Duke NICHOLAS INSTITUTE FOR ENVIRONMENTAL POLICY SOLUTIONS

Duke JAMES E. ROGERS ENERGY ACCESS PROJECT

Policy Brief
July 2022

The Role of Taxes and Subsidies in the Clean Cooking Transition: A Review of Relevant Theoretical and Empirical Insights

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Citation
Das, Ipsita, Marc Jeuland, and Victoria Plutshack. *The Role of Taxes and Subsidies in the Clean Cooking Transition: A Review of Relevant Theoretical and Empirical Insights*. NI PB 22-17. Durham, NC: Duke University. https://energyaccess.duke.edu/publication/taxes-and-subsidies-pol-brief/.

Acknowledgments
We thank the Clean Cooking Alliance for funding the project that led to this policy brief and its accompanying report.

Publication Number: NI PB 22-17

Summary

United Nations Sustainable Development Goal (SDG) 7.1 sets a target of ensuring universal access to affordable, reliable, and modern energy services by 2030. Unfortunately, many low- and middle-income countries (LMICs) are well off course to meet this target, especially with respect to access to clean cooking energy.

Though many challenges impede progress toward use of modern and sustainable energy for cooking purposes, cost barriers are perhaps most significant. Against this backdrop, this brief discusses the role of subsidy and tax policies—levied on both the supply and demand side of this market—in affecting progress toward universal access to clean cooking in LMICs. Moreover, we aim to combat a common myth among those opposing subsidies for clean cooking: we show that a "fear of spoiling the market" with such incentives finds little empirical support in the literature. Based on theory and evidence discussed in additional detail, this brief offers recommendations to policy makers.

EXECUTIVE SUMMARY

United Nations Sustainable Development Goal (SDG) 7.1 sets a target of ensuring universal access to affordable, reliable, and modern energy services by 2030. Unfortunately, many low- and middle-income countries (LMICs) are well off course to meet this target, especially with respect to access to clean cooking energy.

Though many challenges impede progress toward use of modern and sustainable energy for cooking purposes, cost barriers are perhaps most significant. Against this backdrop, this brief discusses the role of subsidy and tax policies—levied on both the supply and demand side of this market—in affecting progress toward universal access to clean cooking in LMICs.[1] Moreover, we aim to combat a common myth among those opposing subsidies for clean cooking: we show that a “fear of spoiling the market” with such incentives finds little empirical support in the literature.

Based on theory and evidence discussed in additional detail in this brief, our recommendations are the following:

(1) **Deploy more aggressive subsidies for clean cooking solutions across LMIC contexts.** Empirical evidence from various LMIC experiences shows that demand for clean cooking is typically price-sensitive, especially among lower-income populations who are not currently using such solutions. This implies that relatively large subsidies are needed to achieve socially efficient levels of clean cooking and to make these solutions affordable, especially for the rural poor.[2]

(2) **Remove taxes and other levies on these solutions.** Taxes on clean cooking solutions harm progress toward achieving SDG 7 because they raise such technologies’ prices and therefore discourage price-sensitive consumers from adopting clean technologies in the first place or push households just beginning to transition back toward polluting technology. These impacts are especially large for low-income consumers.

(3) **Enhance targeting of subsidies and financing solutions to low-income households.** Many energy and clean fuel subsidies as currently designed and implemented primarily benefit urban and wealthy consumers, who are furthest along the clean energy transition and least require these incentives. Enhanced targeting therefore increases the efficiency of subsidization, while also reducing the public sector burden of subsidy supports.

(4) **Adopt a more holistic and coordinated perspective on subsidies and taxes for various types of clean cooking solutions, based on local constraints and realities.** The relative value of subsidizing specific solutions will vary across settings according to local technology constraints and realities, as well as socioeconomic and cultural factors: urban versus rural, country A versus country B, grid versus off-grid, etc. For example, support for electric cooking may be especially beneficial where power is reliable and produced from renewable sources, whereas gas subsidies may be more appropriate in urban locations with unreliable power. Energy-efficient biomass stoves, meanwhile, may be most appropriate to subsidize in settings where clean fuels are expensive or difficult to supply.

