Green Patents in an Oligopolistic Market with Green Consumers

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Introduction: Broader context

- Developing climate change mitigation technologies are critical to reaching net-zero emissions (Barrett, 2009; Galiana and Green, 2009; Probst *et al*, 2021)
  - Large scale efforts to promote green innovation (G8 summit, COP 21, 22, 23, 24, 26)
- **No consensus** on what are the most effective policy instruments to encourage the development of green (less polluting) technology

Introduction: Related literature

- Green innovation: **Environmental** externality + **Knowledge** externality

- **Environmental policy tools to foster green innovation:** carbon tax, cap-and-trade system, ...
  - Porter Hypothesis (e.g. Porter, 1991; Porter and van der Linde, 1995; Ambec *et al*., 2013; Dechezleprêtre and Sato, 2017; Cohen and Tubb, 2018)

- **Innovation policy tools to foster green innovation:** (e.g. Popp, 2006, 2019; Fischer and Newell, 2008; Acemoglu et al., 2012; Hepburn et al., 2018; Lehmann and Söderholm, 2018)
  - R&D subsidies
  - **Patent policy tools**: Langinier and Ray Chaudhuri (2020); Langinier and Ray Chaudhuri (2022) (this paper)

Introduction: Motivation

- **Green patents on the rise:**
  - 2000-2011: Green patent applications rose by: 78% (OECD); 528% (BRICS)
  - 2000-2011: All patent applications rose by: 3.9% (OECD); 363% (BRICS)
  - Probst *et al* (2021): Annual growth rate in high-value invention of climate change mitigation technologies across 170 countries: 10% (1995 to 2012); 6% (2013 to 2017)

- **No consensus on role of green patents** (Hall and Helmers, 2013)
  - International organizations advocate excluding green technologies from patenting
  - Fast-track patenting system for green innovations (Australia, Brazil, Canada, China, UK, US, Japan, South Korea): reduced the time from application to grant by up to 75% (Dechezleprêtre, 2013)

Introduction: Research question

- How do **patent policies** impact the efficacy of **emission taxes** in terms of fostering green innovation and reducing emission levels?
  - patenting costs
  - patentability requirements

- Key factors driving our results:
  - Endogenizing firms' **licensing** decisions within an **oligopolistic** market
  - Heterogeneity of **environmentally friendly (green) consumers** (e.g. Bansal and Gangopadhyay, 2003; Bansal, 2008; Doni and Ricchiuti, 2013)
    - eco-labeling is on the rise: e.g. 50% of the market share for certain products consists of the environmentally friendly variant in Sweden; green marketing in transportation and electricity markets

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output

- Each firm i can invest $I_i \in \{0, I_P\}$ to reduce **emission-output ratio**

$$\gamma_i = \begin{cases} \gamma_H & \text{if } I_i = 0 \\ \gamma_P & \text{if } I_i = I_P \end{cases}$$

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- with $\Delta \equiv \gamma_H - \gamma_P >> 0$

Model Setting

- **Environmental conscious** consumers can observe the emission-output ratio of each firm, γ_i (effective eco-labeling)
- Examples:
  - share of renewables in energy (22.1% in EU in 2020, but unprecedented transformation in the energy system necessary to meet the target of 32% set for 2030
  - proportion of recycled inputs used in production the process: recycling in EU increased by 34% (2005-2016)

Model Setting

Demand side

- $N = 1$ consumers
- Each consumer buys 0 or 1 unit of the good
- Fraction λ (resp., $1 - \lambda$) of **green** conscious (**non-green** conscious) consumers
- Green conscious consumers care about the greenness (γ) of the product
- Non-green conscious consumers only care about prices

Model Setting

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- Utility of a **non-green conscious** consumer

$$U_{NG} = \begin{cases} v - \min\{p_1, p_2\} - P(e) & \text{from buying the good at } p \\ \\ -P(e) & \text{from not buying} \end{cases}$$

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  - G degree of environmental friendliness
  - G is uniformly distributed on $[\underline{G}, \overline{G}]$; $\overline{G} = \underline{G} + 1$ and $\underline{G} > 0$

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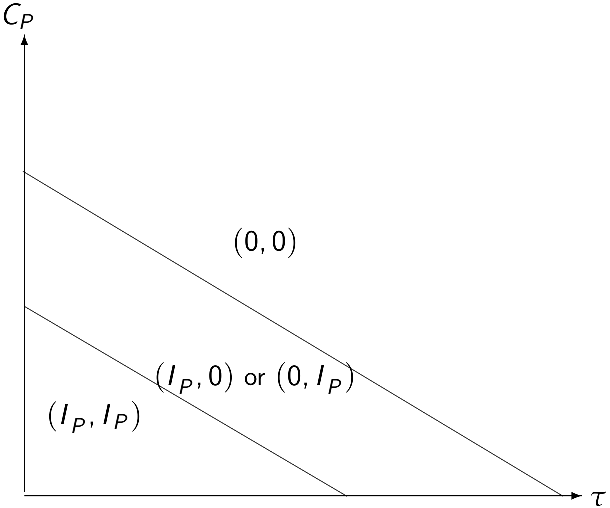
- At $t = 2$, both firms choose their prices p_1 and p_2

