Breaking the Efficiency–Environment Trade-off: The Role of Fiscal Policies, Market Power, and Responsible Consumers

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SIEP Conference 2025

Boosting and Enhancing YOungs' Next generation awareness for E.S.G. values Development

Co-funded by the European Union

Call 2024 Round 1 KA2 KA220-HED
Cooperation partnerships in higher education
Project: 2024-1-IT02-KA220-HED-000251303

Motivation

Growth vs. sustainability trade-off	Balancing economic performance with environmental quality is a core challenge (eg debate within EU on the timing of green transition)
Market power & innovation	Large firms may innovate but also reduce competition and reduce incentives for innovations which could be beneficial for green transition.
Role of responsible consumers	Consumer environmental preferences may shape firm incentives.

Research Questions

Market power & sustainability?

- Does concentration help or harm environmental outcomes?

Effective fiscal instruments?

- Which policies mitigate the trade-offs most effectively?

Impact of consumer concern?

- How do SR consumers affect production, abatement, and profits?

Contributions

Dynamic Cournot model with abatement

- Firms decide output and pollution abatement dynamically

Endogenous firm entry (second part of the paper)

- Entry depends on firm value relative to fixed entry costs.

Interaction with consumers & fiscal instruments

- Environmental preferences amplify or mitigate policy effects.

New trade-off

- Green technology diffusion vs. rising concentration.

Related Literature I: Market Power, Growth & Environment

- **Market power & growth**: rising concentration reduces productivity & wages (De Loecker & Eeckhout, 2018; Syverson, 2019).
- **Endogenous growth & rents**: innovation requires some monopoly power (Schumpeter, 1942; Romer, 1990; Grossman & Helpman, 1994; Aghion & Howitt, 1992).
- **Competitive innovation**: innovation can also thrive under competition, excessive market power may slow diffusion (Boldrin & Levine, 2009).

- **Market structure & environment**: imperfect competition can hinder or stimulate innovation (Montero, 2002).
- **Directed technical change**: policy steers clean vs. dirty innovation (Acemoglu et al., 2012).
- **Empirics**: more competition fosters green innovation, market power worsens outcomes (Calel & Dechezleprêtre, 2012; Nesta et al., 2012, 2018; Aghion et al., 2023).

Related Literature II: Policies, Consumers & Entry

- **Environmental taxes & subsidies**: double dividend debated (Fullerton & Metcalf, 1997; Goulder & Parry, 2008).
- **Subsidies vs. taxes**: well-designed subsidies break trade-off better than pollution taxes (Renström, Spataro & Marsiliani, 2021).
- **Policy design matters**: fixed subsidies less distortive; premium/market-based may reinforce market power (Bohland & Schwenen, 2020; Barwick et al., 2024).
- **Consumer behavior**: social pressure & norms drive CSR and abatement (Baron, 2009; Nyborg et al., 2016); environmental preferences enhance green innovation (Aghion et al., 2020).
- **Market entry**: heterogeneous firms & barriers shape productivity (Melitz, 2003); extended to green competition (Growiec & Schumacher, 2020).

Model Setup (fixed N)

Firm objective. Maximize present value of profits:

$$\max V_i = \int_0^{\infty} e^{-rt} \pi_i(t) dt \quad \text{with:}$$

$$\pi_i(t) = P(Q(t), E(t))Q_i(t) - C\big(A_i(t)\big) - C\big(I_i(t)\big) - T(t)E_i(t)$$

Demand: negative linear function of total output $Q(t)$ and of "perceived emissions" $\gamma E(t)$:

$$P = P_0 - \beta Q(t) - \gamma E(t)$$

with $\gamma E(t) = \gamma \sum_{i=1}^{N} E_i(t)$ total net emissions as perceived by consumers.

Net Emissions: Proportional to production and limited by the abatement activity.

$$E_i(t) = \phi\big(1 - A_i(t)\big)Q_i(t)$$

with $\phi Q_i(t)$ unabated emissions, $(\phi > 0)$, $\phi A_i(t) Q_i(t)$ abated emissions.

