Energy efficiency improvements and energy demand: Is the rebound effect different in a multi-person household?

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Résumé

Energy efficiency policies aim at reducing greenhouse gas emissions (GHG) by lowering the energy usage. However, the increase in demand for energy following an efficiency improvement, known as the rebound effect, partially reduce energy savings and the policy impact. Traditionally, researchers have approached the rebound effect by modeling household energy demand based in the standard household theory (unitary model). Nevertheless, recent literature suggests that the resource allocation process within the household may have an impact in the consumption decisions, an effect that traditional models fail to capture. In this paper, we enhance the traditional approach following the collective household theory, which allows us to address the distribution of income and the existence of public goods within the household. We model the demand for energy services having strong public elements (e.g. heating) and analyze how the intra-household negotiation process affects the demand for such services and the rebound effect. Our model suggests that the negotiation process can significantly impact the demand for energy services and, when ignored, it can lead to over or under-estimated rebound effects.

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1 Introduction

In their latest report, the IPCC (2018) have concluded that the Paris agreement's target, namely limit global warming to 1.5°C above pre-industrial levels, can only be achieved by halving Greenhouse Gas (GHG) emissions by 2030. The combustion of fossil energies is the main cause

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of GHG emissions and they grow proportionally (OECD, 2010). In light of these findings, energy systems have to be drastically transformed across all sectors such that energy conservation is at the center of operational strategy. A way to achieve energy saving is by improving energy efficiency, thus by providing the same level of energy services using lower energy inputs (IPCC, 2018).

Despite all the proved benefits, the impact of energy efficiency improvements and environmental taxation is limited by the rebound effect. When an energy system becomes more efficient, the real cost of unit energy service may fall. In such case, people would have incentives to consume more energy services, thus increasing the demand for energy. This increase in the demand for energy corresponds to the rebound effect, meaning that the effectiveness of the policy at reducing energy consumption and the associated GHG depends on magnitude of the rebound (SORRELL, DIMITROPOULOS, 2008 ; STERNER, 2012).

Usually, environmental policies aim to direct individual demand towards greener option by means of market mechanisms, such price signals (e.g. taxation). However, these market mechanisms do not take into account potential cognitive bias, inherent to human behavior, that may lead individuals to identify some other incentives and make choices regardless of environmental consequences (KRISTRÖM, 2008).

The literature on the rebound effect (e.g., A. GREENING, GREENE, DIFIGLIO, 2000 ; CHAN, GILLINGHAM, 2015 ; SORRELL, DIMITROPOULOS, 2008) explains how this phenomenon is an example of such behavior and underlines the importance of understanding the household decision process to better target policies aiming to reduce energy consumption, specially, given the magnitude of households' demand for energy. Indeed, in 2016, the residential sector[1] make up for a quarter of final energy consumption in the European Union (EU) and demand is expected to rise by 2040 (BISHOP, 2015). Furthermore, transports accounts for over 30% of energy use, with light-duty vehicles (i.e. households demand for fuel) consuming more energy that all modes of freight transportation combined (EIA, 2016).

Traditionally, researchers have approached the rebound effect by modeling household energy

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[1] Households : energy use for space and water heating, space cooling, cooking, lighting and electrical appliances and other end-uses, excluding transportation

demand based in the standard household theory. This approach in known as the unitary model. Two of the main underlying hypothesis of this model are that households act as a single decision-making unit, regardless of the number of household members, and that only total exogenous income explains household behavior (income pooling) (VERMEULEN, 2002).

Critics of this approach point out several unsatisfactory elements in this theory. First, one could argue that different members of the household have their own rational preference, not necessarily identical. However, according to Arrow's impossibility theorem, a group of individual not necessarily behave as a single one. Moreover, the income pooling hypothesis has been repeatedly rejected in empirical studies, suggesting that the way income is distributed among households members (after a negotiation process) can affect consumption decisions (For more details see DONNI, 2008 ; VERMEULEN, 2002).