[1] A more detailed companion report is forthcoming.

[2] The socially efficient level of clean cooking is where the economic net benefits to society from clean cooking are maximized. We discuss this concept and relevant considerations from tax theory later in this brief.

(5) **Supplement subsidies with complementary adoption-enhancing interventions.** Evidence from interventions in cooking and other sectors suggests that subsidies alone are often insufficient to achieve rapid and full transitions to improved technology. Among other aspects, it is critical to

- relax poor households' tight liquidity constraints via financing or pay-as-you-go instruments,
- improve fuel distribution networks (for liquefied petroleum gas [LPG] and electricity) and strengthen supply chains for stove delivery,
- leverage the knowledge and trust of local implementers, and
- invest in raising awareness of the several benefits of clean cooking.

(6) **Draw on the many lessons from implementation of subsidies in related sectors, especially where service coverage has expanded with more success.** While progress toward achieving cooking energy transition goals has been unsteady at best, interventions to promote other health-improving technology—most notably vaccines, bed nets, and sanitation—have achieved more success and offer many lessons and insights that can help accelerate universal clean cooking.

MOTIVATION

As of 2019, 2.6 billion people, or nearly one-third of the global population, still relied on dangerous or polluting energy technologies and fuels for cooking. Moreover, population growth over the 2010–2018 period essentially offset the modest (approximately 1 percentage point per year) gains in access to clean cooking fuels and technologies (IEA et al. 2021). Without more aggressive policies to accelerate adoption of improved cooking technology, a vast majority of the global population, and particularly the rural poor, will remain in cooking energy poverty, bearing heavy time and health burdens of reliance on inefficient technology, and contributing to environmental and climate harms on their local communities and the global commons. Myriad challenges related to lack of stove and fuel affordability, promotion of inappropriate and inconvenient technology, weak and underdeveloped supply chains, and ineffective or counterproductive policy action impede progress today.

This brief focuses on policies related to stove and fuel prices, which affect the affordability of improved cooking technology. Many governments today intervene in the market for fuels and cooking technologies with subsidies and/or taxes. A number of countries (e.g., Indonesia, India, Ecuador, Peru) have sought to accelerate household cooking transitions by subsidizing LPG, and have seen considerable success in shifting household energy use toward this cleaner fuel. Other countries have offered tax exemptions to the sector. Still others have taken a less consistent approach, and experienced setbacks (e.g., Ghana and Kenya). Figure 1 provides a summary of several prominent experiences whose success has also been assessed in research studies, as summarized.

In what follows, we describe major considerations from tax theory that relate to improved cooking technologies and fuels and review relevant real-world experiences with pricing policy instruments and their impacts on cooking transitions. We also discuss similar technologies or goods in other sectors. We then focus on what is known about the distributional consequences of such policies, and especially how well they target lower-income households. Finally, we discuss practical difficulties and common fears policy makers or donors have about taxes and subsidies in the sector, and close with recommendations for policy action.

Figure 1. Summary of main impacts estimated or predicted from national-level cooking fuel policies

Cooking fuel subsidy interventions

Ecuador
LPG subsidy
from the **1970s**

Trend over time: Share of primary LPG users ↑ from 87% (2000) to 92% (2018) (WHO 2018)

Published correlational analysis of LPG subsidy:
- In rural areas, nearly 89% of LPG-using households primarily use LPG, but >75% use wood fuel weekly
- Of the 17% rural households owning electric induction stoves, only 1% are primary users (Gould et al. 2018)

India
LPG "PMUY" subsidy
from **2016**

Trend over time: Share of primary LPG users ↑ from 22% (2000) to 47% (2018) (WHO 2018)

Published causal impact analysis of LPG subsidy:
- Probability of purchase of an LPG cylinder after PMUY: ↑ 3.3-3.6 ppts
- Use of LPG: PMUY households (below poverty line) consume ↓ 7.4 kgs LPG per year than non-PMUY households (above poverty line) (Gill-Wiehl et al. 2020)

