

Environmentally-Friendly Technological Change Among Mexico's Traditional Brickmakers:

A Final Narrative Report to the Tinker Foundation

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Resources for the Future

February 15, 1999

Grant Amount: \$100,000 (1995 -- \$50,000; 1996 -- \$50,000)

Date of award: December 14, 1995

One year no-cost extension granted in December, 1997

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1. Overview of original project goals and objectives

Most sizable cities in Mexico are home to dozens if not hundreds of small-scale traditional brick kilns that supply building materials for low-cost housing. True micro-enterprises, these kilns are typically ten meters square, employ a half dozen people, and generate profits on the order of \$100 per month. Because they use a variety of cheap highly polluting fuels including used tires, plastic refuse, wood scrap, and manure, traditional kilns are a notorious source of urban air pollution. In some cities like Cd. Juárez, traditional kilns are a leading contributor to city-wide air pollution. In practically every city, they constitute a serious health hazard to those living in the impoverished neighborhoods that commonly abut brickyards, as well as to brickmakers themselves.

Mexico's traditional brick kilns are an archetypal example of a whole class of small-scale and informal polluters such as leather tanneries, auto repair shops, and metalworkers. Since small-scale and informal firms are ubiquitous in developing countries, they can have devastating environmental impacts. But regulating such firms by conventional means is virtually impossible since they are usually unregistered, numerous, geographically dispersed, highly competitive, and only marginally profitable. Hence, environmental management must be innovative. One especially promising approach is to introduce so-called 'environmentally friendly technologies'—technologies that prevent pollution without raising costs. The hope is that firms will adopt such technologies voluntarily, or at least with minimal prodding, easing the burden on regulatory authorities. Other innovative approaches include 'peer monitoring'—creating incentives for polluters to monitor each other—and educational campaigns designed to inform firm owners about the health consequences of pollution.

The broad goal of our study was to improve the ability of policy makers to control pollution created by small-scale and informal firms. Our specific goals were to: (i) identify the principal barriers to and incentives for the adoption of clean-burning propane by Ciudad Juárez's traditional brickmakers; (ii) determine how these findings apply to the adoption of environmentally friendly technologies by traditional brickmakers in other Mexican cities; and (iii) explore the implications of this case study for environmental management in developing countries.

2. Activities that took place as a result of the grant

Our project focused on producing and then disseminating the following six products:

- An econometric analysis of our Cd. Juárez survey data designed to identify the principal barriers to and incentives for the adoption of propane.
- A study of the institutional and historical factors that underpinned Cd. Juárez propane initiative.
- A critical review of the literature on controlling pollution from small-scale and informal sector sources.
- A comparative study of efforts to control pollution from traditional brick kilns in four study cities—Cd. Juárez, Saltillo, Torreon, and Zacatecas—designed to identify what types of environmental management strategies work best.
- A cost-benefit analysis of reducing emissions from traditional kilns in Cd. Jaurez.
- A study of the borrowing and marketing behavior of traditional brickmakers.

Below we provide an annotated chronological list of the specific activities that took place as a result of the Tinker grant.

1996

- a. Coded Cd. Juárez survey data (January–February). ... with the help of Maria Melendez, a graduate student at Johns Hopkins University.
- b. Interviewed Cd. Juárez project stakeholders (December–May). ... including officials of FEMAP, (the Mexican NGO that led the project), academics at local universities, representatives of El Paso Natural Gas, municipal environmental officials, and a representative of the Environmental Defense Fund in El Paso. These interviews were conducted during a visit to Cd. Juárez in December and by telephone.
- c. Wrote a qualitative analysis of Cd. Juárez propane initiative (December–April). Based on the above interviews, simple descriptive statistics culled from our survey data, and a review of secondary sources pertaining to US-Mexico border environmental issues, we wrote our first paper on the Cd. Juárez experience, “Cross-Border Environmental Management and the Informal Sector: The Cd. Juárez Brickmakers’ Project.” We sent draft versions of the paper to several of the interviewees listed above, and made revisions based on their comments. This paper was written for an edited volume on cross-border environmental management titled, *Cooperation and Conflict: Case Studies of Environmental Management on the Borders*. Abridged versions were published in two

newsletters, *Encuentros* and the *North American Institute Newsletter* (see publications in Section 9 below).