Finally, even if there is no consensus regarding the size of the rebound effect, researchers agree on the fact that households heterogeneity plays an important role in the size of this effect. Indeed, households' energy consumption is closely related to socio-economic factors such as income level, expenditure pattern, average age or residential environment, since these characteristics determine the possibility for households of switching to more efficient technologies. Furthermore, lifestyle and particular needs (e.g. needs of children and elderly family members) can equally affect the energy consumption. Therefore, as different household profiles have different capabilities to adapt their consumption choices, a model that do not account for such heterogeneities would misspecify effects and, presumably, generate results with restricted validity.

In light of this findings, in this paper we follow an alternative to the unitary model, the collective household approach first presented by APPS, REES (1988), CHIAPPORI (1992) et CHIAPPORI (1988). We propose a new theoretical framework for the rebound effect. We enhance the traditional approach by integrating the key elements outlined in the collective household theory. This new framework allows us to address the distribution of income within the household. In that sens, it provides a theoretical background to account for within household heterogeneities and income distribution. Moreover, under this setting we can allow for the existence of public services within the household, such as heating, for which optimal demand results from a negotiation process among household members.

First, we use the general household production framework to characterize the demand for energy services. A given energy service is produced with a combination of energy and a certain technology of given efficiency level (Chan, Gillingham, 2015 ; Sorrell, Dimitropoulos, 2008). This part of the model accounts for technical aspects of energy-saving technologies. Furthermore, we add the collective dimension which lets us introduce a public energy service (e.g. heating) and characterize energy consumption decisions within the household. To the best of our knowledge, this theoretical model would be the first to assess the rebound effect from a collective household perspective and to include the public element.

The preliminary results of our model suggest that the intra-household decision process can define the size and direction (positive or negative) of the rebound effect. Therefore, by ignoring the intra-household dynamic, rebound effect estimates can be misleading, either under or over-estimating the effect. In particular, we find a direct rebound effect corresponding to the one that is identified in the current literature. In addition, we find a indirect rebound effect arising from the negotiation process. This indirect effect can be both positive or negative depending on the power distribution among household members. Meaning that depending on power distribution the direct rebound effect can be increased, compensated or even completely absorbed.

The structure of the paper is as follows. Section 2 presents the traditional theoretical approach for the rebound effect. Section 3 lays the basis for the new theoretical framework, based in the collective household theory. Section 4 presents a collective analysis of welfare and its implications. Finally, section 5 concludes and addresses future extensions.

2 Literature review

Since households access to energy services is a great determinant of final energy consumption, it is important to understand the decision-making process and how rebound effects originates. There are few theoretical works (e.g., Chan, Gillingham, 2015 ; Hunt, Ryan, 2015) addressing the microeconomics behind the rebound effect. To the best of our knowledge, none of these works include intra-household dynamic in the model.

The standard model for energy consumption characterizes the demand for energy services based in the household production framework. In this model, households derive their utility from consuming energy services, s^i, (rather than from consuming directly energy commodities) and a non-energy numeraire good[2] x. These services are produced with a combination of energy, e^j, and a certain technology of efficiency level η^{ij}. Thus, the amount of energy required for the production of service i by using energy j is given by e^{ij}. This model considers two energy services $i = 1, 2$ and two types of energy $j = 1, 2$. For simplicity, this model assumes a one-to-one correspondence between energy services and sources of energy, meaning that a given type of energy can only produce one energy service and viceversa. Finally, the price of the numeraire is set to 1 and p_i is the price of the energy i (Chan, Gillingham, 2015). The maximization program following this specification is defined as :

$$\begin{aligned} \max_{x,s^1,s^2} \quad & U(x, s^1, s^2) \qquad (1) \\ \text{subject to} \quad & s^1 = \eta^{11}\, e^{11} \\ & s^2 = \eta^{22}\, e^{22} \\ & w = x + p_1\, e^{11} + p_2\, e^{22} \end{aligned}$$

Considering the case where energy service 1 benefits from an energy efficiency improvement, the direct rebound effect is quantified as the efficiency elasticity of the demand for energy services : $\varepsilon_{s^1,\eta^{11}}$ (Sorrell, Dimitropoulos, 2008).

This standard household model, which follows the unitary approach, assumes a common set of fixed preferences among household members, hence the maximization of a single utility function constrained by a household budget. Under this framework, households act as a single decision-making unit, regardless of the number of household members, and only total exogenous income explains household behavior (income pooling). Furthermore, we cannot account for the public element in the consumption of energy services (such as heating) within the household (Donni, 2008 ; Vermeulen, 2002).

