Efficiency Gap and Optimal Energy Conservation Incentives

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Outline

- **Motivation**
- Model
- Optimal incentives
  & no internalization (policy and market failure)
  & (perfect) internalization (only market failure)
- Examples
- Final remarks

Model - Assumptions

- Consumers benefit from services (e.g. miles driven), $s = e\eta$,

ex post $w(\eta, p) := \max_e [u(e\eta) - ep] \Longrightarrow w_\eta = u'e > 0, \quad e = E(\eta, p) : u' = \frac{p}{\eta}.$

ex ante $\max_\eta W := tw(\eta, p) - K(\eta). \quad \eta_0(t) : tw' = K' \Longrightarrow \frac{p}{1-\alpha} = -\frac{K'/t}{E'}.$

- Distortions 1. **payback gap** (market failure), $t := \int_0^L \exp(-\rho x)dx, \; t \in [\underline{t}, \bar{t}]$
  is private information
  2. **too low energy price**, $p = c$ (policy failure)
- A benevolent & paternalistic government designs conservation: efficiencies $\eta \geq \eta_0$ are backed up by subsidies z that maximize the expected (with respect to the distribution F of the types t) NPV of social surplus (accounting for external costs d and costs of public funds δ).

Remarks about payback gap

- The existence of a payback gap is crucial for conservation programs, in particular if government corrects its failure
- But questionable
  Görlich and Wirl (2012) on cars & Hunt and Michael Greenstone (2017) find no evidence on informational and behavioral failures
- Short payback times can be compatible with fully rational agents if the planning horizon is short (or highly uncertain)
- Hayek (1945) "*... an economic actor on average knows better the environment in which he is acting and the probable consequences of his actions than does an outsider, no matter how clever the outsider may be*"

No internalization of external costs

$$\max_{\{\eta(t)\geq\eta_0(t),\ z(t)\}} \int_{\underline{t}}^{\bar{t}} \bar{t}\left\{\left[w\left(\eta\left(t\right)\right) - dE\left(\eta\left(t\right)\right)\right] - K\left(\eta\left(t\right)\right) - \delta z\left(t\right)\right\} dF\left(t\right).$$

$$U\left(t\right) := U\left(t,t\right) > U\left(\hat{t},t\right) := tw\left(\eta\left(\hat{t}\right)\right) - K\left(\eta\left(\hat{t}\right)\right) + z\left(\hat{t}\right),\ \forall t,\hat{t}\in\left[\underline{t},\bar{t}\right]$$ **IC**

$$U\left(t\right) \geq U_0\left(t\right)\ \forall t\in\left[\underline{t},\bar{t}\right]$$ **IR**

$$\max_{\eta\geq\eta_0} \int_{\underline{t}}^{\bar{t}} \bar{t}\left[w\left(\eta\right) - dE\left(\eta\right)\right] - K\left(\eta\right) + \delta\left[tw\left(\eta\right) - K\left(\eta\right) - U\right] dF,$$

$$\dot{U} = w\left(\eta\right),$$ **IC**

$$U \geq U_0 = tw\left(\eta_0\right) - K\left(\eta_0\right)\ \forall t\in\left[\underline{t},\bar{t}\right].$$ **IR**

Optimal program – no internalization

Subsidize energy efficiency upgrades for all, $\eta(t) > \eta_0(t) \forall t$ based on the trade off

in terms of kWh: $$-\frac{1+\delta}{T}\frac{K'}{E'} = -\frac{w'}{E'} + \frac{\bar{t}}{T}d.$$

