and why they succeed and fail for certain targeted groups can be improved by explicitly detailing the composition and power structure of development partnerships. Adopting a dual adoption analytic framework is an important first step. This framework underscores how the mobilization process spans planning, implementation, and postinstallation phases of development and proceeds through a cross-scale 'collaborative technology mobilization process'.

Technology innovation outcomes in Western Maharashtra

A survey of development outcomes under the NPIC and CBFCD programs reveals mixed success for targeted communities. In story 1 improved fuel-efficient chulha not only supported the mitigation of a misdiagnosed problem, but also produced technologies with incompatible fuel requirements for many households in Southwestern Maharashtra. Moreover, anti-deforestation policies became instantiated in the design of chulha resulting in devices that were not only ostensibly benign to the issue of indoor air pollution, but also installed and calibrated in ways that produced more smoke than traditional models. Although the primary objective of the NPIC was to ensure stove compatibility through the delivery of 'appropriate technologies' to households, cooking technologies under the NPIC largely failed in this capacity and instead found success actualizing employment and affordability objectives (see table 2). Employment opportunities were generated through artisan raw material subsidies and program guidelines issuing guaranteed payments to artisans. These efforts in turn drove down stove prices resulting in affordable chulha for even the poorest households.

Story 2 illustrates how sector privatization and global flows of financial capital in support of market entrenchment alter production and delivery regimes for artisans and other supply chain actors. Development through market expansion has marginalized disadvantaged households and limited their access to development benefits and environmental resources (Bakker, 2002; McCarthy and Prudham, 2004; Paulson et al, 2003; Smith, 2004). Households in Pharandwadi and Ganesh Nagar, for example, have witnessed a stark rise of nearly 50% in the price structure of improved chulha—an outcome that directly contradicts ESMAP's prognostications for lower chulha costs. In sum, the environmental benefits of marketization accumulate within wealthier sectors of society while the burdens of indoor environmental degradation disproportionately

Table 2. Appropriate technology design and distribution innovation outcomes.

	Appropriate technology program objectives[a]			
	local employment generation	ecologically appropriate	culturally appropriate	financially appropriate
National Program for Improved Cookstoves	New opportunities for nongovernmental organization field officers and local artisans	*Higher levels of smoke in fuel-efficient improved cookstoves during early part of campaign*	*Limited fuel input possibilities due to woodfuel emphasis in efficiency-oriented cookstoves*	Program subsidy structures kept cookstove prices at affordable levels for most households
Shell Foundation's 'Commercialization of Biomass Fuel and Cooking Devices' program	*Employment and enterprise development consolidated amongst a few well-connected artisans*	Emphasis on smoke reduction generated cookstoves that reduce indoor air pollution levels	In most cases commercial distribution has resulted in culturally appropriate devices	*Increased stove prices as a result of subsidy rollbacks and altered supply-chain conditions*

[a] Outcomes contravening objectives are given in italics.

afflict poorer segments of the population (Awanyo, 2001; Guha and Martinez-Alier, 1997). The Shell Foundation program, therefore, has had the effect, as Swyngedouw (2000, page 53) suggests, of shielding "the bodies of the powerful while leaving the bodies of the poor to their own devices." Moreover, overall entrepreneur involvement in chulha production has declined as a small cadre of well-connected artisans accumulate revolving funds from the Shell Foundation which, in turn, gives them a comparative advantage over their market competitors. While the Shell Foundation program largely fails to promote equitable outcomes, the marketization process has found its greatest success delivering culturally and ecologically compatible technologies to households throughout Western Maharashtra. With clear authority to establish design criteria consistent with household preferences, artisans fabricate improved cookstoves that reduce air pollution and coincide with regionally differentiated household fuel requirements.

Interestingly, each technology innovation and diffusion program fails in areas that were considered to be points of funding agency emphasis. The NPIC program targeted households as a principal unit of intervention by emphasizing mass delivery of appropriate technologies. Program success and failure were measured by the number of homes adopting improved fuel-efficient cookstoves (Hanbar and Karve, 2002). The Shell Foundation meanwhile targets artisans and emphasizes the cultivation of sustainable enterprises and market competition that will eventually lead to lower stove prices for consumers. Market success is determined by the number of new and preexisting enterprises remaining viable over time, and also by the sustained overall price reduction of cooking technologies (Shell Foundation, 2005). And yet, as table 2 indicates, these areas of emphasis by each program have proven least successful. The NPIC is often critiqued for delivering chulha that were quickly discarded by households due to compatibility problems (Hanbar and Karve, 2002; Kishore and Ramana, 2002; NCAER, 2002). And, despite the Shell Foundation's emphasis on cultivating sustainable artisan enterprises, the CBFCD program has failed to promote financial stability for many artisans or affordable stoves for households (Simon, 2009). In short, development policies directly reflecting funding agency planning efforts largely fail to generate equitable development outcomes for many household and artisan communities.

