Prosumers

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Abstract

Prosumers are individuals or entities who act both as producers and consumers of a good or service. Examples of prosumers include but are not limited to rice farmers, electricity providers, households, and countries. We analyze the equilibrium outcomes and welfare when individuals can act as prosumers as well as effects of policies such as taxes, subsidies, and price and quantity controls.

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1   Introduction

Prosumers describe individuals or entities who act both as producers and consumers of specific goods or services. Examples of prosumers include but are not limited to: (i) farmers who produce a crop but also may leave some for own consumption and may adjust production and consumption based on market conditions (Zhou et al., 2024), (ii) households who consume electricity but also provide excess production to the network (List, Pragidis, and Price, 2024), (iii) households who decide on household production and market labor supply.

2   Model

Consider a unit mass of agents who can be producers and consumers. To start, suppose each agent can produce at most one unit and demand at most one unit. An agent is described by her cost $c \in [\underline{c}, \overline{c}]$ of producing the good and value $v \in [\underline{v}, \overline{v}]$ of consuming the good. In general, let $F(c, v)$ denote the joint CDF; assume it is atomless. The marginal distributions are $F_s(c) = F(c, \overline{v})$ and $F_b(v) = F(\overline{c}, v)$. For illustration, let us first focus our attention on the case of uniform distribution: $F(c, v) = c \cdot v$, $F_s(c) \sim Unif[0, 1]$, $F_b \sim Unif[0, 1]$. Given market price p, an type-(c, v) agent receives $v - p$ from consuming the good, $p - c$ from producing the good, and $v - c$ from doing both.

The timing of the model is as follows. First, each individual simultaneously decides her role in the society regarding production and consumption. The following are possible choices of an individual: (i) (market producer) supply to the market only: produce a unit of the good for the market without consumption; (ii) (market consumer) demand from the market only: demand a unit from the market without production; (iii) (market prosumer) supply to the market and demand from the market; (iv) (household prosumer) household production and consumption: produce and consume a unit at home without sending it to the market; and (v) (hibernator) no production or consumption.

Let $\rho_r(c, v)$ denote the probability of a type-(c, v) agent choosing role r. Without loss of generality, assume the probability is type-symmetric. Let $\rho(c, v) = (\rho_r(c, v))_r$ denote the strategy of a type-(c, v) agent. The overall population strategy is summarized by $\rho(\cdot)$.

Based on the aggregate demand and supply on the market, a uniform price p is determined and transactions occur. Goods are randomly allocated; the choice of allocation mechanism does not affect market outcome or welfare calculation since the good is homogeneous.

If there were excess demand or supply in the market, there would be individuals who

do not receive a good on the market, or individuals who are left with a good. In case an individual does not receive a good and has not produced, she can produce a good to consume. If she supplied the good to the market and has not consumed a unit, she can consume the good herself. Note that these scenarios happen when the market does not clear. For many scenarios, market clears in equilibrium, so these scenarios do not happen and need not be considered.[1]

Let $\rho(c, v)$ describe the population strategy of type-(c, v) agents. We focus on the rational expectations equilibrium $(p^*, \rho^*(\cdot))$ in which (i) p^* is the equilibrium price given market demand and supply calculated based on $\rho^*(\cdot)$ and (ii) ρ^* is payoff-maximizing given market price p^*.

3   Equilibrium analysis

3.1   Benchmark equilibrium

First, consider the competitive equilibrium. Fix a market price p and suppose market clears so that there is no excess market supply or excess market demand (which will happen in equilibrium). An agent produces and consumes if

$$p - c > 0 \text{ and } v - p > 0 \Rightarrow c < p \text{ and } v > p. \qquad \text{(prosumer)}$$

Note that in the current benchmark setting, there is no strict difference between (i) being a market prosumer (supplying to the market and demanding from the market) and (ii) being a household prosumer (producing a unit and consuming it). Equilibrium price will not be affected by how individuals choose between these two options, since market will balance. An agent only produces and does not consume if

$$p - c > 0 \text{ and } v - p < 0 \Rightarrow c < p \text{ and } v < p. \qquad \text{(producer)}$$

An agent does not produce and only consumes if

$$p - c < 0 \text{ and } v - p > 0 \Rightarrow c > p \text{ and } v > p. \qquad \text{(consumer)}$$

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[1]We do not need to expand the choice possibility sets to accommodate these "second-period" choices. They are aftermaths of choosing to supply to the market and/or demand from the market.

