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Equity effects of energy affordability interventions

Niall Farrell[a,b*]

a) Economic and Social Research Institute, Dublin, Ireland
b) Trinity College Dublin, Dublin, Ireland

*Corresponding Author:
Dr Niall Farrell
Economic and Social Research Institute,
Whitaker Square, Sir John Rogerson's Quay,
Dublin, Ireland
Email: Niall.Farrell@esri.ie

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Abstract

This paper compares the distributional effects of price cap and lump sum transfer policies to aid the affordability of subsistence electricity consumption.
A lump sum transfer is more progressive than a comparable price cap on all units of electricity. We identify conditions under which these policies have equal distributional effects. We prove that both interventions are progressive.

JEL Codes: D30, D60, E62, H22, H23, H24, Q4, Q52, Q54, Q58

1 Introduction

The affordability of subsistence electricity consumption is a salient policy priority. Common policy interventions in response to the 2022 energy price shock have included price caps (either explicit or implicit in changes to indirect tax) and lump sum transfers [for a review, see 6, 2]. Cost-effective policy maximises the affordability of subsistence consumption for a given cost. This paper provides theoretical conditions to guide an effective policy choice. Price cap and lump sum transfer policies are both progressive. A lump sum transfer is more progressive than a price cap when applied to all units of electricity. We identify that both policies have equal distributional effects if (i) the price cap extends to subsistence units of consumption only, or (ii); the price cap and lump sum transfer have an equal effect on the affordability of subsistence consumption. A price cap is more expensive under (ii), however.

This is the first theoretical work to consider the distributional effect of energy affordability interventions. Numerical studies, contained within the 'grey' policy-oriented literature, prevail [e.g. 1, 3, 5]. Much applied work examines burdensome energy costs more generally [for a review, see 4].

We build on the stylised theoretical framework of [8]. Our model features two consumption goods, electricity and a composite good. Households differ only in their productivity and must consume a subsistence amount of electricity to survive [see 7]. The explicit modelling of subsistence consumption makes the theoretical framework of [8] suitable for this analysis. It is through this subsistence consumption that we model distributional effects.

We consider interventions funded through the imposition of a linear income tax to assess relative cost. We make the implicit assumption that this increase in government expenditure will be transferred, at least in part, to households. A linear tax increment applied to all interventions facilitates a comparison of cost while abstracting from the distribution of the tax schedule. This is a policy choice particular to a given jurisdiction.

2 Model

Our model comprises households and government sectors. We follow [8] and [7] by explicitly modelling subsistence consumption (E_0) to elicit distributional impacts.

Preferences are therefore non-homothetic.

Households.

Utility-maximising households consume a composite good (A_i), electricity (E_i) and leisure (l_i). Household i's utility function is

$$U(A_i, E_i, l_i) = A_i^{\alpha}(E_i - E_0)^{\beta} l_i^{\gamma}, \tag{1}$$

where α, β, $\gamma > 0$. Households consume at least E_0, therefore the utility function is not defined for $E_i < E_0$. For ease of exposition, we assume $\alpha + \beta + \gamma = 1$, as assumed by [8]. The composite good faces a price p_A, while electricity faces a price p_E.

Households are distinguishable by their productivity, ϕ_i. Households are endowed with one unit of a production factor, a share of which is used at home for leisure, l_i. The remainder incurs a rental rate w. Households pay a tax t_0 on a share of their income. Total electricity demand (E_T) equals total supply in equilibrium:

$$\sum_{i}^{N} E_i = E_T \tag{2}$$

To aid affordability, households may receive a lump sum transfer, L_i, financed by a linear tax increment t_L. Alternatively, a price cap may be implemented, where the electricity price falls by ψ. This is an exogenous parameter chosen by policy. The price cap is funded by a linear tax increment, t_c.

