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Arresting the Killer in the Kitchen: The Promises and Pitfalls of Commercializing Improved Cookstoves

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Summary. — In a shift exemplary of neoliberal approaches to development, major funders of household energy interventions have begun to emphasize market-based stove dissemination over partially subsidized models. Stove promoters are increasingly expected to operate as self-sustaining businesses. This shift is viewed as a way to “scale-up” in order to reach millions of poor households lacking access to clean cooking technologies. Using the case of GIRA, an NGO that has successfully distributed cookstoves in Mexico’s Central Highlands for nearly two decades, we demonstrate how this trend presents challenges for organizations operating effectively with outside funding in highly contextual local conditions.

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Key words — improved cookstoves, household energy, public health, social enterprise, Mexico, Latin America

1. INTRODUCTION

This paper analyzes market-based interventions in household energy and health in the developing world. A recent shift in favor of market solutions and social entrepreneurship has raised challenges for grass-roots NGOs promoting health-improving technologies and behavioral change in household energy use. While there are some advantages to commercialized approaches, both current and historical experience justify continued state and/or donor support of improved stove programs. Rather than presenting an “either/or” choice of commercialization or continued subsidization, the evidence we present justifies a balanced approach acknowledging that the adoption of certain business practices would lead to a more successful stove dissemination, but also accounting for the difficulty of establishing viable commercial enterprises in the places where the disease burden from household energy is highest and acknowledging that the links between household energy and health are characterized by public goods and may deserve long-term state and/or donor support. The challenge lies in identifying a combination of commercialization and state or donor support that works in the highly varied geographic space where woodfuel-dependency persists.

Two to three billion people worldwide depend on biomass as a cooking fuel (IEA., 2004). With most cooking done indoors over open fires, air pollution concentrations can exceed the United States EPA’s air quality standards for exposure by a factor of 100 or more (WHO, 2006). The World Health Organization (WHO) estimates wood smoke contributes nearly 3%

to the total global burden of disease, resulting in 1.6 million premature deaths each year, including 900,000 children under five.¹ This is similar in magnitude to the burden of disease from malaria and tuberculosis (WHO, 2002). However, the causal factors of ill health from exposure to wood smoke are quite distinct from the vectors that cause other major diseases. Reducing health impacts associated with household energy requires changing technology and individual behaviors in and around the kitchen: a complex social space that is both critical to the material well-being of the household and imbued with deep cultural meaning, which raises a unique set of challenges.

Development interventions aimed at household cooking date to the 1970s. They were initially motivated by a perceived link between deforestation and household energy (Arnold, Kohlin, Persson, & Shepherd, 2003). Occurring concurrently

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with the global “energy crises” of the 1970s and 80s, this “other energy crisis” (Eckholm, 1975) drew the attention of development organizations and donors. However, the pace of interventions slowed when it became clear that forest degradation and loss could not be stopped by handing out new cookstoves (Arnold *et al.*, 2003; Leach & Mearns, 1988; Masera, Ghilardi, Drigo, & Trossero, 2006). More recently, health impacts of solid fuel use have come to the fore (Smith *et al.*, 2004; von Schirnding *et al.*, 2001). As a result, improved cookstoves (ICS) have recaptured the attention of development organizations and donors (WHO, 2006). Dozens of organizations have developed projects to promote cookstoves as health interventions since the mid-1990s, but few have been able to scale up beyond a few thousand stoves. These numbers are impressive, but are not sufficient to impact public health at the population scale. Stove developers face numerous challenges in reaching the affected populations, which we discuss below.²

Renewed attention in ICS programs has occurred in tandem with an increasing emphasis from the donor community for stove developers to adopt business-like approaches to stove dissemination. Stove developers are expected to shed donor-dependency and become “more innovative, efficient and profitable at what they do as a business” (Hoffman, West, Westley, & Jarvis, 2005, p. 11). While such a shift carries some promise, it also represents a risk for many small organizations that have been at the forefront of the effort to reduce exposure to harmful emissions among woodfuel-dependent populations.

The commercialization of cookstoves raises important questions about the appropriateness of different models of service delivery when public health is at stake. In Section 2 of this paper, we describe the context in which current improved stove programs operate. In Section 3, we place the trend toward market-based approaches to service provision in a broader political economic context and discuss the difficulties that small-business start-ups face in developing countries. In Section 4, we present details of the Mexican case study and compare the Mexican experience to past stove interventions in Kenya and China, which are both examples of commercialized stove dissemination. We close with a discussion of the strengths and limitations of commercial models for improved stove dissemination.

2. BACKGROUND

The household use of solid fuels is most prevalent in sub-Saharan Africa and South Asia, where they are used by 80–90% of households (International Energy Agency, 2006). In Latin America, commercial fuels such as liquid petroleum gas (LPG) have become popular and the prevalence of solid fuel use is lower than other developing regions: roughly 15% of the total population (International Energy Agency, 2006). Nevertheless, in many rural areas, communities are still wholly reliant on wood for their energy needs. This pattern holds in Mexico, where many rural families have adopted LPG, but as a complement to wood rather than a substitute (Masera, Guerrero *et al.*, 2005). During 1960–2000, the proportion of fuelwood users who also use LPG increased from just 5% to nearly 30%. However, the total number of fuelwood users has remained roughly fixed between 25 and 30 million (Masera, Diaz, & Berrueta, 2005). This expansion of fuel options challenges the traditional “energy ladder” model, which posits that households shift from less sophisticated fuels as they become more wealthy or better fuels become available (Barnes & Qian, 1992; Leach, 1992; Masera, Saatkamp, & Kammen,

2000). In Mexico, households use multiple fuels to take advantage of the most appropriate one for a given task and to hedge against price or supply shocks (Masera, Diaz *et al.*, 2005).

In Mexico, as in much of the developing world, most fuelwood is used in open fires or simple three-sided enclosures that emit smoke directly into the kitchen. Resulting concentrations of PM_{2.5} can exceed WHO guidelines by a factor of 30 (Smith *et al.*, 2007). Reliance on woodfuels also has negative impacts on the household economy and on local resources. Low combustion and heat transfer efficiencies drain resources from poor households, which spend up to 10% of their income on fuel (Valencia, 2004).

