



Exposure to firewood: Consequences for health and labor force participation in Mexico

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ABSTRACT

Indoor air pollution (IAP) originating from firewood used as cooking fuel relates to respiratory problems and can generate economic losses. IAP is associated with 1.6 million deaths worldwide annually. We assess the mechanisms behind the cooking fuel choice – in particular, firewood or LPG –, if the exposure to IAP due to firewood usage causes respiratory problems, and if this has implications for the probability to participate in the labor market. A small economic-theoretical model is proposed in which an individual maximizes utility generated by the fuel choice, consumption, health status, and the time dedicated to health and leisure, under financial and time constraints. For an empirical test, we use the 2002 Mexican Family Life Survey (MxFLS), estimating a trivariate recursive probit model. Our study finds that the usage of firewood as the household's fuel for cooking results in an increased prevalence of respiratory problems among women (but not among men), probably related to the traditional duties in the household. In the labor participation decision, we find a negative impact of respiratory problems on participation; hence, especially for women we find a strong causal channel from exposure to IAP to health problems to a reduction of labor force participation. A possible policy to break the circle of negative effects could involve the provision of improved firewood or LPG stoves that provoke less pollution and therefore reduces the health risks.

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1. Introduction

Fuel is an important resource for household activities such as cooking and heating. In rural areas, especially in developing countries, households consume more solid biomass fuels (firewood, dung, charcoal, and crop residues) than in urban areas or in developed countries, where the use of liquefied petroleum gas (LPG) and electricity is much more common. Three billion people in the world use biomass fuel for cooking and heating, 90% of them in rural households located mainly in developing countries (Boy, Bruce, Smith, & Hernández, 2000; WHO, 2002; World Bank, 2011). In countries such as Bangladesh and India, 70% of the households use biomass fuel (Balakrishnan, Mehta, Kumar & Ramaswamy, 2004; Dasgupta, Huq, Khaliquzzaman, Pandey, & Wheeler, 2006a, 2006b; Pandey & Chaubal, 2011). The advantages

associated with consumption of LPG and electricity are their efficiency in cooking and the much lower levels of indoor air pollution (IAP) that are generated. However, implementation requires accessibility and infrastructure, and households must pay start-up costs like installation and the cost of a stove. In developing countries, especially in rural areas, the use of nearby firewood is more affordable.

Solid biomass fuels like firewood are inefficient means for generating energy compared with fuels such as LPG or electricity, which implies that a greater quantity must be used. Firewood is subject to incomplete combustion (Smith, Rogers, & Cowlin, 2005), which emits toxic carbon monoxide and particulates (WHO, 2006). Burning solid fuels produces extremely high levels of IAP, which is associated with health problems such as a cough, acute respiratory infections, and chronic obstructive pulmonary disease (COPD) (Smith et al., 2005; Duflo, Greenstone, & Hanna, 2008; Rahut, Behera, & Ali, 2016a; Lu, Chen, Hao, Wang, & Song, 2017), causing 1.6 million premature deaths annually (Junaid et al., 2018; WHO, 2002). Health problems from exposure to the contaminants from burning firewood may cause difficulties in carrying out activities such as studying, domestic tasks, and

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participation in the labor market, which in turn can generate economic losses, specifically lost wages and increased medical expenses. Respiratory and other health problems caused by IAP may raise the overall burden of disease among the population, which could in turn affect the performance of health systems by demanding increased economic resources and medical personnel.

In addition to the indirect economic impacts through health, the use of biomass fuels can also directly affect the time availability, particularly of women in rural areas of developing countries; the time required to collect firewood reduces their available time for activities such as paid labor outside the household, as is shown by [Burke and Dundas \(2015\)](#) for many countries. [Hanna and Oliva \(2015\)](#) found that exposure to pollution in Mexico City resulted in reductions in labor force participation, and [Zhang, Zhao, and Harris \(2009\)](#) found a negative effect of chronic disease on labor force participation in Australia. The relationship between the use of fuel and IAP means that it is important to understand the fuel choice in households. Two visions prevail in the literature, one seeking economic explanations of fuel choices ([Leach, 1992](#)), while the other focuses more on cultural practices and preferences ([Maser, Saatkamp, & Kammen, 2000](#)). As it is not possible to establish *ex ante* which model applies, it is important to analyze which factors determine household fuel choice.