Indonesia
LPG subsidy
from **2007**

Trend over time: Share of primary LPG users ↑ from 5% (2000) to 79% (2018) (WHO 2018)

Published causal impact analysis of LPG subsidy:
- LPG subsidy ↑ the number of households using LPG by 36 ppts (Imelda 2020)

Cooking fuel tax increases or subsidy rollbacks

Ghana
LPG subsidy from
1990, then removed
in **2013**

Trend over time: Share of primary LPG users ↑ from 6% (2000) to 19% (2013) and 26% (2018) (WHO 2018)

Published causal impact analysis of subsidy removal:
- Net price ↑: 50% for LPG; 20% for diesel
- Rural: Firewood use for cooking ↑ by 2-3 ppts
- Urban: Substitute charcoal for LPG, ↑ charcoal use by 10-15 ppts (Greve and Lay 2022)

Indonesia
Kerosene subsidy
removed in **2007**

Trend over time: Share of primary kerosene users ↓ from 42% (2000) to 2% (2018) (WHO 2018)

Published causal analysis of kerosene subsidy removal:
- LPG subsidy program ↓ the number of households using kerosene by 35 ppts (Imelda 2020)

Kenya
LPG/ICS VAT exempt
from **2016**,
exemption removed
in **2020**

Trend over time: Share of primary LPG users ↑ from 1% (2000) to 9% in (2018) (WHO 2018)

Published model-based analysis of VAT exemption removal:
- Share of households using traditional cooking technology ↑ by 1-2 ppts
- Net economic losses (889 million USD) nearly double the gain in VAT revenue (457 million USD) (Jeuland et al. 2021)

Source: Gill-Wiehl et al. 2020.
Abbreviations: LPG: liquefied petroleum gas, PMUY: Pradhan Mantri Ujjwala Yojana, ppts: percentage points, ppts: percentage points, and ICS: improved cookstoves.

GENERAL THEORY AND EVIDENCE ON SUBSIDIZATION OF STOVES AND FUELS

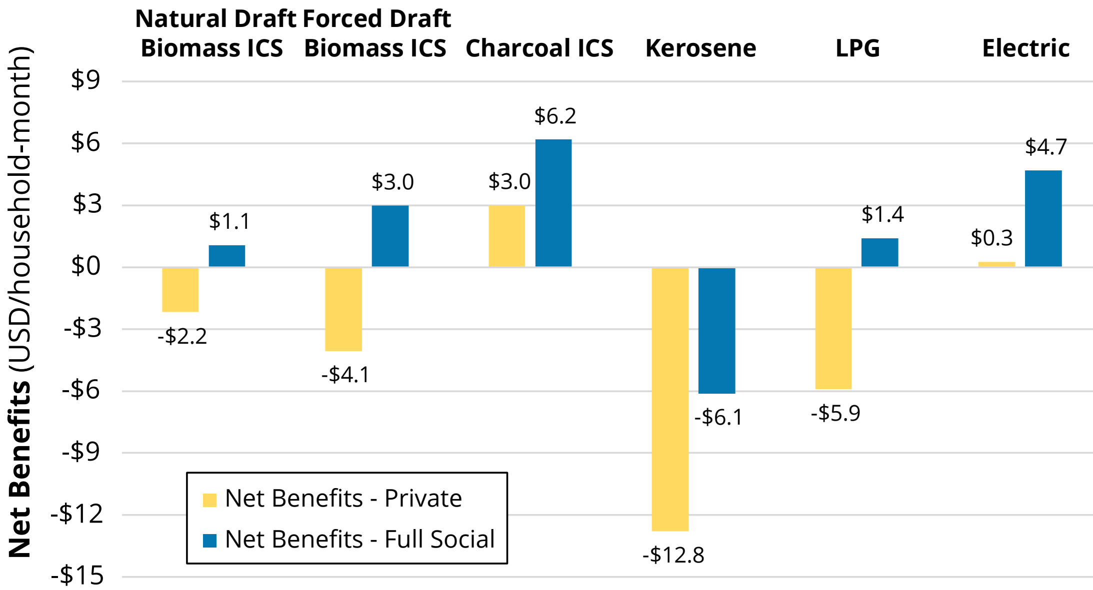
There are two main arguments for price interventions aimed at altering households' use of improved efficiency cooking stoves and clean fuels: The first is based on enhanced economic efficiency and internalizing ***externalities***,[3] and the second on the need to overcome the significant affordability challenges that reduce willingness to pay for clean solutions, especially among the poor.

