Information transmission among unequal individuals within households

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Abstract

This paper uses a theoretical model to ask whether information campaigns promoting cleaner technologies are better directed at males or females within the household. The choice of information recipient is non-trivial if the interested party and the decision maker are distinct from each other. A trade-off is likely to exist because in most households, males make major financial decisions but females tend to be more receptive to the benefits of cleaner technologies because of their exposure to the outcomes. We formulate the question in the framework of Crawford and Sobel's (1982) model of strategic information transmission. The main finding of this paper is that the optimal targeting policy will depend on two critical factors: (a) whether the decision is binary or continuous (b) the degree to which male and female preferences diverge. In binary choice problems, targeting information campaigns at females is likely to induce cleaner choices only if conflict of interest within the household is small. This is not the case for continuous choice problems.

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1 Introduction

Subsidies have been in place for decades to promote immunisation programmes, building of toilets, institutional deliveries and the use of clean fuels and improved stoves, among other development initiatives. Yet, price incentives for clean technology may not be enough to change behaviour to the extent needed. In this paper, we consider the use of fuel technologies and the issue of household air pollution. According to the World Health Organisation, globally, around three billion individuals use solid fuels such as coal, charcoal, firewood and bio mass to cook food. More than 4 million premature deaths are attributed to household air pollution caused by the use of these fuels.[1]. While poverty and the price premium for clean energy surely play a role, there is also evidence of a substantial information deficit regarding the health risks associated with commonly used fuels (Miller and Mobarak, 2014) and the availability of alternatives. Therefore, information campaigns to create awareness about cleaner fuels and better ventilation technologies can have significant welfare effects, and should be part of a multi-pronged strategy to combat household air pollution. Governments and NGOs are increasingly focusing on educating the population about fuel and technological choices.

However, information campaigns face an important strategic dilemma arising from potential intra-household conflict of interest. Women are more exposed to household air pollution than men, especially when cooking is its main source.[2] Studies have also shown (Wardle et al., 2004) that women on average place greater weight than men on health and education than consumer goods. These factors imply that women are likely to be more responsive to information about health risks and demonstration of cleaner options like light emitting diode (LED) lamps, chimney-fitted stoves and LPG cylinders. From this perspective, information campaigns should perhaps be targeted at female household members to be most effective. Gender selective targeting has been an explicit strategy in other areas of development policy, such as micro lending and unconditional cash transfers (Yoong et al., 2012). However, a second aspect — gender inequality and power imbalance

[1] `http://www.who.int/mediacentre/factsheets/fs292/en/`

[2] Indirect evidence for this is found in Anderson and Ray (2010) , who show that the 'missing women' problem in India—too few women relative to men—is a cumulative one, i.e., women have relatively higher mortality not only at birth or early childhood but through the entire adult life span. One of the significant correlates of this differential mortality is cardio-vascular diseases, which affect women more than men (relative to the 'natural' incidence of such diseases for each gender). It is noteworthy that household air pollution is a leading cause of respiratory and cardio-vascular illnesses.

within the household—makes the issue of targeting non-trivial. In the typical family unit, the male household head has financial control, so the decision to purchase costlier fuels, or cooking and lighting equipment that cuts down pollution, requires his approval. It is not enough to persuade the women if they, in turn, fail to change their husbands' minds about fuel and equipment choices.

Information campaigns, then, face the dilemma of whether to direct their message at women, who may be more willing to change behaviour, or men, who control the finances. This paper will analyze the effects of gender based targeting of information provision theoretically.