Take for instance the case of a private energy service s^1 under the conditions described in (1) (unitary approach). When a household member upgrade one of its energy devices, the same

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[2] Low requirements of energy input

amount of s^1 can be produced with less energy (more efficiently), hence making it cheaper. As usual in the rebound effect theory, we have substitution and income effects. Provided that s^1 have close substitutes within the household, this individual can substitute them with the new technology. In this case, we would have a direct rebound effect, because the demand for s^1 increases as a result of an efficiency improvement. Due to the income effect, this individual can also increase the demand for other goods, energy or non-energy intensives.

In the collective setting, the household program is subject to a unique household income, but it takes into account the distribution of that income among household members and, therefore, the weight of each persons' preferences in the decision-making process. In other words, the income effect can change the distribution of power among household members, either by balancing out or overcompensating their influence.

Assuming that we have only pure public energy goods in the household, the optimal allocation of a public good is when the sum of the marginal benefits equal the marginal cost of providing the public good. In other words, when the some of the willingness to pay (or lindahl price) equals the cost of the public good. In this case, an efficiency improvement will decrease the marginal cost of the public good which can in turn decrease the individual willingness to pay and the demand for the public energy good, once again, having an impact in the distribution of power.

Having this in mind, the mechanisms of the rebound effect is not straight forward in the collective household model. Which implies that the negotiation process within the household can significantly change the size and "direction" (positive or negative) of the rebound.

In the next section we lay the basis for the collective model for energy demand. We amplified the model in (1), including the collective household and the public good dimension presented by BLUNDELL, CHIAPPORI, MEGHIR (2005) et DONNI (2009).

Finally, based in this framework, we analysis the public consumption of energy services, the associated rebound effects and how the distribution power within the household affects the decisions of energy consumption and energy efficiency improvements.

3 A collective model for energy demand

3.1 General framework

In this section we develop the foundations of the model of energy demand based on the collective household model presented in (Blundell, Chiappori, Meghir, 2005). We consider a version of the collective model for a two-member ($i = 1, 2$) household, with household production and public goods. The notion of private (e.g. meals) and public (e.g. heating) good within the household follows the usual definition these goods and services. For simplicity, we exclude the possibility of impure goods, meaning that each good is either purely private or purely public.

Individuals derive their utility from the consumption of a composite non-energy numeraire x^i and a public energy service denoted as G. The public energy service is obtained from the combination of energy (E) and an energy conversion device of efficiency level η (Chan, Gillingham, 2015 ; Sorrell, Dimitropoulos, 2008).

The individual individual preferences of agent i are represented by a well-behaved utility function U, defined over the individual consumption of the non-energy numeraire x^i and the amount of public energy service G. We assume that our individuals are egoistic meaning that their utility function only depends on their own consumption. Further, the public service production function is given by (3). The maximization program is defined as :

$$U^i = U^i(x^i, G) \tag{2}$$

$$G = g(E, \eta) \tag{3}$$

The budget constraint of the household is defined as :

$$p(x^1 + x^2) + p_e E \leqslant Y \tag{4}$$

and

$$x^i \geqslant 0, \quad G \geqslant 0, \quad E \geqslant 0 \tag{5}$$

Where p and p_e, respectively, denote the price for the composite non-energy good and the price of fuel, E, and Y denotes the total expenditure[3].

The main assumption behind the collective models is that the negotiation process within the household results in Pareto-efficient outcomes and no additional assumption is made about the decision process (Donni, 2008). In other words, this means that there is a scalar ϕ such that the household behavior can be described as a solution to the program :

$$\max_{x^1,x^2,G} \quad H(x^1,x^2,G) = \phi_1 U^1(x^1,G) + \phi_2 U^2(x^2,G) \tag{6}$$

Subject to constrains in (4) and (5) (for $i = 1, 2$). The Pareto-weight, ϕ, represents the intrahousehold distribution of power. It is defined as a function of exogenous variables that may affect the power distribution, such as prices p, p_e, total expenditure y or distribution factor z.

By definition, a distribution factor is a variable that affects the distribution power (Pareto-weights ϕ) but no the individual preferences or the budget constraint (Browning, Chiappori, 1998). In this work, we argue that the efficiency of energy conversion devices acts as a distribution factor.