Tax theory principles suggest that economic efficiency would be enhanced by making the use of polluting traditional stoves and fuels more expensive by using a tax. This is because traditional cooking generates substantial ***negative externalities*** for society, in the form of health and environmental harm. Unfortunately, most such technologies are not purchased but rather collected (as for firewood) or constructed with households' own labor (as for traditional stoves). Even when traditional technologies are purchased in markets, those transactions tend to occur in the informal, untaxed sector of the economy. Thus, taxes that raise prices are impractical.

Given this, a second-best option is to subsidize efficient stoves and fuels. Households will respond to the resulting price reductions with greater adoption and use of these improved options, which in turn generate positive externalities. Indeed, taxes and duties on improved and clean cooking technologies, whether locally-produced or imported, are doubly damaging, because they shift an already inefficient market—where there is too little adoption of improved technology—to even greater levels of inefficiency.

[3] Externalities are impacts that are not directly felt by consumers of the polluting cooking services, and in this setting come in the form of negative health (illness and mortality related to respiratory and cardiovascular illnesses, among others) and environmental (local deforestation, regional air quality degradation, and global climate forcing) spillovers.

Figure 2. Private and social net benefits of household transitions from traditional firewood to various improved cookstoves (ICS) and commercial fuels in USD/household-month, with base case ("average") parameter assumptions



Source: Jeuland et al. 2018.
Note: The charcoal ICS transition is slightly different as it shows a shift from traditional charcoal cooking.

Economic modeling has established that these externalities and inefficiencies are typically quite large, depending on the nature of the technologies involved (Jeuland et al. 2018).[4] Figure 2 presents a comparison of typical levels of private (excluding externalities) versus social (including externalities) costs and benefits for a common set of technology transitions. While social net benefits are positive for all transitions except traditional firewood to kerosene, private benefits are generally negative or near zero because of the high costs of cleaner technologies. Thus, externalities are responsible for substantial deviations from socially efficient clean cooking technology use, and private individuals will adopt and use too few of these solutions. Subsidies facilitate internalizing the large positive externalities of technology adoption. Indeed, subsidies are efficiency-improving for a broad range of similar technologies: mosquito control or bed nets to avert malaria (Brown and Kramer 2018), water treatment and sanitation (Ashraf et al. 2013; Blum et al. 2014; Guiteras et al. 2015), vaccines (Cook et al. 2009), and many others.

A key reason why households in LMICs adopt too few improved cooking technologies is that their demand is generally ***price elastic***, especially among lower-income and rural households.[5] Such price sensitivity leads to particularly large inefficiencies because private rates of adoption are so far from the socially optimal level. In considering the results shown in Figure 2, this is not surprising; households may not privately benefit from taking up clean technologies, owing to the high costs of the required stoves and fuels.