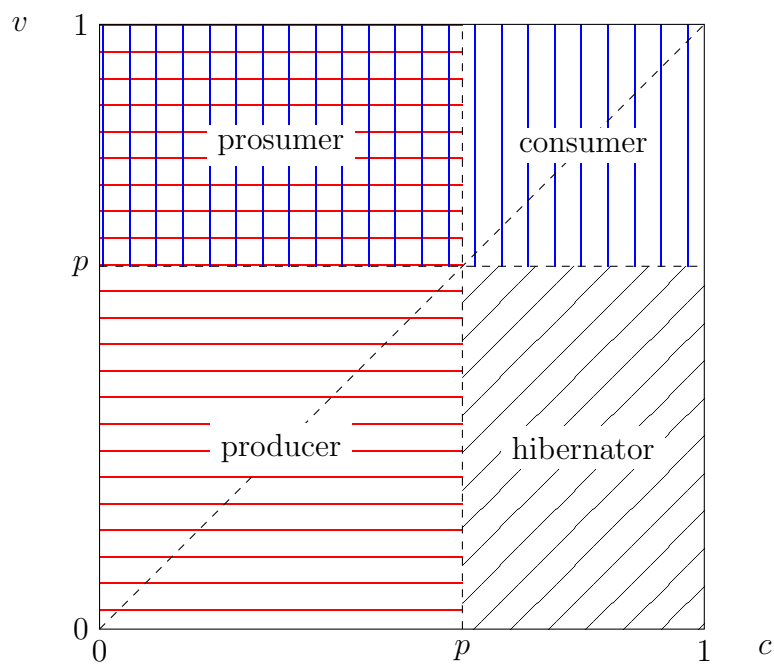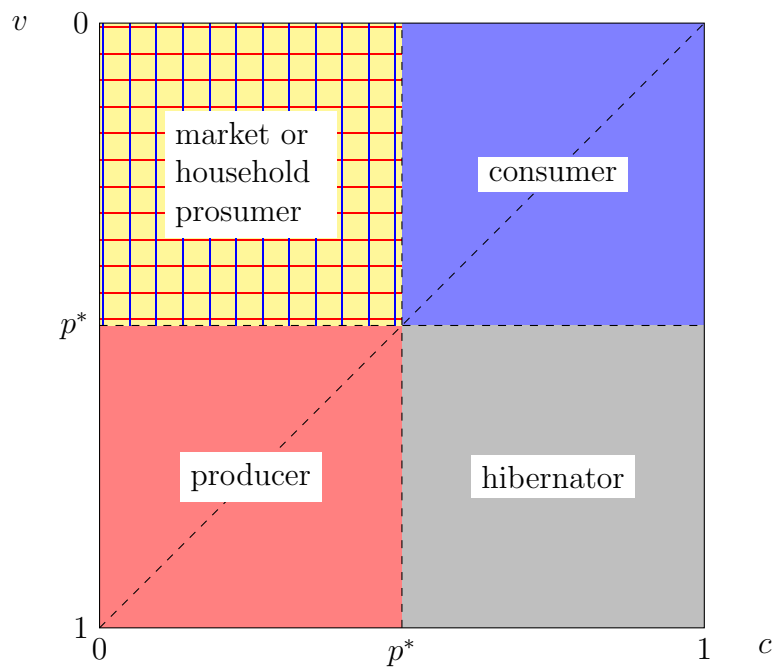Figure 1: Production and consumption decisions in the benchmark model

Figure 2: Equilibrium in the benchmark model

An agent neither produces nor consumes if

$$p - c < 0 \text{ and } v - p < 0 \Rightarrow c > p \text{ and } v < p. \qquad \text{(hibernator)}$$

We illustrate these roles in the two-dimensional c-v plane.