Take for instance two identical households. Each has two individuals with different preferences. If the only thing differentiating the households is the efficiency level of the public energy service (say heating), the Pareto-optimal solution of the respective household programs will be different. For any given level of efficiency, the public consumption will be different which would lead to a different Pareto-optimal outcome from the bargaining process. Furthermore, other distribution factors would be linked to behavioral aspects such as habits.

3.2 Conditional sharing rule and indirect utilities

The program (6) can be expressed as a two-stage process. First, individuals agree on public expenditures as well as the particular distribution of Y. Second, each member freely choose the level of consumption of the composite good, conditional on the level of public expenditures G.

Take $x_i^*(Y, z)$, $G^*(Y, z)$ and $E^*(Y, z)$ as the solution of the problem (6). The conditional sharing

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[3] Total income net on savings

rule is defined by δ_1 and δ_2, where :

$$\delta_i(Y,z) = px^{*i}(Y,z) \tag{7}$$

In other terms, δ_i represents the share of total expenditures allocated to i, after the purchase of the public good (hence, the conditioning). We can then re-write equation (4) as :

$$\delta_1 + \delta_2 = Y - p_e E \tag{8}$$

Thus, by taking $G = G^*(Y,z)$ as given, the functions $x_i^*(Y,z)$ solve the second-stage individual program :

$$\begin{aligned} &\max_{x^i} \quad U^i(x^i, G) \\ &\text{subject to} \quad px^i = \delta_i \end{aligned} \tag{9}$$

This means that each agent maximize their private consumption under the constraint that they cannot spend more than their share of residual total expenditures.

In addition, program (9) can be expressed in terms of the indirect utility (conditional on G) :

$$\begin{aligned} U^i(x^i, G) = &\min_{\delta_i} \quad V^i(\delta_i, G) \\ &\text{subject to} \quad px^i = \delta_i \end{aligned} \tag{10}$$

Notice that $V^i(\delta_i, G)$ depends only on i's preference and it does not directly change with a particular decision process, however, its argument δ_i does it.

3.3 Determining the optimal level of public good

Taking $x_i^*(Y,z)$ as the solution to the sub-problems (10) and using the individual indirect utilities, we are left then with the first stage of the two-stage problem, in which household members decide the optimal level of public service G and the underlying sharing rule δ_1 and δ_2.

$$\max_{x^1,x^2,G} \quad \phi V^1(\delta_1, G) + (1-\phi)V^2(\delta_2, G) \tag{11}$$
$$s.t. \quad Y = \delta_1 + \delta_2 + p_e E$$
$$G = g(E, \eta)$$

The fist order condition of this program gives us :

$$\phi\frac{\partial V^1}{\partial \delta_1} = (1-\phi)\frac{\partial V^2}{\partial \delta_2} = \lambda_3 \ , \quad \phi\frac{\partial V^1}{\partial G} + (1-\phi)\frac{\partial V^2}{\partial G} = \lambda_4 \quad \text{and} \quad \frac{\lambda_4}{\lambda_3} = \frac{p_e}{\partial g/\partial E} \tag{12}$$

Leading to the following Pareto-optimal condition for the public service :

$$\frac{\partial V^1/\partial G}{\partial V^1/\partial \delta_1} + \frac{\partial V^2/\partial G}{\partial V^2/\partial \delta_2} = \frac{p_e}{g_e} \tag{13}$$

The ratio $(\partial V^i/\partial G)/(\partial V^i/\partial \delta_i)$ corresponds to i's marginal willingness to pay (MWP^i) for the public good. Equation (13) implies that the implicit individual's MWP^i must add to the price of the public energy service, which is a function of the energy price p_e and of $g_e(E, \eta)$.

4 Collective Analysis of Welfare

Having the theoretical framework for collective household behavior, we can now analyze the welfare implications of energy efficiency policies, which can help us to understand energy consumption decisions within the household and issues such as the rebound effect.

First, we want to study how a change in efficiency can affect the power distribution ϕ within the household and the demand for the public good G. Then, we want to study how the change in the distribution power ϕ, following a efficiency improvement, affects the sharing rule δ_i and again the demand for the public good.