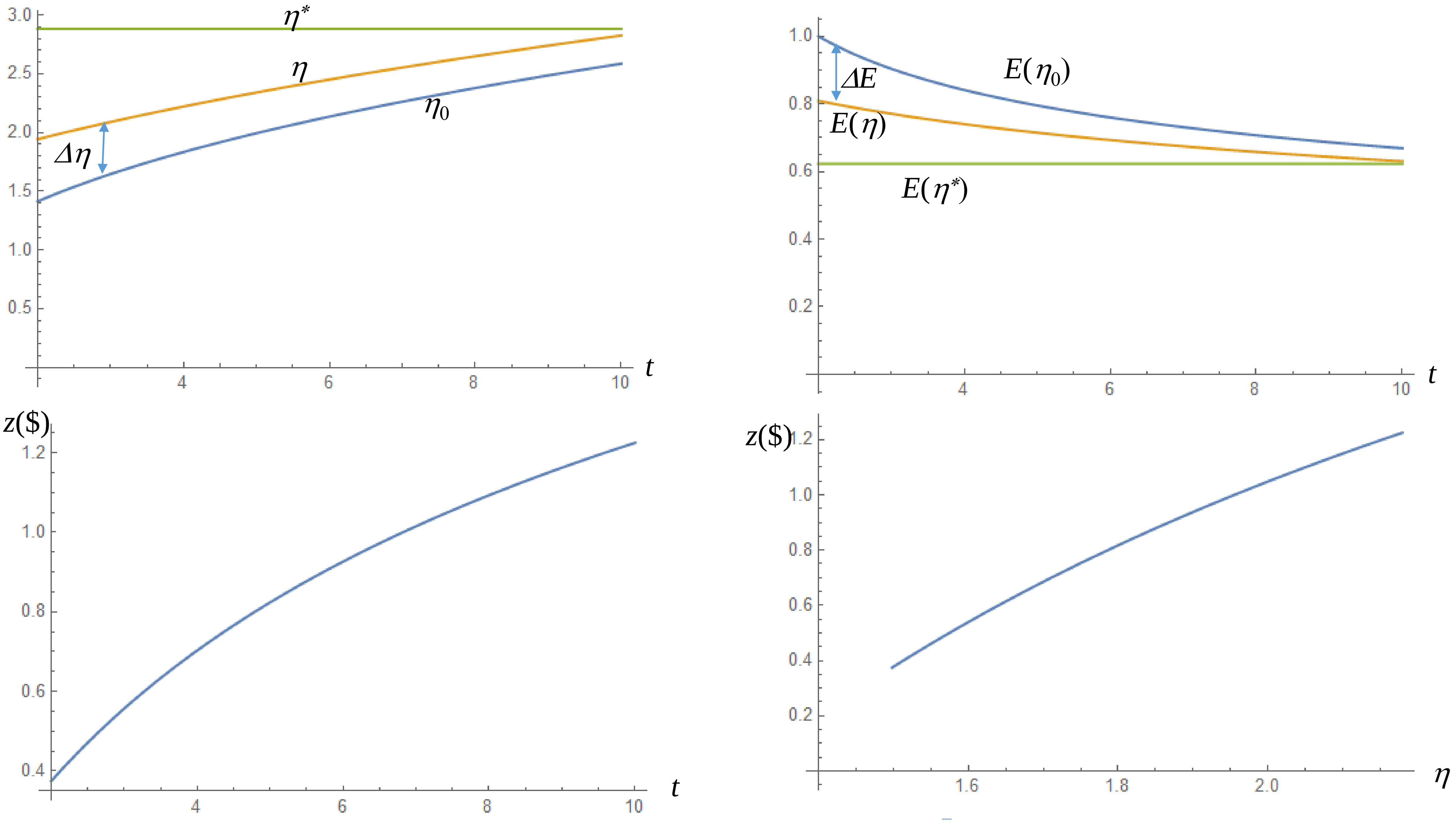
the annuity of investment into a last 'negawatt-hour' based on the government's implicit payback time:

$$\frac{T}{1+\delta} < \bar{t} \text{ for } t < \bar{t}.$$

$$T(t,\delta) := \bar{t} + \delta\left(t - \frac{1}{h}\right)$$

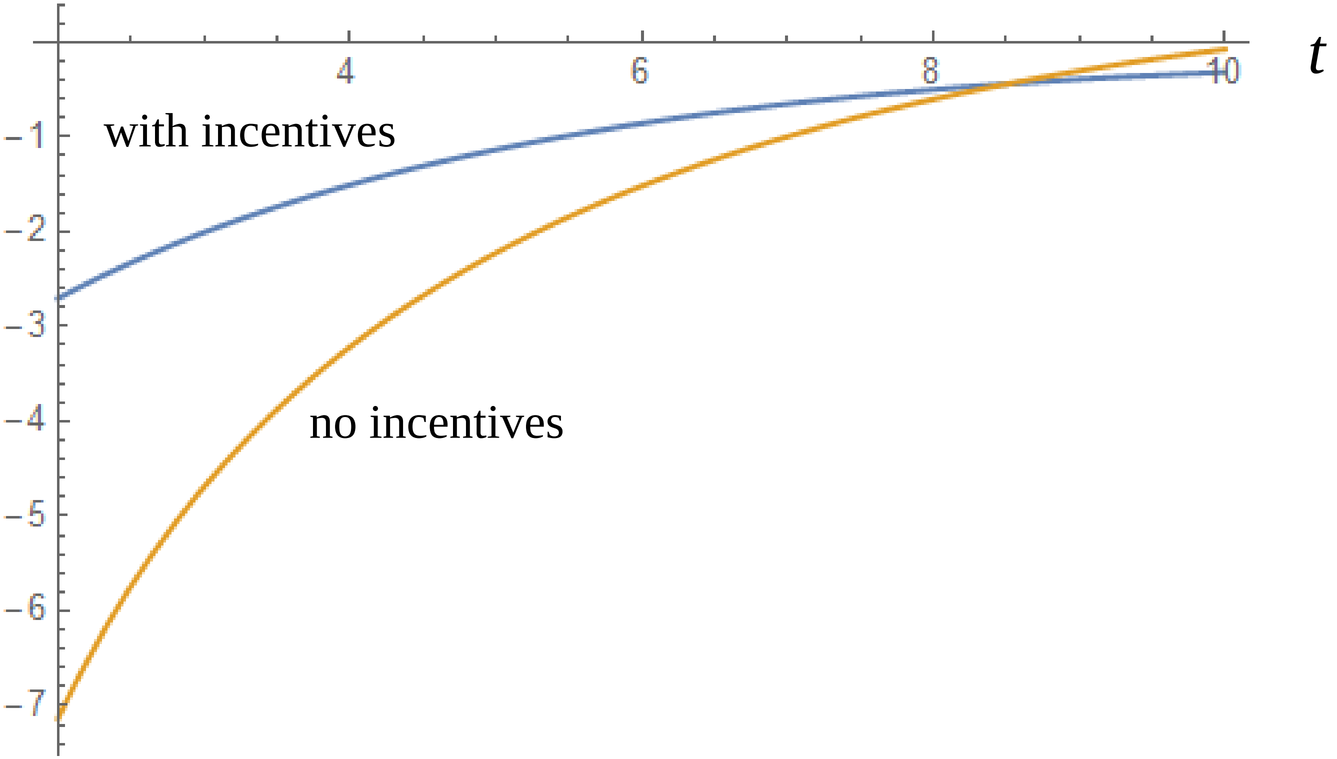
marginal consumer surplus from this reduction by one kWh (-w'/E') plus the associated reduction in external costs (dt/T).

Higher types are asked to choose higher efficiencies and receive larger subsidies.



Optimal conservation program, $A = 1,\ \theta = 3,\ \underline{t} = 2,\ t = 10,\ \delta = ½,\ d = 1,\ u_0 = 22^{1/4}$

Government's payoff with respect to types with and without incentives



Example: $A = 1$, $\theta = 3$, $\underline{t} = 2$, $t = 10$, $\delta = ½$, $d = 1$, $u_0 = 22^{1/4}$

Internalizing the external costs

Assumptions: Pigouvian tax, $\tau = d$ => consumers pay $c + d$, but are reimbursed for the average tax payment by lump sum transfers. ~s identify this case:

$$\tilde{\omega}(\eta) := \max_{e}\left[u(e\eta) - (c+d)e\right] \Longrightarrow e = \tilde{E}(\eta) : u'\eta = c + d.$$

As a consequence, $\eta_0(t) < \tilde{\eta}_0(t) : t\tilde{\omega}' - K' = 0.$

and: $\tilde{\eta}_0(\bar{t}) > \eta(\bar{t})$ *the efficiencies chosen by high types exceed the subsidized ones but absent internalization (characterized in Proposition1) even at low costs of public funds. In fact, the most efficient type chooses already the first best policy.*

Definition: total energy after conservation

$$\bar{\varepsilon} := \int_{\underline{t}}^{\bar{t}} \tilde{E}(\tilde{\eta}(t))\, dF(t).$$

The optimization problem – non-standard

$$\max_{\{\tilde{\eta}(t)\geq\tilde{\eta}_0(t),\ \tilde{z}(t)\}} \int_{\underline{t}}^{\bar{t}} \{\bar{t}\tilde{w}(\tilde{\eta}(t)) - K(\tilde{\eta}(t)) - \delta\tilde{z}(t)\}\, dF(t), \qquad (30)$$

subject to

$$U(t) := U(t,t) > U(\hat{t},t) := t\left[\tilde{w}(\tilde{\eta}(\hat{t})) + \bar{e}d\right] - K(\tilde{\eta}(\hat{t})) + \tilde{z}(\hat{t}) \qquad (31)$$

$$U(t) \geq t\left[w(\tilde{\eta}_0(t)) + \bar{e}d\right] - K(\tilde{\eta}_0(t)) \ \ \forall t \in [\underline{t}, \bar{t}]. \qquad (32)$$

$$\max_{\{\tilde{\eta}\geq\tilde{\eta}_0\}} \int_{\underline{t}}^{\bar{t}} \{\bar{t}\tilde{w} - K + \delta\left[t(\tilde{w} + \bar{e}d) - K - U\right]\}\, dF$$

$$\dot{U} = \tilde{w} + \bar{e}d = \tilde{w} + d\int_{\underline{t}}^{\bar{t}} \tilde{E}(\tilde{\eta}(s))\, dF(s)$$