Equilibrium price is determined by supply and demand. We can construct market supply and demand curves:

$$S(p) = p^2$$

and

$$D(p) = (1 - p)^2$$

The price that equates market quantity demanded and market quantity supplied is

$$D(p^*) = S(p^*) \Rightarrow p^* = 1/2.$$

3.2 Taxes

3.2.1 Producer tax

Suppose there is a tax $\tau > 0$ on goods supplied to the market, but not on goods produced and consumed at home.

Because $\tau > 0$, any prosumer will strictly prefer to be a household prosumer who produces and consumes $(v - c)$ to a market prosumer who supplies to and consumes from the market (payoff $v - p - p - c - \tau = v - c - \tau$). Given market price p, an agent chooses to be a prosumer if it is better than

$$\text{hibernating: } v - c > 0$$
$$\text{producing: } v - c > p - c - \tau \Rightarrow v > p - \tau$$
$$\text{consuming: } v - c > v - p \Rightarrow c < p$$

Equilibrium price is determined by

$$S(p) = (p - \tau)^2$$

and

$$D(p) = (1 - p)^2.$$

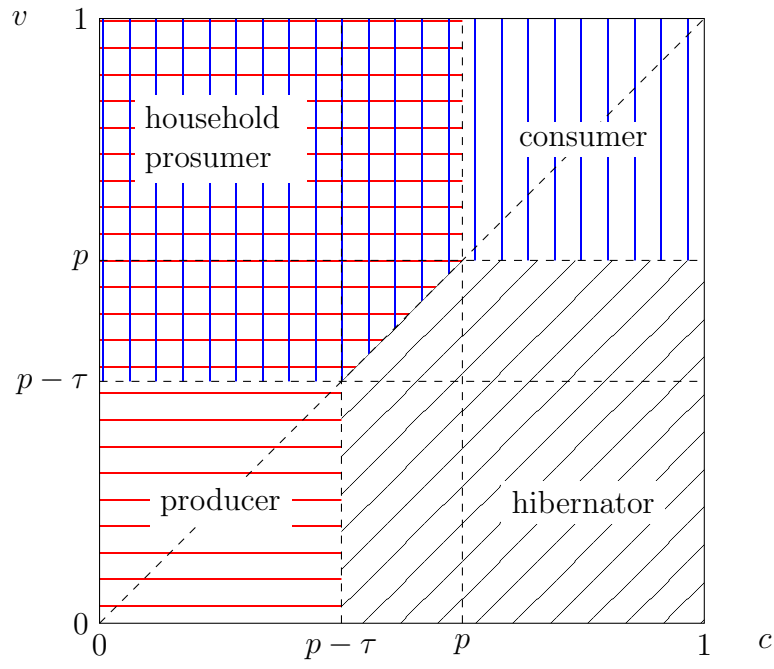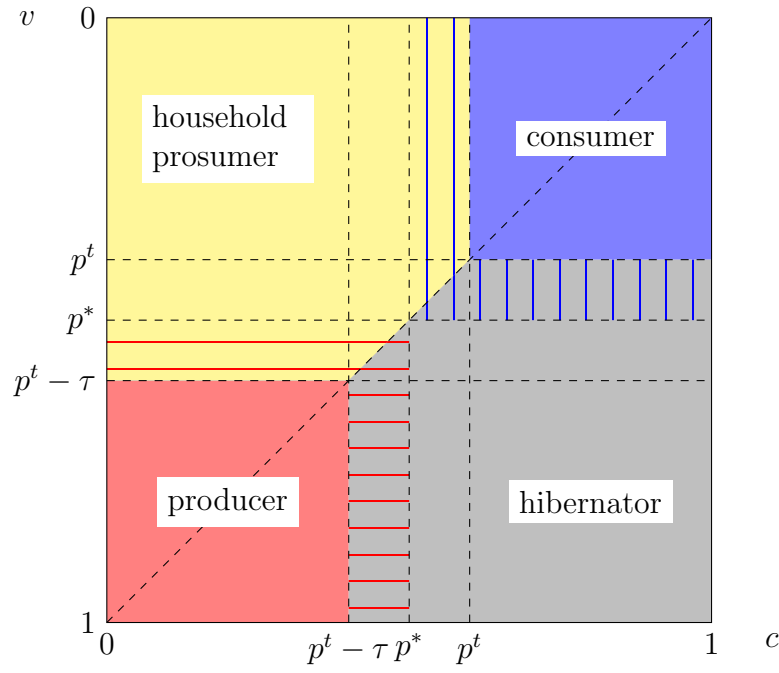Figure 3: Production and consumption decisions with producer tax