Fuelwood use can also deplete local resources by exceeding regeneration rates (Masera *et al.*, 2006). The Purhépecha region, located in the state of Michoacán (Figure 1) has been identified as a priority area where wood consumption is outstripping supply (Masera *et al.*, 2006). The region has a variable topography with elevations ranging from 1,800 to 3,800 m. The climate varies from temperate to sub-humid. Frost is common at higher elevations and seasonal heating is needed. Average rainfall is 800–1,100 mm/yr; falling primarily from May to July (López-Ridaura, Keulen, Ittersum, & Leffelaar, 2005). The average annual income in the region is US\$ 380/person: well below the country’s rural poverty line (Cortés, Hernández, Hernández, Székely, & Vera, 2002; Valencia, 2004). Fourteen percent of the population are indigenous Purhépecha, and, though the state’s infrastructure is well developed and access to electricity is nearly universal (Gil, 2006), one third of the population cooks exclusively with wood (Masera, Diaz *et al.*, 2005).

(a) *The Interdisciplinary Group for Appropriate Rural Technology (GIRA)*

GIRA is a non-governmental, non-profit organization based in Pátzcuaro, Michoacán. Founded in 1985, the organization assists with rural energy needs in the Purhépecha region and is also active in thirteen other Mexican states (Masera *et al.*, 2007). Since the mid-1990s, GIRA has worked with the National Autonomous University of Mexico’s Center for Ecosystems Research (CIEco) to promote sustainable energy in rural Mexican households.³ By the start of 2007, GIRA had disseminated roughly 8,000 Patsari stoves.

(b) *ICS projects as health interventions*

Research has shown that ICS projects can improve health (Ezzati *et al.*, 2004), and do so in a cost-effective way (Hutton, Rehfuess, Tediosi, & Weiss, 2006).⁴ ICS projects compare well with interventions in other major diseases (von Schirnding *et al.*, 2001). Figure 2 shows high and low estimates of cost effectiveness, measured in dollars per Disability Adjusted Life Year (DALY),⁵ for treatment options related to eight major

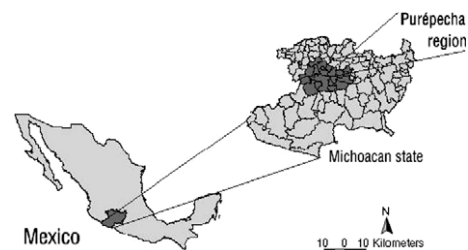


Figure 1. The Purhépecha region of Mexico in Michoacán State.

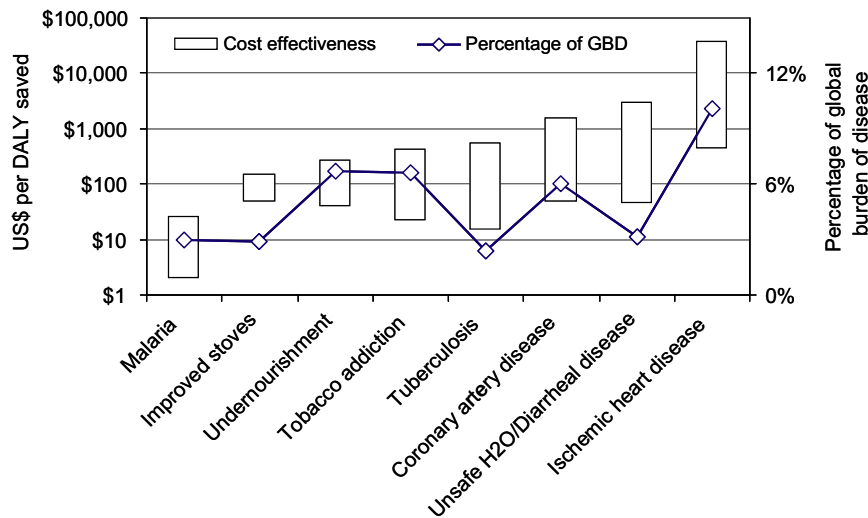


Figure 2. Estimated range of cost-effectiveness of interventions in US\$ per DALY avoided (DCPP, 2006) and percentage contributions to the global burden of disease from eight major risk factors and diseases (WHO, 2002). Note the left-hand vertical axis uses a logarithmic scale.

risk factors accounting for 40% of the global burden of disease (DCPP, 2006).

To date, research on improved stoves has focused largely on technical aspects of stoves: efficiency, emissions, and pollution exposures (Berrueta, Edwards, & Masera, 2008; Ezzati *et al.*, 2004; Sinton *et al.*, 2004; Smith *et al.*, 2007). Other studies have examined large state-sponsored distribution efforts (Aggarwal & Chandel, 2004; Barnes & Kumar, 2002; Kishore & Ramana, 2002; Sinton *et al.*, 2004; Smith, Shuhua, Kun, & Daxiong, 1993). Little attention has been given to commercialization, its effect on organizations involved with project implementation at the grass-roots level, and the role of state or donor support in facilitating stove commercialization. Organizations operating at the local level are impacted by the pressure to commercialize. In the following section we explore the roots of this trend and its implications for organizations working on household energy issues in developing countries.

3. THEORY AND CONTEXT

The commercialization of improved stoves attempts to shift stove dissemination from civil society to private, possibly *social*, enterprise. Terms such as *social enterprise*, *social entrepreneurship*, and *social marketing* are related concepts in which business principles are applied to a variety of social problems.⁶

This shift in development practice is an example of a widespread shift toward neo-liberal policies that have gained traction with major donors and international financial institutions (McCarthy & Prudham, 2004). Adherents promote a minimal role for the state and a rollback of public service provision. Minimally regulated markets are seen as the most efficient means to allocate scarce resources (Peet & Watts, 1993) including services that were traditionally the domain of the state, such as electric power (Greacen & Greacen, 2004; Williams & Dubash, 2004; Williams & Ghanadan, 2006), water and sanitation (Liverman & Vilas, 2006; Shrivastava, 2007; Wilder & Lankao, 2006), and public health (Armada, Muntaner, & Navarro, 2001; Bond & Dor, 2003; Homedes & Ugalde, 2005; Navarro, 2004).