d. Presented qualitative paper (April). ...at the Annual Borderlands Scholars Association Meetings in Reno, Nevada. (Tinker funds were not used to cover time and travel for this conference or of the conferences listed below).

e. Conducted an econometric analysis of the Cd. Juárez survey data (April–June). Developed analytical and econometric models of propane adoption and used them to analyze our survey data. Completed a first draft of a paper titled, “Community Pressure and Clean Technology in the Informal Sector: An Econometric Analysis of the Adoption of Propane by Traditional Brickmakers in Cd. Juárez, Mexico.”

f. Translated an abridged version of the qualitative paper into Spanish (June). This version was published in *La Jornada Ecologia*.

g. Presented the econometric paper at two academic conferences (July–August). ... the Western Economic Association Meetings in San Francisco and the American Agricultural Economics Association Meetings in San Antonio, TX. We received valuable feedback from discussants and conference participants at each venue.

h. Field research in Mexico (July). The second broad goal of the project was to “determine how [the Cd. Juárez findings] apply to the adoption of environmentally friendly technologies by traditional brickmakers in other Mexican cities.” Toward this end, we visited four cities in central Mexico where brick kilns create serious air pollution problems: Saltillo, Coah., Torreon, Coah., Zacatecas, Zac., and Guadalupe, Zac. We spent three or four days in each city interviewing brickmakers, local environmental authorities, and other stakeholders.

i. Presented the econometric paper at a minority economists seminar (August). ... at the University of Texas at Austin (the ‘Summer Program for Minorities in Economics’ provides intensive training for top minority economics undergraduates matriculating in graduate programs).

j. Prepared the qualitative paper on Cd. Juárez for publication (August–September). We broadened the focus of the qualitative paper on Cd. Juárez from ‘cross-border environmental management’ to ‘pollution control in the informal sector,’ revised and updated it, and submitted it to the *Natural Resources Journal*.

k. Presented a policy seminar at RFF (September). Invitees included representatives of Agency for International Development, the World Bank, and the Inter-American Development Bank.

l. Prepared the econometric paper for publication (November). Revised the paper and submitted it to the *Journal of Environmental Economics and Management*.

1997

- a. Wrote a first draft of a comparative policy paper (March–May). ... detailing efforts to control brick kiln emissions in Cd. Juárez, Saltillo, Torreon, and Zacatecas. The original title of this paper was, “Traditional Brickmaking in Four Cities in Northern Mexico: The Problem of Pollution Control in an Informal Industry.” The current title is, “Policy Options for Pollution Control in the Informal Sector.”
- b. Presented research overview (April). ... at the University of Maryland, Department of Agricultural and Resource Economics.
- c. Presented the comparative policy paper (April). ... at the Association of Borderland Scholars Annual Meetings, Albuquerque, NM.
- d. Revised the qualitative paper on Cd. Juárez in light of referees’ comments (February–May).
- e. Preliminary research on valuing the benefits of reducing kiln emissions (June–August). Andres Lerner, a summer intern at RFF, prepared a report detailing the data and modeling requirements for a cost-benefit analysis of reducing kiln emissions.
- f. Revised econometric paper in light of referees’ comments (July–September).
- g. Presented revised econometric paper (September). ... at the University of Wisconsin at Madison, Department of Agricultural and Resource Economics.
- h. Presented a lecture reviewing research (September). ... at Ripon College, Campus Lecture Series, Ripon, Wisconsin.
- i. Presented the revised econometric paper (December). ... at Princeton University, Science, Technology, and Public Policy Program Seminar.

1998

- a. Presented an overview of research (June). ... at the World Congress of Environmental and Resource Economists, Venice, Italy.
- b. Presented a seminar on the implications of the research for cross-border pollution control (August). ... at the Dallas Federal Reserve Bank Conference on Air Quality and Economic Growth, San Antonio, Texas.
- c. Prepared a review of the literature on small-scale polluters (September). ... to underpin the comparative analysis of efforts to control kiln emission in our four study cities.

d. Preliminary research on the borrowing and marketing behavior of Cd. Juárez brickmakers. (September–December). With the assistance of Pam Jagger, a Research Assistant at RFF, we have begun to look at our Cd. Juárez data with an eye toward trying to explain brickmakers' borrowing behavior and their decisions about whether to sell on formal or informal markets. This preliminary work included a literature review and data analysis.

e. Constructed an air dispersion model for Cd. Juárez-El Paso (October–December). Jih-Shyang Shih, a fellow at RFF, and an environmental planner, took the lead in this effort.

f. Revised comparative policy paper (October–December). This paper is now in near-final form and will be submitted to *World Development* by the end of March, 1999.