Benchmark case: Non-green consumers only ($\lambda = 0$)

- **Licensing always occurs in equilibrium**
  - Patent holder chooses royalty rate to obtain monopoly profit
  - Non-patent holder's outside option is zero

Benchmark case: Non-green consumers only

Investment decisions in Stage 1



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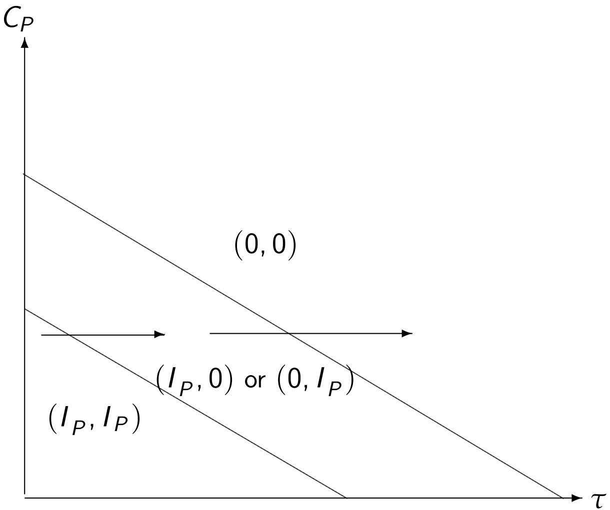


Benchmark case: Non-green consumers only

- $I_1 = I_2 = 0$:
    - Bertrand competition in homogeneous (dirty) product with $p_1 = p_2 = c + \tau\gamma_H$
    - both firms get zero payoffs

- If one or both firms invest and patent holder, firm 1, **does not license**
    - Bertrand competition with heterogeneous marginal costs with $p_1 = c + \tau\gamma_H - \varepsilon$
    - $\Pi_1 > 0$ and firm 2 does not produce

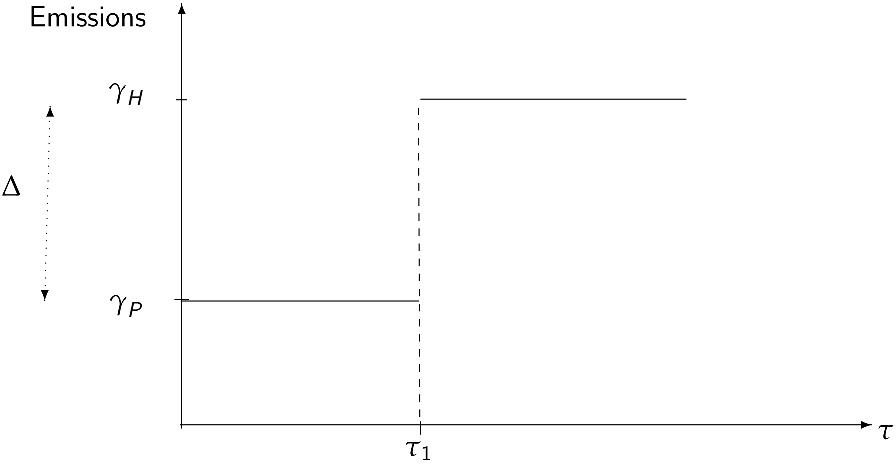
- If one or both firms invest and patent holder, i, **does license**
    - both firms produce the cleaner product γ_P
    - Firm 1 offers a license (r, F) where
        - r is the per-unit royalty rate
        - F is a fixed fee

- There is a unique Nash equilibrium in prices in which both firms choose
$$p_{1P}^L = p_2^L = c + \tau\gamma_P + r$$
- Firm 2 accepts the license only if
$$D_2(p_{1P}, p_2; \gamma_P)(p_2 - c - \tau\gamma_P - r) - F \geq 0$$
- The unique equilibrium: **licensing always occurs**
$$(r^*, F^*) = (v - c - \tau\gamma_P, 0) \text{ and } p_{1P}^L = p_2^L = v$$
- Stage 2: Firm 1 obtains monopoly proft: $(v - c - \tau\gamma_P) > 0$; Firm 2 gets zero payoff
- **Patenting decision**: the innovator patents if and only if
$$v - c - \tau\gamma_P - C_P \geq 0$$