Production: Output is produced according to the following technology:

$$Q_i(t) = K_i^{\alpha_K}(t)$$

with $\alpha_K \in (0,1)$ the output elasticity with respect to installed capital in firm *i*, K_i.

Costs and capital accumulation

Abatement cost is quadratic with respect to abatement per unit of abated emission:

$$C\big(A_i(t)\big) = (1 - S_A)\phi A_i(t)Q_i(t)\left(1 + \frac{\delta_A}{2}\frac{\phi A_i(t)Q_i(t)}{\phi Q_i(t)}\right) = (1 - S_A)\phi A_i(t)Q_i(t)\left(1 + \frac{\delta_A}{2}A_i(t)\right)$$

S_A is subsidy on abatement costs and $\delta_A > 0$ is the “marginal” abatement cost.

investment cost in physical capital is quadratic

$$C\big(I_i(t)\big) = (1 - S)p_k I(t)\left(1 + \frac{\epsilon}{2}\frac{I_i(t)}{K_i(t)}\right)$$

where S is a public subsidy on investment.

Each firm’s physical capital accumulates according to the following dynamic law:

$$\dot{K}_i(t) = I_i(t) - \delta K_i(t)$$

with $\delta > 0$ instantaneous capital depreciation rate. T is the tax on emissions.

Focs for firm i

- $\frac{\partial H(t)}{\partial I_i(t)} = (1-S)p_k\left[1+\epsilon\frac{I_i(t)}{K_i(t)}\right] - \lambda(t) = 0 \Longrightarrow \lambda(t) = (1-S)p_k\left[1+\epsilon\frac{I_i(t)}{K_i(t)}\right]$

so that $I_i(t) = \frac{K_i(t)}{\epsilon}\left[\frac{\lambda(t)}{(1-S)p_k} - 1\right]$

- $\dot{K}_i(t) = I_i(t) - \delta K_i$
- $\dot{\lambda}(t) = r\lambda(t) - \frac{\partial H(t)}{\partial K_i(t)}$

- $\frac{\partial H(t)}{\partial A_i(t)} = \left[\frac{\partial P(t)}{\partial E(t)}\frac{\partial E(t)}{\partial E_i(t)}Q_i(t) - T(t)\right]\frac{\partial E_i(t)}{\partial A_i(t)} - \frac{\partial C\left(A_i(t)\right)}{\partial A_i(t)} = 0 \Longrightarrow$

- so that: $A_i(t) = \frac{\frac{[\gamma Q_i(t)+T(t)]}{(1-S_A)} - 1}{\delta_A}, \in (0,1)$

Dynamic system

- $\dot{\lambda} = -\frac{1}{2\epsilon}\frac{\lambda^2}{(1-S)p_k} + \left(r + \delta + \frac{1}{\epsilon}\right)\lambda - (1-S)p_k\frac{1}{2\epsilon} - \alpha_K\left[\left\{P_0 - T\phi + \phi\frac{[T-(1-S_A)]^2}{2(1-S_A)\delta_A}\right\}\frac{Q_i}{K_i} - (N+1)\left[\beta + \gamma\phi\frac{(1-S_A)(\delta_A+1)-T}{(1-S_A)\delta_A}\right]\frac{Q_i}{K_i}^2 + \frac{\gamma^2\phi}{(1-S_A)\delta_A}\left(N+\frac{1}{2}\right)\frac{Q_i}{K_i}^3\right]$
- $\dot{K}_i = \left\{\frac{1}{\epsilon}\left[\frac{\lambda(t)}{(1-S)p_k} - 1\right] - \delta\right\}K_i = \frac{\lambda(t)-(1-S)p_k(1+\epsilon\delta)}{\epsilon(1-S)p_k}K_i,$

+ initial condition on capital ($K_i(0) = K_{i0}$ *given*) and transversality condition $\lim_{t\to\infty} e^{-r\tau}\lambda(t)\,K_i(t) = 0$

Steady state (Cournot equilibrium)

