Informal Sector Pollution Control: What Policy Options Do We Have?

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Discussion Paper 00-02

December 1999

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ABSTRACT

In developing countries, urban clusters of informal firms such as brick kilns and leather tanneries can create severe pollution problems. However, these firms are quite difficult to regulate for a variety of technical and political reasons. Drawing on the literature, this paper first develops a list of feasible environmental management policies. It then examines how these policies have fared in four independent efforts to control emissions from informal brick kilns in northern Mexico. Our case studies suggest the following: (i) conventional command and control process standards are enforceable when buttressed by peer monitoring; (ii) surprisingly, clean technologies can be widely diffused even when they raise variable costs, in part because early adopters have an economic incentive to promote further adoption; (iii) boycotts of "dirty" goods sold in informal markets are unenforceable; (iv) well-organized informal firms can block implementation of costly abatement strategies such as relocation; (v) private sector-led initiatives may be best suited for informal sector pollution control.

Key Words: Informal sector, environmental policy, Latin America, Mexico.

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1. INTRODUCTION[1]

In most developing countries, the informal sector has grown swiftly over the last several decades as a consequence of population growth, rural–urban migration, and regulation. Today it accounts for more than half of nonagricultural employment in virtually all Latin American and African countries (Ranis and Stewart, 1994, 18–20). Although often characterized as a collection of street merchants, the informal sector actually includes many pollution intensive activities such as leather tanning, brick and tile making and metalworking. Given the sheer number of such firms in developing countries, the aggregate environmental impacts can be very significant.

But controlling pollution created by informal firms is especially difficult—even by developing country standards—for a number of reasons. By definition, informal firms have few preexisting ties to the state. In addition, they are difficult to monitor since they are small, numerous, and geographically dispersed. Finally, they sustain the poorest of the poor. As a consequence, they may appear to both regulators and the public as less appropriate targets for regulation than larger, wealthier firms. Given these constraints, the application of conventional regulatory approaches is bound to be problematic, if not completely impractical.

In Mexico, as in developing countries around the world, small-scale traditional brick kilns are a notorious informal sector source of urban air pollution. According to one estimate, there are approximately 20,000 traditional brick kilns in Mexico (Johnson and others, 1994). Many large cities support several hundred kilns. The kilns are fired with a variety of cheap, highly polluting fuels including plastic refuse, used tires, manure, wood scrap, and used motor oil. As a result, in some cities they are a leading citywide source of air pollution. Moreover, they are inevitably a serious local health hazard to the residents of the poor neighborhoods that typically host brickyards, as well as to brickmakers themselves.[2]

Efforts to control pollution from traditional kilns in Mexico have not been coordinated at the national level. Rather, individual municipalities have implemented a variety of strategies that have met with decidedly mixed success. This mixed record provides an opportunity to study which types of policies work and which do not.

Using the existing literature as a starting point, this paper first develops a menu of feasible policy options for pollution control in the informal sector and then examines how these policy options have fared in dealing with traditional Mexican brickmakers. We analyze pollution control efforts in four study cities in northern Mexico: Cd. Juárez, Saltillo, Zacatecas, and Torreon. Our case studies are based on interviews with brickmakers, regulators, and other stakeholders in each city as well as on primary and secondary documents.

The paper is organized as follows. The second section provides some further background on informal sector pollution and develops a menu of feasible policy options. The third section presents the four case studies. The last section distills lessons from these case studies and concludes.

1. This research was funded by a grant from the Tinker foundation. I am grateful to Geoffrey Bannister for invaluable assistance with field research and primary documents and to all of our interviewees in Mexico and Texas.

2. For a survey of research on the health impacts of air pollution in developing countries, see Bradley, and others (1992). Although nonanecdotal information on the particular health risks borne by those living near brickyards is scarce, a cursory study in Saltillo, Couhila found that of 55 subjects tested, only 29 presented with "normal" pulmonary functions (Anonymous, 1994).

2. POLICY OPTIONS

2.1. How Serious a Problem Is Informal Sector Pollution?

Given the heterogeneity of informal sector activities, generalizations about their environmental impacts are likely to be misleading. In most developing countries, the majority of informal activities are retail oriented and create few environmental problems beyond litter and congestion (Perera and Amin, 1996). Those informal activities that are polluting may not be leading sources of emissions. For example, in many urban areas, informal sector air pollution is dwarfed by vehicular emissions.[3]

However, certain types of informal activities can create severe pollution problems. Those that have received the most attention in the literature are: leather tanning, electroplating, metalworking, brick and tile making, printing, auto repair, wood and metal finishing, mining, charcoal making, textile dyeing, dyestuffs manufacture, and food processing (e.g., Bartone and Benavides, 1993; Kent, 1991). Informal firms engaged in these activities can have environmental impacts that belie their diminutive size for a number of reasons. Most important, they are often quite numerous; many urban areas support thousands. Second, some evidence suggests that informal sources are more pollution-intensive than larger sources since they use inputs relatively inefficiently, lack pollution control equipment, lack access to basic sanitation services such as sewers and waste disposal, and are operated by persons with little awareness of the health and environmental impacts of pollution (Kent, 1991). Third, as a rule, informal sources are highly competitive (since barriers to entry are relatively low) and therefore are under considerable pressure to cut costs regardless of the environmental impact. Finally, informal firms are usually a significant source of employment and are often situated in the midst of poor residential areas. As a result, their emissions directly affect a considerable population.

2.2. The Standard Regulatory Instruments: Which Are Feasible?

Environmental regulatory instruments are typically categorized according to three criteria: (i) whether they dictate firms' abatement decisions or simply create financial incentives for abatement; (ii) whether they require the regulator to monitor emissions; and (iii) whether they involve government investment in abatement infrastructure. Policies that dictate abatement decisions are known as "command and control" instruments while those that create financial incentives for abatement are referred to as "economic incentive" instruments. Policies that require the regulator to monitor emissions are called "direct" instruments while those that do not are called "indirect" instruments (Eskeland and Jimenez, 1992). Examples of these different types of policies are given in the top three rows of Table 1.

In addition to these standard instruments, a new class of "information-based" policies has recently received considerable attention. These policies rely on disseminating information about firms' environmental performance and/or about the health impacts of pollution.

In many developing countries, a host of financial, institutional, and political factors hamstring environmental regulation: fiscal and technical resources for environmental protection are generally in short supply; environmental regulatory institutions as well as complementary judicial, legislative and data collection institutions are much weaker than in industrialized countries; public sentiment usually favors economic development over environmental protection; and environmental advocacy—historically a critical stimulus to effective environmental regulation—is generally less

3. Some informal activities such as waste collection and recycling even have environmental benefits (Meyer, 1986; van Beukering, and others, 1997).