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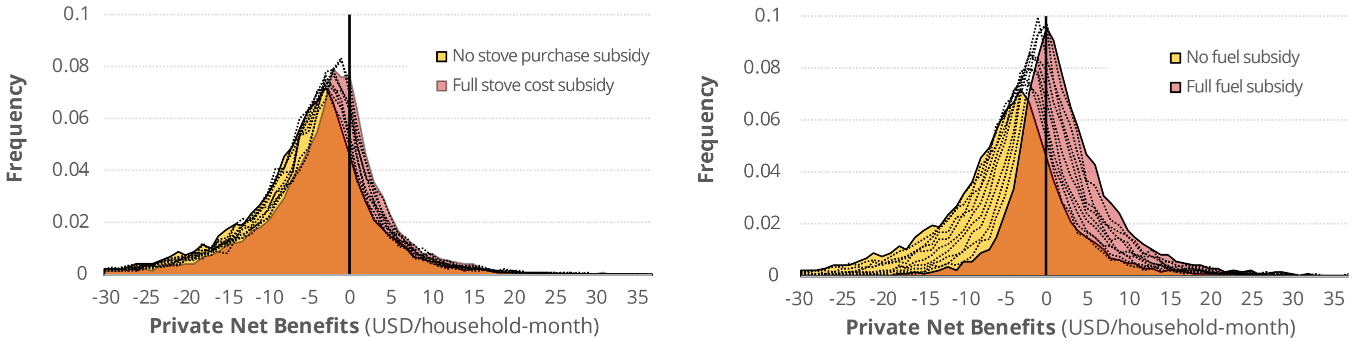
[4] This is because such fuels burn so much more efficiently than biomass. Biomass burning generates climate-forcing emissions of black carbon and other pollutants, and biomass harvesting is not fully sustainable in most countries, such that it contributes to forest degradation and net CO_2 emissions.
[5] The price elasticity of demand for a good is a measure of the responsiveness of quantity demanded by consumers to changes in the price of that good. Elastic demand is a term used when the percent change in quantity is greater than the percent change in price, while inelastic demand indicates the opposite. Supply of a good can similarly be price inelastic or price elastic.

Figure 3. Private net benefits of household transition from traditional firewood to LPG as a function of stove (left panel) and fuel (right panel) subsidies, in USD/household-month



Source: Jeuland et al. 2018.
Note: Results are for simulations with plausible "developing country" assumptions. Thin lines refer to the family of distributions generated by increasing the subsidy fraction by 10% at a time, up to 100%.

LMIC households are price sensitive for many reasons: tight liquidity constraints (Bensch et al. 2015; Berkouwer and Dean 2019); fears about the appropriateness or durability of improved technology (Brown et al. 2013); low prioritization of health risk mitigation (Mobarak et al. 2012); and low bargaining power of women, who bear the highest cost of pollution (Simon et al. 2014; Krishnapriya 2016). Financing of stoves and risk-free trials therefore boost uptake (Beltramo et al. 2015; Levine et al. 2018). Notably, efficient cooking technology is not the only socially beneficial good for which demand is price elastic: a similar phenomenon is observed for water treatment, insecticide-treated bed nets, sanitation, vaccines, and health treatments (Lucas et al. 2007; Null et al. 2012; Bhattacharya et al. 2013; Guiteras et al. 2015; Garn et al. 2017).

The substantial price sensitivity of demand for clean cooking solutions also leads to the second rationale for price intervention, which is to improve affordability for the poor. Subsidies mechanically increase net private benefits for all household types and thus make adoption more likely (Figure 3). Importantly, even highly subsidized clean fuel transitions can lead to increased household energy expenses when, for example, alternative fuels are harvested free of charge (Martínez et al. 2017; Kar et al. 2020).

Fortunately, there is growing experience globally that sheds light on the impacts that subsidies can have for clean stove and fuel affordability and adoption. For example, experimental work has shown that the uptake of various improved cookstoves (ICS) is very responsive to price subsidies (Pattanayak et al. 2019). Long-term national-scale evidence comes from Indonesia's kerosene-to-LPG conversion program, which featured subsidization of LPG coordinated with a phasing out of kerosene subsidies, and effectively ended extreme cooking energy poverty (Andadari et al. 2014).[6] In rural Ecuador, in large part due to generous subsidies, 89% of households now rely on LPG as their primary cooking fuel (Gould et al. 2018).

At the same time, evidence also shows that "stacking" or simultaneous use of combinations of clean and polluting technology may continue even when subsidies are provided. For example, in Peru, Ecuador, Indonesia, Mexico, and India, all of which have subsidized LPG in different ways and to different degrees, households increasingly use LPG, but nonetheless continue to stack that fuel with biomass (Andadari et al. 2014; Gould et al. 2018; Pollard et al. 2018; Troncoso et al. 2019; Gill-Wiehl et al. 2020; Kar et al. 2020). Persistent affordability challenges are a key driver of stacking, but other reasons for this behavior include supply chain constraints of clean technology (Puzzolo et al. 2019), household preferences for traditional technologies (McCarron et al. 2020), and households' consideration of nonhealth outcomes.