- $\lambda = p_k(1 - S)[1 + \epsilon\delta]$
- $D\frac{Q_i}{K_i} - B(N + 1)\frac{{Q_i}^2}{K_i} + \left(N + \frac{1}{2}\right)L\frac{{Q_i}^3}{K_i} + R = 0$

Where:

$L = \frac{\gamma^2\phi}{(1-S_A)\delta_A} > 0,$

$B = \beta + \gamma\phi\frac{(1-S_A)(\delta_A+1)-T}{(1-S_A)\delta_A} > 0,$

$D = (P_0 - T\phi) + \phi\frac{[T-(1-S_A)]^2}{2(1-S_A)\delta_A} > 0,$

$R = -(1 - S)p_k\frac{1}{\alpha_K}\left[\delta\left(1 + \frac{\epsilon}{2}\delta\right) + r[1 + \epsilon\delta]\right] < 0,$

Existance and stability of steady State (fixed N)

Proposition 1: Sufficient conditions for existence and stability of a steady state for K_i are:

- $\alpha_K > \frac{1}{3}$ (unique-positive stable solution)
- $(P_0 - T\phi) > 0$ (existance)
- $\delta_A \geq \frac{1}{\left(\frac{\beta}{\gamma\phi} - 1\right)} \left[1 - \frac{T}{1 - S_A}\right]$ with $\beta > \gamma\phi$ (stability)
- $N < \frac{4P_0 L}{B^2}$ (positive price)

Value,profits and price at steady state

- Profits are equal to:

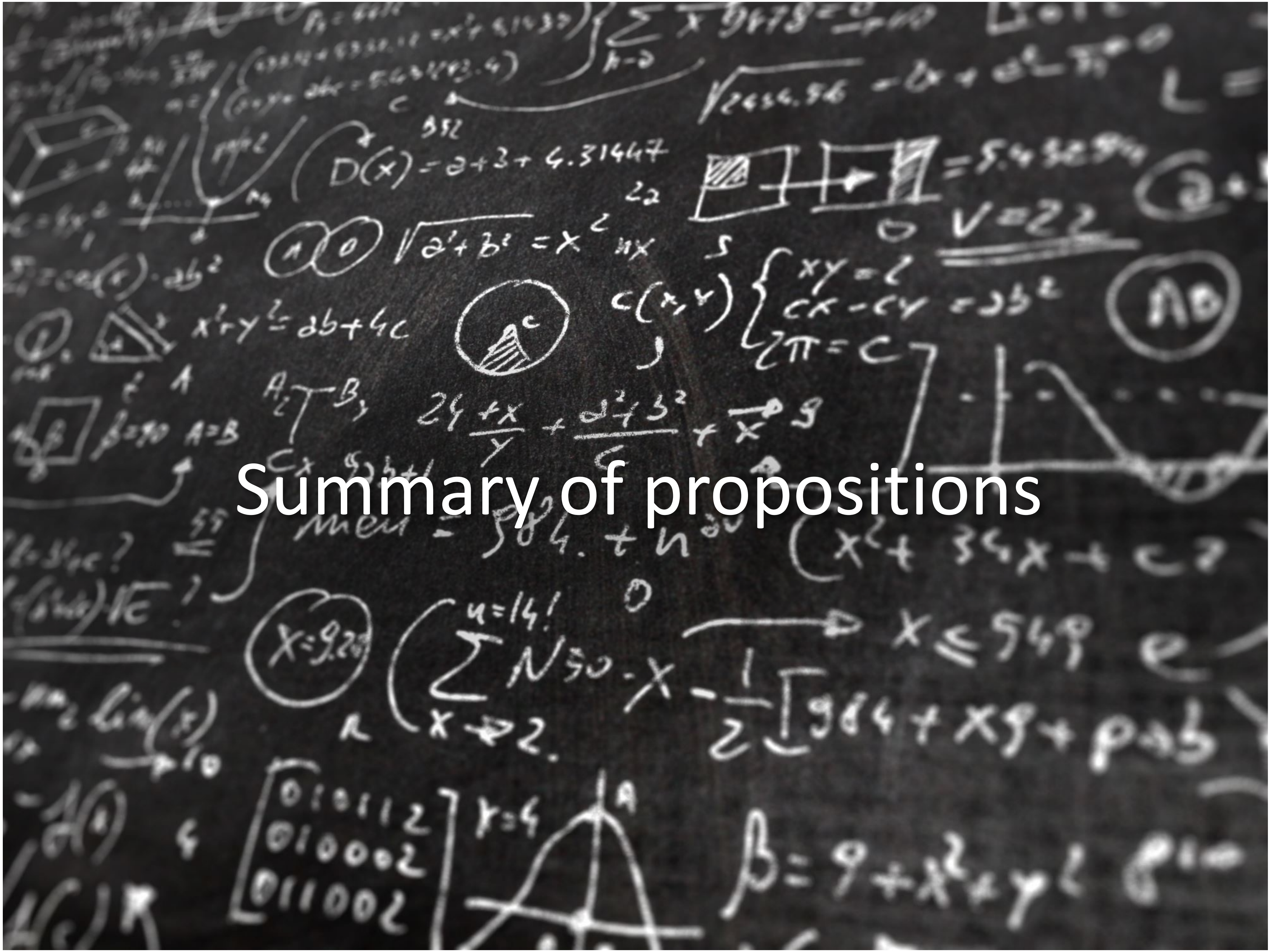
$$\pi_i = rV_i = -LK_i^{3\alpha_K} + BK_i^{2\alpha_K} + \bar{C}K_i$$