Figure 4: Equilibrium with producer tax versus benchmark equilibrium

Hence, $p^t = (1 + \tau)/2$.

3.3 Subsidies

Suppose producers are given a subsidy σ on goods transacted on the market.

Every prosumer prefers being on the market to being a household prosumer. Given price p, an agent chooses to be a prosumer if it is better than

$$\text{hibernating: } v - c + \sigma > 0$$
$$\text{producing: } v - c + \sigma > p - c + \sigma \Rightarrow v > p$$
$$\text{consuming: } v - c + \sigma > v - p \Rightarrow c < p + \sigma$$

The latter two inequalities imply the first one, so an agent is a prosumer if $v > p$ and $c < p + \sigma$.

3.4 Price controls

Suppose there is a price ceiling $\bar{p} < p^*$. There will be strictly more demand and strictly more supply than in competitive equilibrium. Hence, there will always be excess demand, and goods need to be allocated by rationing among willing consumers.

3.5 Quantity controls

TBA

4 Welfare analysis

Figure 5: Production and consumption decisions with producer subsidy
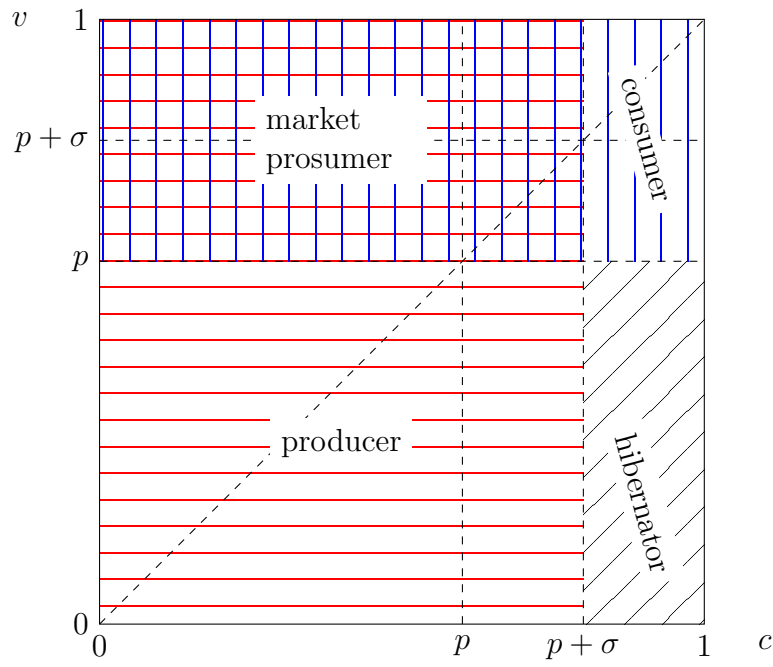