Benchmark case: Non-green consumers only

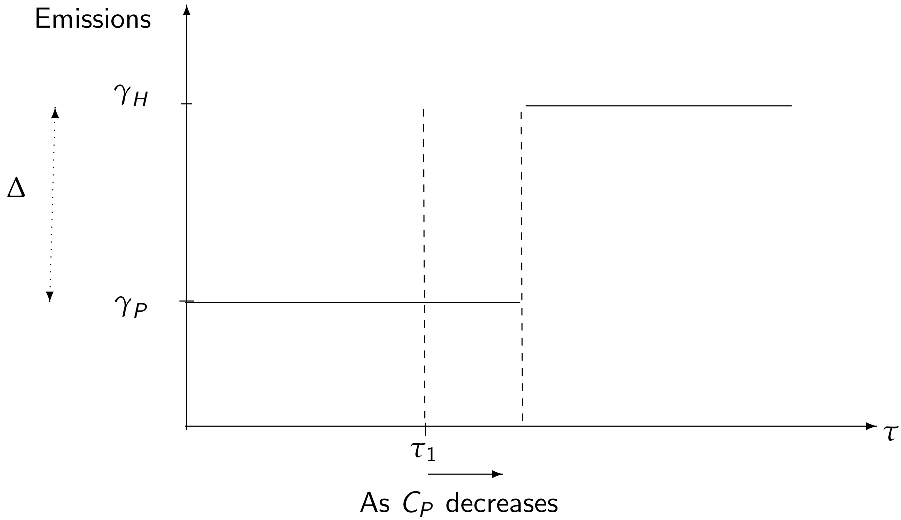
Total emissions when

$\lambda = 0$



Benchmark case: Non-green consumers only

Reducing patenting cost



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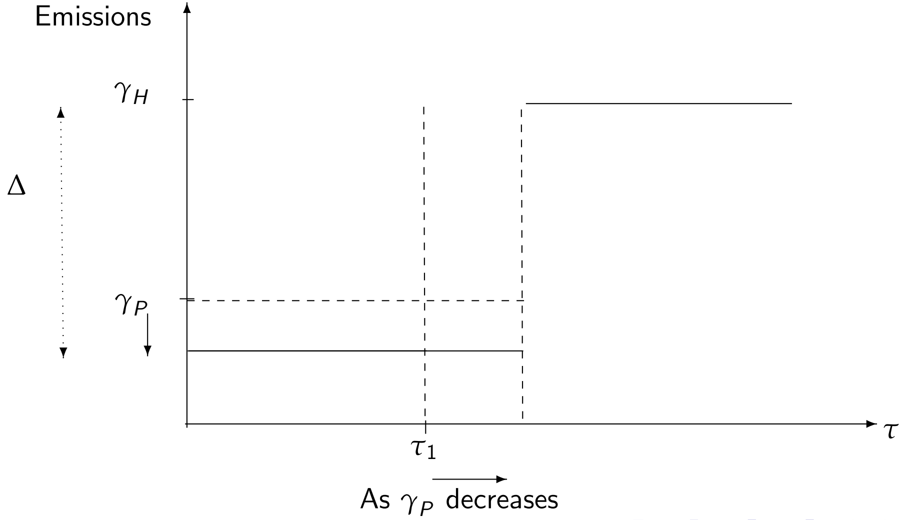
Making patentability requirements stricter



Benchmark case: Non-green consumers only

Policy implications

- **Paradox:** For a given patenting cost, **increasing the emission tax** beyond τ_1 leads to **less innovation** as the tax bill increases
- **Reducing patenting cost**, C_P, (e.g. by fast-tracking green patents) makes it less likely that this paradox occurs
- Making **patentability requirements stricter**
  - makes it less likely that this paradox occurs
  - lowers emission level for $\tau < \tau_1$

Green conscious and Non-green consumers ($0 < \lambda \leq 1$)

- Licensing does NOT always occur in equilibrium
  - For sufficiently large λ, due to **product differentiation**, non-patent holder's payoff from NOT purchasing the license may be strictly positive

Non-Green and Green Conscious Consumers

Price Competition

- If $\tau < \tau_L(\lambda)$, firms differentiate products (no licensing)

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  - If licensing occurs, equilibrium prices are $p_1^L = p_2^L = c + \tau\gamma_P + r$ and payoffs are

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    - **Licensing** occurs in equilibrium