[6] The "extreme energy poor" were defined as households spending more than 10% of their income on energy expenditures and whose useful energy consumption was below 580 kWh.

Evidence of the impacts of subsidies is complemented by that from subsidy removals and tax increases. Analysis from Ghana, for example, shows that the removal of fuel subsidies in 2013 led some households to slide away from LPG and back into use of polluting cooking options (Greve and Lay 2022). More recently, Jeuland et al. (2021) used primary data on fuel demand to show similar slowing of progress on clean cooking goals in Kenya, following the reimposition of a value-added tax on manufactured stoves and on LPG fuel.

Given this evidence, substantial and rapid reductions in the use of polluting fuels would likely require larger subsidies than are commonly used in the sector. The importance of supportive nonprice policy interventions should also not be ignored. Liquidity constraints, highlighted above, can be relaxed by improving financing options for durable goods and appliance acquisition (such as e-cooking technology), or using pay-as-you-go LPG (Beltramo et al. 2015; Usmani et al. 2017).[7] Many households suffer from lack of access due to deficiencies in fuel distribution networks (for LPG and electricity, including upgrading circuit breakers and replacing wiring to assist electric cooking [CCA 2021b]) or because they cannot access convenient stove and fuel deliveries; the latter requires supply chain strengthening interventions (Pollard et al. 2018, Pattanayak et al. 2019). Empowering women both as suppliers and as primary consumers of technology can also accelerate the adoption of modern energy services (Klege et al. 2021). Implementers' local experience in supply has been shown to be critical for boosting demand of various technologies, including: improved cookstoves (Usmani et al. 2018), agricultural productivity improvements (BenYishay and Mobarak 2019), latrines (Cameron et al. 2019), health products (Fischer et al. 2019), and more general development efforts (Vivalt 2020). Personal contact from health promoters, advertisements, group meetings, and other awareness-raising interventions have been found to be effective for sanitation (Hulland et al. 2015; Orgill-Meyer et al. 2019) and clean cooking promotion (CCA 2021a).

DISTRIBUTIONAL ASPECTS OF SUBSIDY PROGRAMS

Despite the positive impacts of subsidies on adoption of improved cooking technology, energy subsidies, particularly for clean fuels, tend to disproportionately benefit upper-income households (IMF 2013, Troncoso and da Silva 2017). The richest 20% of households in LMICs, for example, capture six times more in total fuel subsidies (43%) than the poorest 20% (who receive just 7%) (IMF 2013).

Similar patterns hold for many cooking subsidy programs. Research has found that those benefitting the most from LPG subsidies in Indonesia are medium- and high-income households (Andadari et al. 2014), and biogas subsidies (e.g., in China) that go to those with substantial livestock are often highly regressive (Zuzhang 2013). In India, though the current Pradhan Mantri Ujjwala Yojana (PMUY) program is designed to target the poor and uses information technology to directly transfer reimbursements to rural women's bank accounts (Mittal et al. 2017), the poorest and most marginalized households remain hard to reach (Tripathi et al. 2015). To be sure, low-income households are most likely to lack knowledge on the benefits of improved technology, tend to have greater distrust of the institutions delivering such interventions, and may find improved solutions unaffordable even when their prices are discounted.

In low-income countries, equity features prominently among the policy considerations concerning adoption of several other technologies. As with stove and fuel subsidies, targeting is typically overlooked in the electricity and water utilities sectors, where most subsidies are regressive despite widespread use of "lifeline tariffs." This is because many poor consumers are entirely left out, owing to their lack of connections to these types of services, or share meters that imply higher per-connection use (Klug et al. 2022; Komives et al. 2005; Jain 2006; Cardenas and Whittington 2019). Subsidies in some cases appear to

[7] Such instruments should be monitored and regulated, however, to prevent financing organizations from imposing usurious interest rates on the poor.

compromise the integrity of implementation, as seen in efforts to combine subsidy vouchers with bed net distribution in Ghana, Kenya, and Uganda (Dizon-Ross et al. 2017). In these locations, it was observed that a lower percentage of people, especially women, were aware of bed net distribution in areas around clinics offering vouchers, suggesting that subsidies crowded out marketing efforts by promoters.

