PhD defense

Modelling the low-carbon transition: a theoretical approach

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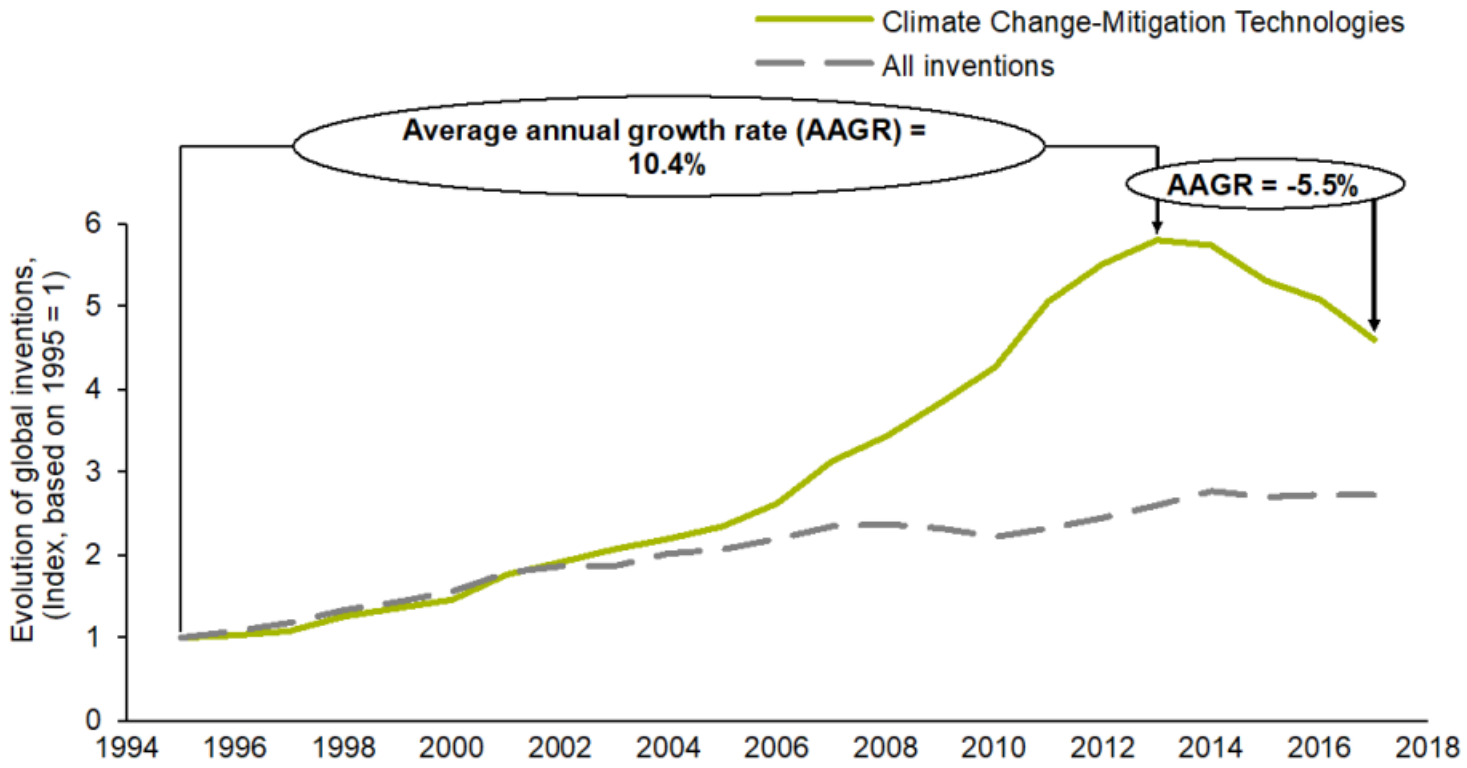
Introduction

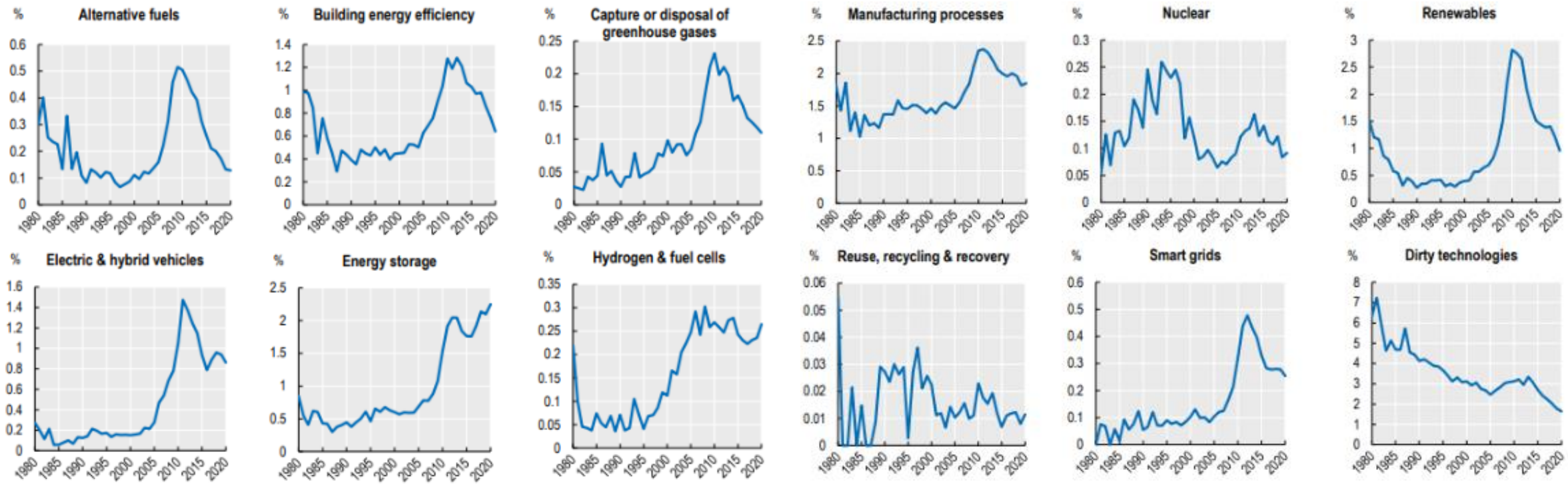
The pace of low-carbon innovations has slowed down…