By using the implicit function theorem on the first order conditions (equations (12) and (13)), we can find the corresponding derivatives and then compute the final impact of an efficiency improvement on G and δ :

$$\left(\frac{\partial G}{\partial \eta} + \frac{\partial G}{\partial \phi}\frac{\partial \phi}{\partial \eta}\right) \tag{14}$$

$$\left(\frac{\partial \delta}{\partial \phi}\frac{\partial \phi}{\partial \eta}\right) \tag{15}$$

The first term in equation (14) corresponds to the direct rebound effect in the demand for the public energy service. This rebound will always be positive and is equivalent to the rebound effect that we traditionally find in the unitary approach. Additionally, we have an indirect effect rebound effect that depends entirely on the household dynamic and acts through the distribution power (second term in (14)). This effect have the same sign as $\partial\phi/\partial\eta$, therefore it may increase or decrease the direct rebound effect. We have three possible scenarios that would be discussed the next sections.

The impact in the share of income (equation (15)) would have the same sign as $\partial\phi/\partial\eta$. It would be negative if the marginal indirect utility of δ_1 is high (low income share). It looks like the efficiency improvement would benefit the individual having the biggest income share.

4.1 Direct welfare effect of an efficiency improvement

First of all, we define $\delta_1 = \delta$ and $\delta_2 = Y - \delta - p_e E$. Furthermore, we know that the function G is a function of (E, η). We assume that G is invertible in E, hence $E = f(G, \eta)$. Then, re-writing the first order conditions and equaling to zero, we have :

$$\phi\frac{\partial V^1(\delta, G)}{\partial G} + (1-\phi)\frac{\partial V^2\left(Y - \delta - p_e f(G,\eta), G\right)}{\partial G} - \phi\frac{\partial V^1(\delta, G)}{\partial \delta_1}\frac{p_e}{g_e} = 0 \tag{16}$$

$$MWP^1(\delta, G) + MWP^2\left(Y - \delta - p_e f(G,\eta), G\right) - \frac{p_e}{g_e} = 0 \tag{17}$$

Now, by using the implicit function theorem on equations (16) and (17), we can find how a change in efficiency can affect the power distribution within the household (ϕ) and the demand for the public good (G) :

$$\frac{\partial G}{\partial \eta} = \frac{\dfrac{\partial MWP^2}{\partial \delta_2}\dfrac{\partial f}{\partial \eta}p_e - \dfrac{\partial^2 g}{\partial \eta \partial E}\dfrac{p_e}{(g_e)^2}}{\left[\dfrac{\partial MWP^1}{\partial G} + \dfrac{\partial MWP^2}{\partial G} - \dfrac{\partial MWP^2}{\partial \delta_2}\dfrac{\partial f}{\partial G}p_e\right]} \tag{18}$$

$$\frac{\partial \phi}{\partial \eta} = -\frac{\left[\phi\left(\dfrac{\partial^2 V^1}{(\partial G)^2} - \dfrac{\partial^2 V^1}{\partial G \partial \delta_1}\dfrac{p_e}{g_e}\right) + (1-\phi)\left(\dfrac{\partial^2 V^2}{(\partial G)^2} - \dfrac{\partial^2 V^2}{\partial \delta_2 \partial G}\dfrac{\partial f}{\partial G}\,p_e\right)\right]}{\left[\dfrac{\partial V^1}{\partial G} - \dfrac{\partial V^2}{\partial G} - \dfrac{\partial V^1}{\partial \delta_1}\dfrac{p_e}{g_e}\right]}\frac{\partial G}{\partial \eta} + C \tag{19}$$

Where :

$$C = \frac{\left[\phi\dfrac{\partial V^1}{\partial \delta_1}\dfrac{\partial^2 g}{\partial \eta \partial E}\dfrac{p_e}{(g_e)^2} - (1-\phi)\dfrac{\partial^2 V^2}{\partial \delta_2 \partial G}\dfrac{\partial f}{\partial \eta}p_e\right]}{\left[\dfrac{\partial V^1}{\partial G} - \dfrac{\partial V^2}{\partial G} - \dfrac{\partial V^1}{\partial \delta_1}\dfrac{p_e}{g_e}\right]}$$

Let the individual preferences be such that ϕ and G are normal goods, meaning that the consumption of private and public good will increase with income. Hence, we have that $\partial V^1/\partial \delta_1$ and $\partial V^2/\partial \delta_2$ are positive. Additionally, $\partial MWP^i/\partial \phi_i$ is positive and $\partial MWP^i/\partial G$ is negative.