With

$$\bar{C} = \frac{1}{\alpha_K}\left(\lambda r + (1-\alpha_K)\frac{C(I)}{K_i}\right)$$
$$= p_k(1-S)\frac{1}{\alpha_K}\left[r(1+\epsilon\delta) + (1-\alpha_K)\delta\left(1+\frac{\delta\epsilon}{2}\right)\right] > 0$$

Given that $= -LK_i^{3\alpha_K} + BK_i^{2\alpha_K} = -\eta(t)^{-1}P(t)Q_i(t) > 0$, then $\pi_i > 0$.

- $P(Q,E) = P_0 - \beta Q - \gamma E = P_0 - BNQ_i + NLQ_i^2$

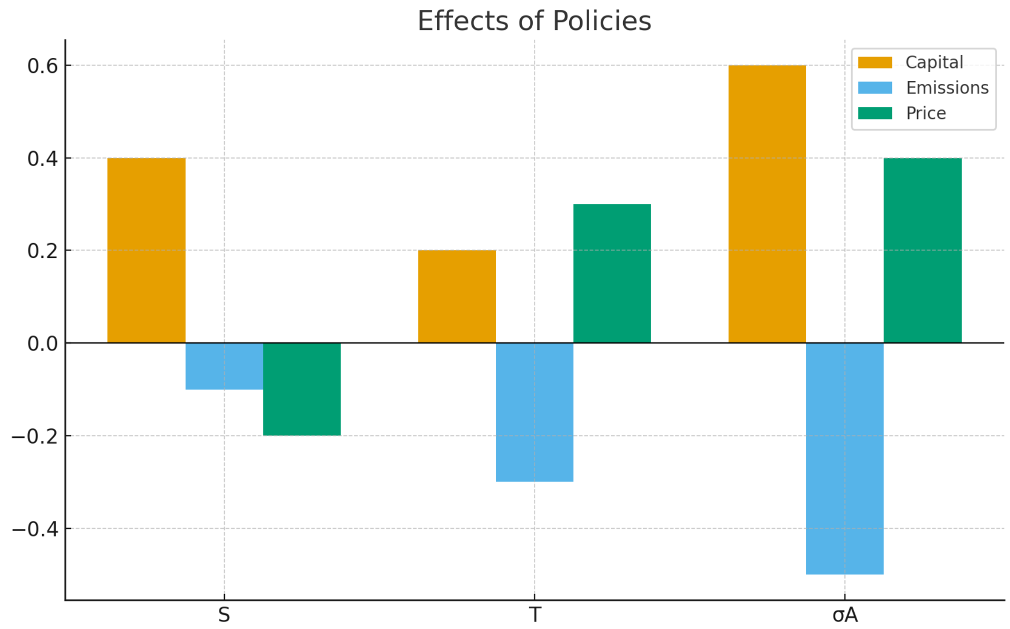

Summary of propositions

Consumer Sensitivity (γ)