The potential health benefits of a particular clean technology depends on the features of the technology as well as the household. For example, the benefits of using a cooking oven fitted with an exhaust chimney will depend on both the suction power of the chimney as well as whether most of the cooking is done indoors or outdoors; the benefits of using LED lamps for lighting will depend on the energy efficiency of the bulbs as well as what alternative lighting source the household is currently using. Once the target of the campaign is informed about the technology, he or she can estimate the health benefits the particular household stands to reap. Ex ante, however, the size of these benefits is a random variable from the provider's as well as the recipient's perspective. If the female receives the information, she can convey the magnitude of the benefit to the male decision maker in order to influence his choices. However, due to conflicting interests, there is an incentive to misrepresent the information (exaggerate the benefits), creating a credibility problem for the informed female. Crawford and Sobel (1982) show that such credibility constraints may lead to substantial coarsening of the information that is conveyed, weakening its impact on decisions. Providing information directly to the male decision maker avoids such information loss, but leaves no room for the woman to manipulate the decision and align it more closely with her preferences. We use the framework of the cheap talk literature to compare male focused and female focused information drives. The main questions of interest are the following. Which information strategy will produce a greater expected shift towards clean energy use? Which will produce higher expected welfare for women?

The analysis compares three kinds of information regimes that the external agency can induce:

1. **Transparency:** Under this informational regime, information about alternative fuels and clean technologies is provided directly to the male decision maker, whose choice therefore

reflects all available information and his own preference.

2. **Cheap talk:** Under this regime, information is provided to the woman, who conveys it to the man via cheap talk messages. She has the opportunity to distort or suppress the information she has received, but the man is aware of this possibility. Final choices will be the product of the cheap talk game played out between the man and the woman.

3. **Opaqueness:** This regime is induced when no information is provided to either party, so that the decision maker must base his choices without knowing the precise benefit of clean energy use for his household. Therefore, the value of information provision, in terms of behavioral change and women's welfare, is not assumed but derived in our model.

The main results are as follows. Two qualitative aspects of the problem play a critical role in determining optimal policy regarding information dissemination: (a) whether the choice between clean and dirty technologies is discrete or continuous (b) the preference distance between the man and the woman. An example of discrete choice is the purchase of capital equipment (such as a chimney-fitted oven or an LED light bulb to replace a kerosene lamp) that reduces household air pollution at a lump sum cost. An example of a continuous choice problem is the *mix* of clean and dirty fuels the household uses (e.g., firewood and LPG or electricity) to meet its energy needs. Literature documents that use of multiple fuels or 'fuel-stacking' is a common practise in households, so a policy that changes the *composition* towards cleaner sources (even if they are not used exclusively) can have significant health benefits. The preference distance refers to the value a household member places on a given quantum of air quality improvement, measured in physical terms. This is parametrized in the model using a quasi-linear utility function defined over clean fuel and other goods (such a functional form is commonly used while studying choices over public and private goods). It is assumed that women have a higher willingness to pay for cleaner air and a healthier home environment.

We find that in discrete choice problems, the information regime that maximizes women's welfare is either transparency or cheap talk, depending on the preference distance between the man and the woman. It is better for a benevolent third party to inform the woman in low conflict households, but in high conflict households, directly informing the male decision maker serves the woman's interest better. The simple intuition is that in high conflict households, an informed woman will fail to persuade the man to adopt clean technology due to credibility constraints, even when the realized benefit is actually high. The same conclusion obtains when the policy objective is to maximize clean energy use rather than women's welfare, as long as the default choice in the absence of information is the use of dirty technology.

The conclusions are dramatically different when the choice between clean and dirty technologies is a continuous one. For a large subset of preferences, it is optimal to inform the decision maker directly (i.e., transparency is the most favourable regime) *regardless of the degree* of intra-household conflict. A simple and empirically plausible sufficient condition can be identified under which this conclusion is obtained—increasing Arrow-Pratt measure of risk aversion applied to the consumption of other goods. If, on the other hand, the coefficient of absolute risk aversion decreases at a sufficiently fast rate, it may be optimal for policy makers to inform the woman, or even, neither. However, the role of preference distance is exactly reversed in such cases. In low conflict households, it is better to directly inform the male decision maker (transparency), whereas in high conflict households, using the woman as the conduit of information (cheap talk) or even withholding information (opaqueness) is the better option.