Table 1. A Taxonomy of Pollution Control Instruments

	Direct	Indirect
Command and Control	• Emissions standard[a]	• Technology and process standards[d] • Relocation
Economic Incentive	• Emissions fee[b] • Marketable permits[c]	• Green taxes[e] • Green subsidies[f]
Government Investment	• Communal treatment facilities • R&D in clean technologies[g]	
Information Based	• Public disclosure programs[h] • Educational programs[i]	

[a]Cap on level of emissions.
[b]Fee charged per unit of emissions.
[c]Allowances to emit a specified amount of pollution that may be traded with other firms.
[d]Mandated abatement technology or production process.
[e]Tax on dirty inputs or outputs.
[f]Subsidy to clean inputs or outputs.
[g]Research and development in pollution preventing technologies.
[h]Publicize information about firms environmental performance.
[i]Publicize information about pollution generally.

prevalent and less well organized than in industrialized countries (Development Research Group, in press; Krupnick, 1997; Eskeland and Jimenez, 1992).

Given these constraints, direct economic incentive and command and control instruments are generally not practical, even when applied to formal firms, because regulators simply do not have the wherewithal to reliably measure emissions and to impose sanctions accordingly (Blackman and Harrington, in press). If direct economic incentive and command and control instruments are generally not practical for formal firms in developing countries, they are clearly not practical for informal firms since, as discussed above, constraints on environmental regulation in developing countries are magnified in the informal sector (Kent, 1991).

Thus, the menu of policy options for pollution controls in the informal sector include the items in gray in Table 1: indirect command and control and economic incentive policies, government investment, and information-based policies. In the next four subsections, we briefly discuss each of these options, drawing on the limited literature on informal sector pollution control.

2.2.1. Indirect Command and Control Instruments

Technology and Process Standards. Technology standards require firms to install and operate certain types of pollution control equipment. They demand relatively little in the way of monitoring: regulators need only check to see that the equipment is installed. Even so, such polices may be ineffective in the informal sector since they generally impose considerable fixed costs on firms with limited financial wherewithal, and since even checking for the installation of equipment among hundreds of anonymous firms may be difficult.

Process standards mandate specific elements of the production process. For example, a process standard may require firms to substitute clean inputs for dirty ones. Monitoring compliance is generally more problematic for process standards than for technology standards.

Relocation. Relocating informal firms may serve three purposes: improving firms' access to communal waste treatment facilities; reducing the exposure of the population to emissions; and providing informal enterprises with secure land tenure which, according to some researchers, improves incentives for pollution control (Perra and Amin, 1996; Sethuraman and Ahmed, 1992). Unfortunately, relocation is generally costly, in part because it usually increases firms' transportation costs: informal firms are typically located close to markets and to their owners' residences (Omuta, 1986).

2.2.2. Indirect Economic Incentive Instruments

Green Taxes. Taxing dirty inputs is a popular policy recommendation for pollution control in countries where direct instruments are impractical. In general, such taxes are relatively easy to administer since in most cases, reasonably effective tax collection agencies already exist (Eskeland and Devarjan, 1996). Taxes have the additional benefit of generating revenue that can be used to defray administration or abatement costs. Unfortunately, environmental taxes have a number of important disadvantages, whether applied in the formal or informal sector. The best known of these is that since input taxes do not target polluting emissions directly, they do not create incentives for pollution control per se. For example, a tax on highly polluting variety of coal creates incentives for firms to switch to cleaner varieties but does not create incentives to install pollution abatement devices. Second, for taxes to be effective, the cross-price elasticity of demand for clean substitutes must be relatively high, that is, firms must have access to less-polluting substitutes at reasonable prices. Otherwise, the tax will simply raise producers' costs without changing their behavior or worse, it will cause them to switch to even dirtier inputs (Biller and Quintero, 1995). Third, ubiquitous black markets make it difficult to target taxes to specific economic activities. As a result, to tax the use of a dirty input (such as chrome) by a specific type of firm (such as tanneries), regulators would have to impose an economy-wide tax on the input, raising costs to firms that use the input without environmental consequences as well as those who do not.

Green Subsidies. Rather than taxing dirty inputs, policymakers have the option of subsidizing clean ones. The principal advantage of subsidies is that they are often more politically palatable than taxes. Their obvious drawback is that they drain scarce fiscal resources.

Boycotts. Although generally not recognized as such, a boycott by downstream buyers of intermediate inputs (such as tanned hides or bricks) produced by particularly dirty informal firms can be thought of as a rather drastic indirect economic incentive policy. The argument for such a policy is that it focuses regulatory effort away from anonymous informal firms and onto formal downstream firms (Biller, 1994).

2.2.3. Government Investment

Communal Treatment. Perhaps the informal sector pollution control strategy that has received most attention in the literature is the construction of communal treatment facilities for solid and liquid wastes (Okasaki, 1987, Chiu and Tsang, 1990, O'Connor, 1996). Communal treatment captures economies of scale in treating wastes and minimizes monitoring effort. In addition, it can overcome important barriers to private treatment including chronic shortages of financial capital, technological know-how, and physical space. But communal treatment has a number of disadvantages as well. Constructing and operating such facilities is costly. When user fees are instituted to finance operating costs, polluters may revert to illegal dumping. Even if polluters are not charged fees, they may still dump wastes since using treatment facilities generally raises labor costs (O'Connor, 1996). In addition, communal treatment creates no incentives for pollution prevention.

Clean Technologies. Although clean technological change and process standards both involve pollution-preventing changes in the production process, the former generally entail more radical changes. Also, unlike process standards, clean technologies ideally *lower* firm's operating costs. Thus, the hope is that firms will adopt them voluntarily or at least with minimal prodding, easing the monitoring burden on regulatory authorities. We categorize clean technologies as a "government investment" policy because public sector financing is often required to develop clean technologies and to subsidize the fixed costs of adopting them.

Clean technologies have received considerable attention in the literature. For example, Biller and Quintero (1995) describe proposals to convert informal tanneries in Colombia to processes that substitute relatively benign chemicals for toxic ones. Most of the literature argues that clean

technologies will not diffuse widely unless they are privately profitable. Given that informal firms generally have slim profit margins and limited access to credit, this implies that successful clean technologies must involve low fixed costs and must reduce variable costs (Kent, 1991, Bartone and Benavides, 1993).[4]

2.2.4. Information-Based Strategies

Information-Based Strategies. In the formal sector, information-based strategies are hypothesized to work by mobilizing a variety of private sector agents to pressure firms to improve their environmental performance. These agents include firm owners and managers, victims of pollution, trade organizations, consumers, suppliers, and competitors (Afsah and others 1999; Tietenberg, 1998). In the informal sector, information-based strategies are especially likely to operate through firm owners since they usually work and live in close proximity to their firms' pollution and therefore are generally among those most severely affected by it (Biller, 1994).