To better reach the poor, subsidies must be better targeted and must be sufficiently generous to offset the higher cost of clean fuels or technology (Lambe 2015, Troncoso and da Silva 2017, Pollard et al. 2018, Kuehl et al. 2021). One approach, widely used for health products such as vaccines, bed nets, and water treatment technology, is to guarantee coverage via free distribution. While not particularly well-targeted to the poor, such a strategy is important when lack of knowledge of the benefits of new technology substantially impedes adoption (Bhattacharya et al. 2013). Free distribution could also be used to guarantee at least a minimal level of coverage and would perhaps be more appropriate for covering one-time costs, such as the purchase price of energy-efficient biomass cookstoves, than for clean fuels because of the high recurring costs of the latter. Alternatively, the targeting of subsidies to poor households could be enhanced using a variety of approaches applied successfully in other domains. These include: quota-based and volumetric targeting (i.e., linking subsidy amounts to consumption volume); categorical targeting (i.e., providing subsidies based on geographic area or observed characteristics [McRae and Wolak 2021]); means-testing based on income, assets, or consumption (Sharma 2019); and use of "ordeal" mechanisms such as requiring travel to specific locations to obtain discounts (Cohen et al. 2015; Dupas et al. 2016). An additional possibility is high-level promotion of voluntary "opting out" such as India's "Give It Up" campaign for LPG, which aimed to pressure wealthier urban households to forgo their subsidized connections. Comparative evaluations of different approaches to targeting are sorely needed to better understand their pros and cons in the context of clean cooking promotion.

REASONS WHY SUBSIDIES ARE NOT WIDELY USED

Despite the strong efficiency and affordability arguments in favor of clean cooking subsidies, and evidence that they help to spur cooking transitions, such interventions are still not widely implemented. Even worse, many governments levy duties on imported efficient stoves, tax commercial cooking fuel purchases or manufactured stoves, or otherwise increase their costs through administrative or licensing barriers.[8] Admittedly, governments in LMICs face tight budget constraints, and subsidy policies have long-term political ramifications that render their removal challenging, even once they have achieved their initial goals (Barnes et al. 1994; IMF 2013), as shown from experience with LPG subsidies in Ecuador (Figari and Gomez 2015). Such considerations highlight the importance of enhanced targeting of subsidies to the poor, discussed in the previous section, while helping households to graduate out of needing such support and leveraging local market distribution channels to mitigate public sector financial burdens (Simon et al. 2014).

LPG and electricity subsidy programs often face an additional concern: they appear to support fossil fuels, and therefore threaten to exacerbate global climate change. Research has shown, however, that use of these fuels for cooking is usually mitigation-enhancing, even for LPG, given the emissions implications of inefficient biomass burning (Jeuland et al. 2018).

Another oft-heard concern is that subsidies "spoil the market" for cleaner cooking technology and fuel. As conventionally stated, there are two somewhat distinct aspects of this argument. First, there is a claim that households will revert to their original behavior—and abandon improved technology—once subsidies are removed or phased out. This argument assumes that consumers' willingness to pay (WTP) will be irreparably reduced due to anchoring on subsidized (or free) provision (Barnes et al. 1994; Dupas

[8] We are not advocating removal of licenses and standards, but finding ways to avoid shifting these costs onto consumers and ICS manufacturers (and onto, for example, carbon finance or other public support) should be explored and promoted.

2014), but this assumption finds little support in the empirical literature. For cooking technology, for example, Bensch and Peters (2020) found that freely distributing ICS to spur initial adoption of an unknown technology—as is often essential—does not reduce WTP over the longer term. For bed nets and sanitation technology, WTP even increases because of positive learning about these technologies (Dupas 2014, Deutschmann 2021).[9] To be sure, when prices rise, there is always the possibility of reversion to prior polluting technology, which is, after all, cheaper. But this is not the same as saying that demand has been "spoiled." Rather, those making this argument appear to misunderstand that the beneficiaries whose adoption is enabled by free or low-cost provision would never have adopted the technology in the absence of discounts.