This theoretical exercise is related to the study of *commitment* in cheap talk games. This refers to both commitment by the decision maker or receiver (i.e., credible promises to transfer decision making authority to an informed subordinate, or sender—what Dessein (2002) calls delegation) and commitment by a sender to reveal information to the receiver according to suitably chosen pre-determined rules (what Kamenica and Gentzkow (2011) call Bayesian persuasion). Gentzkow and Kamenica (2011) study, very generally, scenarios under which the sender can choose, ex ante, *any* information structure (for example, arbitrary partitions of the state space or arbitrary garbling of the information available to the sender). In many applied problems, it may be impossible to commit to arbitrary information structures, yet commitment to simple ones may be possible. In this paper, We study two extreme and simple forms of informational commitment—revealing all information (transparency) and withholding all information (opaqueness). The commitments are made via a third party, the information provider, who chooses to talk to either the man or the woman. Because of much more structure in our model derived from the economic context, the results can be stated in terms of preferences alone, rather than in terms of belief distributions as in Gentzkow and Kamenica (2011).

Another connection worth emphasizing here is that between information and welfare. Under complete contractual possibilities, it is well known from the agency literature that agents with no bargaining power enjoy information rents, i.e., their welfare is higher when they hold private information that is not available to the principal. In contrast, in a class of situations in this model, information rents are negative, i.e., the agent is better off when her private information is made available to the principal by an external agent. This underscores that the adage " information is power" should be assessed carefully in intra-household conflict problems where it is reasonable to assume that household members can communicate but not draw up legally enforceable contracts regarding budgetary allocations.

The paper is organized as follows. Section 2 discusses the general model using quasi-linear preferences preferences. Section 2.1 analyzes the case where the choice is binary, while section 2.2 studies the continuous choice version. Section 2.3 discusses the salient points emerging from the analysis and section 3 concludes.

2 Household model

Consider a two-member representative household comprising of a male decision maker, m and a female, f, who has no decision making power. The household is endowed with a total income, Rs. y. Each member derives utility from two goods—the quantity of clean fuel or equipment used by the household (x), and the money spent on all other goods ($c = y - px$), where p is the unit cost of clean fuel or equipment. We assume a quasi-linear utility function familiar from the public goods literature:

$$U_i(x) = u(y - px) + \rho_i \theta x \tag{1}$$

where $u(.)$ is a twice differentiable, increasing and strictly concave function, θ is the benefit (measured in some physical unit, such as the reduced concentration of pollutants in the air at home) per unit arising from the use of clean fuels or equipment, and ρ_i is the value individual i places ($i = m, f$) on a per unit reduction in pollution levels. Initially, it is common knowledge that θ

follows a uniform distribution on the $[0,1]$ interval. This captures lack of knowledge about the polluting properties of different energy sources as well as their health consequences. Throughout the analysis, We will assume $\rho_f > \rho_m$, which captures the assumption that f values the household public good, clean air, more than m.

The decision maker m will choose x to maximize the expected value of U_m, given all available information about θ. We model an information campaign as follows. It results in the realized value of θ being revealed to the target of the campaign (either f or m). If m is the target, m makes a fully informed choice of x. If f is the target, then f (the sender) and m (the receiver) play a cheap talk game, and m's choice of x is based on whatever information about θ is revealed in the equilibrium of that game. If neither agent is provided any information, m makes a choice based on the prior distribution of θ.

Let X be the action set, i.e., the set of possible values of x that the decision maker can choose from. We study two cases: (i) $X = \{0,1\}$, the discrete (binary) action model (ii) $X = \mathbf{R}$, the continuous, unbounded action model. The former is relevant when the choice involves purchase of capital equipment like a chimney-fitted stove, a pressure cooker or LED lamp, at a lump sum cost. The latter is relevant when the choice is how much clean fuel, like LPG or electricity, to use for household energy needs (the rest of energy consumption will be derived from dirty fuels like firewood). The welfare criterion used throughout this paper is the ex-ante payoff for agents before the state of the world becomes known. It is noteworthy that by Blackwell's theorem (Blackwell et al., 1953), the decision maker always prefers more information over less. The following sections discusses how f's ranking over different information-revelation regimes differs with variation in assumptions about the action space and preferences.