3. CASE STUDIES

In this section, we examine how the policies discussed above have been used in efforts to control emissions from traditional brick kilns in four cities in northern Mexico. The discussion is summarized in Table 2.

3.1. Ciudad Juárez[5]

3.1.1. Background

A quickly growing economically vibrant border city with more than 1 million permanent inhabitants, Cd. Juárez is home to approximately 350 traditional kilns. Principally fired with scrap wood that is often impregnated with toxic finishings, these kilns are frequently cited as the third or fourth leading contributor to air pollution in both Cd. Juárez and its sister city, El Paso, Texas. They constitute an important environmental problem as air quality in Cd. Juárez and El Paso is the worst on the U.S.–Mexican border and among the worst in North America.[6] In addition to contributing to citywide pollution, traditional kilns are a serious local health hazard to those living in the dense residential neighborhoods that surround the majority of Cd. Juárez's eight brick kiln clusters

In Cd. Juárez, as in our other three study cities, a number of factors make it politically difficult to require brickmakers to bear the full costs of pollution control. Brickmaking is a significant source of employment, providing over 2,000 jobs directly and 150 jobs indirectly in transportation and wholesaling. In addition, most brickmakers are impoverished. They typically live next to their kilns in rudimentary houses with no drainage or running water. Finally, brickmakers are well organized. Approximately two-thirds belong to a trade association or other local organization.

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4. Several authors have noted that even if no profitable clean technologies are available, simple low-cost "good housekeeping" measures can both enhance profitability and reduce pollution (Chiu, 1987; Bartone and Benavides, 1993).

5. This section is based on a July 1995 survey of 95 brickmakers in Cd. Juárez, statistical analysis of that survey data; a variety of primary and secondary documents; and interviews with numerous Texan and Mexican stakeholders including leaders of FEMAP, the nonprofit organization that led the Cd. Juárez Brickmakers Project, and representatives of the Cd. Juárez Municipal Ecology Office and the Texas Natural Resources Conservation Commission. It is distilled from in-depth analyses of the Brickmakers' Project presented in Blackman and Bannister (1997) and Blackman and Bannister (1998), which contain complete bibliographies.

6. Nuñez, and others, (1994), 1. In 1995, the city of El Paso was classified by the U.S. Environmental Protection Agency as a "moderate" nonattainment area for both carbon monoxide and particulate matter, and El Paso county was classified as a "serious" nonattainment area for ozone.

Table 2. Summary of Case Studies

	Cd. Juárez	Saltillo	Zacatecas	Torreon
Background				
Approximate no. kilns	350	500	60	165
Principal traditional fuel	scrapwood	used tires	scrapwood, tires	scrapwood, refuse
Leading source air pollution?	reputedly	reputedly	no	no
Brickmakers well-organized?	yes	yes	no	yes
Miscellaneous	cross-border impacts	tile exporters powerful	kilns deemed tourist liability	neighboring cities compete
Policies	• Private-sector-led initiative with public-sector cooperation • Focus on clean technological change (conversion to propane) • Subsidies to fixed adoption costs • R&D in energy-efficient kilns • Process standards (ban on dirty fuels) underpinned by peer monitoring • Public education initiative • Boycott of bricks fired with dirty fuels within Juárez	• Public-sector-led initiative • Initial focus on clean technological change (conversion to propane) • Subsidies to fixed adoption costs • R&D in energy-efficient kilns • Process standards (ban on *exclusive* use of tires) underpinned by peer monitoring and registration • Subsidies to cleaner fuels (scrapwood) • Rights for creosote distribution awarded to brickmakers' union	• Public-sector-led initiative • Clean technological change (conversion to propane) • Subsidies to fixed adoption costs • Process standard (ban on use of tires) underpinned by peer monitoring and registration • Forced relocation of certain kilns • Boycott of bricks fired with dirty fuels from neighboring towns	• Public-sector-led initiative • Clean technological change (conversion to propane) plus relocation • Promised subsidies to fixed relocation and adoption costs • Privately enforced process standards (ban on use of tires, firing limits) underpinned by peer monitoring
Results	• 50% adoption of propane before increases in propane prices led to 100% dis-adoption • Drastic reduction in use of tires and plastics	• 10% adoption propane before increases in propane prices led to 100% dis-adoption • Moderate reduction in use of tires, drastic reduction in plastics, used motor oil	• 100% adoption of propane before increases in propane prices led to 100% dis-adoption • Continued partial use of propane in some kilns • Reduced use of tires	• No relocation or conversion to propane • Drastic reduction in use of tires; firing schedules enforced

3.1.2. Policies

In 1989, the municipal environmental authority in Cd. Juárez initiated a project aimed at convincing traditional brickmakers to substitute clean-burning propane for dirty fuels. This strategy is best thought of as clean technological change since adopting propane involves significant set-up costs and significant changes in the production process. In 1990, the "Brickmakers' Project" as it came to be known, was handed off to the Mexican Federation of Private Health Associations and Community Development (FEMAP), a private nonprofit social services organization based in Ciudad Juárez which had expertise in grass roots organizing in poor neighborhoods. FEMAP was able to attract considerable funding and participation from both sides of the border. The majority of the funding came from the Mexican government while key participants included propane companies in Cd. Juárez, the municipal government of Cd. Juárez, El Paso Natural Gas, and Los Alamos Natural Laboratories.

Participants in the Brickmakers' Project used a broad range of polices to promote propane adoption. First, they subsidized various costs associated with adoption. Propane companies in Cd. Juárez made propane tanks and vaporizers available free of charge to brickmakers and a number of organizations (including local propane companies, FEMAP, El Paso Natural Gas, and local universities) provided training. In addition, motivated by the fact that the cost of propane per unit of energy was considerably higher than the cost of traditional dirty fuels, engineers from El Paso Natural Gas, Los Alamos National Laboratories and FEMAP devoted considerable effort to developing new energy-efficient kilns. However, most of their designs involved completely rebuilding existing kilns, a prohibitively expensive proposition for most brickmakers. Engineers also worked to develop low-cost measures for improving fuel efficiency such as optimizing the fuel mixture, the manner in which bricks are stacked, and the way that the kiln opening is covered.