The second part of this argument concerns a supply-side effect that holds that subsidization of technology decreases incentives for market innovation. While such an effect is plausible since subsidies could disproportionately benefit incumbent, lower-quality technologies, there has been little empirical work to evaluate it. Moreover, donors and governments already routinely subsidize suppliers of ICS by investing heavily in training and equipment or offering results-based financing (World Bank 2014).[10] It is unclear why such instruments, which also disproportionately favor incumbents, would be immune from negative effects on innovation, in contrast to demand-side subsidies that target beneficiaries and maintain incentives for competition on product quality.

RECOMMENDATIONS

Given the theoretical explanation and empirical evidence on taxes and subsidies on clean cooking, we conclude this brief with the following recommendations:

(1) **Deploy more aggressive subsidies for clean cooking solutions across LMIC contexts to achieve greater adoption of these socially beneficial solutions and enhance economic efficiency and affordability.** There is substantial evidence that generous subsidies of these solutions consistently increase social net benefits relative to market provision, even after accounting for leakage.

(2) **Remove taxes and other levies on all clean and improved cooking solutions wherever access to modern cooking energy services remains well short of universal.** Such taxes produce relatively limited revenue, are extraordinarily inefficient, and greatly impede progress toward achieving SDG 7 and capturing its many social benefits.

(3) **Given that resources for subsidization are scarce, enhance targeting to low-income households who are most price-sensitive and most likely to rely on traditional technology.** Depending on the context, such targeting could be geographic, or based on means-testing and systems such as the LPG subsidy and Aadhaar (unique individual identifier) linking for below-poverty-line households in India. Other options include quota-based and volumetric targeting (i.e., determining subsidy access based on consumption volume), or even free provision for some basic level of cooking services.

(4) **Give more holistic consideration of the technologies and fuels that should benefit from subsidization, based on local constraints and realities.** The relative value of subsidizing specific solutions will vary across settings according to local technology constraints and

[9] Note that in the case of negative learning, beneficiaries of free or subsidized technology learn that it does not actually meet their needs, and their demand accordingly decreases (Fischer et al. 2019; Krishnapriya et al. 2021). This should not be interpreted as "spoiling demand;" rather, it is indicative that a technology is not meeting consumers' needs.

[10] See, for example, EnDev's program: https://endev.info/approach/.

realities, as well as socioeconomic and cultural factors: urban versus rural, country A versus country B, grid versus off-grid, etc. For example, supports for electric cooking may be especially beneficial where power is produced from renewable and reliable sources, whereas gas subsidies may be more appropriate in urban locations with unreliable power. Energy-efficient biomass stoves, meanwhile, may be most appropriate to subsidize in settings where clean fuels are expensive or difficult to supply.

(5) **Increase implementation of complementary adoption-enhancing interventions.** Evidence from interventions in cooking and other sectors suggests that subsidies alone are often insufficient to achieve rapid and full transition to improved technology. Moreover, subsidies can be challenging for budgetary or political reasons. Among other aspects, it is critical to deploy cost-effective interventions that

- relax poor households' tight liquidity constraints via financing or pay-as-you-go instruments,
- improve fuel distribution networks (for LPG and electricity) and strengthen supply chains for stove delivery,
- leverage the knowledge and trust of local implementers, and
- invest in raising awareness of the several benefits of clean cooking.

(6) **Draw on the many lessons from related sectors (e.g., electricity, health-improving goods, sanitation, water treatment) where service coverage for the poor has been successfully expanded.** Subsidies for many such goods have been shown to be efficiency-improving, particularly in the long-term, where learning and positive spillovers are important. Other sectors also offer insights on alternative methods for targeting: relevant strategies include guaranteed access (e.g., distributing locally accepted ICS free of charge), reducing costs with generous and well-targeted discounts to the poorest populations, and use of "ordeal" mechanisms to allocate benefits, rather than payment in cash, among others.

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