2.1 Discrete actions

We assume $x \in \{0,1\}$, where, if $x = 1$, the clean alternative is used, and if $x = 0$, the dirty option is exercised. In a full information world, agent i's preference can simply be described by a cut-off rule: he/she prefers the clean alternative if and only if θ is above some cutoff value. Agent i prefers $x = 1$ iff $U_i(1) \geq U_i(0)$, i.e.,

$$\begin{aligned} u(y-p)+\rho_i\theta &\geq u(y) \\ \text{or,}\;\; \theta &\geq \frac{u(y)-u(y-p)}{\rho_i} \equiv \theta_i \end{aligned} \tag{2}$$

An agent prefers action 1 (respectively 0) if the conditional expected value of the state is above (below) his or her cutoff. Since $\rho_f \geq \rho_m$, We have $\theta_f \leq \theta_m$, i.e., the woman prefers clean energy for a strictly greater subset of states.

First, consider the cheap talk game between an informed woman and the uninformed male decision maker. If a non-babbling equilibrium exists in this game, it always takes the following form: the woman sends a message $z=1$ if $\theta \geq \theta_f$ and $z=0$ otherwise, and the man chooses an action $x=z$. In other words, the woman urges the purchase of cleaner fuels or equipment whenever she herself prefers such purchase, and the man always follows her recommendation.

Checking the woman's best response is trivial; if the message affects the decision-maker's choices at all, the sender will always induce the action she likes best in that state-of-the-world. Turning to the man's incentive constraint, We have the following inequalities:

$$\mathbb{E}[U_m|\theta < \theta_f] = u(y-p)+\frac{\theta_f}{2}.\rho_m \leq u(y) \tag{3}$$

$$\mathbb{E}[U_m|\theta \geq \theta_f] = u(y-p)+\frac{(1+\theta_f)}{2}.\rho_m \geq u(y) \tag{4}$$

Using (2), (3) boils down to the condition: $\theta_m \geq \frac{\theta_f}{2}$, which is always true, while (3) reduces to: $\theta_m \leq \frac{1+\theta_f}{2}$. The last condition, which states the cutoff points for the man and woman should be close enough, requires restrictions on parameters, which can be expressed as follows after a little manipulation:

$$\frac{2}{\rho_m}-\frac{1}{\rho_f} \leq \frac{1}{u(y)-u(y-p)} \tag{5}$$

Note that for a given ρ_m, this places an upper bound on ρ_f , i.e., on the maximum degree of conflict within the household that is still compatible with an informative equilibrium. In what follows, We assume that the non-babbling equilibrium is selected whenever it exists.

When m receives no information, optimal actions are based on the expected value of θ, $\mathbb{E}[\theta] = \frac{1}{2}$. Under opaqueness, the utility for the m is $U_m = u(y)$ when $\frac{1}{2} < \theta_m$ and $U_m = u(y-p) + \frac{1}{2}\rho_m$ if $\theta_m \leq \frac{1}{2}$. On the contrary, if the decision maker is informed, the welfare function (expected utility) for f can be expressed in the following form.

$$W_f^t = \int_0^{\theta_m} u(y)d\theta + \int_{\theta_m}^1 (u(y-p) + \rho_f \theta)d\theta$$

$$= \theta_m u(y) + (1-\theta_m)\left(u(y-p) + \rho_f\left(\frac{1+\theta_m}{2}\right)\right)$$

Although the decision maker always prefers more information to less, the female's rankings over different information regimes varies depending on the distance between their preferences.

Proposition 1. *With binary actions, cheap talk is the information regime that maximizes the woman's ex ante welfare if and only if the cheap talk game has a non-babbling equilibrium, i.e., if and only if (5) is satisfied. Otherwise, the optimal information regime is transparency. If the default action of the man is 0 (i.e., the optimal action based on priors), cheap talk (transparency) is the information regime that maximizes the probability of action 1 if (5) is satisfied (violated).*

Proof. Suppose (5) holds, i.e., a non-babbling equilibrium exists. This equilibrium gives the woman her most preferred choice in every state of the world, i.e., it makes her the *de facto* decision maker. It is then trivial that her ex ante welfare is maximized under cheap talk.

