Research Races: Innovation Policy and Technological Change

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Innovation Policy and Technological Change: Two Sides of the Same Coin?

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Technological Change

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Innovation Policy

- R&D subsidies are an effective method for spurring innovation.
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Are there cheaper alternatives to R&D subsidies that can achieve similar effects?

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Technological Change

- Technological change shapes the landscape for future innovation.
- In particular, different technologies can make it cheaper to perform future research, or cheaper to bring ideas to market.

How do these changing incentives influence the direction of future research?

Model

Model: Firms

- Time is continuous $t \in [0, \infty)$.
- There are two firms: $i \in \{1, 2\}$ competing to research innovations.
- There are two types of innovations: a “radical” innovation and “incremental” innovations.

At each moment in time, the firms choose $a_i \in A_i = \mathbb{R}_+ \times [0, 1] \times \{0, 1\}$.

(i) How much effort to invest in researching $\lambda \in \mathbb{R}_+$;

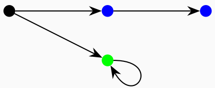
(ii) What fraction of their time is spent on the radical innovation $e \in [0, 1]$;

(iii) Whether to commercialize innovations that they have completed: $p \in \{0, 1\}$.

Model: Researching and Implementation

When a firm invests λ in research during $[t, t + dt)$, it pays a flow cost $\alpha C(\lambda)dt$, and with probability λdt the firm achieves an observable "breakthrough".

- Incremental innovations are repeatable, and require only one breakthrough.
- The radical innovation is unique, and requires two *sequential* breakthroughs.



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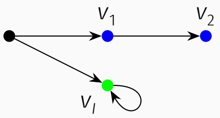
  - Implementing the first part yields v_1, the second part v_2.
  - Implementing the two together yields $v_1 + v_2$.
  - When part one is implemented, both firms can work on part two.



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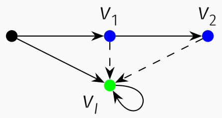

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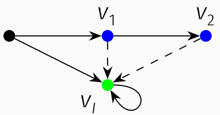

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Assumption

$C : \mathbb{R}_+ \rightarrow \mathbb{R}_+$ is strictly convex, with $C'(0) = 0$ and $C''' \geq 0$.

Model: Payoffs

Firms discount the future at rate r, and aim to maximize their expected discounted payoff from researching and implementing innovations:

$$\int_0^\infty e^{-rt}\Big(\delta_{\{\text{Implement innovation of value } v_t \text{ at time } t\}} \cdot \big(v_t - c_p\big) - \alpha C(\lambda_t)\Big)dt$$

$$v_t \in \{v_I, v_1, v_2, v_1 + v_2\}$$

Motivating Examples

- Pharmaceutical innovations: reformulating an existing drug, or identifying a new biological mechanism and then refining scalability and safety.
- News: working on "simple" general interest stories, or deep investigative stories that require multiple steps of finding leads and verifying information.

Equilibrium Characterization

Theorem

There is a unique Markov Perfect Competitive equilibrium that is symmetric and stable. If r is sufficiently small, this is the only stable equilibrium.

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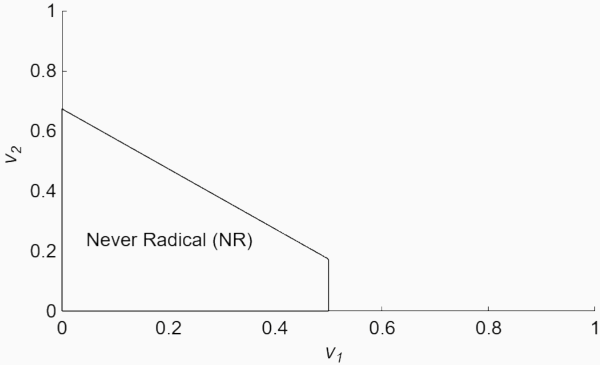

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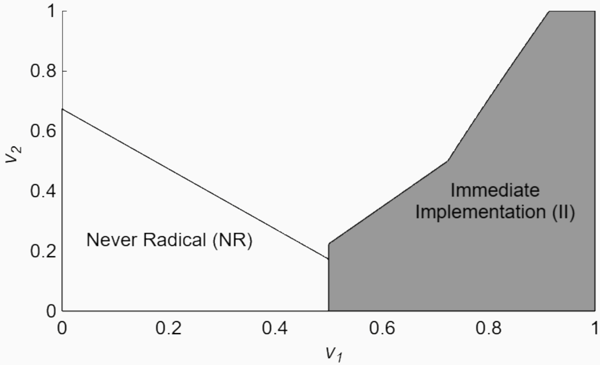