Second, project leaders worked to put in place and enforce process standards prohibiting the use of dirty fuels. In 1992 a newly elected Municipal government banned the use of certain fuels. To facilitate enforcement, the new administration relied on peer monitoring. A telephone hotline was set up to register complaints about brickmakers violating the ban. Enforcement teams with the power to jail and fine violators were dispatched in response to complaints. Project organizers also encouraged local trade unions and neighborhood organizations in communities surrounding brickyards to pressure brickmakers to switch to propane. The brickmaker organizations affiliated with the dominant national political party (the PRI) were in general quite cooperative, enforcing strict rules on permissible fuels in some brickyards.

Third, FEMAP initiated a campaign to raise brickmakers' awareness of the health hazards associated with dirty fuels. Among the mechanisms it used were one-on-one discussions with individual brickmakers, organized training sessions, and the production and distribution of an educational comic book.

Finally, project leaders tried to reduce competitive pressures for brickmakers to use cheap dirty fuels by intervening in the market for bricks. In March of 1993, they helped to negotiate an agreement among leaders of all of the major brickmakers unions to establish a price floor high enough to allow all brickmakers to afford propane. The next year, project leaders obtained a commitment from local construction companies and from INFONAVIT, the federal Workers' Housing Agency, to boycott bricks fired with dirty fuels. Both the price floor and the boycott were quickly undone by rampant cheating.

3.1.3. Results

The high-water mark of the Brickmakers' Project probably occurred in the fall of 1993 when, according to most estimates at least 50% of the Brickmakers' in Cd. Juárez were using propane albeit in (slightly modified) inefficient traditional kilns. However, during the early 1990s Mexico's state-run petroleum company was in the process of phasing out long-standing subsides on propane. As propane prices continued to rise in 1993 and 1994, key participants in the project began to

defect: the municipal government relaxed the ban on burning debris, brickmakers began abandoning propane in droves, brickmaker organizations increasingly dropped out as they were undercut by competitors using dirty fuels, and construction companies and the Federal workers housing agency gave up the pretense of boycotting "dirty" bricks. By 1995 only a handful of brickmakers were still using propane. Despite the disadoption of propane, the Brickmakers' Project has had some lasting impacts: local organizations and city officials continue to enforce a ban on the use of the dirtiest fuels, mainly tires and plastics.

Although the diffusion of propane among the brickmakers in Cd. Juárez was limited and temporary, it nevertheless represents a significant achievement in view of the obstacles involved, especially the drastic reduction in propane subsidies. Which of the broad range of strategies employed by the project accounted for this (temporary) success? Statistical analysis of survey data described in detail in a companion paper (Blackman and Bannister, 1998) suggests that three factors played a key role: peer monitoring applied by neighbors and local organizations affiliated with the city government, a growing awareness of the health risks associated with burning dirty fuels, and subsidies to the costs of propane equipment and training. Efforts to introduce new energy efficient kilns and to intervene in the market for bricks were obviously ineffective.

3.2. Saltillo[7]

3.2.1. Background

An industrial city of approximately 425,000 in the southeast corner of the state of Cohuila, Saltillo is home to approximately 500 traditional kilns, the largest collection of kilns in any of our four study cities. The majority of Saltillo's traditional kilns produce more tile than bricks.[8] Sixty to 80% of the tile produced in Saltillo is exported to the United States where it is prized as an artisanal product. As a result, the political and economic interests in brick and tile making in Saltillo are somewhat stronger than in other cities. The majority of brickmakers in Saltillo belong to a single union that has considerable influence owing to its large membership and its ties to exporters.

Brickmakers in Saltillo rely principally on used tires for fuel. According to Rodolfo Garza, head of the Cohuila Department of Ecology, kilns in Saltillo burn 50 tons of tires per day (*El Norte*, 1994). Supplementary fuels include scrapwood, plastics, used motor oil, and garbage. The emissions from kilns burning tires are a pressing problem for the poor residential neighborhoods that surround the six principal brickyards.

There is some confusion regarding the contribution of traditional brick kilns to citywide pollution in Saltillo. Although the municipal environmental authority claims that fixed industrial sources and a sizable vehicular fleet are the main sources of air emissions, newspaper articles frequently assert that traditional kilns are leading cause of citywide pollution.

3.2.2. Policies

By 1992, worsening pollution and growing environmental consciousness led to a general recognition that kiln emissions in the city were a serious problem. In early 1993, mayor Rosendo Villareal Dávilla's Municipal Office of Ecology initiated an effort to convert traditional kilns to clean-burning propane, the same clean technology strategy adopted in Cd. Juárez. With the financial backing of NAFIN, the federal development bank, the city government commissioned a study to develop a

7. This section is based on interviews with Francisco Javier Rivera Gutierrez, subdirector of the Municipal Ecology Office of Saltillo (July 16, 1996); Pedro de Isla, secretary to the director of the Municipal Ecology Office of Saltillo (July 16, 1996); Professor LeopoldoVega Urbina, director of the Municipal Ecology Office of Saltillo (July 17, 1996); documents provided by these three officials; and interviews with four brickmakers in the La Rosa and Guayulera districts on (July 16 and 17, 1996).

8. Tiles and bricks are usually fired simultaneously. The soil in Saltillo is well suited to tile making.

plan of action. The study recommended building new energy-efficient propane burning kilns costing approximately 73,000 pesos (US $2,433) each and leasing them to brickmakers under a rent-to-own scheme.

Before the rent-to-own plan could be implemented, it was cut short by the election of a new mayor, Miguel Arzipe Jimenez, in December 1993. Under Arzipe, a number of elements of the program were reformed and extended, so that ultimately, as in Cd. Juárez, a multifaceted approach was adopted. First, recognizing that introducing expensive new energy-efficient kilns would be problematic given brickmakers' financial constraints, the city decided to focus instead on simply introducing propane equipment that could be used in existing kilns. The city government subsidized some of the costs of adopting propane. It set up a window at the Municipal Ecology Office that would provide both credit and technical extension to adopters. The city, state, and federal governments provided funds.[9]

In addition, the city government promulgated process standards. In June 1994, a municipal ordinance was passed that forbade the burning of tires after a six-month grace period and prohibited the use of a wide array of dirty fuels immediately (including battery cases, used motor oil, plastics, solvents). This process standard was to be enforced by requiring all brickmakers to register with the city government. Brickmakers violating these provisions were to have their kilns closed down. There was also an attempt to enlist the support of brickmaker organizations in monitoring and enforcing these new rules. The city government convened several meetings with leaders of local brickmaker organizations.