Next turn to the case where (5) does not hold. Note that for this to obtain, the man's default action (based on priors) must be 0, i.e., $\theta_m > \frac{1}{2}$, otherwise (4) will be satisfied for all values of θ_f. Now under cheap talk or opaqueness, the man chooses $x = 0$ for all values of θ. Under transparency, the man will implement his ex post optimal decision, i.e., he will switch to $x = 1$ if and only if $\theta \geq \theta_m$. Since $\theta_f < \theta_m$, the woman strictly prefers $x = 1$ ex post for all such values of θ. This straightforward dominance argument establishes that whenever (5) is violated, the woman is better off under transparency.

Note that the probability of the clean alternative being chosen under a non-babbling equilibrium of the cheap talk regime is $\Pr[\theta \geq \theta_f] = 1 - \theta_f$, while the same probability under transparency is $\Pr[\theta \geq \theta_m] = 1 - \theta_m$. This establishes the rest of the proposition. □

To sum up, in low conflict households, information campaigns targeted at women maximize the probability of clean energy adoption as well as women's welfare. In high conflict households, these ends are best served by targeting the man as the focus of information campaigns. The reason is that in the latter households, the credibility problem arising from the large preference gap between the agents implies the woman cannot persuade the man to buy clean energy even when the benefits are very high.

2.2 Continuous actions

In this section, We assume the action space, x, to be continuous and unbounded such that $x \in [-\infty, +\infty]$.

We start the analysis by comparing the following information scenarios. Suppose it is common knowledge that $\theta \in [a, b]$. We consider (a) a scenario where the man has no further information about the exact value of θ (the uninformed decision maker) (b) a scenario where the man is fully informed about the realization of θ in $[a, b]$ (the informed decision maker). In particular, We will compare the expected value of x and the woman's expected welfare under (a) and (b). The result of that analysis can be recursively applied to derive the results that follow. We start by stating the following *transparency lemma*.

Lemma 1. *(Transparency lemma) Let $A(w) = -\frac{u''(w)}{u'(w)}$ denote the Arrow-Pratt measure of absolute risk aversion. If $A(w)$ is increasing, or if it is decreasing at a slow enough rate, specifically, if*

$$\frac{d}{dw}\left\{\frac{1}{A(w)}\right\} < 1 \tag{6}$$

the woman's expected welfare is higher when the male decision maker is informed rather than uninformed. If (6) is violated, the woman's expected welfare is higher when the male decision maker is informed if and only if $\rho_f - \rho_m$ is small enough.

Proof. In general, the optimal action chosen by the decision maker, x_m, is given by

$$x_m = \arg\max_x \mathbb{E}U_m \tag{7}$$

Consider the case where m is informed about θ. The first order condition for optimal choice is:

$$\Rightarrow u'(y - px) = \frac{\rho_m \theta}{p}. \tag{8}$$

which defines the choice function $x_m(\theta)$ under full information.

When the man is uninformed, the optimal choice x^e is given by the first-order-condition of (7), which yields

$$u'(y - px^e) = \frac{\rho_m \theta^e}{p} \tag{9}$$

where θ^e is the expected value of θ in the interval. Observe from (8) and (9) that $x^e = x_m(\theta^e)$.

Further, using (7), f's welfare under complete knowledge (transparency) can be expressed as function of the corresponding welfare of the decision maker.

$$W_f^t = W_m^t + (\rho_f - \rho_m) \int_a^b \theta x_m(\theta) d\theta \tag{10}$$

On the other hand, if m is uninformed (opaqueness), f's ex ante welfare can be similarly expressed as

$$W_f^o = W_m^o + (\rho_f - \rho_m)\theta^e x_m(\theta^e) \tag{11}$$

Subtracting, We get

$$W_f^t - W_f^o = \left(W_m^t - W_m^o\right) + (\rho_f - \rho_m)\left[\int_a^b \theta x_m(\theta)d\theta - \theta^e x_m(\theta^e)\right] \tag{12}$$

Since the decision maker always prefers full information to no-information, $W_m^t - W_m^o > 0$ by Blackwell's theorem. The sign of $W_f^t - W_f^o$, then, depends critically on the curvature properties of the function $\phi(\theta) = \theta x_m(\theta)$. If it is convex, applying Jensen's inequality, the second term on the right-hand-side above is also positive, implying $W_f^t > W_f^o$. If, on the other hand, $\phi(\theta)$ is concave, the positive first term above is counter-balanced by a negative second term. In this case, the negative second term will dominate if the coefficient $\rho_f - \rho_m$ is large enough. Therefore, We investigate the curvature properties of the $\phi(\theta)$ function further.