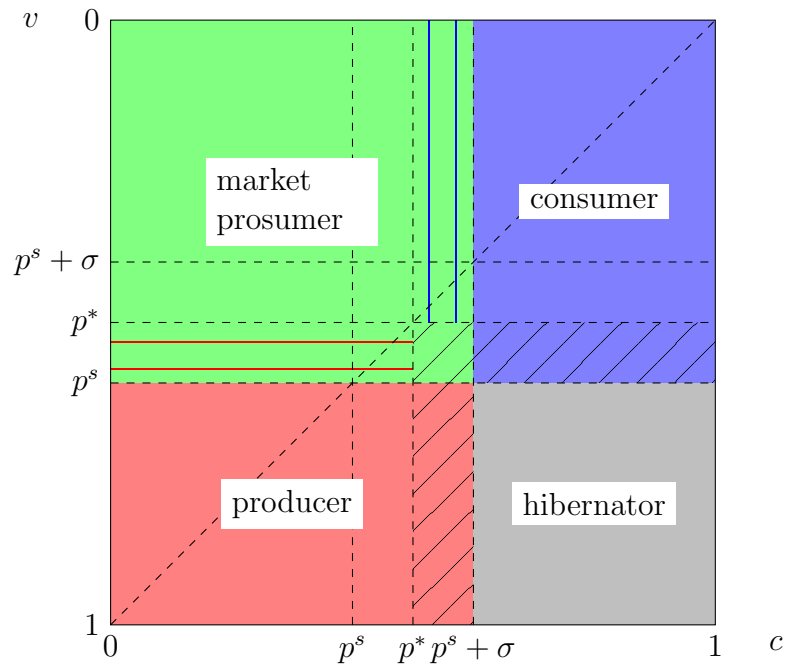Figure 6: Equilibrium with producer subsidy versus benchmark equilibrium