Income (M_i) is given by:

$$M_i = \phi_i w(1 - l_i)(1 - t_0 - t_c - t_L), \tag{3}$$

and the budget constraint is therefore:

$$A_i \cdot p_A + E_i \cdot (p_E - \psi) = M_i + L_i. \tag{4}$$

Households maximise utility (Eq. 1) according to the budget constraint of equation (4), which can be transformed to obtain Marshallian Demand functions A_i^*, E_i^* and l_i^*:

$$A_i^* = \frac{\alpha}{p_A}\Big(\phi_i w(1-t_0-t_c-t_L) + L_i - E_0(p_E-\psi)\Big) \tag{5}$$

$$E_i^* = \frac{\beta}{p_E-\psi}\Big(\phi_i w(1-t_0-t_c-t_L) + L_i - E_0(p_E-\psi)\Big) + E_0 \tag{6}$$

$$l_i^* = \frac{\gamma}{\phi_i w(1-t_0-t_c-t_L)}\Big(\phi_i w(1-t_0-t_c-t_L) + L_i - E_0(p_E-\psi)\Big) \tag{7}$$

Government.

The government sector is non-optimising, with a fixed spending requirement G financed by the pre-existing tax t_0. Publicly-funded price caps (ψ) or publicly-funded lump sum transfers (L_i), must be financed by their respective linear tax increments, t_c and t_L. The government's budget constraint comprises:

$$\overbrace{G}^{\text{Gen. expenditure}} + \overbrace{\sum_i^N L_i + E_T\psi}^{\text{Publicly-financed intervention}} = \overbrace{\sum_i^N \phi_i w(1-l_i)\cdot(t_0+t_c+t_L)}^{\text{Exchequer financing}} \tag{8}$$

3 Results

To measure distributional impact, we follow [8] and concentrate on the ratio of utilities between household i and household j, where $\phi_i < \phi_j$. The ratio of the indirect utilities of households i and j is:

$$\frac{U_i}{U_j} = \left(\frac{\phi_j}{\phi_i}\right)^{\gamma}\left(\frac{\phi_i w(1-t_0-t_c-t_L) - E_0(p_E-\psi) + L_i}{\phi_j w(1-t_0-t_c-t_L) - E_0(p_E-\psi) + L_j}\right) \tag{9}$$

We denote the following utility ratios: (U_i^{BP}/U_j^{BP}) is the utility ratio before policy intervention; (U_i^{C}/U_j^{C}) the price cap utility ratio; and (U_i^{L}/U_j^{L}) the lump sum transfer utility ratio.

$$\frac{U_i^{BP}}{U_j^{BP}} = \left(\frac{\phi_j}{\phi_i}\right)^{\gamma}\left(\frac{\phi_i w(1-t_0) - E_0(p_E)}{\phi_j w(1-t_0) - E_0(p_E)}\right) \tag{10}$$

$$\frac{U_i^{C}}{U_j^{C}} = \left(\frac{\phi_j}{\phi_i}\right)^{\gamma}\left(\frac{\phi_i w(1-t_0-t_c) - E_0(p_E-\psi)}{\phi_j w(1-t_0-t_c) - E_0(p_E-\psi)}\right) \tag{11}$$

$$\frac{U_i^{L}}{U_j^{L}} = \left(\frac{\phi_j}{\phi_i}\right)^{\gamma}\left(\frac{\phi_i w(1-t_0-t_L) - E_0(p_E) + L_i}{\phi_j w(1-t_0-t_L) - E_0(p_E) + L_j^c}\right) \tag{12}$$

Proposition 1:

A lump-sum transfer is more progressive than a price cap applied to all units of electricity, where both policies have equal cost (*i.e.* $\sum_i \phi_i w(1-l_i)t_c = \sum_i \phi_i w(1-l_i)t_L$)

Proof.

It suffices to demonstrate that $(U_i^C/U_j^C) < (U_i^L/U_j^L)$, where $\phi_i < \phi_j$ and policies are of equal cost. We focus on equations (11) and (12). We can ignore the first term, $(\phi_j/\phi_i)^{\gamma}$, which appears in both; this is constant and it hence suffices to work with the second term. Given that $\sum_i \phi_i w(1-l_i)t_c = \sum_i \phi_i w(1-l_i)t_L$, it follows that $t_c = t_L$. Equations (11) and (12) therefore differ according to the terms $E_0\psi$ in equation (11) and L_i in equation (12).