Notice that $g(E, \eta)$ being the production function of the public good, the marginal product of energy is positive ($g_e > 0$) and increasing in η ($g_{\eta e} > 0$). On the other hand, $f(G, \eta)$ is the "production function" of energy and its marginal product of efficiency,f_η, is negative whereas its marginal product of public good, f_G is positive.

Knowing that, we that both the numerator and the denominator in $\partial G/\partial \eta$ are negative. Hence an improvement in efficiency will always increase the consumption of public good, regardless the distribution power within the household.

As for $\partial \phi/\partial \eta$, it could be both positive or negative, meaning that either of the two household member can be favor by an efficiency improvement. The sign would be determined by the size of the marginal utility of the private good for individual 1. If this marginal utility is high, the power of individual 1 within the household, represent by ϕ, will decrease following a improvement in efficiency. A high marginal utility of the private is associated to a low consumption of that good, which in this case suggests a low share of income (δ) and power (ϕ). It would appear then, that the individual having the more power within the household would always benefit from efficiency improvements.

4.2 Indirect welfare effect of an efficiency improvement

The change in the distribution power ϕ following a efficiency improvement, can in turn, affect the sharing rule and again the demand for the public good. Therefore, we use again the implicit function theorem in order to compute $\dfrac{\partial G}{\partial \phi}$ and $\dfrac{\partial \delta}{\partial \phi}$ and we find :

$$\frac{\partial G}{\partial \phi} = -\frac{1}{D}\left[\frac{\partial MWP^1}{\partial \delta_1} - \frac{\partial MWP^2}{\partial \delta_2}\right]\left[\frac{\partial V^1}{\partial G} - \frac{\partial V^2}{\partial G} - \frac{\partial V^1}{\partial \delta_1}\frac{p_e}{g_e}\right] \tag{20}$$

$$\frac{\partial \delta}{\partial \phi} = \frac{1}{D}\left[\frac{\partial MWP^1}{\partial G} + \frac{\partial MWP^2}{\partial G} - \frac{\partial MWP^2}{\partial \delta_2}\frac{\partial f}{\partial G}p_e\right]\left[\frac{\partial V^1}{\partial G} - \frac{\partial V^2}{\partial G} - \frac{\partial V^1}{\partial \delta_1}\frac{p_e}{g_e}\right] \tag{21}$$

Where :

$$\begin{aligned} D = &\left[\frac{\partial MWP^1}{\partial \delta_1} - \frac{\partial MWP^2}{\partial \delta_2}\right]\left[\phi\left(\frac{\partial^2 V^1}{(\partial G)^2} + \frac{\partial^2 V^1}{\partial G \partial \delta_1}\frac{p_e}{g_e}\right) + (1-\phi)\left(\frac{\partial^2 V^2}{(\partial G)^2} - \frac{\partial^2 V^2}{\partial \delta_2 \partial G}\frac{\partial f}{\partial G}p_e\right)\right] - \\ &\left[\frac{\partial MWP^1}{\partial G} + \frac{\partial MWP^2}{\partial G} - \frac{\partial MWP^2}{\partial \delta_2}\frac{\partial f}{\partial G}p_e\right]\left[\phi\left(\frac{\partial^2 V^1}{\partial \delta_1 \partial G} + \frac{\partial^2 V^1}{(\partial \delta_1)^2}\frac{p_e}{g_e}\right) - (1-\phi)\frac{\partial^2 V^2}{\partial \delta_2 \partial G}\right] \end{aligned}$$

In this case, $\partial G/\partial \phi$ and $\partial \delta/\partial \phi$ have the same sing. They can be both positive or negative. However, following Blundell, Chiappori, Meghir (2005), we argue that an increase in the power ϕ would always have a positive impact on δ, therefore, a negative response would be contradictory.