- **Higher γ → more abatement, less emissions**
  - Consumers penalize polluters via demand and price effects.
- **If δ_A is low (developed countries) → virtuous cycle**
  - Capital, output, profits, and abatement all rise while emissions fall.
  - Intuition:
  - $E_i(t) = \phi\big(1 - A_i(t)\big)Q_i(t)$
  - If output increases and δ_A is low, $\varepsilon_{(1-A_i),Q_i} > 1$. Emissions decline although production increases.
- **Moreover, in developed countries, higher competition favours the virtous cycle**

Policy Effects (fixed N)

- **Investment subsidy (S)**
  - Raises capital and abatement, lowers prices; profit and emission effects ambiguous (dependes on elasticity of Ai w.r.t Qi).
- **Pollution tax (T)**
  - Boosts abatement, may cut emissions if δ_A low; raises consumer prices.
- **Abatement subsidy (S_A)**
  - Most effective: raises capital/output, reduces pollution; raises prices & profits.



Competition (fixed N)

- **More firms (N)**
  - Each firm smaller, invests less, abates less (emissions can increase or decrease at firm's level).
- **Aggregate outcome**
  - Aggregate emissions rise; prices and profits fall; environment worsens, installed capital can either increase or decrease.
- **Comment:**

  A higher degree of competition lowers both the equilibrium price and firms' profits, implying that the cost of this policy mainly falls on firms, while worsening environmental quality.
- **Higher competition must be accompanied by fiscal instruments (subsidies on abatement)**

Table 1. Summary of tax and market reforms for the benchmark case (exogenous N).

Parameter or policy instrument	K_i, Q_i	A_i	E_i	K	Q	E	P	π_i
γ	Sufficient for +: $\delta_A < \frac{N}{N+1}\left[1-\frac{T}{(1-S_A)}\right]$	+	–				Sufficient for +: $\delta_A < \left[1-\frac{T}{1-S_A}\right]$	Sufficient for +: $\delta_A < \frac{N-1}{N+1}\left[1-\frac{T}{1-S_A}\right]$
S	+	+	Sufficient for –: $\delta_A < \left[1-\frac{T}{1-S_A}\right]$	Same as K_i	Same as K_i	Same as E_i	–	Sufficient for +: $N < 1+\frac{2\alpha_K}{(1-\alpha_K)+\frac{r(1+\varepsilon\delta)}{\delta\left(1+\frac{\varepsilon\delta}{2}\right)}}$
T	Sufficient for +: $\delta_A < N\left[1-\frac{T}{(1-S_A)}\right]$	+	Sufficient for –: $\frac{dK_i}{dT} > 0$ or $\delta_A < \left[1-\frac{T}{1-S_A}\right]$				+	Sufficient for +: $\delta_A \leq \left[\frac{N-1}{2}\right]\left[1-\frac{T}{1-S_A}\right]$
S_A	+	+	–					+
N	–	–	Sufficient for: +: $\delta_A < \left[1-\frac{T}{1-S_A}\right]$	Sufficient for +: $N \leq \frac{\alpha_K}{1-\alpha_K}$	Sufficient for +: $\frac{dK}{dN} > 0$ or $\delta_A \geq \frac{\left[1-\frac{T}{1-S_A}\right]}{\left(\frac{\beta}{\gamma\phi N}-1\right)}$	+	–	–

Sufficient for stability: $\delta_A \geq \frac{1}{\left(\frac{\beta}{\gamma\phi}-1\right)}\left[1-\frac{T}{(1-S_A)}\right]$ and $\beta > \gamma\phi$.

