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Using stated preference methods to design cost-effective subsidy programs to induce technology adoption: An application to a stove program in southern Chile

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ABSTRACT

We study the design of an economic incentive based program – a subsidy – to induce adoption of more efficient technology in a pollution reduction program in southern Chile. Stated preferences methods, contingent valuation (CV), and choice experiment (CE) are used to estimate the probability of adoption and the willingness to share the cost of a new technology by a household. The cost-effectiveness property of different subsidy schemes is explored numerically for different regulatory objectives. Our results suggest that households are willing to participate in voluntary programs and to contribute by paying a share of the cost of adopting more efficient technologies. We find that attributes of the existing and the new technology, beyond the price, are relevant determinant factors of the participation decision and payment. Limited access to credit markets for low income families can be a major barrier for an effective implementation of these types of programs. Variations in the design of the subsidy and on the regulator's objective and constraints can have significant impact on the level and the cost of reduction of aggregate emissions achieved.

1. Introduction

The problem of air pollution in urban areas caused by households burning wood is important in the developing world and also in some regions of developed countries (see, Lewis and Pattanayak, 2012; GACC, 2011; Pattanayak and Pfaff, 2009; WHO, 2009; World Bank, 2011). In the case of Chile, there are several cities located to the south of the capital city of Santiago, where air pollution -the main environmental problem – is caused by households' wood combustion to supply energy (see for example Kavouras et al., 2001; OCDE and CEPAL, 2005; Celis et al., 2004, 2006).

A representative case of urban pollution problems caused by households burning wood in central-southern Chile is the city of Temuco. In this city of about 350,000 inhabitants around 90% of total emissions of suspended particulate matter is caused by households burning wood. In one of the three monitoring stations in the city it was measured during the year 2012 a total of 92 days with a 24-h average concentration of suspended fine particulate matter ($PM_{2.5}$) exceeding the Chilean legal limit of 50 $\mu g/m^3$ (http://sinca.mma.gob.cl/). From the total 92 days exceeding the norm, 51 correspond to a 24-h average above 110 $\mu g/m^3$, and 22 above 170 $\mu g/m^3$. To put these figures in context, the Air Quality Guidelines of the World Health Organization (WHO) call for limiting the mean 24-h average concentration of $PM_{2.5}$ in urban areas to 25 $\mu g/m^3$ (WHO, 2005). Further information about the air pollution problem in Temuco can be found, for instance in Díaz-Robles et al. (2008), Sanhueza et al., (2009), Cereceda-Balic et al., (2012).

The air pollution problem caused by households burning wood in urban areas is also a major regulatory problem. There are two main aspects of the problem, which make it difficult to solve. First, although individual households' emissions are potentially observable, it is not practical considering that there are tens of thousands

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of discharge points in medium size cities. This is similar to the nonpoint source pollution problem (see for example, Shortle and Horan, 2001). Second, there are several sources of uncertainty related to the problem, including weather conditions, individual households preferences for heating, quality of the fuel used.

The regulatory agency in charge can follow different strategies for controlling the problem, like educational programs or proposal of new technical norm for households' wood combustion equipment. Potentially, the most effective tool is the use of economic incentives in order to induce a change in the behavior of the households concerning the quality of wood, and the technology of wood combustion. The use of economic incentives for pollution control has been widely explored in the context of point source pollution problems, where it is feasible to measure and monitor emissions. However, urban pollution caused by individual households is a different, and less explored, problem from the perspective of regulatory design.

A recent review of the literature by Lewis and Pattanayak (2012) shows that even when improved cook stoves have the potential of providing triple dividends (health, environmental quality and climate benefits) their adoption has been slow. The authors report 32 research studies with 11 analyses of improved stove adoptions in Asia, Africa and Latin America. They conclude that even when the use of stove replacement programs is expanding, the literature remain scarce, scattered and with a wide range of quality and therefore, new studies are required to help improving the implementation of stove replacement programs in the future.

In this paper we study, from an empirical perspective, the effect of an economic incentive based program – a subsidy – to induce adoption of a more efficient technology. We focus our analysis on the decision of individual household to participate in a voluntary program and on their willingness to share the cost of adopting the new technology. The data for our econometric calculation and simulations were collected with a survey in the city of Temuco. The area under study is a representative case of urban pollution problems caused by households burning wood in central-southern Chile. Furthermore, we explore, numerically, the cost-effectiveness property of different subsidy schemes under several possible regulatory objectives. Although our work focuses on the case of a stove exchange program, it could be applied to other problems, i.e. pollution caused by car emissions, energy efficiency, etc.

