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

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December 1999, Revised May 2000 •
Discussion Paper 00–02–REV

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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. The case studies suggest that: (i) conventional command and control process standards are generally only enforceable when buttressed by peer monitoring, (ii) surprisingly, clean technologies can be successfully 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, and (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

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 over half of non-agricultural 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 et al., 1994). Many large cities support several hundred. The kilns are fired with a variety of cheap, highly-polluting fuels such as plastic refuse, used tires, manure, wood scrap, and used motor oil. As a result, in some cities they are a leading city-wide source of air pollution. In addition, they are generally a serious local health hazard to the residents of the poor neighborhoods that typically host brickyards, as well as to brickmakers themselves (Blackman, Shih and Newbold, 2000). 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 which have met with decidedly mixed success. This mixed record provides an opportunity to study what types of policies work and what types do not.

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[1] I am grateful to the Tinker Foundation for financial support, Geoffrey Bannister for invaluable assistance with field research and primary documents, a referee for helpful comments, and all of our interviewees in Mexico and Texas.

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 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 further background on informal sector polluters and develops a menu of feasible policy options. The third section presents the four case studies. The last section distills policy lessons.

2. POLICY OPTIONS

(a) 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.[2]

However, certain types of informal activities can create severe pollution problems. 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 have received the most attention in the literature (e.g., Bartone and Benavides, 1993; Kent, 1991). Informal firms engaged in these activities can have environmental impacts that belie their 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 poor residential areas. As a result, their emissions directly affect a considerable population.

(b) 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

[2] Some informal activities such as waste collection and recycling even have environmental benefits (Meyer, 1986).

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 have recently received considerable attention. These policies rely on disseminating information about firms' environmental performance and/or about the health impacts of pollution.

Table 1. A taxonomy of pollution control instruments

	Direct	**Indirect**
Command and Control	• Emissions standard[a]	• Technology & 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 which may be traded with other firms.
requirement for a specific abatement technology of element of the 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.

Which of these policies are feasible in the informal sector? 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 prevalent and less well-organized than in industrialized countries (Development Research Group, 1999; 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, 2000). If these 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. Thus, the menu of policy options for pollution control 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 sections, we briefly discuss each of these options, drawing on the limited literature on informal sector pollution control.

(c) Indirect command and control instruments

(i) 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 require financially-strapped firms to pay considerable set-up costs, and since even checking for the installation of equipment by 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.

(ii) Relocation

Relocating informal firms may serve three purposes: improving their access to communal waste treatment facilities, reducing the number of people exposed to their emissions, and providing 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).

(d) Indirect economic incentive instruments

(i) 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 Devarajan, 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 disadvantages, whether applied in the formal or informal sector. Most important, 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, 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, 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 (e.g., chrome) by a specific type of firm (e.g., 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.

(ii) Green subsidies

Rather than taxing dirty inputs, policy makers 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.

(iii) 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).

(e) Government investment

(i) 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 (e.g., 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.

(ii) Clean technologies

While 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).[3]

(f) 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 (Tietenberg, 1998). In the informal sector, information-based strategies are especially likely to operate through owners since they usually work and live in close proximity to their firms' pollution (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.

(a) Ciudad Juárez[4]

(i) Background

A sprawling border city with over one million permanent inhabitants, Cd. Juárez is home to approximately 350 traditional kilns which are principally fired with scrap wood. Collectively, these kilns are a significant area-wide source of air pollution. They have attracted considerable attention because air quality in Cd. Juárez and its sister city, El Paso, Texas, is among the worst in North America.[5] The kilns are also a serious local health hazard to those living in the densely populated residential neighborhoods that surround most of the city's brickyards.

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[3] 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).

[4] 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 Texan and Mexican stakeholders including representatives of FEMAP, 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 1998), which contain complete bibliographic information.

[5] In 1995, the city of El Paso was classified by the US Environmental Protection Agency as a "moderate" non-attainment area for both carbon monoxide and particulate matter, and El Paso county was classified as a "serious" non-attainment area for ozone.