IC

$$U(t) \geq U_0 := t\left[\tilde{w}(\tilde{\eta}_0(t)) + d\int_{\underline{t}}^{\bar{t}} \tilde{E}(\tilde{\eta}(s))\, dF(s)\right] - K(\tilde{\eta}_0(t))$$

IR

Optimal Programme

In the interior the choice of efficiency η^i will be based on the trade-off:

$$\tilde{\eta}^i : \tilde{w}' = \frac{K'}{\frac{T}{1+\delta}} - \frac{E_t}{T}\delta d\tilde{E}'$$

optimal: $\tilde{\eta}(t) = \max\left\{\tilde{\eta}^i(t), \tilde{\eta}_0(t)\right\}$

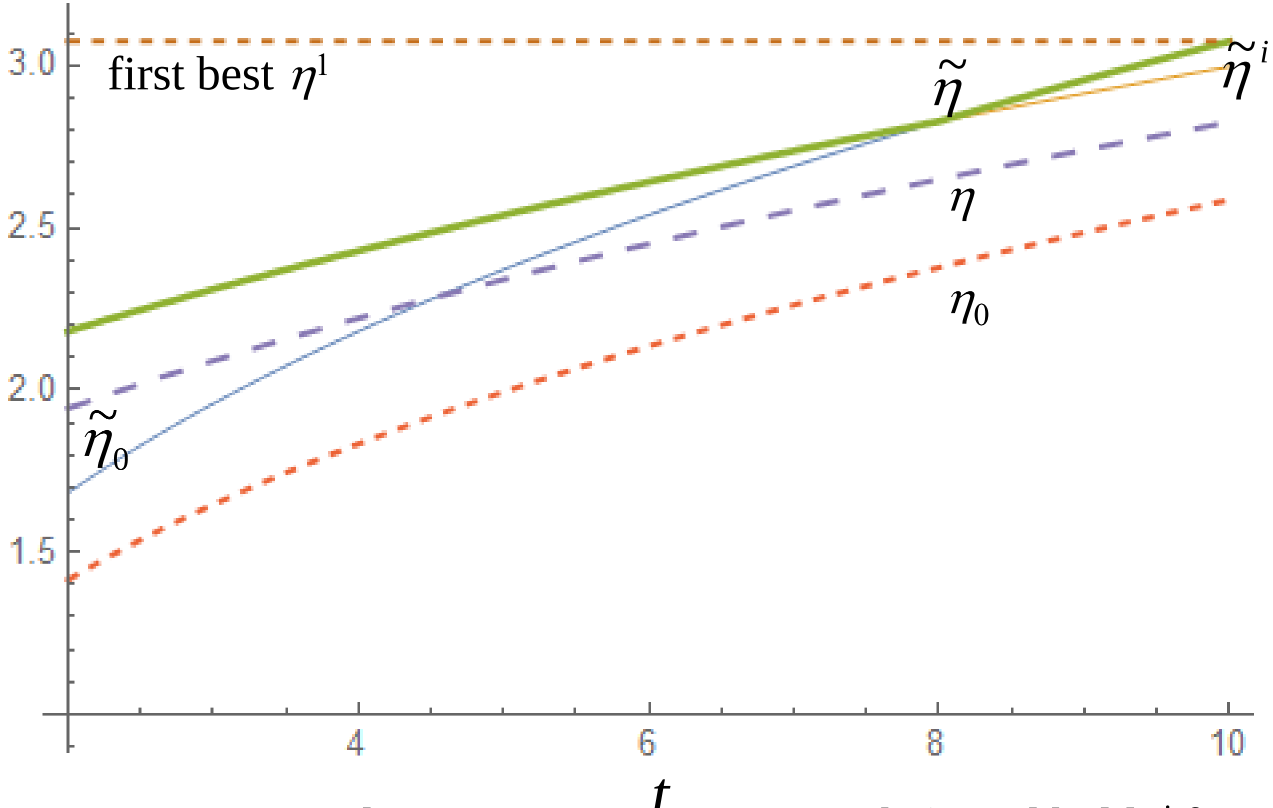
The conservation program yields inevitably a loss of social welfare for the efficient types, who collect the highest subsidies for small or no upgrades at all.