Collaborative technology mobilizations and the role of development intermediaries

Each case study takes stock of how extrinsic agencies, and their local counterparts, share administrative commitments to exert authority over development affairs (Agrawal, 2001). Acknowledging the collaborative nature of technology mobilizations is important, as the outcomes described above would hardly be surprising if generated through unilateral, top-down decision-making frameworks. While the formation of alliances is certainly not new to the study of rural development programs in India (see, for example, Corbridge and Kumar, 2002; Corbridge et al, 2005; Kaushik, 2005; Krishna, 2003; Simon, 2009), what is less immediately clear is how power circulates within partnerships at various stages of the development process and how these relationships influence development outcomes. A review of technology design and distribution innovations reveals that the locus of power during planning and agenda-setting stages of development resides within the offices of NPIC and CBFCD program managers. Funding agencies mobilize cooking technologies and their supply chains in order to advance institutional ideological formations. In story 1 technology supply chains are mobilized by the MNES to recalibrate a line of fuel-efficient wood burning stoves that work alongside emerging forest protection policies such as the 1980 National Forest Conservation Act (Saberwal et al, 2001). Meanwhile, story 2 describes how cooking technologies are transformative and mobilized in order to recalibrate rural technology supply chains and promote and test the World Bank and Shell Foundation's vision for a replicable and scalable stove commercialization template. In this context, cooking technologies are utilized by powerful agencies for their capacity to be both actively transformed and transformative agents of development.

And yet over two decades of cookstove distribution programs in Maharashtra indicate that significant levels of power and influence also reside with local development partners. In each story the objectives of funding agencies as well as the priorities of village-level operatives are routed through ARTI and its partner NGOs. Each case study highlights how these partnership members reinforce certain funding agency program objectives, while also charting alternative development trajectories. While the technology 'mobilization' objectives of funding agencies are oftentimes supported by local partners, these mediating agents also remobilize cookstoves to support both their own needs and also the priorities of targeted village groups. In this sense, although the development process is 'collaborative' as each agency willingly participates in the alliance, not all decisions and actions are necessarily unified across the partnership.

The propensity for local partnership members to act as strategic intermediaries renders the development community as more than a scale of operation, and instead as an evolving and dynamic process—as a source of development outcomes and beginnings, and socioecological effects and affects. As Gibson-Graham (2006) notes, the project of examining a hegemonic formation must also include efforts "to contemplate its destabilization" (page 23) and imagine individuals and communities as "'made' and 'as making' themselves" (page 23). Local collaborators who influence technology innovation programs from intermediary positions illustrate how targeted villages are sources of opportunity and productivity that are both acted upon and activated. In this context, the development community should be viewed as an economic field composed of diverse and contingent economic and innovation design potentials. As I describe in the following section, new economic positions arise within communities of small and large artisan enterprises at different moments in time and in response to evolving technology distribution frameworks, financial transaction systems, and enforcement procedures.

Collaborative technology mobilization under state and market development structures

For local partnership members, collaborating with state and international agencies involves reinforcing development policies in order to bring social and financial capital to their organization. During the planning phase of development, design and distribution innovation decisions are structured around top-down mobilization directives reflecting the objectives of funding agencies. During implementation phases, and with the assistance of local partners, these extrinsic agency commitments continue operating within targeted communities (Agrawal, 2005). Each program presents ARTI and other NGOs with different financial incentives to follow pre-established program protocols. Under the NPIC, funding agency stove design policies were reinforced by a heavily bureaucratic state apparatus utilizing punitive enforcement measures. With the support of an authoritative governance structure threatening to revoke noncompliant artisan licenses, government-sponsored training courses influenced the design of efficient cooking technologies reflecting pervasive state anti-deforestation priorities. Under the Shell Foundation, funding agency commercialization policies are reinforced in large part through their propensity to generate opportunities for lucrative acts of corruption. With investment money flowing through local partner agencies and little enforcement over how that money is distributed, the free market has generated openings for partnership members to develop remunerative relations with program beneficiaries. While each program contains different incentives compelling local partners to reinforce program policies, each composite set of factors has laid the foundation for the establishment and continuation of partnership commitments.

The collaborative mobilization process is also notable for the role local partners play in reworking prescribed technology design and distribution innovation protocols. Each development framework presents different barriers and opportunities for partners to exert control over local development affairs. Only during employment-generation activities under the NPIC were partnership members given latitude to significantly alter development plans. Compared with technology design policies that were subject to strict CAC mandates, protocols for recruiting and training entrepreneurs contained considerably less restrictive enforcement measures. Here ARTI and its partner organizations cultivated employment opportunities for artisans through creative and steadfast engagement with enterprise finance transmission networks.