Table 2. Summary of case studies

	Cd. Juárez	Saltillo	Zacatecas	Torreon
Background				
Approximate number of kilns	350	500	60	165
Principal traditional fuel	scrapwood	used tires	scrap wood, 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	competition fr. nbring. cities
Policies	Private-sector-led initiative with strong public-sector support	Public-sector-led initiative	Public-sector-led initiative	Public-sector-led initiative
	Focus on clean technological change (conversion to propane)	Initial focus on clean technological change (conversion to propane)	Clean technological change (conversion to propane)	Clean technological change (conversion to propane) plus relocation
	Subsidies to fixed adoption costs	Subsidies to fixed adoption costs	Subsidies to fixed adoption costs	Promised subsidies to fixed relocation and adoption costs
	R&D in energy-efficient kilns	R&D in energy-efficient kilns		
	Process standards (ban on dirty fuels) underpinned by peer monitoring	Process standards (ban on exclusive use of tires) underpinned by peer monitoring and registration	Process standard (ban on use of tires) underpinned by peer monitoring and registration	Privately enforced process standards (ban on use of tires, firing limits) underpinned by peer monitoring
	Public education initiative	Subsidies to cleaner fuels (scrap wood)	Forced relocation of certain kilns	
	Boycott of bricks fired with dirty fuels within Juárez	Rights for creosote distribution awarded to brickmakers' union	Boycott of bricks fired with dirty fuels from neighboring towns	
Results	50% adoption of propane before increases in propane prices led to 100% dis-adoption	10% adoption propane before increases in propane prices led to 100% dis-adoption	100% adoption of propane before increases in propane prices led to 100% dis-adoption	No relocation or conversion to propane
	Drastic reduction in use of tires and plastics	Moderate reduction in use of tires, drastic reduction in plastics, used motor oil	Continued partial use of propane in some kilns	Reduction in use of tires; firing schedules enforced
			Reduced use of tires	

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.

(ii) 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 *Federación Mexicana de Asociaciones Privadas de Salud y Desarrollo Comunitario* (FEMAP), a private non-profit social services organization based in Cd. 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 made tanks and vaporizers available free of charge 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 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 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 use 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.

(iii) 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 dis-adoption 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 were responsible? Statistical analysis of survey data described in detail in 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.

(b) Saltillo[6]

(i) 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 in any of the four study cities. The majority of these kilns produce more tile than bricks.[7] Sixty to 80% of the tile produced in

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[6] This section is based on interviews with Secretary, Subdirector and Director of the Municipal Ecology Office of Saltillo (July 16 and 17, 1996, documents provided by these three officials and interviews with four brickmakers in the La Rosa and Guayulera districts (July 16 and 17, 1996).

[7] Tiles and bricks are usually fired simultaneously. The soil in Saltillo is particularly well-suited to tile making

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 Saltillo's brickmakers belong to a single union, which has considerable influence owing to its large membership and ties to exporters.

Brickmakers in Saltillo rely principally on used tires for fuel. According to the Cohuila Department of Ecology, Saltillo's kilns burn 50 tons of tires per day (*El Norte*, 1994). Supplementary fuels include scrapwood, plastics, used motor oil, and garbage. Kiln emissions are an acute 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. Newspaper articles frequently assert that brick kilns are the leading source of Saltillo's air pollution. However, the city environmental authority claims that fixed industrial sources and a sizable vehicular fleet are the most important sources.

(ii) Policies

By 1992, worsening air pollution and growing environmental consciousness led to a general recognition that kiln emissions were a serious problem. In early 1993, the city environmental authority 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 (a federal development bank), the city government commissioned a study to develop a plan of action. The study recommended building new energy-efficient propane burning kilns costing approximately 73,000 pesos (US $24,300) 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 in December 1993. Under the new administration, a number of elements of the program were reformed and extended, so that ultimately, as in Cd. Juárez, a multi-faceted approach was adopted. 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. Using funds provided by the state and federal governments, it set up a window at the Municipal Ecology Office to provide credit and technical extension to brickmakers adopting propane.[8] In addition, the city government promulgated process standards. In June 1994, a municipal ordinance was passed that forbade burning tires after a six month grace period and prohibited using a number of other dirty fuels immediately (including battery cases, used motor oil, plastics, and solvents). The process standard was to be enforced by requiring all brickmakers to register with the city government. Violators were to have their kilns closed down. There was an attempt to enlist the support of brickmaker organizations in enforcing the new rules.

[8] The city government established a fund of 50,000 pesos (US $17,000). 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 (US $333,000) loan fund from NAFIN, the federal development bank. All of the funds were earmarked for brickmakers' investments in propane equipment.

Towards this end, the city government convened several meetings with leaders of local brickmaker organizations.

For reasons discussed below, Saltillo's propane initiative failed. Subsequently, the city focused on limiting the use of used tires for fuel. It promulgated a regulation that allowed brickmakers to use a combination of 50% tires and 50% cleaner fuels—either creosote (a low-grade petroleum distillate) or scrap wood. Peer monitoring was used to enforce this rule. Brickmakers and their neighbors in surrounding residential communities monitored emissions and reported producers who fired their kilns exclusively with tires. Violators were fined. In addition, the city set up an innovative program to subsidize the cost of relatively clean fuels: local factories provided scrap wood to brickmakers free of charge. Finally, as a gesture of goodwill, the city funded the construction of a public square with recreational facilities and market stalls for brickmakers.