Indeed, incentives are only offered iff $\frac{h}{\delta} \geq \frac{1}{\bar{t} - t}$

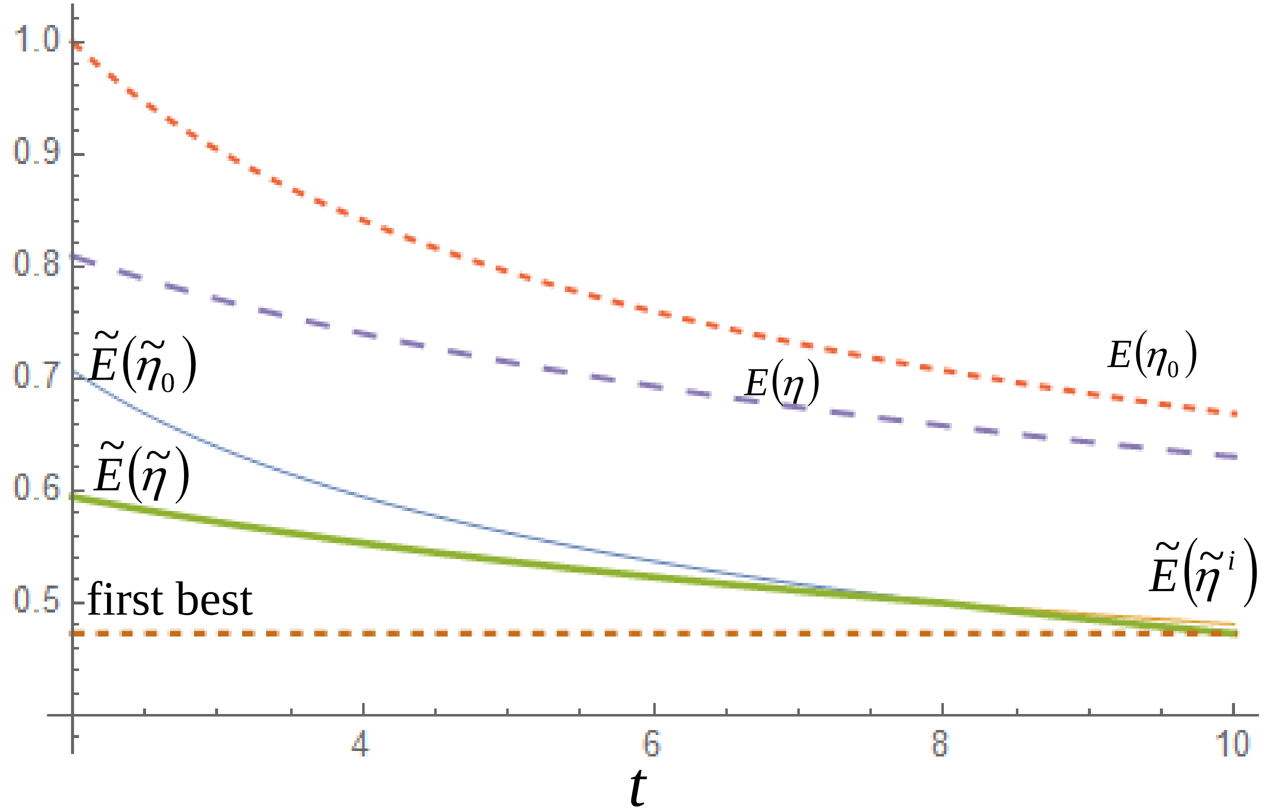
Therefore, no subsidies if t uniform and $\delta > 1$, no matter how large the payback gap.