Assuming a revenue-neutral intervention, the sum of all lump sum transfers equal the sum of all tax receipts:

$$\sum_i L_i = \sum_i \phi_i w(1-l_i)t_L.$$

Similarly, the sum of price supports, for every unit consumed, equal the sum of all tax revenues:

$$\sum_i E_i\psi = \sum_i \phi_i w(1-l_i)t_c.$$

It therefore follows that:

$$\sum_i L_i = \sum_i E_i\psi. \tag{13}$$

Given equation (13) and that $E_0 < E_i$ by definition, one concludes that $\sum_i L_i >$

$\sum_i E_0\psi$. As L_i and E_0 are uniform for all i, it follows that:

$$L_i > E_0\psi \tag{14}$$

Therefore, the L_i term increases (U_i^L/U_j^L) to a greater extent than $E_0\psi$ increases (U_i^C/U_j^C) and it follows that $(U_i^C/U_j^C) < (U_i^L/U_j^L)$. This closes the proof for Proposition 1.

All units of electricity receive public support, some of which are subsistence units. Recall that distributional effects are driven by subsistence consumption, E_0. If policy cost is equal, a lump-sum will be greater than what is received through a price reduction for subsistence consumption. Therefore, the lump sum has a greater effect on the affordability of subsistence consumption and is more progressive.

Proposition 2:
A price cap on all units of electricity, calibrated such that household receipts on subsistence consumption are equal to a lump sum transfer (*i.e.* $E_0\psi = L_i$), *is:*

a *equally as progressive as a lump sum transfer;*

b *more costly than a lump sum transfer.*

Proof.

To prove Proposition 2(a) it suffices to show that the price cap and lump sum have equal distributional effects: i.e. $(U_i^C/U_j^C) = (U_i^L/U_j^L)$, where $\phi_i < \phi_j$, $L_i = E_0\psi$ and the price cap is applicable to all units of electricity.

As with Proposition 1, it suffices to work with the second term of equations (11) and (12). As $L_i = E_0\psi$ in this scenario, equations (11) and (12) differ according to differences in t_c and t_L.

The distributional effects are equal if the following condition holds:

$$\frac{\phi_i w t_c}{\phi_j w t_c} = \frac{\phi_i w t_L}{\phi_j w t_L} \tag{15}$$

Simplifying, we get:

$$\frac{t_c}{t_c} = \frac{t_L}{t_L} \tag{16}$$

Which simplifies to 1 on each side and there is an equal distributional effect. As the positive effects are equal and the negative effects have identical distributional effects, it follows that $(U_i^C/U_j^C) = (U_i^L/U_j^L)$. While t_c is not necessarily equal to t_L, the reform is distributionally neutral as the tax increment is assumed to be linear. This closes the proof for Proposition 2(a).

To prove Proposition 2(b) we must show that the policy cost is greater under a price cap policy, where the price cap is applicable to all units. If the price cap is applicable to all units of electricity and there is a revenue-neutral intervention, then:

$$\sum_i \phi_i w(1-l_i)t_c = \sum_i E_i\psi \tag{17}$$

Similarly, assuming a revenue-neutral lump sum transfer, we know that:

$$\sum_i \phi_i w(1-l_i)t_L = \sum_i L_i \tag{18}$$

By definition, we know that $E_0\psi = L_i$ and therefore $\sum_i L_i = E_0\psi$. As $E_i > E_0$, it follows that $\sum_i \phi_i w(1-l_i)t_c > \sum_i \phi_i w(1-l_i)t_L$, and therefore $t_c > t_L$. To understand the intuition, recall that the lump sum transfer is calibrated to cover subsistence consumption. However, the price cap is applicable to all units of electricity, a subset of which consumption is subsistence. The price cap therefore incurs a greater cost to achieve an effect on subsistence consumption equivalent to a lump sum. This closes the proof for Proposition 2(b).

Proposition 3:

A lump-sum transfer and a price cap have equal distributional effects and equal cost if the price cap is applied to subsistence units of electricity consumption only

Proof.