Eventually, the city hopes to replace all dirty fuels with creosote. To promote the new fuel, the city has commissioned test firings, and has made credit available. Also, it 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 the fuel. Still, in July 1996, no brickmakers in Saltillo were using creosote on a regular basis.

(iii) 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. A number of factors were responsible. 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. Concerns about costs were exacerbated by a macroeconomic recession in Mexico that made investing in a new technology especially burdensome and risky. According to the leader of the brickmakers union, by the end of 1994, sales of bricks and tile had fallen off by as much as 70% compared to the early 1990's. In addition, there was very little enforcement of the June 1994 prohibition on burning tires, despite the fact that over 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). And finally, support for the project among the brickmakers was dampened by internal divisions in the brickmakers' union. In part, this was the result of rumors 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. Although the propane initiative failed, other components of the city's environmental program were more successful. Most notably, there was a decline in the use of the dirtiest fuels such as battery cases and used motor oil.

(c) Zacatecas[9]

(i) Background

A colonial city in north central Mexico and the 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 50 small-scale brick kilns which have traditionally burned used tires, scrap wood, 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 city-wide pollution. They have attracted attention because they are a health hazard to those who live nearby and because municipal authorities have deemed a cluster of kilns near the entrance of the city to be an eyesore and a threat to tourism.

(ii) Policies

In December 1992, the Mayor's office initiated a series of meetings with brickmakers to address the problem of kiln emissions. The city settled on a dual policy. First, 19 kilns near the entrance of the city would be relocated. The city committed to finding a new site for these brickmakers and to providing them with credit to build new kilns. Second, all kilns remaining in the city would be converted 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. It 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 of its brickmakers and had them sign a pledge to adopt propane as soon as financing could be arranged.

(iii) Results

Both of the program's components were ultimately carried out. The 19 kilns near the entrance to the city were relocated, although in a far more draconian manner than originally planned. The city purchased the land where these kilns were located and summarily evicted them. The owners were given the option of purchasing land in a new (somewhat remote) site but financing 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 $50,000) in credit had been extended for the purchase of new equipment and by the end of the year, every kiln in the city was being fired with propane. The project was so successful that plans were made to extend it to all municipalities within 100 kilometers of Zacatecas.[10]

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[9] This section is based on interviews with the Director of the Solidarity Enterprises office in Zacatecas (July 19, 1996), primary documents and newspaper clippings provided by this office, and interviews with seven brickmakers in Zacatecas and Guadalupe (July 18 and 19, 1996).

[10] The municipalities were Jerez, Ojo Caliente, Guadalupe, Tlaltenango, and Fesnillo.

Unfortunately, as in Cd. Juárez, the nationwide removal of subsidies on propane that began in 1992 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 in the city adopted propane), they did face competition from non-adopters in surrounding municipalities. 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 tires. Generally neighbors and competitors who observe violations complain to the municipal police who then issue a fine and temporarily close the offending kiln.

(d) Torreon[11]

(i) Background

A rapidly growing industrial city of 450,000 in the southwest corner of the state of Cohuila, Torreon supports 165 traditional kilns. Most are in one centrally located neighborhood, *ejido San Antonio*. The brickmakers' principal fuels are scrap wood, 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.

Torreon has poor air quality as a result of industrial emissions and a sizable vehicular fleet. Traditional kilns are considered a significant contributor to city-wide air pollution, but 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 in the last decade.

(ii) 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, the federal environmental authority, and FEMAP, the same non-governmental organization that 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* would be relocated, and clean fuels—including propane—would be introduced.

[11] This section is based on interviews with the Director General of Economic Development and the Director General of Public Services and Ecology for the Municipality of Torreon (July 23 and 24, 1996), documents provided by these officials, and interviews with five brickmakers of the *ejido San Antonio* (July 23 and 24, 1996).

Not surprisingly, the communities surrounding *ejido San Antonio* supported relocation. In the early 1990's they had organized demonstrations protesting kiln emissions and repeatedly petitioned the city environmental authority to address the problem. The owners of *ejido San Antonio* also supported relocation because they hoped to develop the increasingly valuable land used by the brickmakers into an industrial park.

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 and pledged to subsidize relocation. It developed a package of incentives that included a half hectare of land, water rights on the land, 10,000 pesos (US $3,300) for each brickmaker (for building 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.