Optimal conservation program with (~) and without internalized external costs

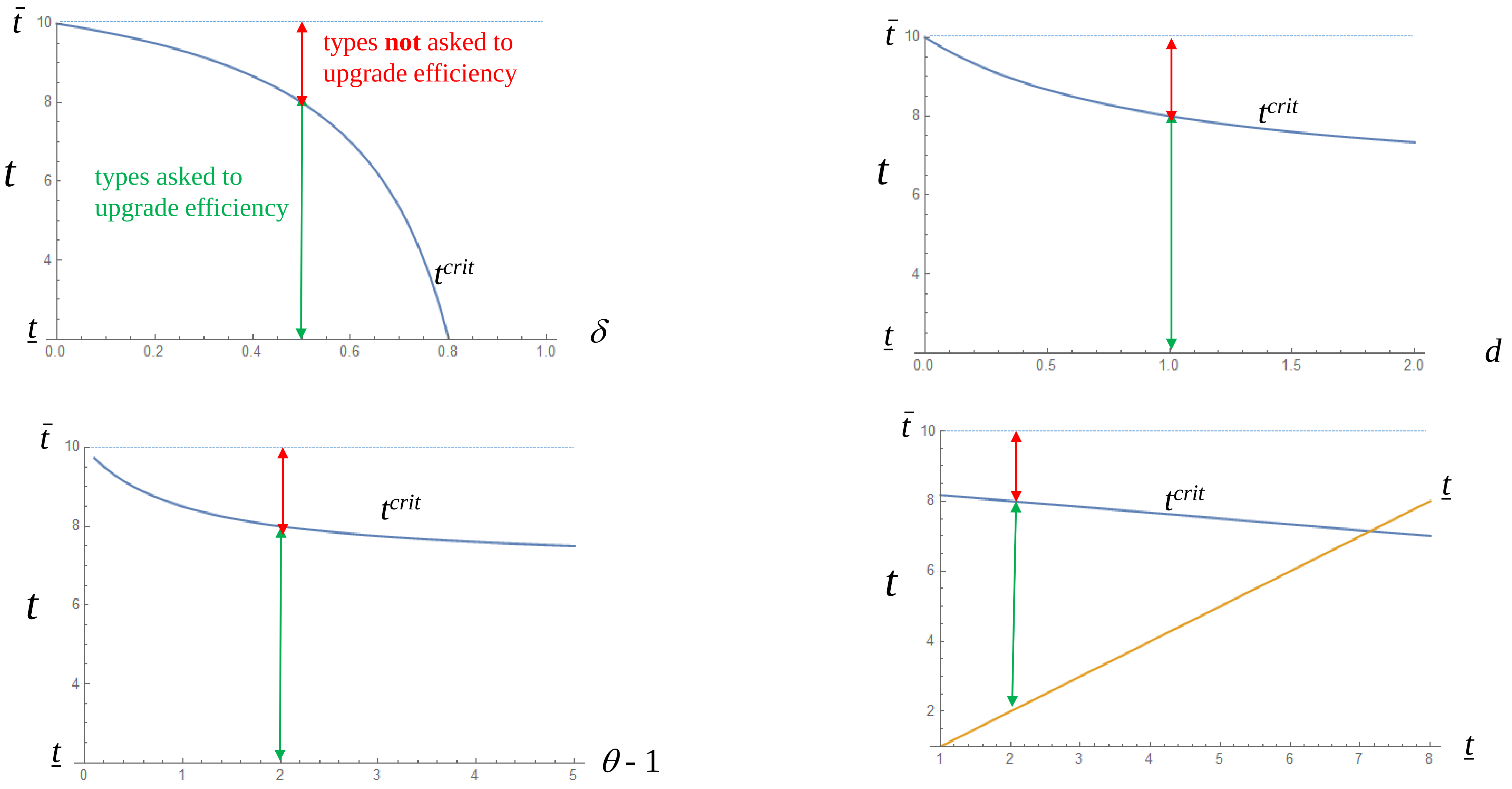
Efficiencies



Energy



Optimal conservation program with (~ and bold, ^{i} for interior solution) and without (dashing) internalized external costs, $A = 1$, $\theta = 3$, $\underline{t} = 2$, $t = 10$, $\delta = ½$, $d = 1$, $u_0 = 22^{1/4}$.



External costs are internalized: Sensitivity of t^{crit} for parameter variations around the reference case; only types $t < t^{crit}$ are asked to upgrade their efficiency as indicated by the arrows located at the reference parameters (from Figs. 1-3).

Concluding Remarks

- Only a fraction of the usually reported conservation potential will be realized if the recipients of incentives hold private information.
- It makes **no** sense to pay high subsidies to inefficient types = those with the highest conservation potential.
- However, efficient types deliver little or no (in the case of internalization) conservation => little conservation for € invested.
  This negative finding applies to many real world incentives in place.
- Given the policy failure, it is awkward to delegate conservation to such a failing government (but handing over to utilities is even worse, *butchers selling fish*).
- Actually the situation is much worse as current policy instruments
  - Joint Implementation, the Clean Development Mechanism,
  - energy conservation across the board, white certificates.
  - electric cars
  do not even try to deter cheating. **Therefore, most conservations exist only on paper.**
- Elias Canetti (Souks of Marrakesh).