Under the CBFCD program there are very few constraints preventing local partners from generating unplanned development outcomes. While the NPIC program implemented its policy agenda through an authoritative structure, particularly in the design phase, the CBFCD program is guided by a laissez-faire implementation structure giving partners opportunities to engage creatively with the development process. Absent of strict program guidelines, intermediaries under the Shell Foundation program are notable for engaging in acts of benevolence and also avarice. During the implementation phase, mediating local agents such as ARTI are shown to use the development process to secure personal gains and consolidate wealth among privileged villagers, relatives, and well-connected entrepreneurs (see Harriss-White, 1999; Jeffrey, 2002). These same individuals also assist in the delivery of development benefits to marginalized village communities and households (Corbridge et al, 2005; Krishna, 2003). For example, without the threat of punitive penalties under the CAC, smaller artisan enterprises utilize NGO support to enhance their flexible production capacity and develop a customizable stove-production framework that better meets diverse household needs.

Analysis of each development environment reveals that market conditions, while more likely to redirect control over development decisions to local partners, also tend to create more opportunities for corruption and the establishment of remunerative relations that can offset more benevolent mediating behavior (Harriss-White, 2004). On the other hand, state-run programs containing numerous bureaucratic encumbrances and enforcement mechanisms are shown to more frequently constrain local partner behavior and ensure they operate within prescribed development parameters that may be ill-suited to meet the needs of targeted communities. These differences are particularly evident in the structure of financial resource transfers under each program. Field officers at ARTI directly handle investments from the Shell Foundation, while under the NPIC they operated only from an advisory position and without direct access to circulated money.

This paper has illustrated how development outcomes tend to best serve the needs of targeted village communities where intermediaries generate new development trajectories by engaging in acts of benevolence and empowerment. And while these findings alone are unsurprising, what are noteworthy are the conditions this study has identified that tend to promote such intermediary activities. Two case studies reveal that this behavior occurs where bureaucratic measures enforcing prescribed policies are at a minimum (ie there is a clear departure from extrinsic agency policies) and where oversight measures are in place to check financial transactions and prevent the establishment of restitutive relations (ie opportunities for corruption and exploitative behavior are low). Under the NPIC these conditions were limited to employment-generating activities, as stove design and fabrication parameters remained closely hinged to funding agency policies. The Shell Foundation program, on the other hand, is plagued by opportunistic behavior during employment-generating activities, while the stove design process that does not involve unmonitored financial transactions is more likely to generate outcomes consistent with household needs. Dividing the mobilization process into planning and implementation phases reveals not only the crucial role local intermediaries play in development affairs, but also how the structure of partnerships—as either administratively heavy handed or committed to free market principles—influences how control is distributed across development partnerships and, ultimately, how those partnerships shape development outcomes.

Conclusion

This paper reconfirms the importance of scrutinizing how technologies are mobilized within programs of development. Rural chulha present a particularly compelling case given their continued enrollment within diverse and multiscale health, environmental, and economic development projects. An examination of over a quarter century of cookstove replacement project outcomes in Maharashtra reveals how extrinsic agencies and local intermediaries mobilize technologies collaboratively. Using a dual adoption analytic framework I have closely interrogated these activities in order to better understand how intrapartnership structures of control shift during the technology innovation process and in turn shape development outcomes. During the planning phase, development strategies closely hinged to the ideological commitments of funding agencies generate supply chain interventions that frequently fail to adequately address the needs of the poorest and least politically connected populations. As part of the implementation phase, local partnership members reinforce these policy agendas while also engaging in acts of opportunism and corruption, both of which further state-based and market-based technology innovation failures. And yet these same local partners serve as agents of equity and benevolence capable of responding not only upwards to funding agencies, but also downwards to the needs and priorities of less powerful village-level groups.

Here, local partners remobilize technologies and activate new development pathways within a diverse artisan economy in order to serve the best interests not only of their organization, but also of targeted entrepreneurs and village households.

This study has also shown how the behavior of local partners, and by extension intrapartnership structures of control, varies between state and market programs. Development outcomes are shown to best serve the needs of participating households and artisans when control over key technology innovation decisions resides with local partners, and also where opportunities for corruption by mediating agents are low. While centrally planned programs tend to restrict levels of control by local partners, they are also shown to minimize opportunities for corruption. Market-based programs, on the other hand, are more likely to devolve control to local partners. And yet market-based programs also encourage development outcomes that are closely aligned with networks of restitution, favoritism, and corruption. Of course, lessons learned from this study concerning the collaborative mobilization of technologies should not be confined to Western Maharashtra and may be productively applied to other design and distribution innovation programs. Of particular note is the proliferation of carbon-offset programs calling for large-scale cookstove replacements in the developing world as a global frontline in the effort to combat climate change.

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