This political shift occurred concurrently with the debt crisis of the 1980s, when cash-strapped states accepted austerity

measures imposed by international financial institutions in order to maintain financial stability (Harvey, 2005). Public spending was cut, state investments sold off, tariffs lowered or removed, and markets opened to foreign competition. In response, civil society organizations proliferated, in part to fill the void left by the state's withdrawal, but also in response to market expansion, which was a source of social and environmental stress.⁷

Thus, the late 1980s and early 1990s saw a mobilization of organizations responding to failures of states and markets to address a range of problems, often with support from foundations, international NGOs, or bilateral and multilateral aid agencies (Bettcher & Lee, 2002; Fisher, 1997; Macfarlane, Racelis, & Muli-Muslime, 2000; Raustiala, 1997). Now, many of the organizations that mobilized to address state and market failures are under pressure to adopt market-based approaches. As Beloe and colleagues state, "Declining government funding, more demanding beneficiaries and donors, and new market entrants increasingly require these groups to 'perform or perish' (2003, p. 8). This is bluntly expressed by donors themselves. One of the largest household energy donor organizations writes:

Socially or environmentally sound projects or enterprises that fail or remain permanently dependent on subsidy help nobody (Hoffman *et al.*, 2005, p. 6)

...donors should act more like investors and less like charities. . . (p. 25)

We also expect our partners to act more like entrepreneurs and businesses in the pursuit of their social and charitable objectives (p. 7).

It is easy to understand the attraction of market-based approaches. Activities that rely too heavily on subsidies or fail to shift toward some degree of cost recovery can founder when funding dries up or priorities shift. Weak states and highly centralized polities with little downward accountability are prone to corruption and may not deliver services effectively (Ribot, 2004). Conventional wisdom also holds that uptake of new technologies is improved if users pay part of the cost (ESMAP, 2000). Further, competition can drive down prices, increase quality, and, at times, outperform state services. For example, since the 1970s, Kenya's state-sponsored rural electrification effort, funded through a tax on utility bills, has reached 180,000 households (Ministry of Energy, 2002). In contrast, in just 10 years, roughly the same number of

households purchased small solar electric systems, primarily through unsubsidized cash sales. Early donor involvement established a market for high-end crystalline solar panels, but the thriving market in cheaper amorphous panels evolved with little outside assistance (Jacobson, 2007).

The few stove programs that have successfully reached large numbers of consumers have done so through some degree of commercialization (see Section 4 below). However, while market-based strategies may be appropriate in some circumstances, they are not necessarily the best choice, particularly when project developers hope to reach lower income households. For example, Kenya's solar market is thriving among the rural middle class, but the majority of Kenyans cannot even afford the cheapest system (Jacobson, 2007). This is also true in health interventions. The dissemination of insecticide-treated bednets in Kenya and Nigeria *via* subsidized cash sales drew little response from poor households, but freely disseminated nets had high rates of adoption (Kyama, & McNeil, Jr., 2007).

Thus, privileging commercial models over subsidized or donor-driven models risk pricing poor consumers out of the market. This not only makes it difficult for the poor to access certain goods and services, but it also places a burden on society. In the case of bednets and improved stoves, public investments in health-improving technologies would reduce costs of medical treatment and lost productivity that occur in the absence of such interventions (WHO, 2006).

(a) *Small business start-up in the developing world*

Even in ideal circumstances, starting a business is difficult. The US has long been a business-friendly society with various national, state, and local laws designed to create an environment that attracts businesses. Nevertheless, an estimated one in four small businesses fails.⁸ In contrast, countries in which solid fuel use is most prevalent are not nearly as kind to emerging businesses.

Figure 3 shows the regional prevalence of residential solid fuel use and the burden of disease attributable to it. Regions with high prevalence of solid fuel use are challenging for emerging businesses. As an example, Table 2 presents indicators of the business environment in China, India, and Nigeria, the populations of which suffer nearly half the world's burden of disease arising from exposure to solid fuel combustion (World Bank, 2006). The table also includes a measure of

corruption, which impacts the ease of doing business (Transparency International, 2006). Mexico and the US are included for comparison. In the first four rows, high rankings indicate a less favorable business environment; in the last row, low numbers reflect greater corruption.

Nigeria, China, and India rank below the global median for two, three, and four of the five indicators, respectively. These low rankings reflect real impediments for local organizations that attempt to commercialize. For example, starting a business in the US can take just six days and is a relatively low-cost endeavor, requiring an investment of less than 1% of *per capita* gross national income (GNI).⁹ In China, starting a comparable business takes six times longer and costs 8% of *per capita* GNI. In Nigeria, start-up takes equally long and can cost 60% of *per capita* GNI. Contract enforcement is another critical area. In India, enforcing a contract can take more than four years and cost up to a third of the entire claim. In the US, the cost averages less than 10% of the claim (World Bank, 2007). Corruption is also problematic: Nigeria consistently ranked among the world's most corrupt counties (Transparency International, 2006).

Mexico offers a more conducive business climate than the other countries included in this discussion. However, contract enforcement is relatively expensive, and corruption in Mexico is perceived to be as problematic as in India or China. The country also is troubled by volatile inflation and interest rates, high taxes, and a cumbersome bureaucracy (Lee & Peterson, 2000; Zamora, Cossio, Pereznieta, Roldan-Xopa, & Lopez, 2004).

Countries where improved stoves are needed also lack institutional support for small businesses. In the US, the Small Business Administration, an independent federal government agency, provides more financial support to US businesses than any private financial institution, with a loan portfolio of more than \$45 billion (Perline *et al.*, 2006). In contrast, businesses in Mexico find it difficult to obtain credit and the country's financial system is "surprisingly shallow," (Klaehn, Helms, & Deshpande, 2006).

Weak lending markets also hurt sales; only 6% of the rural population have access to savings accounts (World Bank, 2006). Mexico's microfinance sector was reorganized in 2001, but many people still lack access (The Microfinance Gateway, 2006). The legal context in Mexico also creates barriers to commercialization (World Bank, 2007; Zamora *et al.*, 2004). Lastly, employment regulations are among the most rigid in

