Appendix for Chapter 8

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Policy responses to the energy crisis in the Nordic countries: Effects on the green transition

For electricity supply, we assume the following cost functions:

$$c(q_i^s) = \Gamma_i q_i^s + \frac{\gamma_i}{2}(q_i^s)^2,$$

where q_i^s is electricity supply from technology i, $i = c,d$ for renewable and non-renewable technologies, respectively, and Γ_i and γ_i are parameters.

From the two marginal cost schedules, we can derive an upward-sloping market-supply curve:

$$P = \bar{\Gamma} + \bar{\gamma} Q^S,$$

where P is the market price of electricity, Q^S is total quantity supplied and $\bar{\Gamma}, \bar{\gamma}$ are parameters comprising the cost parameters Γ_i and γ_i.

Households obtain utility from electricity services χ. Electricity services are produced by electricity in the following way:

$$\chi = \epsilon q_h^d,$$

where ϵ is the efficiency by which electricity is applied in the household, and q_h^d is electricity demanded by households. Households obtain the following utility from electricity services and general consumption, C:

$$u_h(q_h^d, C) = A_h(\epsilon q_h^d) - \frac{\alpha_h}{2}(\epsilon q_h^d)^2 + C,$$

where A_h and α_h are parameters.

The budget restriction for households is:

$$Y - C = \begin{cases} \bar{P} q_h^d + \sigma(P - \bar{P}) q_h^d \text{ if } P \geq \bar{P} \\ P q_h^d \; if \; P < \bar{P}, \end{cases}$$

where Y is income, P is the market price of electricity, $\bar{P}$ is a price limit set by the government, and σ is the share of the electricity bill the government covers for prices above the price limit.

Businesses get the following profit from electricity usage:

$$\pi(q_b^d) = A_b(q_b^d) - \frac{\alpha_b}{2}(q_b^d)^2 - P q_{b,}^d$$

where q_b^d is electricity demanded from businesses, and A_b and α_b are parameters.

By maximising consumer utility and business profits with respect to electricity usage, we derive demand functions for electricity for the two groups. These can also be combined to yield the following inverse aggregate market demand schedule:

$$P = \begin{cases} \bar{A} - \bar{\alpha} Q^d \text{ for } P \geq \bar{P} \\ \tilde{A} - \tilde{\alpha} Q^d \text{ for } P < \bar{P}, \end{cases}$$

where Q^d is total quantity demanded and $\bar{A}, \bar{\alpha}, \tilde{A}$ and $\tilde{\alpha}$ are parameters consisting of the parameters in the utility/profit functions A_j, ϵ and α_j with $j = h, b$. We have $\bar{A} > \tilde{A}$ and $\bar{\alpha} > \tilde{\alpha}$. Hence the demand curve is kinked at $P = \bar{P}$ with a steeper section above $\bar{P}$ (see Figure 8 in the main text). The model can now be solved for the market equilibrium.

Turning to clean technology adoption, we distinguish between two types of technologies:

1. Technologies that reduce the cost of producing renewable electricity

2. Energy-efficiency technologies.

We model technologies of type 1 by assuming that the parameter Γ_c shifts down by a fixed amount Δ_c for every firm that adopts the new technology.[1] However, within the group of clean electricity producers, we introduce a ranking X such that firms with a low adoption cost for the new technology

[1] Technically, this amounts to assuming a population of firms with identical cost functions, given by the cost function above. All firms that adopt will also become effectively identical, albeit with another cost function.

get a low X. In particular, we set $X \in [0,1]$ such that X can be understood as the fraction of firms adopting the new technology. Finally, we let the adoption cost of firm X be given by $F(X) = \theta_X X^2$.

Next, we model energy-efficiency technologies of type 2 by assuming that the parameter ϵ shifts up by a given amount for every household that adopts the technology. We also rank households according to their adoption cost for energy-saving devices. Let the ranking be given by $Y \in [0,1]$ and let the cost of adoption be given by $G(Y) = \theta_Y Y^2$.

A clean energy firm would choose the new technology if:

$$(P - \Gamma_c + \Delta_c) q_c^s(\Gamma_c - \Delta_c) - \frac{\gamma_c}{2}[q_c^s(\Gamma_c - \Delta_c)]^2 - F(X) \geq (P - \Gamma_c) q_c^s(\Gamma_c) - \frac{\gamma_c}{2}[q_c^s(\Gamma_c)]^2,$$

where $q_c^s(\Gamma_c - \Delta_c)$ and $q_c^s(\Gamma_c)$ are the equilibrium quantities supplied with and without the new renewable technology, respectively.

Furthermore, a household would choose the new energy-efficiency technology if:

$$u_h\left(q_h^d(\epsilon + \Delta_\epsilon)\right) - P_h q_h^d(\epsilon + \Delta_\epsilon) - G(Y) \geq u_h\left(q_h^d(\epsilon)\right) - P_h q_h^d(\epsilon),$$

where $q_h^d(\epsilon + \Delta_\epsilon)$ and $q_h^d(\epsilon)$ are the equilibrium quantities demanded with and without the new energy-efficiency technology, respectively. Furthermore, P_h is the price actually paid by the consumers, that is, $P_h = \bar{P} + \sigma(P - \bar{P})$ or $P_h = P$.

To solve the model, we need to find the marginal electricity producer (household), i.e. the producer (household) that is indifferent with regard to switching to the new technology or not. The marginal producer is denoted by $\tilde{X}$, the marginal household by $\tilde{Y}$. Since all producers (households) with a lower ranking than $\tilde{X}(\tilde{Y})$, will switch, $\tilde{X}(\tilde{Y})$ is the share of producers (households) switching. For the electricity market equilibrium, we then have:

$$\tilde{X} q_c^s(\Gamma_c - \Delta_c) + \left(1 - \tilde{X}\right) q_c^s(\Gamma_c) = \tilde{Y} q_h^d(\epsilon + \Delta_\epsilon) + \left(1 - \tilde{Y}\right) q_h^d(\epsilon).$$

Hence, we have three equations that can be used to solve for $P, \tilde{X}, \tilde{Y}$, with and without the price-support scheme.

Regarding calibration of the model, the main text describes the calibration strategy and some details (e.g. about price elasticities). Here, we provide more detail.

We need to make assumptions about the steepness of the marginal cost curves for electricity producers. Here we simply set Γ_i equal to half of the observed price. This is an ad hoc assumption, and we test the implications of assuming other values of Γ_i. Given our model specification, any strictly positive value of Γ_i implies a supply elasticity above unity, which may seem rather high. At the same time, without a strictly positive value of Γ_i, there is no room for technological improvement in our model. Table A1 shows the assumptions used in the calibration.

Table A1. Assumptions used in the calibration of the model

Price elasticity demand – households	-0.2
Price elasticity demand – business	-0.3
Ratio between Γ_c and observed price	0.5
Ratio between Γ_d and observed price	0.5

Based on the observed data in Table 2 and the assumptions in Table A1, we end up with the calibrated parameters in Table A2 (in our benchmark simulations).[2]

[2] Since our model does not include trade, there is a slight deviation between the empirical data in Table 2 and the benchmark simulation. With no trade, the price drops slightly to €36.6/MWh, with marginally higher consumption and lower generation.

Table A2 Calibrated parameters in the model

Parameters	Value
Γ_c	€18.6/MWh
Γ_d	€18.6/MWh
γ_c	€0.064/MWh
γ_d	€0.201/MWh
α_h	€1.58/MWh
α_b	€0.49/MWh
A_h	€223/MWh
A_b	€161/MWh