Thank You for Your Attention!

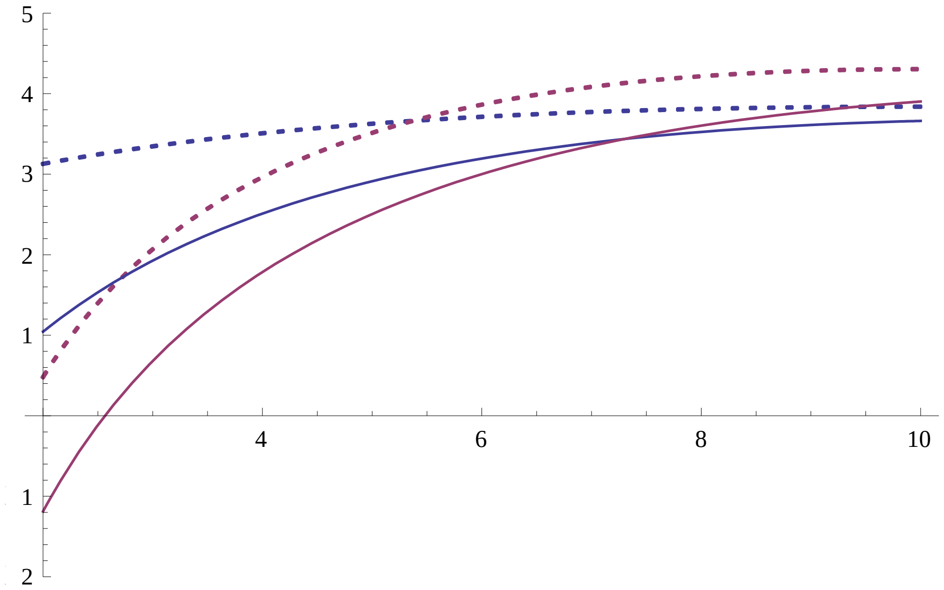
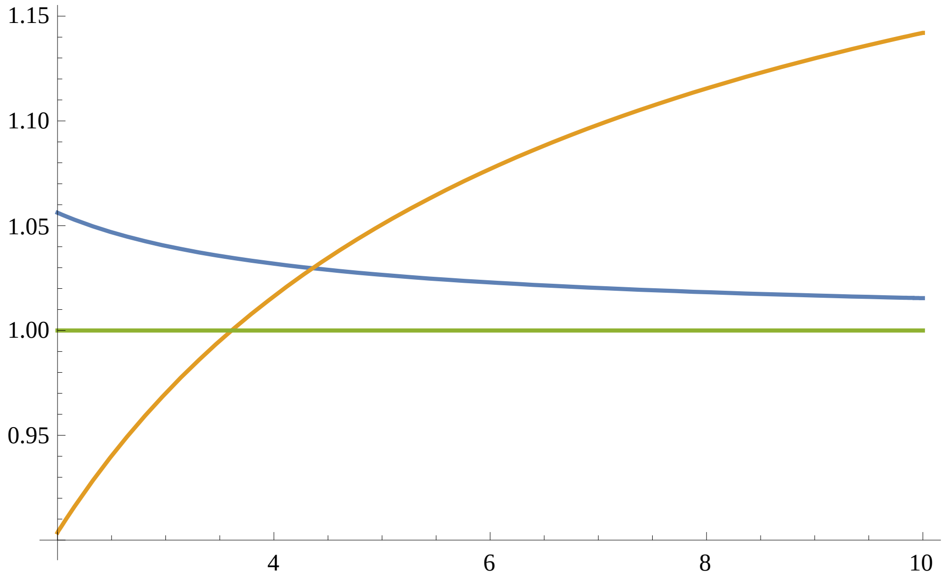


Fig. 2: Social surplus contingent on the agent type with and without conservation program, with and without internalization.

$$\text{"Parameters: "}\left\{A \to 1, g \to 2, a \to 2, b \to 10, k \to 2, m \to \frac{1}{2}, d \to 0.5, \mathrm{u0} \to 22^{1/4}, \mathrm{ebar} \to 0.7067720586076311\right\}$$



$$\text{Plot}\left[\begin{Bmatrix}\text{eratio}/.\{A \to 1, g \to 2, a \to 2, b \to 10, k \to 2, d \to 0.1, m \to .9\}, \\ \text{eratio}/.\{A \to 1, g \to 2, a \to 2, b \to 10, k \to 2, d \to 2, m \to .9\}, 1\end{Bmatrix}\right]$$