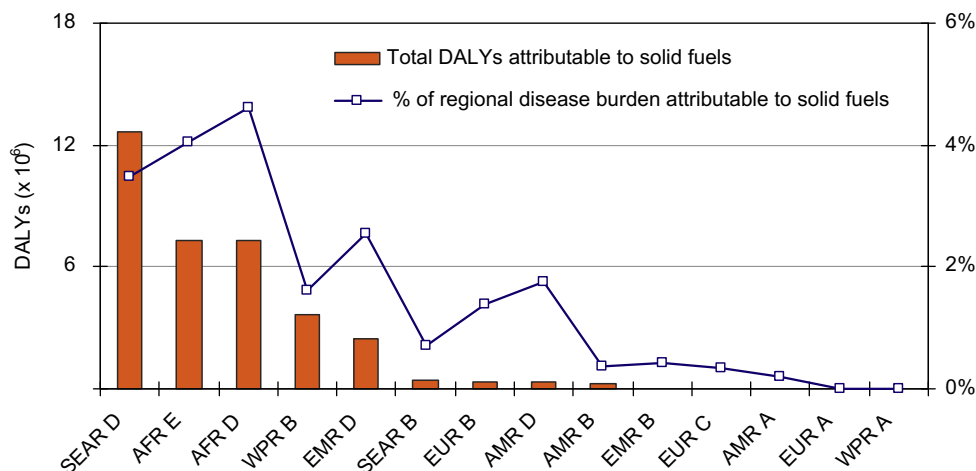


Figure 3. Regional burden of disease from solid fuel use by WHO classification (WHO, 2002).²¹

Table 1. *Patsari Stove Costs (US dollars)^a*

Costs	Per stove	Monthly ^b
<i>Variable inputs</i>		
Materials (sand, brick, mortar, <i>comales</i> , chimney, etc.)	50	4,000
Labor	25	2,023
Gasoline and incidentals: for stove assembly within 100 km of Pátzcuaro (when technicians work in towns further afield, GIRA must also pay for the cost of room and board, which adds to the unit cost)	23	1,818
Follow-up visits (labor and transportation)	5	182
Sub-total	103	8023
<i>Operating costs</i>		
Marketing and Promotion ^c	4	327
Team supervisor, 50% FTE	4	318
Sub-total	8	645
<i>Administrative costs</i>		
Salaries	9	727
Office overhead (book-keeping, rent and electricity) ^d	12	949
Office supplies	1	91
Sub-total	22	1,767
Total	\$133	\$10,435

^a Costs are approximate and assume an exchange rate of 11 Pesos per \$US 1. Discrepancies in totals are due to rounding errors.

^b Monthly data assume 20 working days/month, each technician constructs two stoves per day, with help from an assistant. Construction of one stove includes two follow-up visits by the technician. Thus, the maximum number of stoves per technician, including follow-up, is ~27 stoves/month. Working full-time, GIRA's three technicians would construct 80 stoves per month.

^c This only includes transportation costs and assumes that all marketing is done by GIRA staff. The staff would need to devote about 12 person-days of work to promotional activities to generate 80 stove orders.

^d Currently each division within the GIRA organization contributes 10% of income to cover overhead, this assumes income approximates the production cost (not including overhead) of \$118 per stove.

the world, which offers security for workers who find employment, but also creates a barrier for new businesses.

This does not mean that market-based strategies to reduce indoor air pollution (IAP) cannot succeed, but it does mean that they are likely to take longer, require more external funding, and require specialized local knowledge to negotiate bureaucratic hurdles, locally specific legal and accounting rules, as well as culturally contextual norms of business behavior (Lee & Peterson, 2000; World Bank, 2007). In the following section, we use GIRA's experience to explore this in detail.

4. LOCAL ACTION: THE PATSARI STOVE PROJECT

In 2003, GIRA and CIEco started a 3-year project, "to facilitate the transition of poor households and small enterprises from the central Mexican highlands to a cleaner and more sustainable pattern of energy use" (Masera, Diaz *et al.*, 2005, p. 28). The Patsari Stove Project was supported by the Shell

Foundation in collaboration with the Institute of Engineering at UNAM, and several government agencies.¹⁰ To develop the initial stove design, GIRA and CIEco relied on user participation, as well as laboratory testing and field validation, resulting in a family of stoves that are well suited to local cooking practices, burn less wood, and reduce IAP (in this case, respirable particulate matter and carbon monoxide). The stoves, called "Patsari," meaning "to take care" in the Purhépecha language, reduce both fuel consumption and IAP by over 60% relative to traditional cookstoves (Bailis *et al.*, 2007; Masera *et al.*, 2007).

There are two types of traditional stove or *fogon* that GIRA aims to replace: an open 3-stone fire and a U-shaped hearth. GIRA's stoves also compete with other improved woodstoves as well as gas and electric stoves. However, Patsari adopters do not always relinquish other technologies. Many use the Patsari for tasks that require a hot surface for a long time, like tortilla-making, and rely on a *fogon* for periodic cooking tasks that require heavy pots like *nixtamal* (corn cooked into a loose

Table 2. *Ease of doing business in the US, China, India, Nigeria, Mexico, and the US^a*

Business indicator ^b	USA	China	India	Nigeria	Mexico
Starting a business	3	128	88	118	61
Getting credit	7	101	65	83	65
Enforcing contracts	6	63	173	66	87
Closing a business	16	75	133	72	25
Overall business rank	3	93	134	108	43
Corruption index ^c	7.3	3.3	3.3	2.2	3.3

^a Shaded cells indicate below-median rankings among the countries included in each database.

^b Starting a business, getting credit, enforcing contracts, closing a business, and overall business rank are based on absolute national rankings from 1 to 175 with lower scores indicating better performance (World Bank, 2007).

^c The corruption index is based on surveys of national and international business professionals in each country. Scores are 1 and 10 with lower scores indicating higher levels of corruption (Transparency International, 2006).

slurry, dried, and then ground into tortilla flour). More affluent households use gas stoves, which are especially useful for quick cooking tasks like boiling water.¹¹

The *Patsari* is built *in situ*. GIRA's technicians use a standardized mold to ensure consistent construction of critical components like the combustion chamber and the channels that direct flames to the cooking surfaces (round metal or clay fixtures called *comales*). Production and delivery costs present a challenge. The costs of a typical stove installation are shown in Table 1, but can vary as a result of fluctuations in the price of materials as well as price differences between locations. In addition, the table omits the costs of R&D and monitoring and evaluation, which have proven to be critical to the success of the program.

Most stoves have been partially subsidized with funds from a variety of sources and 600 stoves were installed free of charge in order to gain participants' cooperation in stove efficiency studies (Bailis *et al.*, 2007; Masera, Diaz *et al.*, 2005; Mesara *et al.*, 2007). Stoves have also been offered on credit, usually priced between US \$30 and \$40 per unit. As Table 1 shows, US \$30–\$40 only covers about 25% of unit costs, which total roughly \$133 per unit. Most of the target population is unable to cover the unit cost; even at the subsidized rate of US \$30–\$40 per unit, some customers who bought on credit defaulted on their payments.¹²

Materials are the largest component of GIRA's expenses, requiring an outlay of roughly \$50 per stove. Transport costs are also substantial; technicians use a pickup truck to bring sand, mortar, bricks, wood framing, and metal *comales* to the customer's house. Materials are purchased from suppliers in the local area and volumes are too small to allow much negotiating power. The availability of the materials is also a persistent problem.