For reasons discussed below, the city's propane initiative failed. Since this failure, the city has reorganized its pollution control strategy once again. It has abandoned its plans to convert kilns to propane and is focusing instead on limiting the use of used tires for fuel. The city has promulgated a regulation that allows brickmakers to use a combination of tires and cleaner fuels (50% tires and 50% creosote or woodscrap). Peer monitoring has been used to enforce this rule. Brickmakers and their neighbors in surrounding residential communities monitor emissions and report producers who fire their kilns exclusively with tires. Offenders are fined. In addition, the city has set up an innovative program to subsidize the cost of relatively clean fuels: local factories make woodscrap available free of charge to brickmakers. Finally, as a gesture of goodwill, the city has funded the construction of a public square that contains both recreational facilities and market stalls for brickmakers.

Eventually, the city hopes to replace all dirty fuels with creosote, a low-grade petroleum distillate. To promote the new fuel, the city has commissioned test firings, and has made credit available. Also, the city has awarded a contract for the distribution of creosote to the brickmakers union, hoping the concession will give the union an incentive to pressure its members to adopt creosote. Still, as of July 1996, no brickmakers in Saltillo were using creosote on a regular basis.

3.2.3. Results

Despite the city government's efforts to induce brickmakers to switch to propane, only 14 ever received credit from the loan fund set up to finance new equipment investments and fewer than 40 ever adopted propane. Several factors appear to have been responsible for the failure of the propane initiative. First, and most important, by the time that the program had been launched in earnest, propane prices had risen dramatically relative to the price of debris due to the nationwide reductions in propane subsidies. Second, the recession in Mexico made investing in a new technology especially burdensome and risky. According to the leader of the brickmakers union, by the end of

9. The city government established a fund of 50,000 pesos. The state government was recruited to provide matching funds. With the cooperation of Solidarity Enterprises, the same federal program that funded the Cd. Juárez initiative, this funding was used to leverage a 1,000,000-peso loan fund from NAFIN, the federal development bank. All of the funds were earmarked for brickmakers' investments in propane equipment.

1994 sales of bricks and tile had fallen off by as much as 70% compared to the early 1990s. Third, despite the June 1994 edict, there was very little enforcement of the prohibition on burning tires, despite the fact that more than 300 out of a total of approximately 500 kilns were registered (the holdouts were principally kilns in the brickyards located on the outskirts of the city). Fourth, rumors circulated among producers that bricks and tiles fired with clean fuels were of inferior quality. These rumors persisted despite the several successful test firings designed to allay these concerns. And finally, internal divisions in the brickmaker's union dampened support for the project among the brickmakers.

Although the propane initiative failed, other components of the city's environmental program were more successful. Most important, there was a decline in the use of the dirtiest fuels such as battery cases and used motor oil.

3.3. Zacatecas[10]

3.3.1. Background

A colonial city in north central Mexico and a state capital, the city of Zacatecas is a major domestic tourist attraction. With a population of just over of 110,000, it is the smallest city in our sample. It is home to approximately 60 small-scale brick kilns. These kilns have traditionally burned used tires, woodscrap, manure, used motor oil, and refuse. There are no unions or other local organizations to speak of among the brickmakers.

Unlike kilns in Cd. Juárez and Saltillo, those in Zacatecas are too few in number to constitute a significant source of citywide pollution. They have attracted attention because they are a health hazard to those who live nearby, and probably more important because 19 kilns located near the entrance to the city were deemed an eyesore and a threat to tourism by municipal authorities.

3.3.2. Policies

In December 1992, then Mayor Javier Suarez de Real initiated a series of meetings with brickmakers to address the problem of kiln emissions. The city pursued a policy involving two thrusts. The first involved relocating the 19 kilns near the entrance of the city. The city committed to finding a new site for these brickmakers and to providing them with credit to finance the building of new kilns. The second thrust of the program was to convert all kilns that were not being relocated to propane. With the assistance of two federal credit programs (NAFIN and Solidarity Enterprises), the city set up a loan fund to finance the purchase of new propane equipment. The city offered three-year interest-free loans to several groups of brickmakers who were to share equipment. A firm was chosen to supply equipment and technical extension. To ensure that the propane initiative was successful, the city registered all the brickmakers who were not being relocated. In addition, it had them signed a pledge to adopt propane as soon as financing could be arranged.

3.3.3. Results

Both of the program's elements were ultimately carried out, although not in the manner envisioned in December 1992. Ultimately, relocation of the 19 kilns was not voluntary. The city purchased the land where these kilns were located and summarily evicted them. The owners of these kilns were given the option of purchasing land in a somewhat remote site. However, financing for the purchase of new land and the building of new kilns was never made available. As a result, only six brickmakers from this group eventually relocated. The others found new employment.

The propane initiative was completely, although only temporarily successful. By early 1994, 150,000 pesos (US $50,00) in credit had been extended for the purchase of new equipment. By the

10. This section is based on interviews with Ing. Gerardo Leyva, Solidarity Enterprises (July 19, 1996); primary documents and newspaper clippings provided by Ing. Leyva; and interviews with seven brickmakers in the cities of Zacatecas and Guadalupe (July 18 and 19, 1996).

end of 1994, every kiln in the city was being fired with propane. The project was so successful that plans were made to extend it to the five municipalities within 100 kilometers of Zacatecas.[11]

Unfortunately, as in Cd. Juárez, the nationwide removal of subsidies on propane created strong pressures to revert to burning debris. Although Zacatecas' brickmakers did not face competition from brickmakers using cheap fuel inside the city (since all brickmakers there adopted propane), they did face competition from brickmakers in surrounding municipalities who were using cheap fuels. To ease this pressure, the city briefly attempted to organize a boycott of bricks fired with dirty fuels. The boycott soon collapsed, however, and ultimately propane use fell off dramatically. In the summer of 1996, several brickmakers continued to use propane, but only during a brief initial phase of firing the kiln. One positive legacy of the propane initiative is that brickmakers have reduced their use of tires. As in Saltillo and Cd. Juárez, peer monitoring is used to enforce a ban on the burning of tires and other particularly dirty fuels. Generally neighbors and competitors who observe smoke from such fuels complain to the municipal police who then fine the offender and temporarily close his or her kiln.

3.4. Torreon[12]

3.4.1. Background

A rapidly growing industrial city of 450,000 in the southwest corner of the state of Cohuila, Torreon supports 165 traditional kilns. Most of these are centrally located in one neighborhood, *ejido San Antonio de los Bravos*. The brickmakers' principal fuels are woodscrap, pecan shells, plastics, used tires, and garbage. Virtually all brickmakers belong to one of five local organizations. The brickmakers face stiff competition from the nearby cities of Gomez Palacios and Matamoros.