3. Findings

The following are our principal findings about controlling pollution from small-scale and informal sources. They are detailed at length in our papers.

Community pressure. Since conventional command and control regulatory approaches are impractical, the key to the success of all manner of efforts to control emissions from small-scale and informal sources—including clean technology initiatives—is ‘community pressure,’ that is, creating incentives for firms and organizations with close ties to polluters to pressure them to reduce pollution. This can be accomplished by enlisting the support of trade unions and neighborhood associations and by setting up citizen complaint mechanisms.

Clean technologies. Contrary to conventional wisdom, clean technologies need not be cost-reducing to diffuse widely. The reason is a bit subtle. Since adopters of cost-increasing technologies are at a competitive disadvantage compared to non-adopters, they had an incentive to put pressure on competitors to adopt as well. Adopters are able to apply pressure via trade and neighborhood associations. This suggests that if enough firms can be convinced by hook or crook to adopt a cost-increasing clean technology, eventually competition will ensure that diffusion becomes self-perpetuating.

Political-economy. Regulating small-scale and informal firms is as much a political problem as an economic one. When small-scale polluters are numerous and well-organized, they can preclude policies that impose significant cost burdens.

Education. Our case-study suggests that managers of small-scale and informal firms are not well-informed about the health impacts of exposure to pollution and that educational campaigns can create private incentives to control pollution.

Market intervention. Boycotts, price floors, tax schemes and other attempts to intervene in informal markets are a common regulatory approach. However, they are bound to be futile. Cheating is simply too easy.

First-best solutions. First-best solutions to pollution problems are often prohibitively costly in the informal sector. Therefore, second-best options may be preferable.

Private-sector-led initiatives. These 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. Contributors/obstacles to success

The principal external factor that contributed to the success of the project was the generous cooperation of various stakeholders in Mexico and El Paso. In Ciudad Juárez and El Paso, thanks in large part to introductions provided by Dr. Carlos Rincon of the Environmental Defense Fund, and Dr. Octavio Chavez, formerly of the *Instituto Tecnológico y de Estudios Superiores de Monterrey*, we were able to establish good relationships with a variety of critical stakeholders including FEMAP (the NGO that led the propane initiative), municipal officials, and the leaders of several brickmakers organizations. These relationships proved invaluable. We also enjoyed the cooperation of key stakeholders in Saltillo, Zacatecas, and Torreon. It was our experience that regulators, brickmakers and other stakeholders were quite open and were more than willing to share their views on what they perceived to be an under-appreciated problem.

Internal factors also contributed to the success of the project. Most important, the principal investigators were enthusiastic about working on a project where economic research can have real and immediate impacts, and where findings are relevant to a whole class of little-studied pollution problems. In addition, Resources for the Future proved a fertile environment for the project. For example, Dr. William Pizer, a Fellow at RFF and an econometrician, provided assistance with our statistical modeling, and more recently, Dr. Jih-Shyang Shih, an RFF Fellow who is a computational modeler, was recruited to take charge of our air dispersion modeling effort.

There have been a number of obstacles to the success of the project. Perhaps most important, drastic nationwide cuts in propane subsidies in the mid 1990s, along with the 1995 peso crisis, eviscerated nascent efforts in a number of Mexican cities to convert traditional kilns to propane. These unanticipated events had a number of impacts on the project. First, we had hoped to be able to study the diffusion of propane in ‘real time’ in a number of cities during the two-year project term. The termination of the propane initiatives made this impossible. In Cd. Juárez, we did not need to reconfigure the project very much. Instead of explaining the existing pattern of propane use, we focused on explaining the pattern that existed a year earlier. We were still able to identify the key barriers to and incentives for propane adoption. Moreover, we were able to draw important lessons from the subsequent dis-adoption of propane.