Differentiating the first order condition, (8), w.r.t. θ, I find that

$$\theta x_m'(\theta) = \frac{1}{p}\left[\frac{-u'(y - px_m(\theta))}{u''(y - px_m(\theta))}\right] = \frac{1}{pA(w)} \tag{13}$$

where $A(w)$ is the Arrow-Pratt measure of absolute risk aversion and $w = y - px_m(\theta)$. Using (13), the first derivative of $\theta x_m(\theta)$ wrt θ, D_1, can be written as the following [3].

$$D_1 = x_m(\theta) + \frac{1}{pA(w)} \tag{14}$$

Note that D_1 is positive since $u(y - px_m(\theta))$ is a concave twice differentiable function. Differentiate (14) w.r.t. θ to obtain the second derivative, D_2, gives the following.

[3] The first and second derivative of $\theta x_m(\theta)$ wrt θ are D_1 and D_2, respectively, such that $D_1 = \frac{d}{d\theta}[\theta x_m(\theta)] = x_m(\theta) + \theta x'(\theta)$ and $D_2 = \frac{d^2}{d\theta^2}[\theta x_m(\theta)] = 2x_m'(\theta) + \theta x''(\theta)$.

$$D_2 = x_m'(\theta)\left[1 - \frac{d}{dw}\left\{\frac{1}{A(w)}\right\}\right] \tag{15}$$

$D_2 > 0$ if and only if

$$\frac{d}{dw}\left\{\frac{1}{A(w)}\right\} < 1$$

This establishes all the claims in the lemma. Whenever (6) is satisfied, both terms on the right-hand-side of (8) are positive, implying $W_f^t > W_f^o$. If the opposite is true, the negative term dominates ($W_f^t < W_f^o$) if $(\rho_f - \rho_m)$ is large enough. □

We can now give a simple sufficient condition under which provision of information directly to the male decision maker maximizes the woman's welfare.

Proposition 2. *Suppose $X = \mathbf{R}$, i.e., the set of actions is a continuum and unbounded, and further, (6) holds, i.e., the coefficient of risk aversion, $A(w)$, decreases sufficiently slowly. Then, the woman's ex ante expected welfare is highest under the information regime of transparency, independent of ρ_f and ρ_m. If (6) is violated, transparency is still the optimal information regime if $\rho_f - \rho_m$ is low enough. For high enough values of $\rho_f - \rho_m$, the information regime that maximizes the woman's expected welfare is either cheap talk or opaqueness but not transparency.*

Proof. Under cheap talk, following Crawford and Sobel (1982),one knows that the most informative equilibrium induces a partition of the state space. That is, m learns, before making the decision, that θ lies in one of n intervals: $[\theta_0, \theta_1)$, $[\theta_1, \theta_2)$, ..., $[\theta_{n-1}, \theta_n]$, where $\theta_0 = 0$ and $\theta_n = 1$. One can apply the transparency lemma to establish these claims. Denote by $W_f^t([a,b])$ agent f's interim expected welfare if it is known to the decision maker that θ lies in the interval $[a,b]$, and correspondingly, $W_f^o([a,b])$ as f's expected welfare when the decision maker is uninformed about the true value of θ within the interval. Also, denote by W_f^t, W_f^c and W_f^o the ex ante welfare under transparency, cheap talk and opaqueness respectively. The following expressions are trivial:

$$
\begin{aligned}
W_f^t &= \sum_{k=0}^{n-1} (\theta_{k+1} - \theta_k) W_f^t([\theta_k, \theta_{k+1}]) \\
W_f^c &= \sum_{k=0}^{n-1} (\theta_{k+1} - \theta_k) W_f^o([\theta_k, \theta_{k+1}]) \\
W_f^o &= W_f^o([0,1])
\end{aligned}
$$

If (6) holds, by the transparency lemma, $W_f^t([\theta_k, \theta_{k+1}]) > W_f^o([\theta_k, \theta_{k+1}])$ for all k, hence $W_f^t > W_f^c$. Further, observe that W_f^t can also be written as $W_f^t([0,1])$. By the transparency lemma again, it can shown that $W_f^t > W_f^c$.