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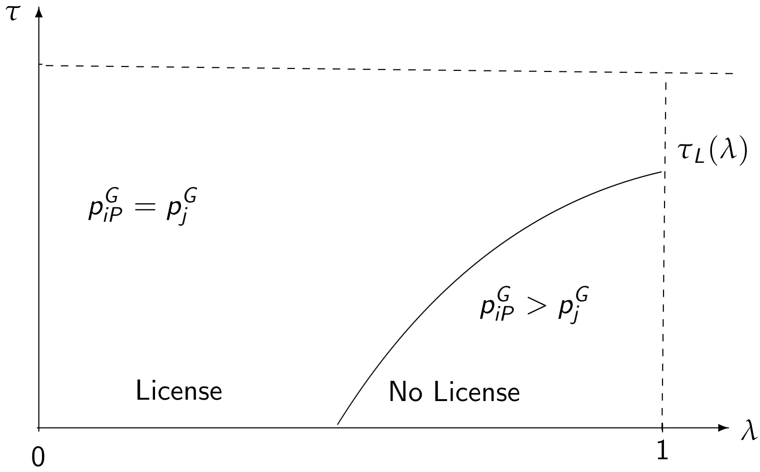
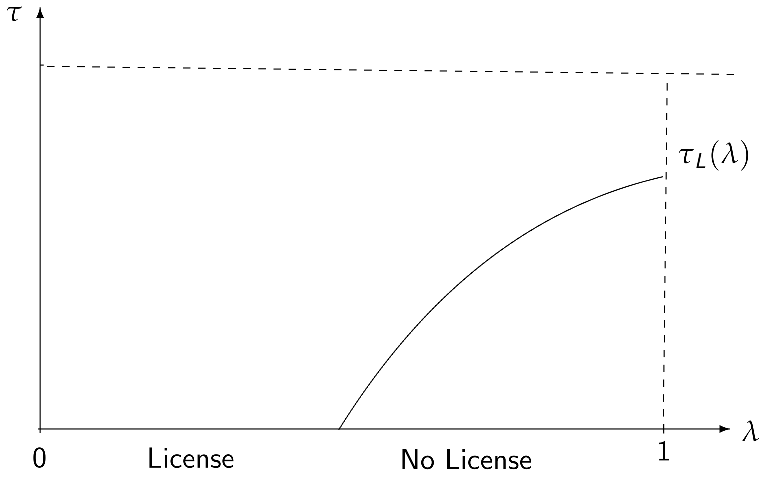
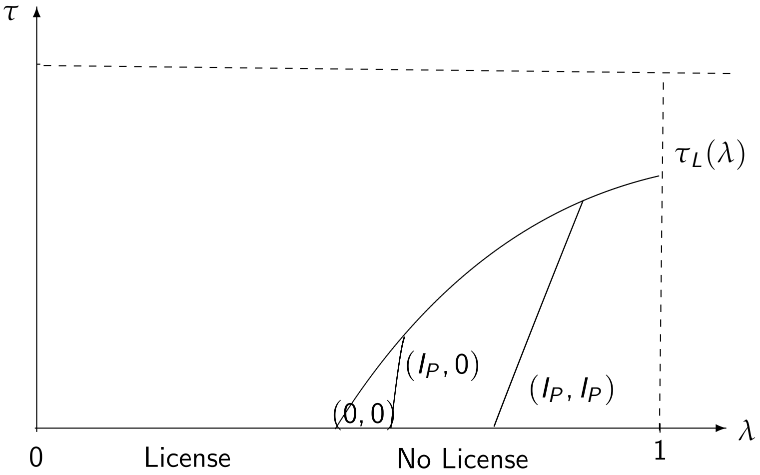


- For large values of patenting cost C_P



Non-Green and Green Conscious Consumers

Investment decisions for large patenting cost



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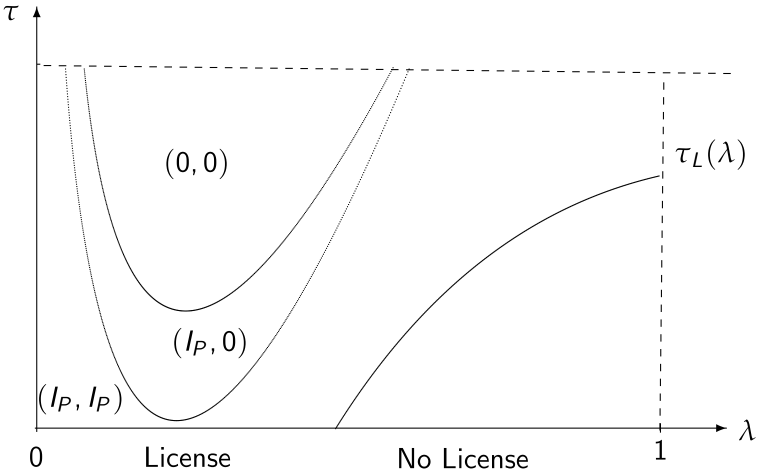