However, we were forced to reconfigure our plans for research outside of Cd. Juárez. We had originally envisioned a second round of survey research and statistical analysis in a city where propane had been adopted by a significant proportion of brickmakers. But we were unable to find another city where propane had diffused widely. As it turned out, most of the propane initiatives outside of Cd. Juárez were just beginning when the 1995 recession hit. Ultimately, we shifted our focus outside of Cd. Juárez to a comparative analysis of the various pollution control strategies adopted by regulators in four study cities. In retrospect, this shift in focus was a definite boon to the project as it led us to consider a range of pollution control strategies rather than just clean technological change.

A second effect of the termination of propane initiatives around the country was that our Cd. Juárez research lost an obvious application—helping to develop plans to convert kilns in other cities to propane. After the rise in propane prices, this technological option was effectively ruled out. Nevertheless, we are confident that our research on the Cd. Juárez propane initiative has been, and will continue to be, very useful to policymakers since our findings are relevant to all manner of clean technologies and small-scale pollution problems. For example, as discussed in Section 7 below, we believe our findings have been helpful in developing plans to convert brickmakers in Cd. Juárez to natural gas (as distinct from propane).

Another obstacle to the success of the project was the loss of Dr. Bannister as co-principal investigator. For personal reasons, Dr. Bannister left academia in the middle of the project. After the winter of 1996-1997, Dr. Blackman was the sole principal investigator. As a Mexican national, Dr. Bannister's comparative advantages in the project were field research and the dissemination of our results in Mexico and Latin America. Thus, Dr. Bannister's departure may have blunted our dissemination activities in Mexico somewhat.

5. Unanticipated results

Importance of community pressure. We were somewhat surprised to find that community pressure was a key feature of every moderately successful pollution control effort in our study cities. For example, in Cd. Juárez, local brickmaker organizations placed significant pressure on brickmakers to stop burning the most toxic fuels.

The adverse health impacts of brickmaking. Though we suspected that brickmakers might be reluctant to admit that their profession was taking a toll on their health, we were surprised that fully 89 percent of the brickmakers surveyed in Cd. Juárez claimed that there were absolutely no adverse health impacts associated with brickmaking. To the extent this result is typical—and there is little reason to suspect otherwise—it implies that educational campaigns can have a significant impact on pollution control.

Political organization. We had not anticipated that informal brickmakers would be so well-organized. In each of our study cities except for Zacatecas, the majority of brickmakers belonged to some type of political organization. We were also somewhat surprised that some of the brickmaker organizations were powerful enough to resist strong-arm measures by the city government. While the political organization of brickmakers is good news in that it implies that there is scope for community pressure, it also implies that pollution control is as much a political problem as an economic one.

Cost of propane relative to debris. Given the relatively high percentage of brickmakers in Cd. Juárez who adopted propane, we did not anticipate that propane would be as costly (relative to debris) as it was. We estimated that in October 1993, when more than half of Cd. Juárez's brickmakers were using propane, firing with propane was over one and a half times as expensive as firing with debris. This implies that clean technologies need not be cost-reducing to diffuse widely.

Insignificance of wealth, firm size, and access to credit in explaining adoption. In our Cd. Juárez study, at first we were surprised that wealth, firm size, and access to credit were not correlated with adoption. Upon reflection however, this makes perfect sense. These variables are usually correlated with technology adoption because adoption usually requires firms to pay significant fixed pecuniary costs (e.g. the cost of buying equipment). But in Cd. Juárez, local organizers heavily subsidized these costs by providing free training and equipment. This result indicates that these subsidies were effective.

6. Target audiences

The two target audiences for our research identified in the original proposal were: (i) policy makers and researchers involved in environmental management in developing countries, and (ii) policy makers responsible for controlling brick kiln emissions in Ciudad Juárez and other Mexican cities.

Our research has clearly had an impact on the first target audience. One indication of this impact has been our success at getting our results published and at getting invited to seminars and conferences. As detailed in Section 9, we have published two journal articles, two book chapters, three articles in the popular press (including one in a Mexican newspaper) and we have presented our research at 12 different seminars.

The most encouraging indication that policy makers are reading our papers and taking them seriously is that the World Bank chose to include a 'box' concerning our Cd. Juárez research in its 1998-1999 *World Development Report*. The *World Development Report* is the World Bank's annual report on economic development issues, and is very widely read in the development policy community. This year's report is on "Knowledge for Development" (the box is number 7.9 on page 114; a copy of is attached).