It suffices to demonstrate that $(U_i^C/U_j^C) = (U_i^L/U_j^L)$, where $\phi_i < \phi_j$, $L_i = E_0\psi$ and the price cap is applicable to subsistence units of electricity only. As $\sum_i \phi_i w(1-l_i)t_c = \sum_i E_0\psi$ and $\sum_i \phi_i w(1-l_i)t_L = \sum_i L_i$, it follows that:

$$\phi_i w(1-l_i)t_c = \phi_i w(1-l_i)t_L. \tag{19}$$

For equations (11) and (12), it may therefore be concluded that there is an equality of utility increasing effects ($L_i = E_0\psi$) and utility-decreasing effects (equation 19). As such, $(U_{i,\psi}/U_{j,\psi}) = (U_{i,L}/U_{i,L})$ where $L_i = E_0\psi$ and the price cap is applicable to subsistence units of electricity only. This closes the proof for Proposition 3.

Proposition 4:

Lump sum transfers and market price caps are both progressive.

Proof.

It has been established by Proposition 1 that a price cap is less progressive than a comparable lump sum transfer. It follows that if a price cap policy is progressive, so too is a lump sum transfer. To prove Proposition 4 it therefore suffices to show that a price cap policy is progressive: i.e. $(U_i^C/U_j^C) > (U_i^{BP}/U_j^{BP})$.

Following [8], we demonstrate progressivity by showing that this policy's utility-increasing term is greater than the utility-reducing term. We define auxiliary variables A and B which transform equations (10) and (11), respectively, into:

$$\frac{U_i^{BP}}{U_j^{BP}} = \left(\frac{\phi_j}{\phi_i}\right)^{\gamma}\left(\frac{\phi_i A - E_0(p_E)}{\phi_j A - E_0(p_E)}\right) \tag{20}$$

$$\frac{U_i^C}{U_j^C} = \left(\frac{\phi_j}{\phi_i}\right)^{\gamma}\left(\frac{\phi_i A(1-\frac{B}{A}) - E_0(p_E - \psi)}{\phi_j A(1-\frac{B}{A}) - E_0(p_E - \psi)}\right), \tag{21}$$

where $A = w(1-t_0)$ and $B = wt_c$. We can ignore the first term which appears in both utility ratios. There are two terms present in equation (21) that are not present in equation (20) which will determine the difference in utility ratios. The first, $(1-B/A)$ becomes more negative as B/A increases. This decreases the utility ratio. The second term, $(E_0(p_E - \psi))$, becomes less negative as ψ increases, increasing the utility ratio. The distributional effect of a price cap is neutral if $B/A = \frac{\psi}{p_E}$.

It thus remains to show that $B/A < \frac{\psi}{p_E}$ to show that the price reform is progressive. By inserting the expressions for A and B, we get

$$\frac{B}{A} = \frac{t_c}{(1-t_0)} < \frac{\psi}{p_E} \tag{22}$$

For a revenue-neutral policy intervention, the sum of all lump sum revenues must equal the sum of all tax surcharges: $t_c w \sum_i \phi_i(1-l_i) = E_T\psi$. Rearranging:

$$t_c = \frac{E_T \psi}{w \sum_i \phi_i (1 - l_i)} \tag{23}$$

We use this relationship to eliminate t_c from equation (22):

$$\frac{E_T \psi}{(1 - t_0) w \sum_i \phi_i (1 - l_i)} < \frac{\psi}{p_E} \tag{24}$$

Rearranging:

$$p_E E_T < (1 - t_0) w \sum_i \phi_i (1 - l_i) \tag{25}$$

The term on the left-hand side represents total energy expenditure, the right-hand side represents disposable income less expenditure on leisure. Since, by assumption, ϕ_i is strictly less than ϕ_j, households with $j > 1$ always consume positive amounts of leisure and/or the composite good. Total spending on energy must therefore be lower than disposable income and the inequality above holds. Therefore $(U_i^C / U_j^C) > (U_i^{BP} / U_j^{BP})$. The price cap policy is therefore progressive and, by extension, so too is a lump sum transfer.

4 Discussion and Conclusion

Energy affordability interventions are common, particularly in the aftermath of the Russian invasion of Ukraine and the associated energy price shock. This is the first theoretical analysis of common policies; price caps and lump sum transfers. We prove their progressivity and identify conditions under which they have comparable distributional effects. Possible extensions include the analysis of targeted transfers and affordability interventions funded by windfall taxes. The findings of this paper may inform the latter analysis, where second-round effects on energy market operation should be incorporated.

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