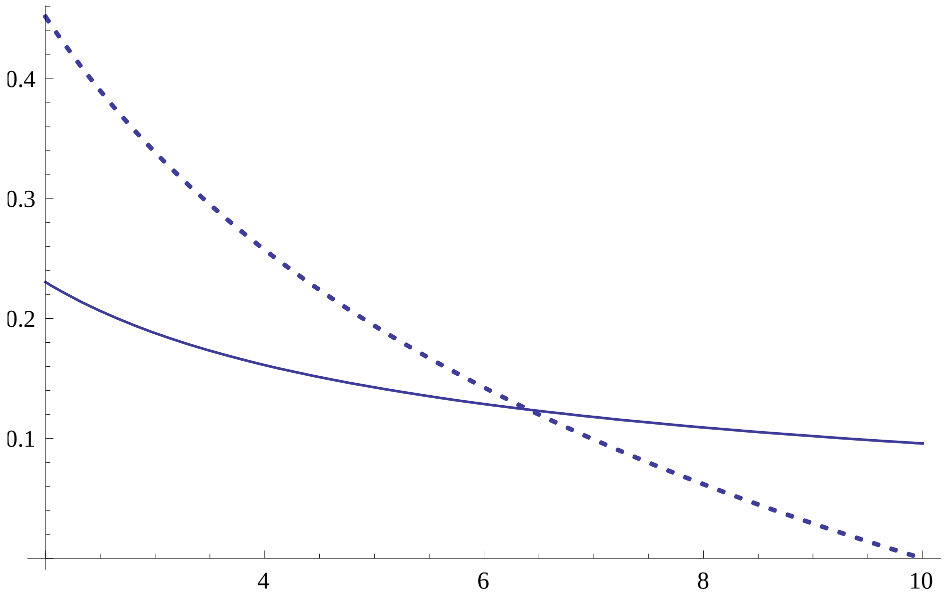
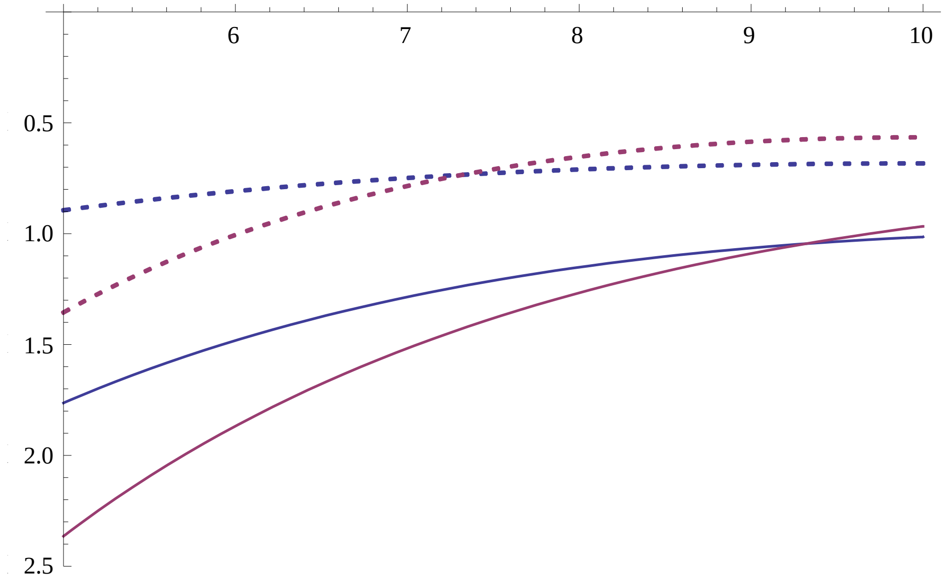


Fig. 4: Efficiency upgrades vs types

$$\text{"Parameters: "}\left\{A \to 1, g \to 2, a \to 2, b \to 10, k \to 2, m \to \frac{1}{2}, d \to 0.5, \mathrm{u0} \to 22^{1/4}, \mathrm{ebar} \to 0.7067720586076311\right\}$$



$$\left\{A \to 1, g \to 2, a \to 2, b \to 10, k \to 2, m \to \frac{1}{2}, d \to 0.5\right\}$$