Like Cd. Juárez, Torreon has poor air quality as a result of industrial emissions and a sizable vehicular fleet. Traditional kilns are considered a significant contributor to citywide air pollution, although not a leading contributor. A more urgent concern is the threat that the kilns pose to the residents of the densely populated low-income communities that have grown up around the main brickyard as the city has expanded in the last decade.

3.4.2. Policies

In 1994, the Office of Economic Development in Torreon began to develop a strategy for reducing emissions from traditional kilns. It organized a series of meetings that brought together representatives of the brickmakers organizations, the Municipal Ecology Office, SEDESOL (then the Federal Environmental agency), and FEMAP (the nongovernmental organization that had organized the propane initiative in Cd. Juárez). As in Zacatecas, a two-pronged strategy emerged involving relocation and clean technology: brickmakers in *ejido San Antonio de los Bravos* would be relocated, and clean fuels—including propane—would be introduced.

Not surprisingly, the communities surrounding the *ejido* supported relocation. In the early 1990s they had organized demonstrations protesting kiln emissions and repeatedly petitioned the Municipal Environmental Authority regarding the problem. In addition, the owners of the *ejido* supported relocation as they hoped to develop the increasingly valuable land used by the brickmakers into an industrial park. The prospect of attracting new potential employers bolstered the surrounding communities' support for relocating the brickmakers.

11.The municipalities were Jerez, Ojo Caliente, Guadalupe, Tlaltenango, and Fesnillo.

12.This section is based on interviews with Lic. Raul Medina Martinez, director general of Economic Development for the Municipality of Torreon (July 23, 1996); Lic. Nicolás Paez Valdez, director general of Public Services and Ecology for Torreon (July 24, 1996); documents provided by these officials; and interviews with five brickmakers of the *ejido San Antonio del Bravo* in Torreon (July 23 and 24, 1996).

After a study of the suitability of soils in different locations, the city chose two sites outside of the city limits to use as new brickyards. The city pledged to subsidize the relocation. It developed a package of incentives that included a half hectare of land, water rights on the land, 10,000 pesos for each brickmaker (for the building of a new kiln), compensation for all inventory on hand on the eve of the move, and training in the use of propane. To spur a shift away from dirty fuels, the city passed regulations banning the burning of particularly dirty fuels such as plastics.

3.4.3. Results

As of July 1996, four of the five brickmaker organizations active in *ejido San Antonio de los Bravos* had signed documents committing their members to relocation, but no brickmakers had actually relocated. The city had not yet secured the funding for the package of relocation incentives. Some brickmakers interviewed in July 1996 doubted that the city would keep its end of the bargain. They viewed the relocation plan as a political ploy designed to win brickmakers' votes.

Like the relocation effort, the city's clean fuels initiative has involved more talk than action. The city regulations banning dirty fuels are infrequently enforced. Not surprisingly, the city's plans to introduce propane were shelved when nationwide subsidies on propane were removed in the early 1990s.

The communities surrounding *ejido San Antonio de los Bravos* have had a more significant impact on kiln emissions than has the city government. As a result of repeated protests, these communities have managed to get the brickmakers to agree to stop burning tires, to fire only at night (when emissions from other sources are at a minimum), and to limit the number of kilns that are fired at any given time. Three of the five brickmaker organizations now enforce a prohibition on the burning of tires.

4. CONCLUSION

In this section, we evaluate how the pollution control policies discussed in Section 2 performed in our four study cities. The main points of the discussion are summarized in Table 3. Before proceeding with a discussion of each type of policy, we make three general observations about the political economy of policy choice, how policies are combined, and the promise of private sector-led initiatives.

4.1. The Political Economy of Policy Choice

Some pollution control policies impose greater costs on firms than others do. For example, relocation and clean technological change are relatively costly to firms while green subsidies and educational programs impose minimal costs. Of course, subsidies can be used to reduce the costs of any policy. For example, subsidizing technical extension, credit, and equipment can reduce the costs of a clean technology strategy.

In each of our study cities, policymakers' choices among various pollution control policies and the extent to which these policies were subsidized appear to have depended on the bargaining power of the brickmakers vis à vis the regulators. Cd. Juárez's approximately 300 brickmakers are well organized and have considerable bargaining power. As a result, although pollution control efforts in Cd. Juárez focused on clean technological change—a relatively costly strategy—they also involved significant subsidies to equipment and technical extension. Saltillo's approximately 400 brickmakers, the largest collection in our sample, are also fairly well organized and have powerful allies in the lucrative tile export sector. Hence, regulatory authorities in Saltillo ultimately opted for a process standard prohibiting exclusive use of tires as fuel—a relatively low-cost strategy; made efforts to reduce the costs of this regulation by providing brickmakers with free woodscrap; and even subsidized the cost of recreational facilities and market stalls to win the brickmak-

Table 3. Lessons from Case Studies

Policy	Lessons
All	• Where informal polluters are numerous or well organized, only combinations of policies with low private costs are likely to be feasible • Private sector-led initiatives with strong public sector support may be best suited to informal-sector pollution control
Command and Control	
Process standards	• Registering informal enterprises and peer monitoring are common strategies for enhancing enforceability • Registration alone is not sufficient to facilitate enforcement • Peer monitoring is a necessary condition for enforcement and appears to be most effective when carried out by local organizations
Relocation	• Imposes relatively high costs on polluters—including costs of purchasing land, rebuilding plant and equipment, and transporting labor and materials—and is therefore likely to meet with considerable resistance
Economic Incentives	
Green taxes	• Easily evaded when informal polluters buy dirty inputs on informal markets
Green subsidies	• Without careful monitoring, may simply encourage the resale of subsidized goods
Boycotts	• Enforcement is highly problematic
Government Investment	
Clean technologies	• Need not be cost-reducing to diffuse widely • Subsidies to early adopters may heighten competitive pressures for further adoption • Must be appropriate: affordable and consistent with existing levels of technology • May be dominated by second-best strategies with lower environmental benefits and lower private costs
Information-Based	
Educational programs	• May affect polluters input choices and facilitate community pressure

ers' goodwill. Zacatecas' 50-odd brickmakers are undoubtedly the least well organized and least powerful group in our sample. They were unable to either prevent the city from imposing costly abatement strategies—relocation and clean technological change—or to convince the city to subsidize their expenses. Finally, in Torreon that has a relatively small but geographically concentrated and politically active group of brickmakers, the city promoted relocation—a costly strategy. However, it tried to do this by offering a very generous incentive package rather than by imposing sanctions as in Zacatecas. Moreover, the city had limited success.