Now consider the case where (6) is violated. Return to the scenario considered in the transparency lemma, i.e., consider whether the woman prefers the man to be informed or uninformed within any interval. Since $(W_m^t - W_m^o)$ is bounded, and the negative second term in (12) decreases unboundedly as $\rho_f - \rho_m$ increases, the right-hand-side of (12) is negative for $\rho_f - \rho_m$ high enough. Take $\rho_f - \rho_m$ to be greater than the common upper bound for all the intervals in the equilibrium partition of the cheap talk game, as well as the domain, $[0,1]$. In that case, transparency is dominated by both cheap talk and opaqueness. We do not give a full characterization of the optimal information regime in this scenario. □

A similar result obtains when the expected value of x is compared across information regimes. Formally,

Proposition 3. *Suppose $X = \mathbf{R}$, i.e., the set of actions is a continuum and unbounded. If*

$$
A'(w) < -\frac{A(w)}{\theta} \tag{16}
$$

for all w, the expected value of x is highest under transparency, independent of ρ_f and ρ_m. If the inequality above is reversed for all w, the expected value of x is highest under opaqueness.

Proof. As in the transparency lemma, consider a scenario where $\theta \in [a,b]$, but m may either be fully informed or fully uninformed about its true value. Since the uninformed choice $x^e = x_m(\theta^e)$, by Jensen's inequality, the expected value of x is higher (lower) when m is informed if the function $x_m(\theta)$ is convex (concave). From (13):

$$x_m'(\theta) = \frac{1}{p\theta A(w)} > 0 \tag{17}$$

Differentiating further,

$$x_m''(\theta) = -\frac{1}{p\theta^2 A(w)} - \frac{A'(w)}{p\theta[A(w)]^2}$$

It is easy to check that $x_m''(\theta) \geq 0$ if and only if (16) is satisfied. Applying the same recursive logic employed in the proof of the previous proposition, it follows that whenever this condition holds, the expected value of clean energy use is highest under transparency because resolution of uncertainty increases the expected value of the $x_m(\theta)$ function.

Now turn to the case where (16) is reversed, i.e., $A'(w) > -\frac{A(w)}{\theta}$ and consequently $x_m(\theta)$ is concave. Applying Jensen's inequality again, We can conclude that the expectation of x is higher under opqueness than under transparency. To complete the proof, we need to show that opaqueness also dominates cheap talk.

Let $[\theta_0, \theta_1)$, $[\theta_1, \theta_2)$, ..., $[\theta_{n-1}, \theta_n]$ be the information partition under any cheap talk equilibrium and let x_k denote m's optimal action whenever he learns that θ lies in the k-th interval, where x_k is characterized by the first-order-condition:

$$u'(y - px_k) = \rho_m\left(\frac{\theta_k + \theta_{k+1}}{2p}\right) \tag{18}$$

On the other hand, under opaqueness, the optimal action x^e is characterized by the first-order-condition:

$$u'(y - px^e) = \frac{\rho_m \theta^e}{p} \tag{19}$$

where $\theta^e = \int_0^1 \theta d\theta = \frac{1}{2}$. Multiplying both sides of (18) by $(\theta_{k+1} - \theta_k)$ and summing over all k, one gets

$$\begin{aligned}\sum_{k=0}^{n-1}(\theta_{k+1} - \theta_k)u'(y - px_k) &= \rho_m \sum_{k=0}^{n-1}\left(\frac{\theta_{k+1}^2 - \theta_k^2}{2p}\right) \\ &= \rho_m \left(\frac{\theta_n^2 - \theta_0^2}{2p}\right) \\ &= u'(y - px^e)\end{aligned} \tag{20}$$