Free Entry (variable N)

- Firms can enter or exit the market, with the only cost represented by a fixed cost F, proportional to the average K in the economy.
- Each firm will enter (exit) the market iff its own value is higher (lower) than the sum of the fixed cost and the shadow value of capital. Formally:

- $\dot{N}(t) \gtreqless 0 \Leftrightarrow \int_t^{\infty} e^{-r\tau}\pi_i(\tau)d\tau \gtreqless F(K_i(t)) + \lambda(t)K_i(t)$

- $F(K_i(t))$ represents a form of externality imposed by existing firms on potential new entrants (not chosen strategically)
- Assumed linear in K_i, i.e. $F\big(K_i(t)\big) = g\, K_i(t), g > 0.$
- **Endogenous entry/exit adds a second state variable**

Dynamic system

$$\dot{\lambda}(t) = -\frac{1}{2\epsilon}\frac{\lambda(t)^2}{(1-S)p_k} + \left(r + \delta + \frac{1}{\epsilon}\right)\lambda(t) - (1 - S)p_k\frac{1}{2\epsilon} - \alpha_K\left[DK_i^{\alpha_K - 1} - (N + 1)BK_i^{2\alpha_K - 1} + L\left(N + \frac{1}{2}\right)K_i^{3\alpha_K - 1}\right]$$

$$\dot{K}_i(t) = \left\{\frac{1}{\epsilon}\left[\frac{\lambda(t)}{(1-S)p_k} - 1\right] - \delta\right\}K_i(t)$$

$$\dot{N}(t) = \frac{(1-\alpha_K)}{\alpha_K}\lambda(t)K_i(t) + \frac{(1-\alpha_K)}{\alpha_K}\int_t^\infty e^{-r\tau}\frac{(1-S)p_k}{2\epsilon}K_i(\tau)\left\{\left[\frac{\lambda(\tau)}{(1-S)p_k}\right]^2 - 1\right\}d\tau + \int_t^\infty e^{-r\tau}\left\{B{Q_i}^2 - L{Q_i}^3\right\}d\tau - F(t)$$

Steady state (Cournot equilibrium)

$$\dot{N}(t) = 0 \Leftrightarrow -LK_i^{3\alpha_K - 1} + BK_i^{2\alpha_K - 1} + C = 0$$
$$\dot{K}_i(t) = 0 \Leftrightarrow \lambda = p_k(1 - S)[1 + \epsilon\delta]$$
$$\dot{\lambda}(t) = 0 \Leftrightarrow N = \frac{DK_i^{\alpha_K - 1} - \frac{L}{2}K_i^{3\alpha_K - 1} + R + C}{-C}$$

$$\pi_i = rF(K_i) + r\lambda K_i = rF(K_i) + rp_k(1 - S)[1 + \epsilon\delta]K_i$$
$$P = P_0 + NCK_i^{1-\alpha_K}$$

where:

- $C = p_k(1 - S)\frac{(1-\alpha_K)}{\alpha_K}\left[r(1 + \epsilon\delta) + \delta\left(1 + \frac{\delta\epsilon}{2}\right)\right] - r\frac{F(t)}{K_i(t)} < 0,$
- $R = -(1 - S)p_k\frac{1}{\alpha_K}\left[\delta\left(1 + \frac{\epsilon}{2}\delta\right) + r[1 + \epsilon\delta]\right] < 0$
- and $R + C = -r\frac{F(t)}{K_i(t)} - p_k(1 - S)\left[r(1 + \epsilon\delta) + \delta\left(1 + \frac{\delta\epsilon}{2}\right)\right] < C < 0.$

Consumers & Policy Effects (variable N)

Consumer sensitivity (γ)

- ↑ γ → ↓ pollution per firm.
- If δ_A is low → virtuous cycle: ↑ capital, ↓ aggregate pollution.

But also ↓ competition (fewer firms), ↑ prices & ↑ profits.

Free entry & SR consumers will produce »good results» in developed countries

Fiscal instruments

- **Investment subsidy (S):** ↑ capital, output & abatement.
  - Effect on number of firms ambiguous.
  - Pollution ↓ only if output elasticity w.r.t. capital is low.
- **Pollution tax (T):** ↑ abatement & profits, ↓ N, ↓ pollution.
- **Abatement subsidy (S_A):** similar to T → ↑ abatement & profits, ↓ N, ↓ pollution.