Although there is an extensive literature regarding the determinants of fuel choice, the IAP associated with diseases and mortality, and the health problems associated with labor force participation, the literature does not integrate the mechanisms behind fuel choice, exposure to contaminants, the presence of health problems, and labor force participation, and therefore does not establish the kinds of causal relationships proposed by [Maddala \(1983\)](#), [Pearl \(2009, 2016\)](#), and [Imbens and Rubin \(2015\)](#). For instance, the literature dealing with health problems arising from exposure to pollution from solid biomass fuel addresses the issue by considering exposure as an exogenous variable ([Balakrishnan et al., 2004](#); [Dasgupta et al., 2006a, 2006b](#); [Naeher, Smith, Leaderer, Neufeld, & Mage, 2001](#); [Vanker et al., 2015](#); [Wang, Liu, & Li, 2016](#); [Zhang et al., 2017](#)). However, it is likely that there are factors, such as gender, ethnicity, and decisions regarding the allocation of roles and tasks within the household, for example in meal preparation, that imply that the exposure to such pollution is not random. [Pitt, Rosenzweig, & Hassan \(2005\)](#) studied the effect of IAP on the incidence of respiratory disease in Bangladeshi households, where the endogeneity of IAP exposure derives from the choice of which woman in the household is assigned to cook, based on the customs of Bangladeshi society. If health status is determined by the effects of exposure to firewood pollution, the estimation of the relationship between health and labor force participation should consider both endogenous relationships.

The purpose of this paper is to assess the mechanism that defines the type of fuel—firewood or LPG—that is used in Mexican households. It also seeks to determine whether exposure to IAP from firewood causes respiratory problems, and if such problems have implications for the probability of labor force participation. A theoretical economic model is proposed in which an individual maximizes utility generated by fuel choice, consumption goods, health status (determined by health inputs purchased in the market and time investment), and the time dedicated to health and leisure. Utility is maximized under financial and time constraints, which depend on the labor supply function, which in turn depends on the wage rate and health status. From the model, it can be derived that if a fuel is harmful to health, an individual will purchase less of it than non-harmful fuels. For the empirical estimation of the model we use the Mexican Family Life Survey (MxFLS), a nationally representative survey of the Mexican population. In particular, we estimate a trivariate recursive equation model with discrete variables that explain the household fuel

choice (firewood vs. LPG), the effect of fuel choice on the presence of respiratory problems, and the effects of fuel choice and respiratory problems on labor force participation.

The contributions of our paper are threefold. This is the first paper that proposes and estimates a holistic model jointly analyzing the determinants of fuel choice, the role of the latter in causing respiratory problems, and the effects of fuel choice and respiratory problems on labor force participation. Our recursive econometric framework, based on the theoretical model and identified through exclusion restrictions and non-linearity, permits a causal interpretation of these relationships. Moreover, our paper contributes to the scarce empirical literature on these issues in Mexico, a large developing country.

Mexico was chosen because, according to the 2010 population census, 4.1 million households in that country (15%) use biomass fuels (principally firewood), including about half of the households in rural areas. These households could be at risk of respiratory problems and economic losses. There are, however, no studies in Mexico that attempt to estimate the causal relationships between fuel choice, IAP, health problems, and labor force participation. [Margulis \(1992\)](#) analyzes pollution-related economic losses, but considers only the gross estimation of factors such as water pollution, soil erosion, and outdoor but not indoor air pollution. In their studies of the economic impact of health problems in Mexico, [Parker \(1999\)](#) and [van Gameren \(2008\)](#) report that poor health reduces hourly earnings and labor force participation among the elderly, but they do not link health problems and the attendant economic loss to the potential causes of poor health, such as fuel choice and IAP.

The remainder of this paper is structured as follows. Section 2 briefly reviews the literature on each aspect of the problem (fuel choice, health problems, and labor issues). In Section 3 an integrated theoretical model is developed, while Section 4 discusses the econometric strategy. The data are introduced in Section 5, and the estimation results are presented in Section 6. The main conclusions are discussed in Section 7.

2. Previous studies

For each of the outcomes analyzed in this paper there is an extensive literature. However, there is a lack of integration in this literature, a shortcoming we intend to overcome in this paper. We briefly describe the main findings in each of these three areas of previous study and the effects on labor force participation.

2.1. Fuel choice determinants

Households use fuels for basic activities such as cooking and heating, activities that are important for the general well-being of each household member ([Chen, Heerink, & van den Berg, 2006](#); [Heltberg, Channing, & Udaya, 2000](#)). Fuel is fundamental for a household; when households have problems in covering fuel requirements or when they spend more than 10 percent of their total expenditure on fuel, they are considered to be in “fuel poverty” ([Legendre & Ricci, 2015](#)).

Although the geographical context is important, it is within households that the fuel choice decision is made. Depending on the context, each family uses one or more fuels, including biomass fuels, like firewood, coal, charcoal, crop residues, and dried cattle dung, and “modern” fuels, like LPG, biogas, and electricity. One of the factors that determines which fuels are used is availability and accessibility ([Heltberg, 2005](#)). For instance, delivery of LPG requires highways, and it also requires a gas stove in the household. Firewood, on the other hand, does not require a special kitchen stove. In many countries biomass fuels are less expensive

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