Thus, our case studies suggests that in cities where informal polluters are politically weak because they are few in number, disorganized, and without economic allies, policymakers can impose whatever abatement strategy they wish regardless of the cost to polluters. But in cities where informal polluters are not weak, policymakers must choose policies that are politically feasible—generally some combination of subsidies and sanctions. Importantly, wherever informal polluters are a significant problem, they are not likely to be weak, simply because they are bound to be numerous.

4.2. Combining Policies

As Table 2 illustrates, the policymakers in our four study cities combined a wide range of different pollution control policies, rather than simply relying on one or two. For example, in Ciudad Juárez, the key policy was clearly clean technological change, but this policy was buttressed by a program

of research and development, subsidies, an educational campaign, a boycott of brickmakers using dirty fuels, and a command and control prohibition of dirty fuels. The fact that pollution control policies were not implemented one at a time makes them difficult to evaluate. Nevertheless, it is possible to draw some conclusion about each.

4.3. The Promise of Private Sector-Led Environmental Initiatives

If we discount the Zacatecas experience because of the relatively small number of kilns involved, then of the remaining three pollution control initiatives, the most successful was the Cd. Juárez Brickmakers' Project that managed to convince more than 150 brickmakers to adopt propane, albeit for a limited time. This effort was also the only one we studied that was led by a private sector organization, a fact that suggests that private sector-led initiatives hold considerable promise as a means of addressing informal sector pollution problems.

Private sector-led initiatives would seem to enjoy a number of advantages over state-run programs. First, the willingness of the majority of the brickmakers in Cd. Juárez to cooperate with the project suggests that private sector-led initiatives may be best suited to engage firms that by their nature are bound to be wary of sustained contact with regulatory authorities. Second, the enthusiasm that the Cd. Juárez Brickmakers' Project generated among founders, participants, and the public at large suggests that private sector-led projects may be able to draw more freely on public sympathy for environmentalism than top-down bureaucratic initiatives. And finally, the projects' success at consensus building among a diverse set of stakeholders suggests that private sector-led initiatives may be better able to sidestep the politics and bureaucracy that often plague public sector-led initiatives. The city-led initiatives in our sample were rife with such problems. In Torreon brickmakers belonging to a union affiliated with a political party opposed to the municipal government, were impelled to oppose the city's abatement initiative. In Saltillo, the propane initiative was disrupted twice by changes in the municipal government, first in December 1993 and again in December 1996. In Torreon, even those brickmakers who supported the city's relocation initiative were reluctant to put great store in a promised package of relocation incentives for fear that it was politically motivated. Finally, in Torreon and Zacatecas, a difficult effort to forge a consensus among unwieldy bureaucracies in neighboring municipalities was needed in order to promote pollution abatement efforts among brickmakers in each.

The qualified success of the Cd. Juárez Brickmakers' Project, however, does not imply that informal sector environmental problems are best be left to private sector organizers. In all likelihood, the Cd. Juárez Brickmakers' Project would not have had as much success without unusually strong U.S. and Mexican federal support, the support of the municipal and state governments, and the leadership of a well-established politically savvy nongovernmental organization.

Thus, our case studies suggest that private sector-led initiatives can work—indeed they may be more effective than public sector initiatives—but they require strong public sector support and some ability on the part of project organizers to leverage this support.

4.4. Command and Control Process Standards

Regulators in each of our four study cities attempted to promulgate regulations prohibiting the use of certain types of fuels. In Cd. Juárez, Zacatecas and Torreon, these prohibitions ultimately succeeded in eliminating some of the most toxic fuels such as plastics and used tires. Policymakers have relied on two strategies—registration and peer monitoring—to overcome the difficulty of monitoring and enforcing these prohibitions.

In Saltillo, Zacatecas, and Torreon regulators attempted to compile registries of brickmaking enterprises. In Saltillo, the effort to register kilns was clearly fruitless. Brickmakers continued to

violate prohibitions with immunity. In Torreon, it is hard to judge the impact that registration had since peer monitoring appears to have played a strong role in the shift away from the dirtiest fuels. In Zacatecas, registration clearly had an impact on enforcement. For a short period, all brickmakers in the city were used propane exclusively and there is no evidence that peer monitoring or other strategies were primarily responsible. However, the success of the registration effort in Zacatecas was very likely due to the fact that there are fewer than 50 kilns remaining in the city. As a result, monitoring is not prohibitively costly. Also, given their small number, brickmakers did not have the political power to block enforcement.

Thus, our case studies suggest that simply registering informal polluters is not sufficient to facilitate enforcement. Evidently, the anonymity of informal polluters is not the principal barrier to environmental management. Rather, it is the high cost of monitoring and enforcement. Registering informal firms may give regulators some added leverage by laying the groundwork for inspections and fines, but it does not solve the underlying problem of too few regulatory resources chasing too many firms.

Perhaps the one most striking finding from our study is that in each study city, enforcement of command and control regulations depended critically on peer monitoring. In most cases, local organizations played a key role. For example, in Cd. Juárez, trade unions and neighborhood associations imposed sanctions on brickmakers who used certain dirty fuels. In addition, to enforce a ban on burning debris, the municipal environmental authority relied on citizen complaints to identify violators. In Saltillo, the enforcement of a prohibition on the exclusive use of tires as fuel depended on peer monitoring and on the cooperation of the brickmakers' union. Similarly, in Zacatecas, brickmakers reported violations of the ban burning tires to the city environmental authority. Finally, in Torreon, demonstrations and petitions organized by residents of the communities surrounding the main brickyard have been instrumental in getting the brickmaker organizations to agree to fire only at night, and to limit the number of kilns burning at any given time, and to stop burning tires.

Thus, our research suggests that peer monitoring is a necessary condition for effective command and control regulation. Moreover, peer monitoring seems to be most effective when facilitated by local organizations. One must note, however, that the effectiveness of peer monitoring in our case studies depended on the fact that neighbors see or smell toxic smoke. Other types of informal sector pollution, such as the dumping of untreated effluents into sewers by leather tanners would not be so easily detected.

4.5. Relocation

As noted above, relocation is probably the costliest pollution control strategy for brickmakers. It requires that brickmakers purchase new land and build new kilns. In addition, it usually increases transportation costs since most brickmakers live next to their kilns and sell their goods locally. The only city where relocation was actually implemented was Zacatecas, the one city in our sample where brickmakers had very little political power. Relocation was never even seriously discussed in either Cd. Juárez or Saltillo where brickmakers have considerable political power. Thus, relocation is only feasible when regulatory authorities enjoy considerable bargaining power or have the resources to pay significant subsidies.