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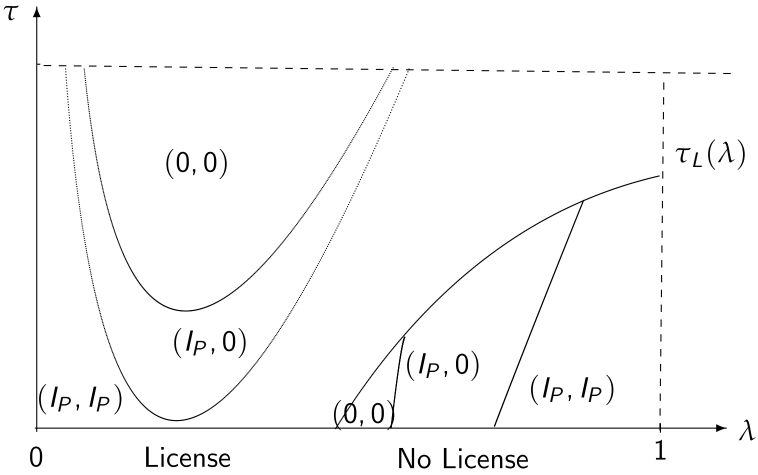
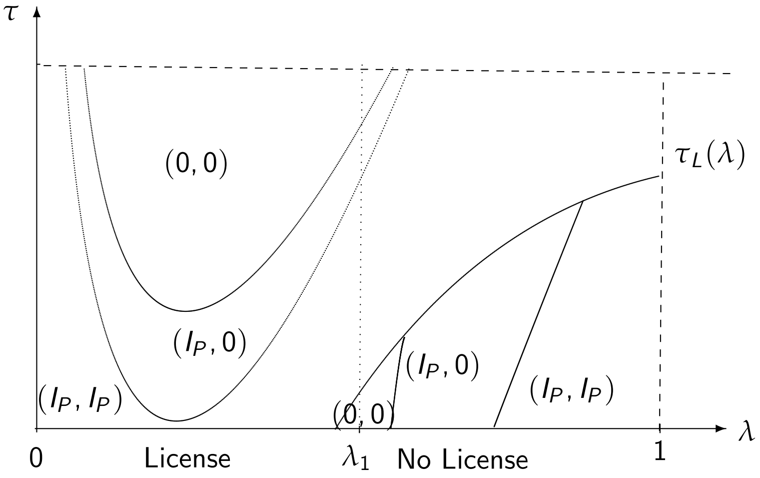
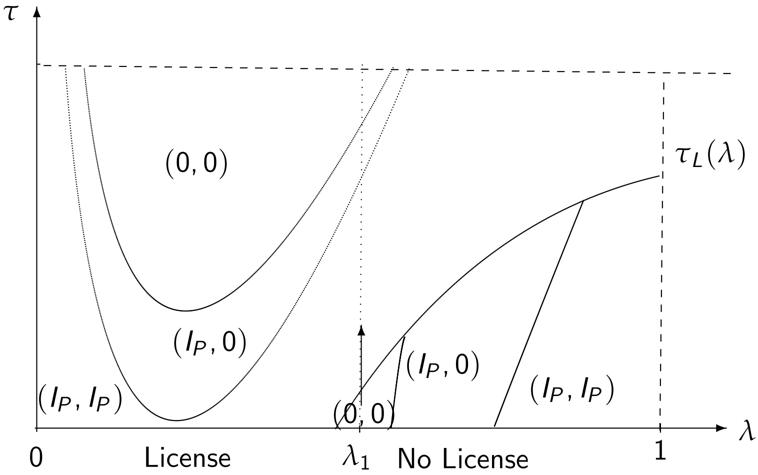




τ
$(0, 0)$
$\tau_L(\lambda)$
$(I_P, 0)$
$(I_P, 0)$
(I_P, I_P)
(I_P, I_P)
$(0, 0)$
λ
0
License
λ_1
No License
1

Non-Green and Green Conscious Consumers

Investment decisions for large patenting cost



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Investment Decisions

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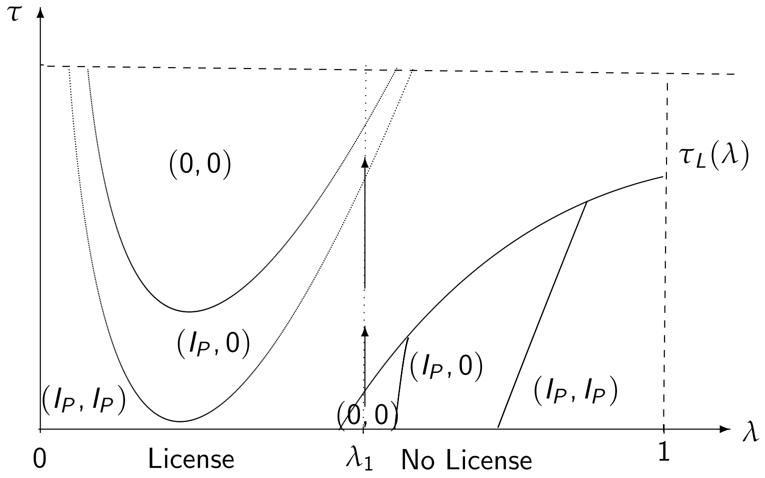