(iii) Results

As of July 1996, four of the five brickmaker organizations active in *ejido San Antonio* 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 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 following nationwide reductions in propane subsidies.

The communities surrounding *ejido San Antonio* have had a more significant impact on kiln emissions than has the city government. After 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. In addition, three of the five brickmaker organizations now enforce a prohibition on the burning of tires.

4. CONCLUSION

This section distills policy lessons from the four case studies. It makes three general observations about environmental management in the informal sector and then evaluates the performance of the pollution control policies discussed in Section 2. The main points of the discussion are summarized in Table 3.

(a) The political economy of policy choice

Some pollution control policies impose greater costs on firms than others. For example, relocation and clean technological change are relatively costly to firms compared to educational programs. Of course, subsidies can be used to reduce the costs of any policy. For example, the costs of a clean technology strategy can be reduced by subsidizing technical extension, credit, and equipment. In each of our study cities, the ability of policy makers to pursue pollution control strategies that imposed significant costs on brickmakers depended critically on the brickmakers' political power. In both Cd. Juárez and Saltillo, brickmakers were numerous and well-organized and, as a result, they were able to

block costly strategies. In Cd. Juárez, although pollution control efforts focused on clean technological change—a relatively costly strategy—they also involved significant subsidies to

Table 3. Lessons from case-studies

Policy	Lessons
All	When informal polluters are numerous and/or well-organized, they can block enforcement efforts. In such cases, only combinations of policies with low private costs are likely 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 and is therefore likely to meet with considerable resistance.
Economic Incentives	
Green subsidies	Without careful monitoring, may simply encourage the resale of subsidized goods.
Boycotts	Unlikely to be effective because 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 derailed by input price instability. Intertemporal and place-based factors matter: universal solutions are improbable.
Information-based	
Educational programs	May bolster pollution control efforts.

equipment and technical extension. In Saltillo, regulatory authorities ultimately opted for a process standard prohibiting exclusive use of tires as fuel—a relatively low-cost strategy—and made efforts to reduce the costs of this regulation by providing brickmakers with free scrap wood and subsidizing the cost of recreational facilities and market stalls. In Torreon which had a relatively small but geographically concentrated and politically active group of brickmakers, regulators promoted relocation—a costly strategy. However, they tried to do this by offering a generous incentive package rather than by threatening sanctions. Moreover, city authorities had limited success with this policy. By contrast, Zacatecas' brickmakers were both few in number and completely unorganized. They were unable to either prevent regulators from pursuing costly abatement strategies—relocation and clean technological change—or to convince them to subsidize their expenses.

Thus, our case studies suggest that even though informal firms might appear to be politically ineffectual, actually they are often very capable of blocking costly pollution control policies. This is especially likely to be true in cases where informal sector polluters have significant environmental impacts, simply because in such cases they are bound to be numerous. Hence, policy makers grappling serious informal sector pollution problems will generally be unable to pursue policies that impose significant costs on polluters.

(b) 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 which managed to convince more than 175 brickmakers to adopt propane, albeit for a limited time. This effort was also the only one in our sample that was led by a private-sector organization, a fact 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 Brickmakers' Project generated among funders, 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. Even those brickmakers who supported this initiative were reluctant to put great store in a promised package of relocation incentives for fear that it was politically motivated. In Saltillo, the propane initiative was twice disrupted by changes in the municipal government, first in December 1993 and again in December 1996. Finally, in both Zacatecas and Torreon, 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 United States and Mexican Federal support and the support of the municipal and state governments. 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.

(c) Combining policies

As Table 2 illustrates, the policy makers in our four study cities used combinations of several of different pollution control policies, rather than simply relying on one or two. For example, in Cd. 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.

(d) Command and control process standards

Municipal environmental authorities in each of our four study cities promulgated command and control regulations prohibiting the use of certain types of fuels. In Cd. Juárez and Zacatecas, these regulations helped to temporarily dramatically boost propane use, and in Cd. Juárez, Zacatecas and Torreon, they ultimately succeeded in permanently eliminating the use of particularly dirty fuels like plastics and used tires. Policy makers relied on two strategies to overcome the difficulty of monitoring and enforcing these regulations: registration and peer monitoring.

In Saltillo, Zacatecas and Torreon, municipal authorities compiled registries of informal brickmakers. This strategy was only clearly effective in one of these cities. In Saltillo, registration was clearly futile. Brickmakers continued to violate prohibitions on burning tires with impunity. It is hard to judge the impact that registration had in Torreon since peer monitoring appears to have played a strong role in the shift away from the dirtiest fuels. By contrast, in Zacatecas, registration undoubtedly had a significant effect. For a short period, all brickmakers in the city used propane exclusively and there is little evidence that peer monitoring or other strategies were responsible. But the success of the registration effort in Zacatecas was very likely due to the fact that there were only about 60 kilns in the city. As a result, monitoring was not prohibitively costly. Also, brickmakers did not have the political power to block enforcement.