4.3 Final welfare effect of an efficiency improvement

Recall, the final impact of an efficiency improvement on G and δ is given by :

$$\left(\frac{\partial G}{\partial \eta} + \frac{\partial G}{\partial \phi}\frac{\partial \phi}{\partial \eta}\right) \quad \text{and} \quad \left(\frac{\partial \delta}{\partial \phi}\frac{\partial \phi}{\partial \eta}\right)$$

The impact of an efficiency improvement on G gives insights about the rebound effect, whereas the impact on the share of income δ gives us further understanding in the power distribution.

We have three possible scenarios for the rebound effect (equation (14)). First, when both the direct and indirect rebound effects are positive. In this case the rebound effect would be greater than that of the unitary case. We would be in this scenario when the marginal indirect utility of the private good is low (high consumption of the private good). Meaning that, an additional unit of private good for individual 1 is less valuable (since its consumption is already high), increasing instead the consumption of the public service and the overall household welfare. Furthermore, (14) would be positive as well, meaning that the share of income of individual 1 would increase.

The other two scenarios arise when the two effects have opposite signs. This situation means that the gains from the efficiency are split for private and public consumption. This would be the case whenever the private consumption of the individual 1 is low and its marginal indirect utility exceeds the differential of the marginal utilities of the public service.

Our second scenario is when the direct effect dominates the indirect, thus having a positive but diminished rebound effect. It means that the increase in public consumption exceeds that of private consumption. The third scenario is when the indirect effect overrides the direct effect. In this case, the rebound effect would be negative, meaning that we would have superconservation. Nevertheless, it would benefit mostly the private consumption of individual having the most power in the household (2).

Finally, the impact in the share of income would have the same sign as $\partial\phi/\partial\eta$. It would be negative if the marginal indirect utility of δ_1 is high (low income share). Once again, it looks like the efficiency improvement would benefit the individual having the biggest income share.

5 Conclusions

According tho IPCC (2018), the internationally agreed target for limiting global warming to 1.5°C above pre-industrial levels, can only be achieved by drastically transforming energy systems across all sectors. Today, improvements in energy efficiency are being encouraged and implemented as way to achieve such energy savings. Despite all the proved benefits of these policies, their impact is limited by the increase in demand for energy following an efficiency improvement, known as the rebound effect, which partially reduce energy savings. It means that the effectiveness of the policy at reducing energy consumption and the associated GHG will depend on magnitude of the rebound.

Traditionally, researchers have approached the rebound effect by modeling household energy demand based in the standard household theory, know as the unitary approach. However, several studies has pointed out the limits of this approach, by saying that it fails to account for heterogeneities among household members and the influence of such differences on household energy consumption decisions. Alternatively, recent research has pay more attention to the collective model. The collective approach provides a theoretical background to account for within household heterogeneities and income distribution. Moreover, this setting allows for the existence of public services within the household, such as heating, for which optimal demand results from a negotiation process among household members.

In this paper, we propose a new theoretical framework for the rebound effect that enhances the traditional approach by integrating the key elements outlined in the collective household theory. Hence, accounting not only for technical aspects of energy-saving technologies but also for the decision-making process within the household. To the best of our knowledge, this theoretical model would be the first to assess the rebound effect from a collective household perspective and to include the public element.

The preliminary results of our model suggest that the intra-household decision process can define the size and direction (positive or negative) of the rebound effect. Therefore, by ignoring the intra-household dynamic, rebound effect estimates can be misleading, either under or over-estimating the effect, and the actual impact of efficiency policies cannot be accurately assessed.

In particular, we find a direct rebound effect corresponding to the one that is identified in the current literature and a indirect rebound effect arising from the decision-making process. We distinguish three possible scenarios, 1) when both the direct and indirect rebound effects are positive, the rebound effect would be greater than that of the unitary case. We would be in this scenario when the marginal indirect utility of the private good is low (high consumption of the private good), therefore the demand for the public good can potentially increase improving the overall household welfare. 2) when the two effects have opposite signs, but the direct effect dominates the indirect, thus having a positive but diminished rebound effect. It means that the increase in public consumption exceeds that of private consumption. 3) when the indirect effect overrides the direct effect. In this case, the rebound effect would be negative, meaning that we would have superconservation.

Further work includes microsimulation using a parametric version of our model. Furthermore, on the basis of Experimental Economics, we will design and implement a set of experiments in the lab.

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Références

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