Trade-offs

- Policies (T, S_A) break efficiency–environment trade-off, but **exacerbate concentration** (fewer firms, higher prices).
- Consumers bear the cost (↑ prices), while firms capture higher profits.

Table 2. Summary of tax reforms for the case with variable number of firms

<table>
<tr><th>Parameter or Tax instrument</th><th>K_i</th><th>A_i</th><th>N</th><th>E_i</th><th>E</th><th>Q, K</th><th>P</th><th>π_i</th></tr>
<tr><td>γ:</td><td>Sufficient for +: $\delta_A < 1 - \frac{T}{1-S_A}$</td><td>Sufficient for +: $\delta_A < 1 - \frac{T}{1-S_A}$</td><td>Sufficient for −: $\delta_A < 1 - \frac{T}{1-S_A}$</td><td>−</td><td>Sufficient for −: $\delta_A < 1 - \frac{T}{1-S_A}$</td><td>Sufficient for −: $\delta_A < min\left[1 - \frac{T}{1-S_A}, \frac{\phi[T-(1-S_A)]^2}{(P_0 - T\phi)(1-S_A)}\right]$</td><td>Sufficient for +: $\delta_A < 1 - \frac{T}{1-S_A}$</td><td>Same as K_i</td></tr>
<tr><td>S</td><td rowspan="3">+</td><td rowspan="3">+</td><td>Sufficient for −: $\alpha_K \leq \frac{\sqrt{5}-1}{2}$</td><td>Sufficient for −: $\delta_A < 1 - \frac{T}{1-S_A}$</td><td>Sufficient for −: $\alpha_K \leq \frac{\sqrt{5}-1}{2}$</td><td>Sufficient for +: $\alpha_K \leq \frac{\sqrt{5}-1}{2}$ and $\delta_A < \frac{\phi[T-(1-S_A)]^2}{(1-\alpha_K)(P_0 - T\phi)(1-S_A)}$</td><td>Sufficient for +: $\alpha_K \leq \frac{\sqrt{5}-1}{2}$</td><td>Sufficient for +: $\lambda \geq \frac{(2\alpha_K - 1)F}{2(1-\alpha_K)K}$</td></tr>
<tr><td>T</td><td rowspan="2">−</td><td rowspan="2">−</td><td rowspan="2">−</td><td rowspan="2">Sufficient for −: $\delta_A < \frac{\phi[T-(1-S_A)]^2}{(P_0 - T\phi)(1-S_A)}$</td><td rowspan="2">+</td><td rowspan="2">+</td></tr>
<tr><td>S_A</td></tr>
</table>

Conclusions (I)

- **Main finding:** fiscal instruments can reconcile efficiency and environment, but effectiveness depends on technology (δ_A) and market structure.
- **Fixed N:**
  - Only abatement subsidies always reduce emissions and increase output (but higher prices)
  - Pollution taxes and investment subsidies work only if δ_A is low.
  - More firms (greater competition) reduce prices but increase aggregate pollution.
- **Free Entry:**
  - Abatement subsidies and pollution taxes effective regardless of δ_A in reducing aggregate pollution and may break the growth-sustainability trade-off
  - But they reduce number of firms, raise prices, and increase profits → new trade-off: sustainability vs. competition.

Conclusions (II)

Role of consumers (γ):

- When δ_A is low, higher γ triggers virtuous cycle (↑ capital, ↑ output, ↓ emissions, ↑ profits)
- When δ_A is high, higher γ reduces per-firm emissions but may not boost efficiency.

Policy implications:

- Advanced economies: abatement subsidies & green taxes complement consumer preferences; higher prices tolerated.
- Less advanced economies: competition can ease consumer burden but must be combined with strong environmental instruments.
- **Overall message:** optimal policies must be tailored to technology and market maturity; consumers ultimately bear the cost through higher prices.