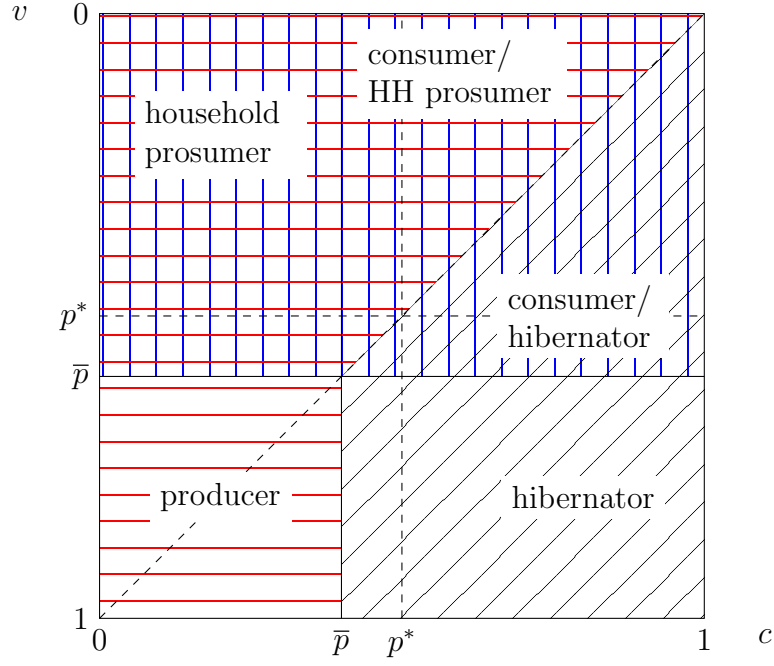Figure 7: Production and consumption decisions with price ceiling
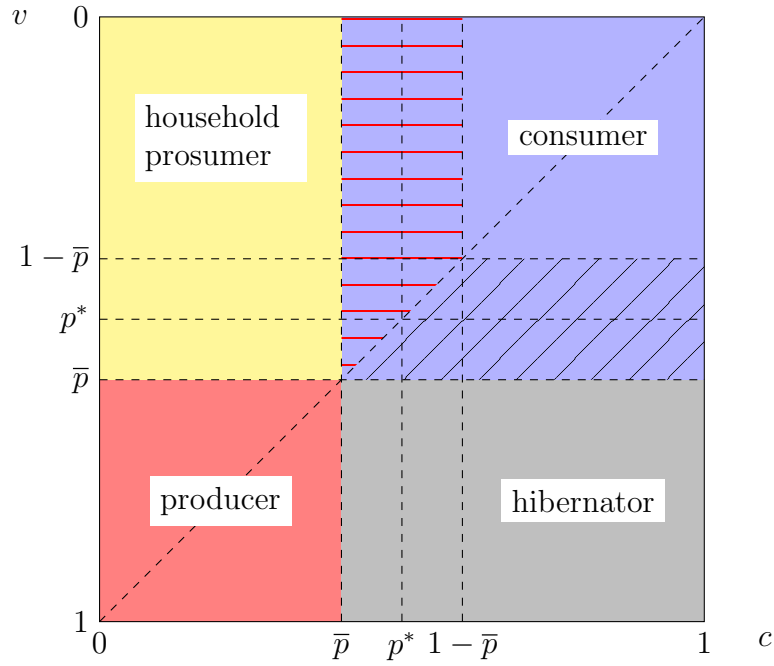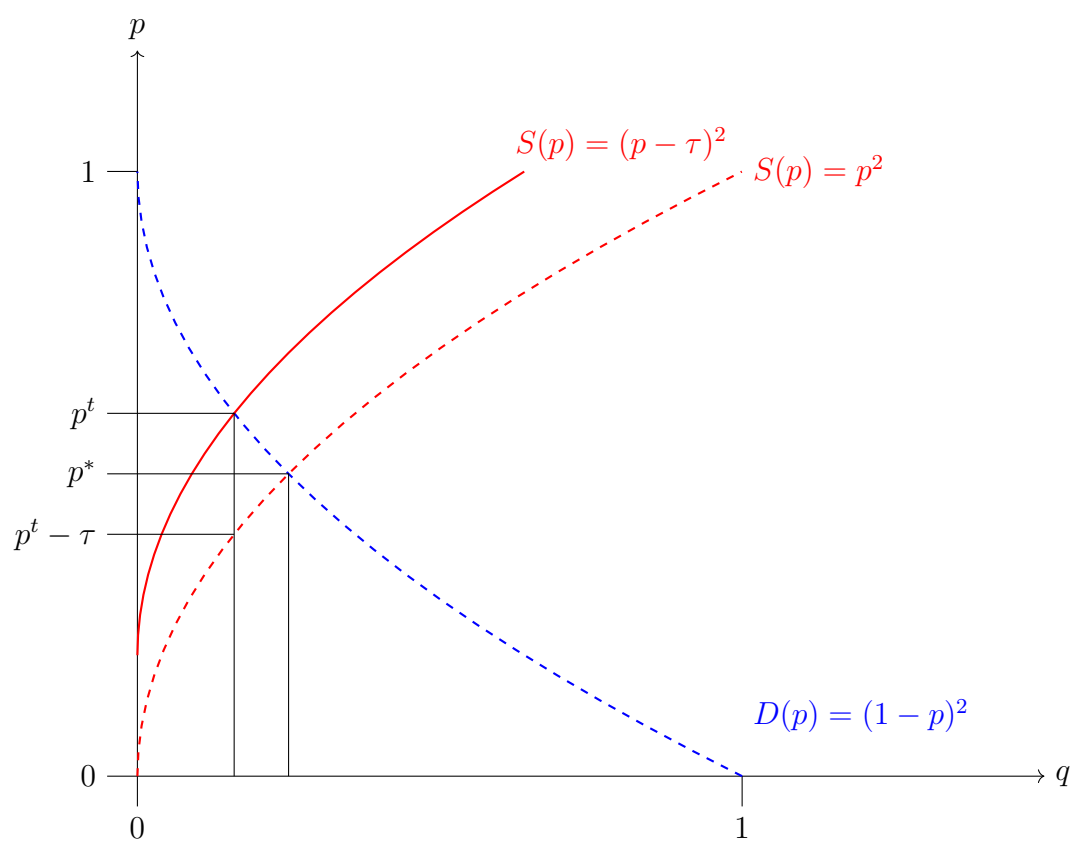

Figure 8: An equilibrium with price ceiling $\overline{p} < p^*$

Figure 9: Supply and demand with production tax τ

p

1

$S(p) = (p - \tau)^2$

$S(p) = p^2$

p^t

p^*

$p^t - \tau$

$D(p) = (1 - p)^2$

0

0

1

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References

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