Thus, our case studies suggest that in general, simply registering informal polluters is not sufficient to facilitate enforcement of command and control regulations. Evidently, the fact that informal polluters are anonymous is not the principal barrier to enforcement. Rather, the key obstacles are the high cost of monitoring and the political considerations discussed above. 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 single 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 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, to limit the number of kilns burning at any given time, and to stop burning tires.

Thus, our case studies suggests that peer monitoring is a necessary condition for effective command and control regulation in the informal sector. They also suggest that peer monitoring is most successful when facilitated by local organizations. It is important to note, however, that the success of this strategy in our study cities depended on the fact that neighbors could easily see or smell brick kiln emissions. Peer monitoring would probably be less effective for other types of polluters (like leather tanneries) whose emissions are less visible.

(e) Relocation

Relocation is probably the most costly pollution control strategy for brickmakers. It requires them to 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 in our sample where kilns were actually relocated was Zacatecas which was also the only city where brickmakers had very little political power. Relocation was never even seriously discussed in either Cd. Juárez or Saltillo, cities 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.

(f) Green subsidies and taxes

There were no attempts to use green taxes or subsidies in any of our study cities. The explanation most likely has to do with a number of practical considerations. First, all of the pollution control efforts we studied were led either by municipal governments or non-governmental organizations. Neither institution 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 scrap wood—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 these inputs to make quick profits. In fact, according to regulatory authorities in Cd. Juárez, one reason federal propane subsidies were lifted in the early 1990s 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.

(g) Boycotts

Although green taxes and subsidies were absent in our case studies, boycotts of brickmakers using dirty fuels were attempted in two cities: Cd. Juárez and Zacatecas. In both cases, they 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 simply does not work; monitoring is too difficult and cheating is too easy.

(h) Clean Technological Change.

In three of our study cities, Cd. Juárez, Zacatecas, and Saltillo, policy makers 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—Cd. Juárez and Zacatecas—adopted propane and continued to use it for over a year. This phenomenon runs counter to the conventional wisdom that to be viable, clean technologies must reduce variable costs.

Part of the explanation for this phenomenon 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 who 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 policy makers 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 attempted to develop and diffuse new 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. 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. These experiences illustrate well-established principals for introducing new technologies in low-income settings. First, to the extent possible, intended adopters should participate in designing the innovation. And second, new technologies must be "appropriate", that is both affordable and consistent with existing levels of technology.

Finally, are there any lessons to be learned from the fact that technological change initiatives in Cd. Juárez, Zacatecas and Saltillo were undermined by nation-wide reductions in propane subsidies? This

might be seen as evidence of a failure on the part of the Mexican government to coordinate conflicting policy initiatives. While the government funded efforts to convert brickmakers to propane (through Solidarity Enterprises and NAFIN), it simultaneously pursued an economic liberalization program that undermined these efforts. But this liberalization program was part of a broad economic reform and the benefits of this reform may well have outweighed the costs, including the environmental costs. To reduce the environmental costs, the Mexican government might have subsidized propane use by those consumers who were likely to substitute into dirty fuels. But such a policy would have been difficult to implement and almost certainly would have created a black market in subsidized propane.

Should the organizers of the propane initiatives in each city be blamed for failing to recognize that propane was an economically unsustainable option? It seems unfair to fault the organizers of the Cd. Juárez program. Propane prices only began to rise in 1992 by which time this initiative had completely organized itself around engineering a switch to propane. But the leaders of the Zacatecas and Saltillo programs might have forseen the difficulties of promoting propane since their projects were not launched until 1993 and 1994. Their failure to do so may have stemmed from the fact that in the early 1990s, the Cd. Juárez experience was being widely touted as a model initiative by both its leaders and funders. In 1994, with federal financing, the Mexican non-profit that spearheaded the Cd. Juárez project established ECO-TEC, a "national" center for brickmaking training and research that strongly advocated conversion to propane.

Hence, the demise of the propane initiatives in three of our study cities holds two lessons. First, in developing economies where input prices are often unstable, market-based technological change initiatives among enterprises that are sensitive to variations in these prices are bound to be somewhat fragile. Second, intertemporal and place-based factors matter: what works at one time and in one place will not necessarily be a universal solution.

(i) 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 information campaigns regarding the health impacts of emissions can bolster pollution control efforts.

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