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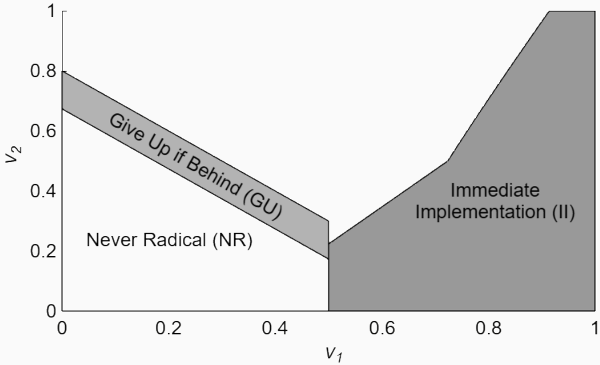

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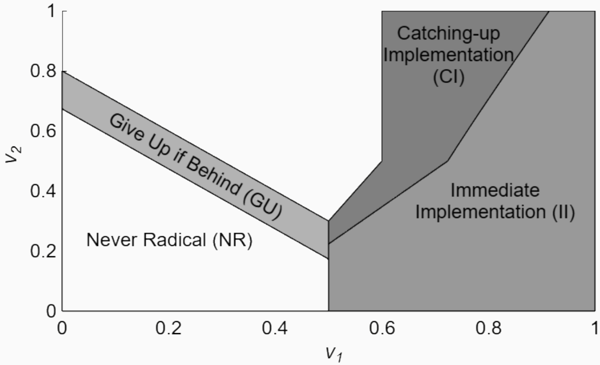

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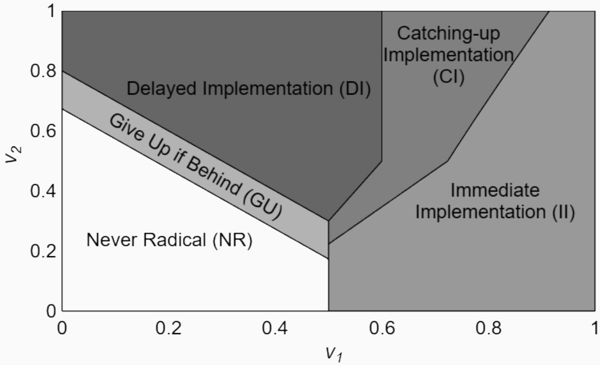

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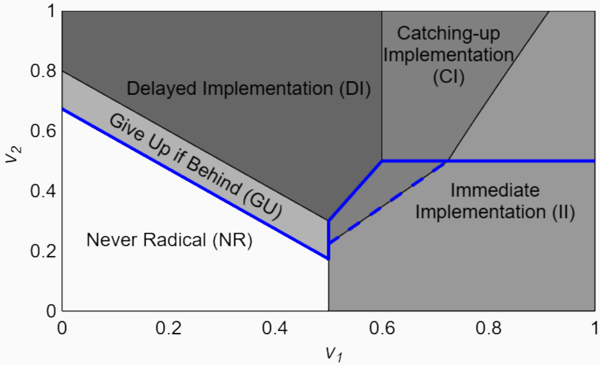

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Policy and Technological Change

Key Parameters: research and implementation costs

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- α is influenced primarily through R&D subsidies; while
- c_p can be increased through patenting fees, clinical trials, etc. or decreased by subsidizing commercialization.

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Technological Change

- Both α and c_p decrease when technology evolves: research and implementation both become easier; however
- Some technologies primarily affect the research process, while others ease the implementation of completed ideas.

Effect of Parameter Changes

Definition

A parameter change is said to

(i) *increase investment within regions* if, for all (v_1, v_2) such that equilibrium region doesn't change, equilibrium investment increases in each state.

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(ii) *increase focus on the radical innovation* if the region NR shrinks.

(iii) *encourage continuation* if region II shrinks and region DI expands.

It *places emphasis on the radical innovation* if both (ii) and (iii) hold.