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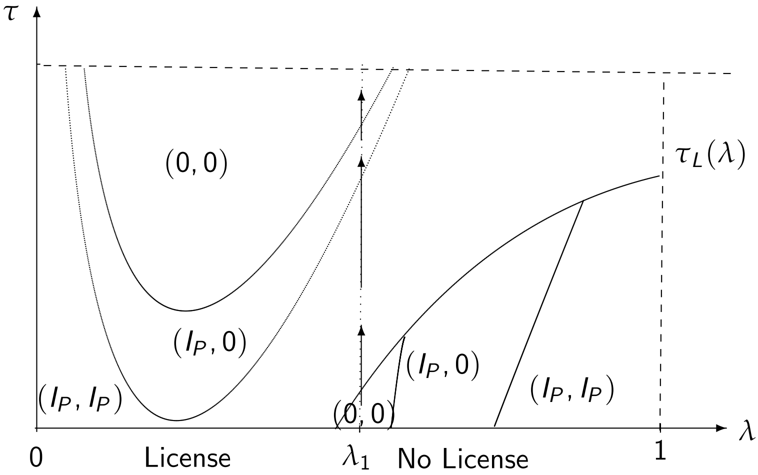
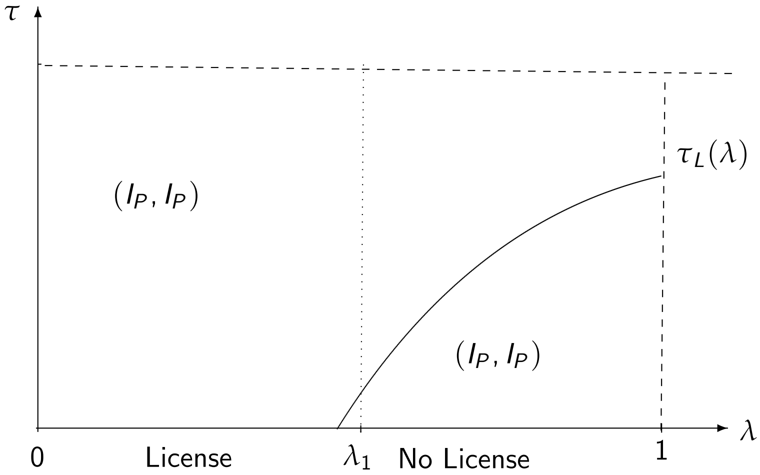


Non-Green and Green Conscious Consumers

Investment Decisions for small patenting cost



Non-Green and Green Conscious Consumers

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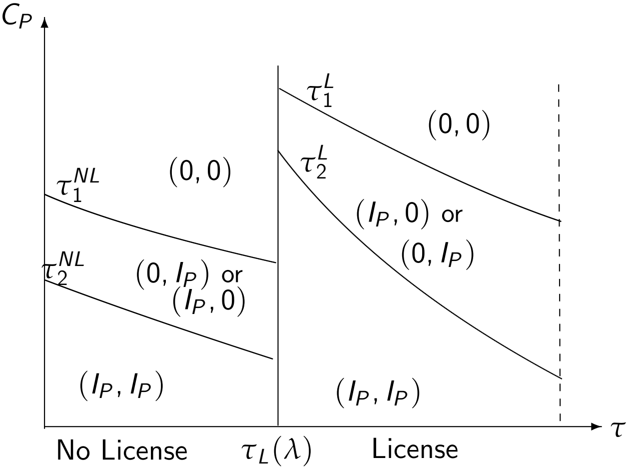

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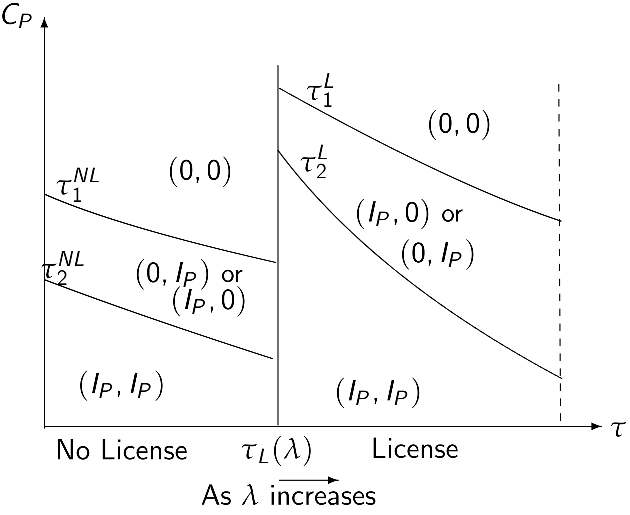

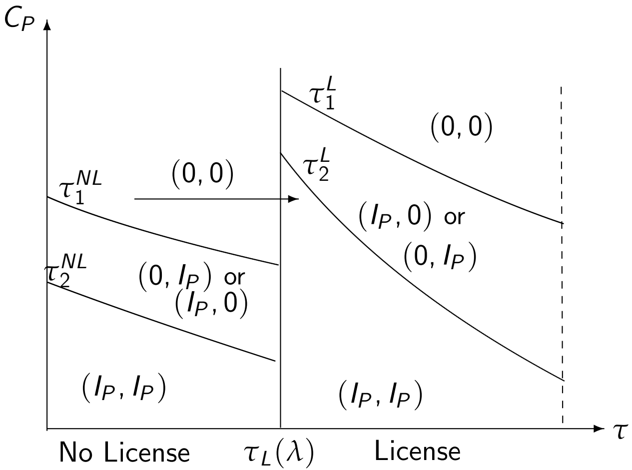

C_P
τ_1^{NL}
$(0, 0)$
τ_2^{NL}
$(0, I_P)$ or
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τ
No License
$\tau_L(\lambda)$
License