4.6. Green Subsidies and Taxes

There were no efforts to use green taxes or subsidies in any of our study cities. The explanation most likely has to do with number of practical considerations. First, all of the pollution control efforts we studied were led either by a municipal governments or by a nongovernmental organiza-

tion. Neither is likely to have the fiscal resources to provide substantial sustained subsidies. Second, the dirty inputs into brickmaking that are the appropriate targets for green taxes—used tires, plastic wastes, and scrapwood—are sold on informal markets where tax collection institutions are absent and easily avoided. Third, given the level of poverty among brickmakers, attempts to subsidize clean inputs (like propane) would likely induce brickmakers to resell subsidized inputs to make quick profits. In fact, according to regulatory authorities in Cd. Juárez, part of the rationale for the removal of federal propane subsidies was to squelch a rampant cross-border black market in propane. Thus, our case studies suggest that, in general, when informal polluters buy their inputs in informal markets, green taxes are not feasible.

4.7. Boycotts

Although green taxes and subsidies were absent in our case studies, boycotts of brickmakers using dirty fuels were attempted in two study cities: Cd. Juárez and Zacatecas. In both cases, the boycotts were utter failures. Buyers simply continued to buy bricks from whomever was selling at the best price. These experiences suggest that in most cases, contravening market forces in the informal sector of developing countries simply does not work; monitoring is too difficult and cheating is too easy.

4.8. Assigning Property Rights

Our case studies turned up an economic incentive policy that has not been mentioned in the literature—assigning property rights in such a way as to give polluters an economic stake in the diffusion of a clean fuel. Environmental authorities in Saltillo gave the brickmakers union the sole right to distribute creosote. As a result, the union presumably had an incentive to promote the diffusion of creosote. Yet we have no evidence that this strategy worked in Saltillo or that it can work elsewhere. Moreover, the feasibility of such a strategy depends on the regulators' ability to assign property rights. For example, the city of Saltillo was able to grant a concession for creosote to the brickmakers union because none existed in Saltillo. By contrast, the municipal authorities in Cd. Juárez could not have assigned rights to distribute propane because several distributors already existed.

4.9. Clean Technological Change

In three of our study cities, Cd. Juárez, Zacatecas, and Saltillo, policymakers adopted pollution control strategies that, temporarily at least, centered around converting kilns to propane, a process that we have argued constitutes technological change. In practice, all of the propane initiatives in our study cities turned out to differ in an important way from what is conventionally thought of as clean technological change: due to reductions in propane subsidies, conversion to propane increased variable costs rather than reducing them. Nevertheless, the majority of brickmakers in two of our study cities—Ciudad Juárez and Zacatecas—adopted propane and continued to use it for over a year. This phenomenon runs counter to the conventional wisdom that clean technologies are only likely to be viable if they are privately profitable once adopted.

Part of the explanation for why propane was adopted despite its cost undoubtedly has to do with the effectiveness of regulatory pressure and peer monitoring. But another part of the explanation may have to do with the interplay between competition and peer monitoring. The market for bricks is highly competitive and, as a result, brickmakers that use high-cost clean fuels are liable to be undercut by competitors using dirty fuels. Thus, initially, competition in the market for bricks seems to work against the introduction of cost-increasing clean fuels. But, our case studies suggests that, ironically, once diffusion of the clean fuel has progressed past a certain stage, competition can work *in favor* diffusion because those who have adopted have an incentive to ensure that

their competitors adopt as well. Moreover, adopters generally have some leverage over those of their competitors who are neighbors and/or fellow union members. This suggests that, in general, if a critical mass of informal firms can be convinced by hook or crook to adopt a cost-increasing clean technology, eventually diffusion can become self-perpetuating. One would expect this dynamic to be strongest in situations where the firms are geographically and politically unified and therefore have some influence over a relatively high percentage of their competitors, and to be weakest in situations where there are strong jurisdictional, or political divisions among firms. The observed pattern of adoption in Cd. Juárez was consistent with this story. Once an initial cadre of brickmakers had been convinced to adopt, neighbors and fellow union members quickly followed suit. The same dynamic may have been played out in Zacatecas, speeded by the fact that the entire pool of brickmakers was relatively small. The lesson for policymakers is that subsidies to early adopters may heighten pressures to adopt on other firms.

The case studies also suggest lessons concerning what types of technologies are appropriate in the informal sector. Project leaders in Cd Juárez and Saltillo promoted efforts to design and diffuse energy-efficient kilns. In both cities, experimental kilns were designed by highly trained engineers, involved radical departures from existing kilns, and would have required brickmakers to finance sizable investments in new equipment and in training. It is not surprising that these efforts were unsuccessful. By contrast, with the benefit of the Cd. Juárez experience, city authorities in Zacatecas promoted the use of low-technology and low-cost methods of firing existing traditional kilns with propane. The experiences in Cd Juárez, Saltillo, and Zacatecas illustrate well-established principals for introducing new technologies in low-income settings. First, to the extent possible, intended adopters should participate in designing and building the innovation. And second, new technologies must be "appropriate," that is both affordable and consistent with existing levels of technology.[13]

Finally, the case studies may imply something about the wisdom of attempting first-best technological solutions. The contrast between the collapse of the technological change initiatives in each city and the success of efforts at fuel switching suggests that, in retrospect, it might have been a better strategy for the various regulators to have promoted conversion to relatively clean traditional fuels like untainted sawdust instead of pushing for the adoption of propane. In the informal sector where firms operate on slim profit margins and where the costs of implementing any pollution control strategy are likely to be high, it is critical that policymakers weigh the costs of various strategies against the benefits. In some cases, the strategies that provide the greatest environmental benefits may be less appropriate than intermediate strategies that confer fewer benefits at lower cost. Just as certain first-best technologies may be inappropriate in the informal sector, certain first-best pollution control strategies may also be inappropriate.

4.10. Education Initiatives

In only one study city, Cd. Juárez, did project leaders attempt to use an information campaign about the health hazards associated with burning dirty fuels to promote a shift to cleaner fuels. Even this campaign was limited in scope and duration.

Yet, statistical analysis of survey data from Cd. Juárez reveals a positive correlation between awareness of the health hazards associated with burning dirty fuels and the adoption of propane (Blackman and Bannister, 1998). This finding suggests that, if pursued more vigorously, information campaigns regarding health have the potential to influence fuel choices. In addition, although we have no direct evidence, it is quite likely that the educational campaign in Cd. Juarez enhanced the pressure to abate placed on brickmakers by residents of the communities surrounding brickyards.

13. See Barnes (1993), Stewart (1977).

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