R&D subsidies: decreasing investment costs

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Fix v_I, c_p, and r. A decrease in research costs from α to α'

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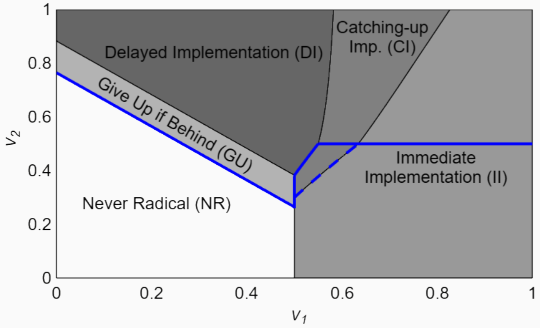

(a) $\alpha = 3$

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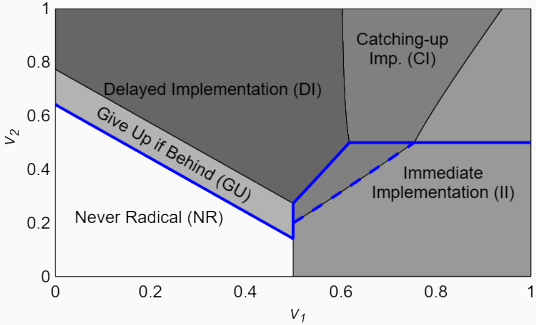

(a) α = 0.5

Optimal Policy: R&D Subsidies

Decreasing research costs is unambiguously beneficial.

- R&D subsidies and research-side technological changes push firms to work harder on projects, and to pursue longer, more complicated research.

Proposition

Fix v_I, r. Let $T(c_p, \alpha; v_1, v_2)$ denote the expected time to the implementation of the full radical innovation.

- The value of α that minimizes expected time is zero: $\operatorname{arginf}_{\alpha \geq 0} T(c_p, \alpha; v_1, v_2) = 0$.

Patent costs: increasing implementation costs

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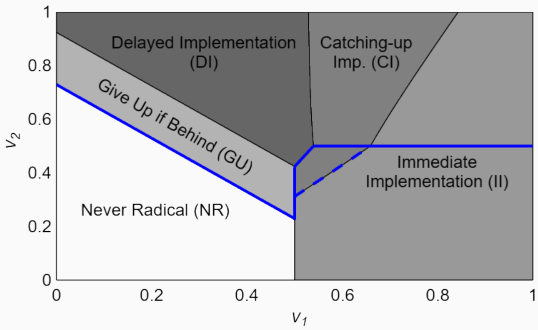

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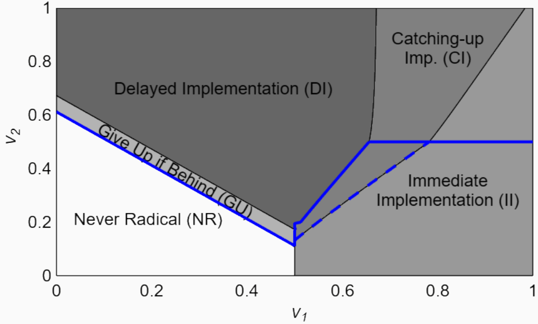

(a) $c_p = 0.45$

Optimal Policy: Implementation Costs

Making commercialization and implementation easier has a nuanced effect.

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Proposition

The value of implementation costs c_p that minimizes expected time is not always zero: there exist (v_1, v_2) such that $\text{argmin}_{c_p \geq 0} T(c_p, \alpha; v_1, v_2) > 0$. Moreover,

- For v_2 sufficiently low, $\text{argmin}_{c_p \geq 0} T(c_p, \alpha; v_1, v_2)$ is decreasing in v_1 for low v_1 and increasing in v_1 for large v_1.
- For v_2 sufficiently high, $\text{argmin}_{c_p \geq 0} T(c_p, \alpha; v_1, v_2) \equiv 0$ for all $v_1 > 0$.

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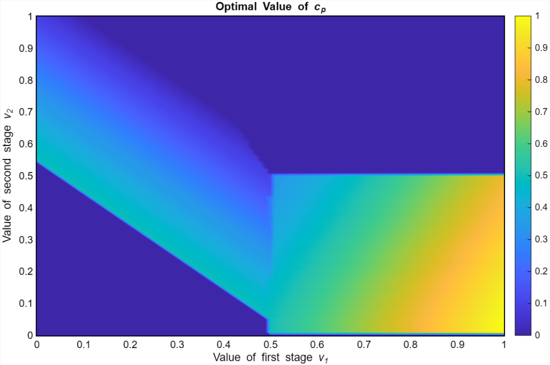

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What changes when firms' breakthroughs are unobservable?

- Characterize the unique Markov equilibrium: results qualitatively do not change.

Conclusion

Innovation Policy

- R&D subsidies both increase research and redirect it.
- Higher commercialization costs redirect research, but decrease it.
  - This is especially valuable when firms would halt inefficiently early.

Given fiscal constraints, more creative policy should consider these trade-offs, as opposed to deferring to solely R&D subsidies.

Technological Change

- Technologies that make research easier are unambigiously good.
- Technologies that make it easier to bring products to market may undermine the research process by redirecting efforts.