Finally, we have been contacted several times by practitioners seeking advice on small-scale source pollution problems in developing countries (including Colombia, the Philippines, and India).

With regard to the second target audience (policy makers responsible for controlling kiln emissions in Ciudad Juárez and other Mexican cities), in the first two years of the project, we were in frequent contact with key stakeholders in the Cd. Juárez Brickmakers Project, including representatives of FEMAP, the Environmental Defense Fund, local universities, the EPA's El Paso Office, and the TNRCC's El Paso office. We interviewed these representatives in the course of our research, sent them preliminary drafts of our papers for comments, and then sent final drafts. We have periodically been in contact with them in the last year to exchange information on what is happening in the sister cities, and to update them on our progress.

Our efforts to influence Mexican policy makers involved in controlling kiln emissions have not been as successful as we had hoped. One of the main reasons is that in the aftermath of the 1995 peso crisis, efforts to control emissions from traditional kilns were put on hold; the economic survival of these microenterprises during the economic recession took priority.

We will continue to attempt to inform efforts to control brick kiln emissions in Mexico. We plan to have completed our research on the benefits of reducing kiln emissions by the end of the summer of 1999. We will present our findings to stakeholders involved in ongoing efforts to develop a bi-national plan for air pollution control in Cd. Juárez and El Paso.

7. Short-term impact

In the short term, I think that we were successful in convincing stakeholders in Cd. Juárez and El Paso that several of our key findings should be taken into account in planning new efforts to control brick kiln emissions by introducing natural gas-fired kilns (as distinct from propane-fired kilns). In particular, we conveyed that: attempts to intervene in informal markets would be futile; community pressure can be quite effective; and new clean technologies must be "appropriate."

8. Longer-term impacts

As detailed in Section 6 above, I think we already have promising indications that our research has had, and will continue to have, an impact on policymaking and research. This project was the first stage of a planned multi-year program of research on small-scale source pollution control. We hope that the long-term impacts of this research will be to: build a widely applicable policy 'tool kit' for small-scale source management; establish the topic of small-scale source management as an important one in the field of Environment and Development; and set an agenda for future research.

9. Products

Peer-reviewed journal articles

A. Blackman and G. J. Bannister. 1998. "Community Pressure and Clean Technology in the Informal Sector: An Econometric Analysis of the Adoption of Propane by Traditional Mexican Brickmakers." *Journal of Environmental Economics and Management*. 35(1), 1-21.

A. Blackman and G. J. Bannister. 1997. "Pollution Control in the Informal Sector: The Ciudad Juárez Brickmakers' Project." *Natural Resources Journal*. 37(4), 829-56.

Articles to be submitted to peer-reviewed journals

A. Blackman. 1999. "Policy Options for Informal Sector Pollution Control: A Literature Review and Case Study," Mimeo. To be submitted to *World Development* in March 1999.

Book chapters

A. Blackman and G. J. Bannister. 1999. "Pollution Control in the Informal Sector: The Ciudad Juárez Brickmakers' Project." Russell Frye (ed.) *Economic Development and Environmental Protection: Challenges and Opportunities*. Kluwer Law International. Forthcoming.

A. Blackman and G. J. Bannister. 1998. "Cross Border Environmental Management and the Informal Sector: the Ciudad Juárez Brickmakers Project." in R. Kiy and J. Wirth (eds.) *Cooperation and Conflict: Case Studies of Environmental Management on the Borders*. College Station: Texas A&M Press.

Popular Press

A. Blackman and G. J. Bannister. 1996. "Los Ladrilleros de Ciudad Juárez: de Cómo Evitar una Mayor Contaminación Atmosférica." *La Jornada Ecología*, Año 4, Numero 48, Julio 18, pp. 6-7.

A. Blackman and G. J. Bannister. 1996. "Cross Border Environmental Management and the Informal Sector: the Ciudad Juárez Brickmakers Project." *Encuentros*, Volume 3, No. 1, 8-10.

A. Blackman and G. J. Bannister. 1996. "Cross Border Environmental Management and the Informal Sector: the Ciudad Juárez Brickmakers Project." *North American Institute Newsletter*, October, pp. 2-4.