The subsidies we consider are intended to minimize aggregate emissions of suspended fine particulate matter (PM_{10}) or total cost of pollution control. Another option would be to consider an efficient subsidy as proposed by Chávez et al., 2011. This intervention would need households' specific combustion technology subsidies that internalize the external benefit and cost of the households' wood combustion technology choice. Our focus on subsidies that induce cost-effective pollution control instead of fully efficient intervention is motivated by the difficulties to measure the external benefits from individual households' choices on combustion technology. Moreover, in practical terms, a pollution control policy in an urban area may pursue, instead of economic efficiency, another objective, for example to maximize emissions reduction with a given fixed budget.

We use stated preferences methods -Contingent Valuation (CV) and Choice Experiments (CE)- to study the probability of adoption of a new technology of wood combustion by a household and the type of technology they would acquire. Most of environmental valuation studies using stated preferences have focused on cost-benefit analysis of environmental policies (see Bateman and Willis, 1999; Kanninen, 2007). Because these studies use stated preferences methods to evaluate the benefit (or cost) of a policy intervention, their main objective is an efficient and reliable estimation of the willingness to pay (WTP or willingness to accept, WTA) for a change in the environmental quality. Our goal in this paper is somewhat different because we are interested in using the stated preference techniques to design a subsidy program to provide proper incentives for adoption of new technologies of wood combustion. From that perspective we are not only interested in the WTP but also in the set of attributes of the technology and attributes of individuals that would affect the probability of adoption. Urban households differ in attributes and preferences (heterogeneous) and they may react differently to the same economic incentive (subsidy) and technological stimulus (attributes of a new technology). Identifying how households' characteristics and technology attributes affect their decisions, as for instance their propensity to participate in a program or the specific technology to be adopted, can contribute to the appropriate design of a subsidy program to achieve environmental goals and efficiency objectives.

The design of the subsidy program in our case involve not only the price of the new technology (and implicitly the subsidy), but also characteristics of different types of households. This information will allow us to simulate people's responses to the attributes design of the program and will inform policy makers about the optimal design according to different goals and restrictions. For instance, the government might be interested in finding a design to maximize the number of replacements given a limited budget, or to maximize the impact of the program on air pollution, each objective may have a different optimal design.

Different econometric techniques have been used for studying the effects and the determinants of adoption of programs oriented to replace stoves and substitute fuels, see for a systematic review Lewis and Pattanayak 2012. As pointed out in this review, the literature on adoption is scattered. In particular, we are not aware of any study that uses econometric results of stated preferences in order to explore the design of the subsidy structure and also to improve the cost-effectiveness of the subsidy program.

Our research efforts have produced four main results. The first result is that households are not only willing to participate in voluntary programs, but also to contribute by paying for more efficient technologies. This suggests that a cost-effective design of an incentive-based program should consider sharing the costs of acquisition of new technologies between the public and private households.

Our second result is that attributes of the existing and the new technology, beyond the price, are relevant determinant factors of the participation decision and payment. The third result is that the imperfection of credit markets that restrict access to credit for low income families can be a major barrier for effective implementation of these types of programs. A consequence of these results is that the design of a cost-effective program should consider, beyond the subsidy, at least two aspects: the heterogeneous preferences of families; and the need of access to credit for the poor.

The fourth result is that the specific design of the subsidy affects the individual decision to participate and contribute to the payment for more efficient technology. Variation in the design of the subsidy and on the objectives of the regulator can have significant impact on the level of reduction of aggregate emissions achieved. The numerical analysis also shed light on possible targeting strategies of subsidies on households' types, which greatly vary depending upon the regulatory objective.

The rest of the paper is organized as follows. In Section 2 we discuss an empirical model of participation in a voluntary stove program and estimate the determinant factors of individual participation as well as households' willingness to pay for the new technology. Section 3 contains the analysis of a cost-effective subsidy program for urban pollution control considering different regulatory objectives and alternative designs of the subsidy scheme. We conclude in Section 4.