Next, observe that

$$\frac{d}{dw}A(w) = \left[\frac{u''(w)}{u'(w)}\right]^2 - u'''(w)u'(w)$$

Therefore, a necessary condition for $A(w)$ to be decreasing in w (which, in turn, is necessary for (16) to be violated) is $u'''(w) > 0$. Assume this to be true. Since $u'(w)$ is then a convex function, by Jensen's inequality, the following is obtained

$$u'\left(\sum_{k=0}^{n-1}(\theta_{k+1} - \theta_k)(y - px_k)\right) < \sum_{k=0}^{n-1}(\theta_{k+1} - \theta_k)u'(y - px_k) = u'(y - px^e)$$

Recalling that $u'(w)$ is also a decreasing function (since $u''(w) < 0$), one can write;

$$\sum_{k=0}^{n-1}(\theta_{k+1} - \theta_k)(y - px_k) > y - px^e$$

which in turn implies (since $\sum_{k=0}^{n-1}(\theta_{k+1}-\theta_k)=1$)

$$\sum_{k=0}^{n-1}(\theta_{k+1}-\theta_k)x_k < x^e$$

This establishes that the expected value of x is higher under opaqueness relative to the cheap talk equilibrium whenever (16) is reversed. Collecting the various strands, We conclude that opaqueness maximizes expected purchase of clean energy under this condition.

□

2.3 Discussion

1. We have established that under certain conditions (the coefficient of risk aversion does not rise sufficiently fast), the degree of intra-household conflict of preferences does not matter for optimal policy. Under these conditions, it is better for the external agency to directly inform the male decision maker, whether the objective is to maximize adoption of clean energy or women's welfare. This stands in stark contrast to the discrete action model studied in section 2.1, where the degree of conflict always plays a role.

2. Under certain other conditions, the degree of intra-household conflict matters for optimal targeting of information from the perspective of women's welfare. However, the pattern in the continuous action model is exactly the opposite of what was obtained in the binary choice model. For close preferences, focusing information campaigns on the male decision maker best promotes women's welfare (transparency is the optimal regime). However for more distant preferences, it is better to focus information provision on women or none at all.

3. Proposition 3 shows that if the objective is to maximize the expected use of clean energy, the optimal information regime is either transparency or opaqueness, but never cheap talk. Put differently, if the information campaign has potentially positive impact on clean energy use, it should always target men. The proposition also illustrates that in some situations, clean energy usage is maximized under uncertainty, i.e., by withholding information. There

is no firm reason to assume that information campaigns have positive value or should always be directed at household members who are most responsive to positive information about benefits.

4. (6) is satisfied whenever (16) is satisfied, but not vice-versa. To see this, observe that since $\phi(\theta) = \theta x_m(\theta)$, and hence

$$\phi''(\theta) = 2x_m'(\theta) + x_m''(\theta)$$

Therefore, convexity of $x_m(\theta)$ implies $\phi(\theta)$ is convex but not vice versa. If direct information provision to the male decision maker raises the expenditure on clean energy on average, it will also increase women's welfare, but not necessarily the other way round. There may be situations where the objectives of increasing clean energy use and raising women's welfare are in conflict.

3 Conclusion

This paper analyzed decision making within households with respect to clean energy choice. Empirical evidence suggests that there is substantial intra-household conflict in preferences over clean fuels and appliances and other consumer goods, with women typically having a stronger preference for cleaner heating and lighting technologies and better household air quality. However, women also have a much weaker bargaining position in making financial decisions. Information campaigns that aim to spread awareness about the benefits of clean fuels or appliances face a strategic choice—whether to target women or men. Since women are more responsive to such information, it seems tempting to conclude that they should be the targets. Our analysis shows that there are subtle effects in the opposite direction. The conflict of interest leads to strategic communication between the woman and the man, which could result in significant coarsening of information at the decision making stage. This paper has identified conditions under which the information loss is large enough to warrant men be targeted for the provision of information, whether to promote clean energy use or women's welfare. It also establishes that there is no theoretically unambiguous reason to rank different dissemination strategies—which approach will be more effective is an empirical issue.

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