Reviews of research

“Information, Community Pressure and the Adoption of Clean Technology in Ciudad Juárez.” Box 7.9 in “Knowledge for Development,” World Development Report 1998/99. World Bank: Washington, DC, p. 114.

Working papers

A. Blackman and J.-S. Shih. 1999. “Valuing the Benefits of Reducing Emissions from Small-scale Brick Kilns. Preliminary Report on Phase I: Air Dispersion Modeling” Mimeo. Resources for the Future: Washington, DC (December).

A. Blackman and G. J. Bannister. 1997. “Community Pressure and Clean Technology in the Informal Sector: An Econometric Analysis of the Adoption of Propane by Traditional Mexican Brickmakers.” *Resources for the Future Discussion Paper 97-16-REV*.

A. Blackman and G. J. Bannister. 1998. “Pollution Control in the Informal Sector: The Ciudad Juárez Brickmakers' Project.” *Resources for the Future Discussion Paper 98-15*.

A. Blackman and G. J. Bannister. 1997. “Cross Border Environmental Management and the Informal Sector: the Ciudad Juárez Brickmakers Project.” *Resources for the Future Discussion Paper 96-22*.

Papers in progress

A. Blackman and J.-S. Shih. 1999. “Valuing the Benefits of Reducing Emissions from Small-scale Brick Kilns.”

A. Blackman and Pam Jagger. 1999. “*Coyotes* and Construction Companies: Explaining Borrowing and Marketing by Informal Mexican Brickmakers”

Presentations

August 1998. Dallas Federal Reserve Bank Conference on Air Quality and Economic Growth. San Antonio, Texas. “Cross-Border Pollution Control.”

June 1998. World Congress of Environmental and Resource Economists. Venice, Italy. “Addressing Environmental Problems in Less Developed Countries: Can Economists Make a Difference?” (Panelist).

December 1997. Princeton University, Science, Technology, and Public Policy Program Seminar. “An Econometric Analysis of the Adoption of Propane by Traditional Brickmakers in Cd. Juárez, Mexico.”

September 1997. University of Wisconsin at Madison, Department of Agricultural and Resource Economics. "An Econometric Analysis of the Adoption of Propane by Traditional Brickmakers in Cd. Juárez, Mexico."

September 1997. Ripon College, Campus Lecture Series, Ripon, Wisconsin. "Pollution Control in Developing Countries."

April 1997. University of Maryland, Department of Agricultural and Resource Economics. "Environmental Management in the Informal Sector of Developing Countries: The Case of Traditional Mexican Brickmaking."

April 1997. Association of Borderland Scholars, Albuquerque, NM. "Traditional Brickmaking in Four Cities in Northern Mexico: The Problem of Pollution Control in an Informal Industry."

September 1996. Resources for the Future, Washington, DC. "Environmental Management in the Informal Sector of Developing Countries: The Case of Traditional Mexican Brickmaking."

August 1996. University of Texas at Austin American Economics Association Summer Minority Program. "An Econometric Analysis of the Adoption of Propane by Traditional Brickmakers in Cd. Juárez, Mexico."

July 1996. American Agricultural Economics Association Meetings, San Antonio, TX. "An Econometric Analysis of the Adoption of Propane by Traditional Brickmakers in Cd. Juárez, Mexico."

June 1996. Western Economic Association Meetings, San Francisco, CA. "An Econometric Analysis of the Adoption of Propane by Traditional Brickmakers in Cd. Juárez, Mexico."

April 1996. Association of Borderlands Scholars Meetings, Reno, NV. "Pollution Control in the Informal Sector: The Ciudad Juárez Brickmakers' Project."

10. Value as a model for future work

At least two aspects of this project are innovative and will hopefully serve as a model for future work. First, very little economic research has been done on informal-sector or even small-scale pollution problems. We hope that our research will help to convince others that this is a critically important area, and that rigorous economic research is needed. Second, our econometric paper is the first to formally model clean technology adoption by small-scale firms. The models we developed can serve as a template for empirical work in a variety of developing country settings.

11. Project personnel

The principle investigators for the project were Dr. Allen Blackman, a Fellow at Resources for the Future, and Dr. Geoffrey J. Bannister, formerly an Assistant Professor at the University of New Mexico. However, as discussed in Part 4 above, for personal reasons, Dr. Bannister has left academia. As a result, after the winter of 1996-1997, Dr. Blackman was the sole principal investigator.