Among potential stove users, fuel savings and air quality are of modest concerns. For example, in a survey of traditional *fogon* users in three Purhépecha communities, roughly 40% of respondents expressed concern about the health impacts of smoke and an equal percentage expressed concern that smoke dirties their cooking utensils (Troncoso, Castillo, Masera, & Merino, 2007). The same study surveyed improved stove adopters and found only half cited fuel savings as an important factor in their decision to adopt the new stove. Many respondents considered the esthetics of the stove important. In addition, several noted a valuable co-benefit of improved indoor air quality: family members spend more time in the kitchen (Troncoso *et al.*, 2007). From the cooks' perspective, not all the benefits of improved air quality are related to health.

In-home surveys show that the *Patsari* uses less fuel. On average, families reduced consumption by 67%: about three and a half tons of wood annually (Berrueta *et al.*, 2008).¹³ In 2006, the price of fuelwood was roughly \$US 6 for a 60 kg *carga* or donkey load. Thus, households buying wood save roughly \$300/year on fuel and enjoy a simple payback period of just three to five months depending on the price paid for the stove. However, the stoves do not suit everyone. Some users complain that the *Patsari*'s cooking surface is not sturdy enough to support the large pots used to cook foods like *nixtamal* and that the stove contributes little to space heating in the chilly mountain climate. The small firebox, a key feature in reducing fuel use, requires extra effort to chop wood into small pieces, which some users have complained about. Some have also noted that it is difficult to light while others have noted that it requires more maintenance than other stoves (Troncoso *et al.*, 2007).

Marketing is a critical component of stove dissemination, but marketing costs present a barrier. In rural areas of Mex-

ico, many types of goods are marketed directly. Vendors drive trucks through a community making sales pitches *via* loud-speaker. They may also set up stands in local markets. Radio and television advertising is possible, but it is costly and may not be effective for rural communities. GIRA avoids direct marketing and focuses on communities in which they already have a presence or where a collaborating government program provides an entry point. GIRA offers workshops where communities are informed of health risks associated with wood smoke and other benefits of fuel-efficient stoves such as fuel savings and cleaner kitchens. In donor-supported models of stove delivery, the cost of getting the message across may be absorbed by the donor. In a purely commercial model, it is an expense that must be recovered in order to remain in business.

Additional challenges arise once the message about health and other benefits of the stove is delivered. Families concerned about their health risk may be unable to pay for a stove, which can equal three weeks salary among poor households. Surveys in the Purhépecha region show *Patsari* adopters are significantly better off than non-adopters (Troncoso *et al.*, 2007). In purely donor-driven models, discrepancies between willingness and ability to pay can be addressed by subsidizing stoves. Micro-credit, offered by GIRA or through a third party banking facility, could provide an alternative to direct subsidies and facilitate increased cost recovery.

Technical interventions in public health require monitoring to assure effectiveness. As is discussed above, under donor-driven models of stove dissemination, demands for accountability of NGOs have become more pronounced in the recent years (Beloe *et al.*, 2003; Nalinakumari & MacLean, 2005). Thorough monitoring is needed to show that stove adoption is having its intended impacts and to identify factors that reduce program effectiveness, but it can be costly and technically demanding. GIRA's technicians conduct up to three post-installation visits to help customers with difficulties they encounter (Troncoso *et al.*, 2007). GIRA found that this follow-up increases long-term adoption rates from 50% to 85%. One risk of shifting to a commercial model of stove dissemination is that rigorous follow-up and monitoring for effectiveness will be neglected, particularly if the costs of those activities must be passed on to the consumer.

By the end of 2007, roughly 8,000 stoves were installed in 13 regions of Mexico (~3,000 in Michoacán). However, this is a small fraction of the population exposed to poor indoor air quality. In addition, not all aspects of the project have been successful. Attempts to establish stove-building enterprises within rural communities did not succeed because the volume of demand in rural villages was not sufficient to keep local, independent entrepreneurs financially afloat. Thus, GIRA is now considering a centralized commercialization strategy, in which stoves would be manufactured and distributed from a central location. However, current stove designs, which rely on custom installations with cement or brick, are not compatible with long-distance transport. Consequently, a new round of design is required.

The project is at a critical stage. In four years GIRA has reached less than 1% of the 5.5 million Mexican households cooking with wood. Families contribute 25–30% of the stove's full cost; to date, donor funding has covered the balance of their costs while research grants paid for R&D and rigorous monitoring. With this support, GIRA gained insights into how to deliver health-improving socially appropriate technologies to poor consumers. However, GIRA is now under pressure to wean itself from support. The stoves, which improve air quality and reduce fuel consumption, are too expensive

for their neediest constituents and not amenable to mass production. Thus, under a delivery model that had been based on grants with only partial cost recovery from stove adopters, GIRA developed a stove that turned out to be the most appropriate under the circumstances in which they are operated. These circumstances were characterized by cost and material constraints as well as specific cooking needs and cultural preferences among end users, but this led to a design that is not amenable to scale-up.¹⁴

GIRA is not alone in facing these barriers. Hoping to have an impact commensurate with the scale of the problem, funding organizations are urging other improved stove developers to commercialize their operations. However, as we have outlined here, commercialization presents numerous challenges for NGOs that have been reliant on donor support – particularly those who target poor families most at risk from illness associated with solid fuel use (Gakidou *et al.*, 2007).

(a) *International experience with improved stove commercialization and scale-up*

In spite of the risks involved in shifting from a donor-based model of service delivery to a commercial one, there are examples of programs that have successfully combined donor and/or government support with commercialization. Experiences in China and Kenya provide some insight into the strengths of this approach.¹⁵ China's massive National Improved Stove Program (NISP) initially combined a strong government-backed effort with some profit-oriented components and gradually evolved into fully commercial operations (Sinton *et al.*, 2004; Smith *et al.*, 1993). NISP stretched from the early 1980s until the late 1990s in three distinct phases¹⁶; each of which involved a shift toward increasing commercialization (Sinton *et al.*, 2004; Smith *et al.*, 1993):

Phase 1 (1983–1990): Counties received funding to promote improved stoves. The central government supplied a small fraction and county governments provided additional funds, but consumers paid the largest fraction of the stoves' costs. NISP was not designed to target the poor, but some counties subsidized stoves to households that could not afford the full cost.