Non-Green and Green Conscious Consumers

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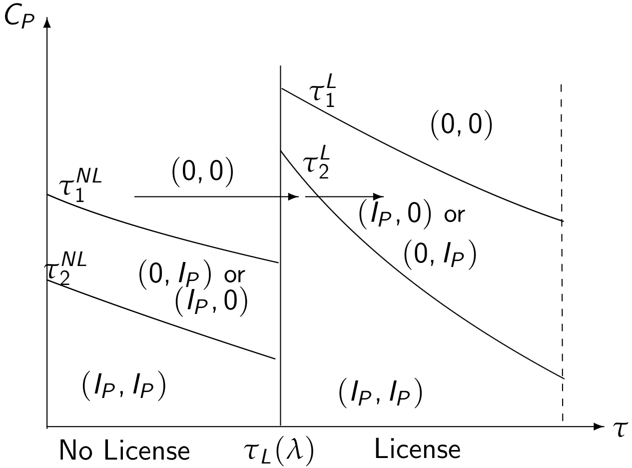

Non-Green and Green Conscious Consumers

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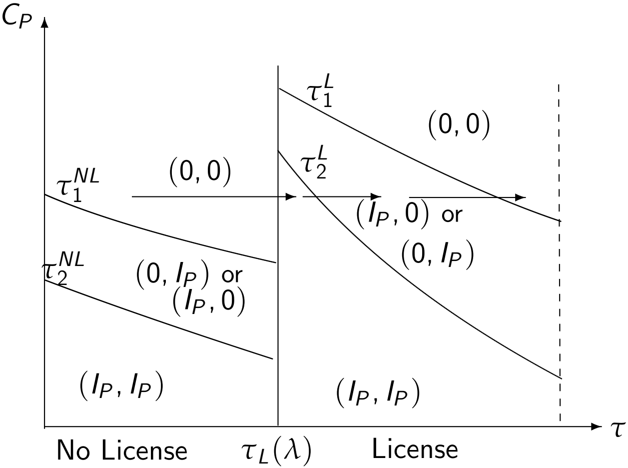
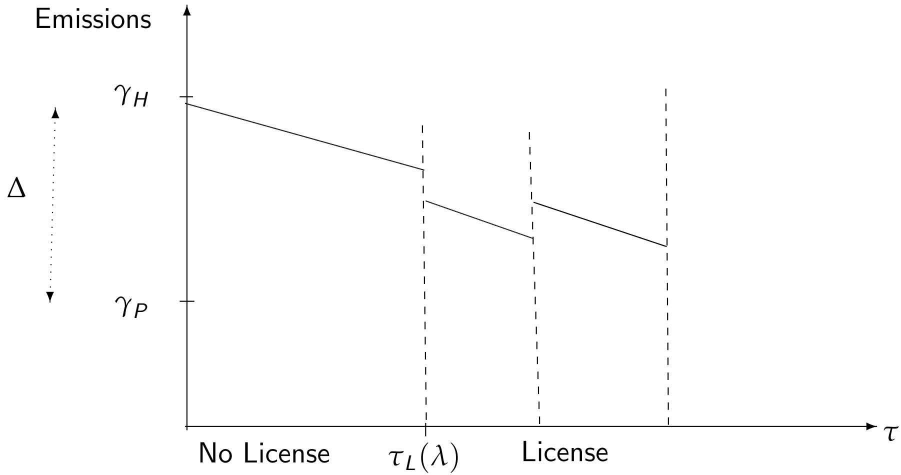


Non-Green and Green Conscious Consumers

Emission Levels for large patenting cost



Non-Green and Green Conscious Consumers

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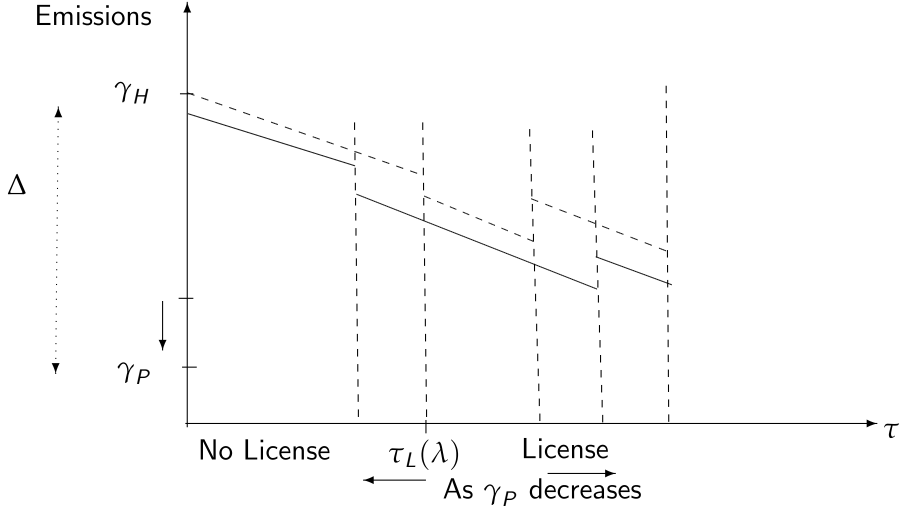