Dr. Jhih-Shyang Shih, an environmental planner with expertise in air dispersion modeling, joined RFF staff as a Fellow in 1998. Dr. Shih was recruited onto the project to perform the air dispersion modeling needed to conduct a cost-benefit analysis of reducing kiln emissions in Cd. Juárez.

A succession of excellent Research Assistants and Interns have worked on the project. A graduate student at Johns Hopkins University, Maria Melendez, helped code the Cd. Juárez survey data. Tim Vandenberg, the Research Assistant designated for this project in our proposal, left RFF in the Spring of 1996. Tim's departure did not have any affect on the project as his successor, Brian Kropp, did a tremendous job. Brian's role was to help perform the statistical analysis needed for the econometric paper. In the summer of 1997, Andres Lerner, an RFF Summer Intern, wrote a memo that laid the groundwork for Jhih-Shyang Shih's air dispersion modeling. Finally, recently Pam Jagger, a new Research Assistant has taken the lead in the preliminary research we have done on Cd. Juárez brickmakers' borrowing and marketing behavior.

12. Project budget

The project funds were adequate for the activities described in the original proposal. However, we will need additional funds to compete several related activities that were not included in the proposal: the cost-benefit study of reducing emissions from traditional kilns, the research on brickmakers' borrowing and marketing behavior, and any revisions to the comparative policy paper suggested by the referees' at *World Development*.

There was a change in the allocation of funds in the original proposal. We originally proposed to spend \$60,000 on staff, \$20,000 on travel, and \$20,000 on research support. In December 1996, we asked for and received approval to change this allocation to \$70,000 on staff, \$5,000 on travel, and \$25,000 on research support. We spent less on travel than anticipated because (for reasons discussed in Section 4 above) we did not conduct extensive survey research in two study cities as originally planned. Instead, we conducted survey research in only one study city (Cd. Juárez) and approximately thirty interviews in three other study cities. The interviews required only one extended trip comprised of three-four day visits in each study city. We spent more on research support than anticipated because we used RFF Research Assistants to help us with data analysis.

13. Impact on Resources for the Future

This project's most important impact on RFF has been the development of ties with researchers and policy makers in Mexico. These ties will ensure that RFF continues to expand its activities in Mexico. For example, RFF is now involved in efforts to help the University of Guanajuato set up Mexico's first ever graduate program in environmental economics.

This project also made a significant contribution to RFF's recent efforts develop a full-fledged Environment and Development (E&D) program. These efforts have involved a strategic planning exercise, the commitment of significant RFF funds to new E&D projects, hiring three new junior staff with expertise in E&D in the last two years, establishing ties with developing country counterparts, and a search for a Senior Fellow to lead the new program.

14. Future activities

This project represents the 'cornerstone' of a planned multi-year program of research on small-scale source environmental management in developing countries. We plan to extend our research in a number of directions:

Study of small-scale leather tanning in Leon. We will conduct a second rigorous case study of small-scale polluters in Mexico. The purpose will be to see whether and how the findings of our brick kiln study generalize across sectors. We will study small-scale leather tanners in Leon, Mexico. In Leon, over 1000 leather tanneries, three-quarters of which employ fewer than 6 workers, dump untreated toxic effluents directly into the Turbio River. The pollution contaminates ground water, destroys irrigated agricultural land, and has serious health impacts. Both formal and informal regulation of tanning is virtually non-existent. Therefore, clean technological change represents the most promising pollution control strategy. We plan to conduct a survey to understand why (absent regulation) some firms have adopted clean technologies and others have not. This will enable us to identify policy levers to promote future adoption.

Policy 'tool kit.' The second focus of future research will be to draw together the findings from our case studies of brick kilns and leather tanneries to develop a widely applicable set of policy recommendations for small-scale source environmental management.

Formal economic models. A third focus will be to develop a set of economic models to formalize the insights from our empirical work and to lay a solid theoretical foundation for future work.

Benefit estimation. Finally, we intend to continue with our efforts to estimate the benefits of reducing pollution from small-scale sources. In the short term, this will involve

completing our study of the benefits of reducing emissions from informal brick kilns in Cd. Juárez.