Phase 2 (1990–1995): Consumer subsidies were rapidly scaled back in favor of a commercialization strategy. Businesses were assisted with tax breaks and favorable loans.

Phase 3 (1995–2002): State support shifted to technical advice. However, the state continued to set standards and offer certification to ensure consumer confidence in new designs. State standards include product labeling analogous to the USEPA's "EnergyStar" label.¹⁷

Over 20 years of activity, NISP created a strong infrastructure consisting of private enterprises, R&D facilities, and state agencies that are equipped to develop and market improved solid fuel stoves throughout many of China's rural areas. However, if support is not sustained over such long periods of time, results are likely to be much more modest. For example, in Africa there have been dozens of improved stove programs since the 1980s, but few have seen sustained support over long periods of time and there are few success stories to discuss. One qualified exception is the Kenya Ceramic Jiko (KCJ), which has reached over two million households in Kenya and has had its design replicated across the region.

Originally funded by USAID in the early 1980s, the KCJ was designed in partnership with local and outside technical experts. During design and early testing, there was also significant input from aid groups and local women's organizations (Hyman, 1987; Kammen, 1995). After finalizing the design, the project focused on enterprise development by training

skilled artisans already working within Kenya's thriving informal sector. After four years of sustained funding equivalent to over half a million current (2006) US dollars, KCJ components were being produced by 15 major enterprises and over 100 independent artisans. Critically, the program received a second injection of funding, equivalent to an additional half million (2006) US dollars, from a US-based NGO (Hyman, 1986). The second round of funding was meant to provide "training, technical assistance and loans covering 75% of the capital costs of establishing production of the improved stoves in up to 20 existing Jiko production units throughout the country," as well as "public education, a marketing program and a quality control certification process" (Hyman, 1986, p. 151).

The KCJ is now widely available across Kenya and its distinctive hourglass design has been replicated in markets across sub-Saharan Africa. By 2001, over 2 million Kenyan households (roughly 40% of charcoal users) were using a KJC (Ministry of Energy, 2002). However, this degree of saturation took nearly two decades to achieve and was initiated by eight years of sustained funding equivalent to over a million dollars in current terms. Several additional circumstances contributed to the KCJ's success. For example, the initial program worked with the existing networks of urban artisans who already possessed many of the requisite technical skills. In addition, the stove, which initially retailed for the equivalent of \$US 4–5, was sold through the existing markets.¹⁸ Finally, the technology itself is distinct from woodburning stoves. The KCJ burns charcoal, primarily an urban fuel, and urban consumers are accustomed to paying for both fuel and stoves. These circumstances contrast with the prevailing conditions in most rural areas where households rely on wood, construct their own stoves from local materials and frequently gather their own fuel. Market linkages, though present, are less developed and the ability to pay for new technologies is lower.

Thus, while the experiences of China and Kenya demonstrate that it is possible to attain large-scale improved stove dissemination by shifting from donor-supported models of improved stove dissemination to commercial models, those transitions occurred for specific types of technologies and under particular conditions that may not exist elsewhere. They certainly do not prevail in the regions of Mexico where GIRA operates. Moreover, in both China and Kenya, the transition was gradual, with substantial support—from the state in China's case and from outside donors in Kenya's case—extending over seven or eight years.

Programs in both China and Kenya went through an extended phase during which elements of both donor-reliance and commercialization co-existed. In China's case, state support still plays a role in stove dissemination. The state still funds permanently staffed provincial and county-level offices that provide technical advice and services such as stove inspection and certification (Sinton *et al.*, 2004). In contrast, Kenya has no certification programs for artisanal stoves and the KCJ has been plagued by quality control problems since its inception.¹⁹ Moreover, although both countries now have thriving improved stove industries, they continue to receive support for stove-related activities. For example, from 2004 to 2006, the Shell Foundation provided ~\$US 400,000 to stove programs in China and \$US 750,000 to Kenyan programs (Shell Foundation, various years).

5. DISCUSSION AND CONCLUSIONS

The experiences in China and Kenya show that direct state or donor support was central to the commercialization

process. It played an important role in the early design and development phases for nascent stove enterprises. However, funding was maintained beyond the initial establishment of those enterprises and evolved as programmatic needs changed. This is where current commercialization approaches are straying from practices that were successful in the past. The evolution of funding for fledgling social enterprises from direct to indirect support is a critical issue that deserves further attention from funders as well as applied researchers. To date, successful scale-up has been both limited and contextually distinct, making it difficult to draw generalizable conclusions. We use the cases discussed above to identify five areas in which support by donor or state-funded action can be crucial to the success of stove interventions: research and development (R&D), marketing, financing, monitoring and evaluation (M&E), and quality control.

(a) *R&D*

The private sector generally underinvests in research and development (Jones & Williams, 1998; Nemet & Kammen, 2007). The nature of technical innovation as a public good creates disincentives for investment. These disincentives are magnified in developing countries where patent enforcement is weak or non-existent and purchasing power among target consumers is low (Trouiller *et al.*, 2002). In developed economies, the state often invests in R&D, especially to spur innovation in sectors characterized by public goods such as health, energy, and national defense. Although a private good, the impacts of improved stove adoption extend well into the public sphere because of links between household energy, health, and environmental issues (WHO, 2006). Thus, there is justification for state-funded R&D, or donor support when state funds are lacking. Such support can be channeled through the stove developers themselves, as well as universities or state-run research agencies. Even with subsidized R&D, competition among stove developers can still be encouraged. For example, the Shell Foundation recently funded a stove design competition among engineering firms in China (Spautz, Charron, Dunaway, Fangzhou, & Xiaofu, 2006).

(b) *Marketing*

At the retail level, consumer goods are typically promoted by the firm that sells them or by a marketing agency that the firm hires. The costs of marketing are passed on to the consumer so that the firm still profits from the sale in spite of marketing costs. For organizations hoping to promote behavioral change or the adoption of a socially beneficial technology, the costs of effectively communicating a message about the benefits can be a difficult barrier to overcome.