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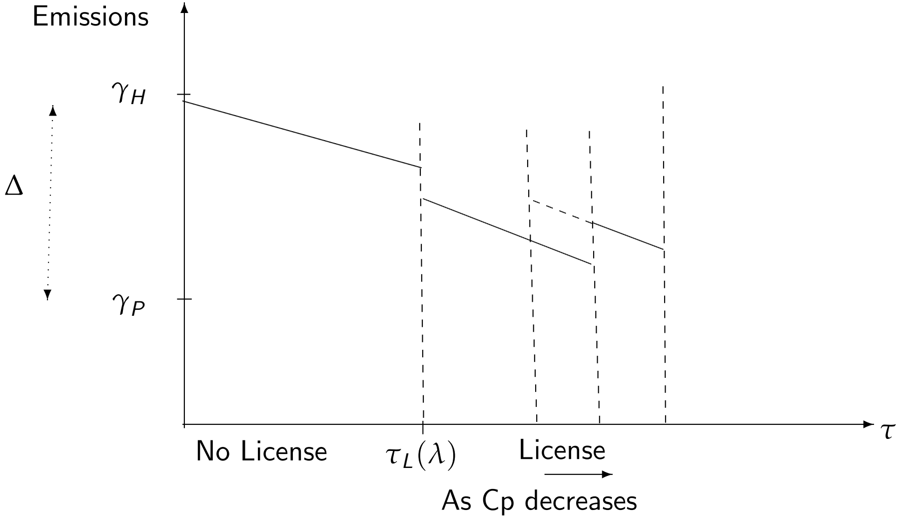

Non-Green and Green Conscious Consumers

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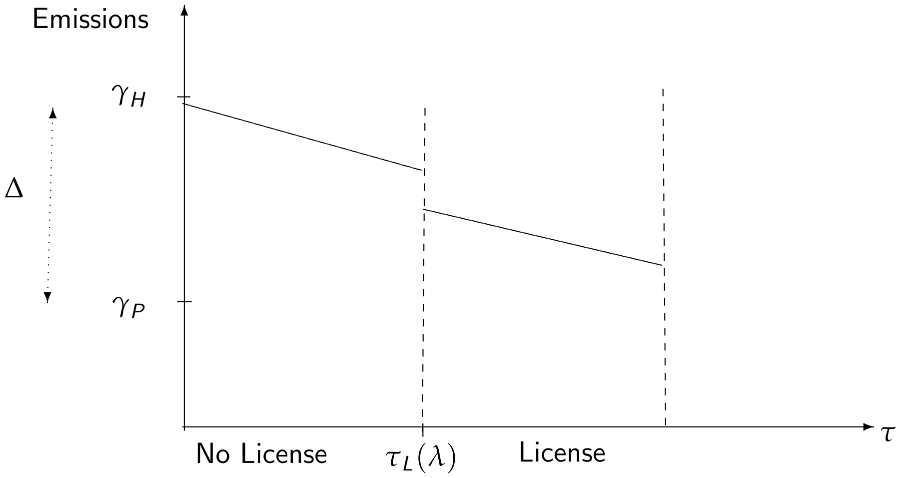

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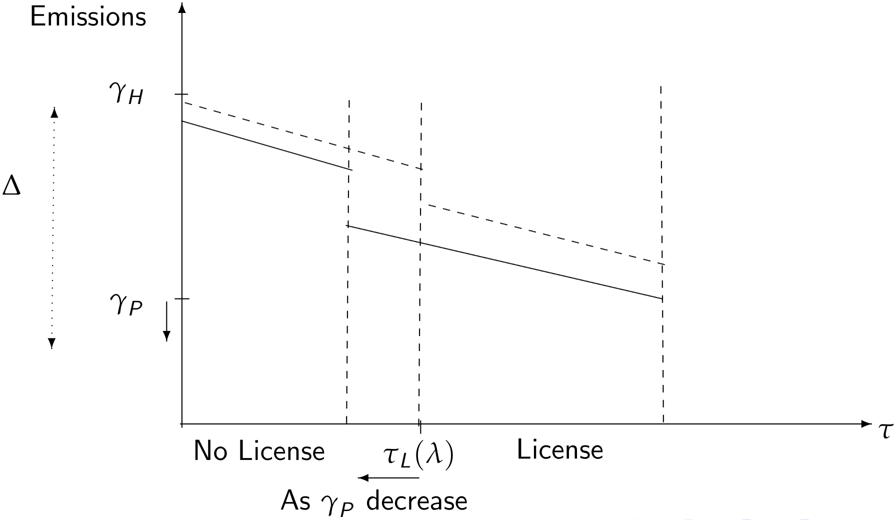

Conclusion

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- Policies to reduce emissions when λ is high

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