In addressing other public health challenges, practitioners have relied on social marketing, in which state or donor support raises awareness about a problem and suggests that goods be purchased (e.g., stoves, condoms, or bednets) with the goal of changing behaviors so that impacts associated with the problem are reduced. To utilize social marketing, funds may be directed to an ad agency or a specialized social marketing firm. Subsidized marketing of improved stoves could be compatible with commercialization. For example, state or donor support could be channeled to social marketers, who raise awareness of the health risks of wood smoke and the means to reduce risk without endorsing a particular product, while individual stove developers could market their own product based on its unique attributes.

(c) *Financing*

For GIRA, one of the biggest barriers to operating without donor support is customers' inability to pay the full costs of the stove. Credit-based sales can remove this barrier, particularly among households that purchase wood, who are accustomed to periodic expenditures to meet the family's energy needs. A simple analysis shows that in GIRA's case, with financing, households would experience immediate monthly savings, for stoves financed over periods as short as six months.²⁰ However, microfinance is not easy to establish. GIRA's attempts at credit-based sales have led to defaults and additional costs for the organization. Relying on experienced microfinance lenders with the capacity to assess and diversify credit risk could remove the burden from GIRA and other stove developers. However, traditional microfinance institutions usually lend for income-earning assets rather than consumer goods. They may balk at loans for stoves even if it is very likely to yield immediate savings for borrowers. Donor support could facilitate credit by providing loan guarantees to micro-lenders.

(d) *Monitoring and evaluation*

One factor contributing to GIRA's effectiveness is the rigorous monitoring they have deployed in order to demonstrate the Patsari's effectiveness. Monitoring is difficult for NGOs, particularly in the case of public health outcomes, which require sophisticated equipment and rigorous protocols to accurately quantify (Smith *et al.*, 2007). Improved stove interventions have a poor history of field assessment, even for relatively basic outcomes such as adoption rates or fuel savings. Some past evaluations have used laboratory-based tests to make broad generalizations about real-world impacts, with potentially misleading results (Bailis *et al.*, 2007; Kishore & Ramana, 2002; Sinton *et al.*, 2004). Yet field assessments are costly. GIRA has done rigorous monitoring because of close relationships with academic institutions and cooperation with government agencies. This has enabled the organization, with support from its own funders, to access research grants that would not typically be available to grass-roots NGOs. Under a purely commercial model of stove delivery, thorough monitoring would likely be prohibitively expensive.

(e) *Quality Assurance and Quality Control (QA/QC)*

The final aspect of improved stove dissemination that deserves consideration for donor or state support is quality control, including the development of objective standards and certification. A common assumption is that the private sector operates more efficiently than donor-dependent NGOs as a result of competition, or the threat of it. However, competition can also create incentives for firms to make questionable claims about product benefits. Firms may also cut corners in order to gain an advantage over competitors. Similarly, unintentional design flaws arising from lack of technical capacity or faults in the production process can lead to lower quality products. Where markets function well, this type of producer would soon be out of business, although some consumers would suffer. The larger challenge comes when markets do not function well. For health-improving technologies, the stakes extend beyond simple monetary loss: poorly functioning stoves can put a person's health at serious risk. State- or donor-funded QA/QC can reduce the risk consumers face from poorly designed products. Support could take a variety of forms including mandatory or voluntary standards for

stove design, performance, and emissions. Indirect support could be linked to social marketing efforts such as informing consumers about what to look for in well-designed stoves.

(f) *Closing thoughts*

This paper explores some of the challenges facing organizations that promote improved cookstoves as a means of reducing exposure to harmful emissions from solid fuel combustion among primarily rural consumers. These organizations have historically relied on donor funding and are now under pressure to operate in a more business-like manner. This shift, initiated by the donor community, is supposed to bring greater efficiency and accountability, with the ultimate goal of expanding to a scale equivalent to the magnitude of the problem. However, we have demonstrated that extended state and/or donor support has played a vital role in the success of past interventions and question the idea that it be reduced or removed.

Without disputing the notion that business-like approaches have the potential to bring creativity and innovation to the development and dissemination of improved stoves, we caution that the drive for commercialization carries risks for stove producers and their potential beneficiaries that appear to be downplayed by the proponents of commercialization. Examples of successful transitions to commercialization show that external support was present for many years in various forms beyond simple direct subsidies to consumers: these include basic R&D, technical advising, entrepreneurial training, and quality assurance. In China, state support persists and in Kenya, where there is no state support for the KCJ, a moderate quality control effort could correct problems that persist 25 years after the stove's introduction.

In Mexico, GIRA has relied on a mix of donor and state support as well as partnerships with academic research institutions. NGOs like GIRA face numerous obstacles in the transition to commercial operations. We described barriers facing new businesses in the countries where exposure to biomass emissions takes the greatest toll on human health. Establishing viable businesses in these contexts, regardless of the

businesses' profit-seeking motives, will take time. Nascent businesses may need an extended period of nurturing similar in nature to the support that NGOs have relied on to operate in the traditional donor-supported model.

However, in addition to the challenging business environment, other structural factors create hurdles that need to be overcome. The failure of biomass-reliant households to prioritize improved stoves calls for social marketing to convey the message that stoves are a worthwhile investment that carries numerous benefits: one of which is cleaner indoor air. Also, understanding that direct subsidies are not part of the *social business* model, low purchasing power among the majority of rural biomass users requires financing to spread costs over an acceptable period of time.

At a more fundamental level, strict adherence to the ideology that donors should behave as investors rather than charities when attempting to reduce the health risks faced by the world's poorest creates a fundamental tension between neo-liberal discourse and global health. It is easy to argue that anti-malarial drugs and TB treatments should be subsidized, if not distributed freely to the world's poor. However, though the toll on global health resulting from exposure to wood smoke is similar in magnitude to malaria and TB, the dissemination of low-emission stoves is more challenging than disseminating medication or bednets. Improved stoves blur the line between health-improving technology and household consumer goods. They are distinct from other health interventions because of their fundamental link to consumption and food culture. We argue that while there is space for stove developers to commercialize, they should not be expected to do it too quickly. Nor should they do it without substantial effort from either the state or donors to create a conducive commercial environment in which they can survive. Further, the factors that determine a "correct" pace of commercialization and define what constitutes a "conducive business environment" must be recognized as contextual and dynamic. Finally, insofar as public finances and donor funding continue to subsidize health care in developing regions, it would be a mistake to completely withdraw subsidies from interventions to fight one of the world's top killers of children under five.

NOTES

1. This is based solely on three disease outcomes and is likely an underestimate (see Smith, Mehta, & Maeusezahl-Feuz, 2004 for details about how this estimation was made).

2. For an overview of organizations active in stove development and their project activities (see Sparknet, 2009).

3. GIRA is the acronym of the group's name in Spanish: the *Grupo Interdisciplinario de Tecnología Rural Apropiable*. CIEco is an acronym for the *Centro de Investigaciones en Ecosistemas*.

4. The WHO estimates the return on investment in stove dissemination on a massive scale would be roughly 60:1. This is based on the assumption that providing half the world's biomass users with improved stoves costs \$2.3 billion/year and yields the following annual benefits over a 10-year period: \$37 billion in fuel savings, US\$32 million in direct health care savings, US\$88 billion in time saved in cooking and collecting fuel, US\$14 billion in avoiding illness and death, and 2.3 billion in avoiding environmental damage (Hutton et al., 2006).

5. DALYs are a composite measure of a population's departure from optimal health, calculated by weighting illnesses by severity and adding the

aggregate population's time spent on suffering from all illnesses to the total years lost to premature death (Murray & Lopez, 1996).

6. A *social enterprise* provides goods or services, but, in contrast to traditional businesses, it has a socially oriented mission that may coexist with, or replace, the profit motive. *Social entrepreneurship* is related in that social entrepreneurs act through *social enterprise*. The term implies that actors deploy certain principles in their organization: a degree of innovation, efficient use of resources, and "a heightened sense of accountability to the constituencies served and for the outcomes created." (Dees, 1998, p. 4). *Social marketing* relates to activities rather than entities: a social entrepreneur uses social marketing to promote the goals of the social enterprise. The use of marketing to promote social goals was first introduced in the 1950s (Wiebe, 1951), but did not attract much attention until the 70s (Kotler & Zaltman, 1971).

7. There is a broad literature on the social-environmental effects of the neo-liberal shift. See, for example Bryant and Bailey (1997), Harvey (2005), McCarthy and Prudham (2004), Mohan, Brown, Milward, and Zack-Williams (2000) and Peet and Watts (1993).

8. Based on data from 1998 to 2003, a time of relative prosperity in the US (Perline, Axtell, & Teitelbaum, 2006).

9. In this case, a “typical” business is represented by a commercial or industrial firm with up to 50 employees and start-up capital of 10 times the nation’s *per capita* gross national income (World Bank, 2007).
10. Government partners include the National Forest Commission (*Comisión Nacional Forestal* or CONAFOR), the National Commission for Prevention of Health Risks (*Comisión Federal para la Protección contra Riesgos Sanitarios* or COFEPRIS), and the National Institute of Ecology (*Instituto Nacional de Ecología* or INE).
11. Notably, field measurements showed that gas consumption decreased significantly among households using both wood and cooking gas upon adoption of the Patsari (Berrueta et al., 2008).
12. At the start of the project, GIRA offered credit to some users in order to boost demand. Some defaulted on their payments and the cost of repeated visits to the community exceeded the value of the outstanding loans.
13. Consumption was measured in a random sample of 14 households: 10 using only wood and 4 using wood + LPG. Daily visits were conducted for one week while using the traditional stove and then for a second week while using the Patsari (see Bailis et al., 2007). With the Patsari, daily wood use was reduced by 10 ± 4 kg (mean \pm standard deviation) in wood-only households and 4.7 ± 3.1 kg/day in households using LPG and wood together.
14. We thank an anonymous reviewer for pointing out this result.
15. In addition to China and Kenya, India hosted a large-scale program that ran from the mid 1980s until 2002 (Greenglass & Smith, 2006). Over two decades, the National Program on Improved Chulhas (NPIC) disseminated ~ 30 million stoves (Hanbar & Karve, 2002). However, NPIC is not included in this discussion because the program itself is largely thought of as a failure (Greenglass & Smith, 2006; Sinha, 2002). It relied almost entirely on subsidies and failed to commercialize in an appreciable way. Moreover, few data were collected concerning actual adoption rates, so the impacts of the program are speculative (Kishore & Ramana, 2002; Sinha, 2002). Still, NPIC yielded lessons for the current generation of stove developers and India now hosts a substantial amount of donor-supported activity (Greenglass & Smith, 2006; Shell Foundation., various years).
16. Smith et al. (1993) note that NISP began in 1983, but there were state-sponsored activities at least five years prior to that, an important factor when considering the dissemination rate that was eventually achieved.
17. EnergyStar is a popular government-sponsored program promoting energy-efficient appliances in the US.
18. The retail price of an average-sized KCJ in Nairobi has remained roughly constant in real terms since the 1980s. It originally sold for 65–85 Kenyan Shillings (KSH) when the shilling was valued at 16 KSH = 1 \$US. In 2005, KCJs in Nairobi sold for 350–450 KSH and the shilling was valued at about 75 KSH = 1 \$US.
19. Quality control was noted as a problem in the mid-1980s (Hyman, 1987). Recent evidence indicates that the problem persists (Ministry of Energy., 2002). Kenya’s Bureau of Standards considered creating standards for charcoal stoves, but has yet to take any action. In addition, there is little capacity to enforce regulations.
20. Financing the \$133 stove over six months at 20% annual interest requires monthly payments of \sim \$24 for a total expenditure of \$144. Average household wood use is 16 kg/day, which costs \sim \$44/month. If the household reduces fuel use by 67%, which is the average reduction measured in field testing (Bailis et al., 2007), then monthly fuel costs would decrease to \$14/month. This results in a net outlay of \$38/month for *fuel and stove payments*. Thus, financing enables an immediate savings of \$6/month, which increases to \$30/month after six months when the stove is paid off. These savings are robust across a range of interest rates and payback periods. Of course, the transaction costs of providing loans are not considered.
21. The WHO labels countries by region and mortality: sub-Saharan Africa (AFR), the Americas (AMR), the Eastern Mediterranean (EMR—including the Middle East and North Africa), Europe (EUR), SE Asia (SEAR), and the Western Pacific region (WPR). Regions are further divided by health status denoted by letters A–E, signifying relative levels of child and adult mortality: A = very low child and adult mortality, B = low child and adult mortality, C = low child but high adult mortality, D = high child and adult mortality, and E = high child and very high adult mortality (WHO, 2007).

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