Evolution of global inventions in climate change-mitigation, 1995-2017

Source: Probst et al. (2021)

… in almost all climate-related sectors



Evolution of climate change mitigation innovations by sector, 1980-2020

Source: Probst et al. (2021)

Path dependency of green innovation

- There is a path dependency of green innovation
  - More green innovation today is expected to lead to even more green innovation in the future
  - Theoretical side: Acemoglu et al. (2012) « The Environment and Directed Technical Change »
  - Empirical side: Aghion et al. (2016) « Carbon Taxes, Path Dependency, and Directed Technical Change: Evidence from the Auto Industry »

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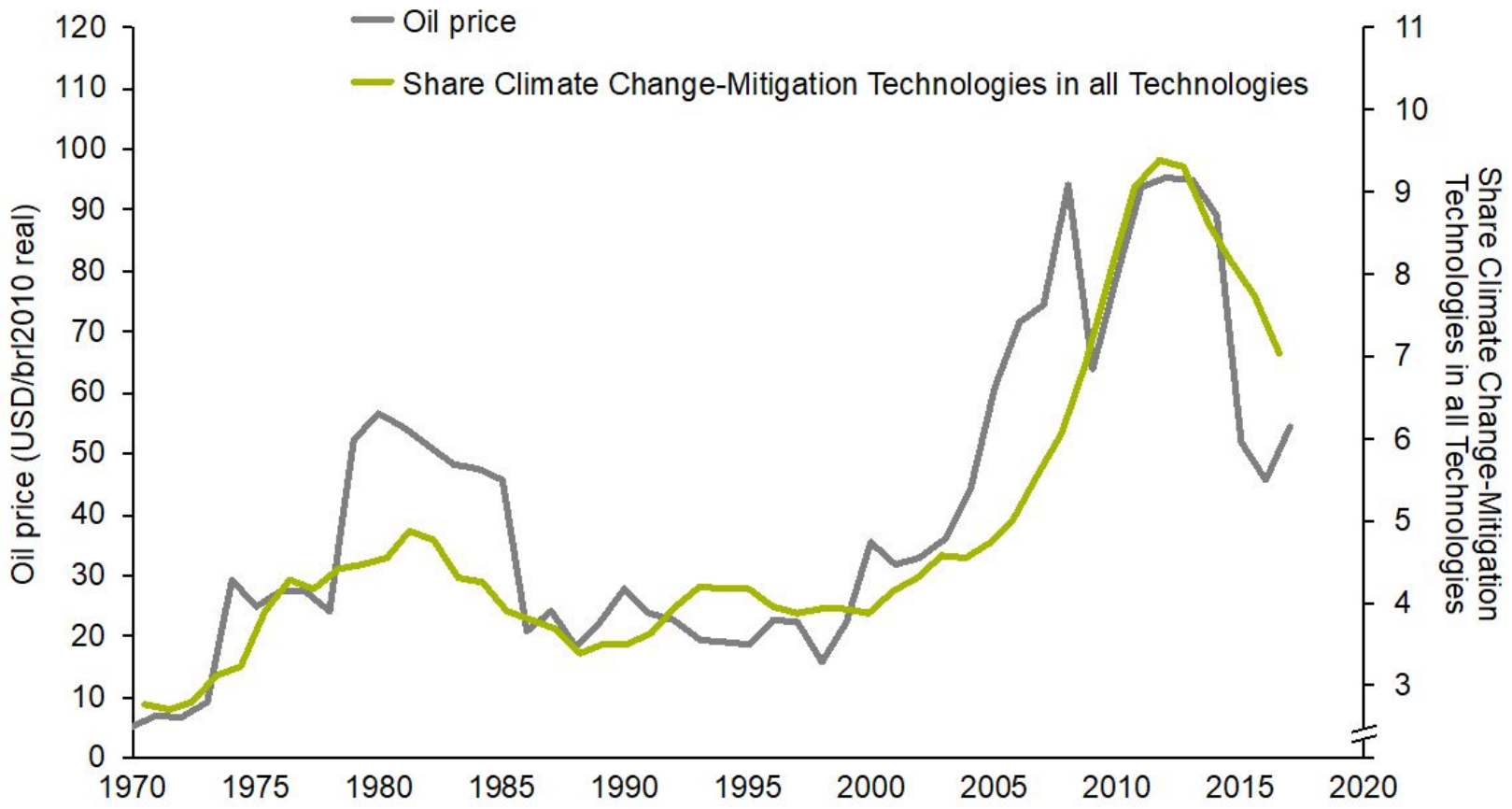
- The trajectory of green innovation over the past twenty years seems inconsistent with this concept of path dependency

- Why did green innovation suddenly decline after increasing for nearly two decades?

Literature

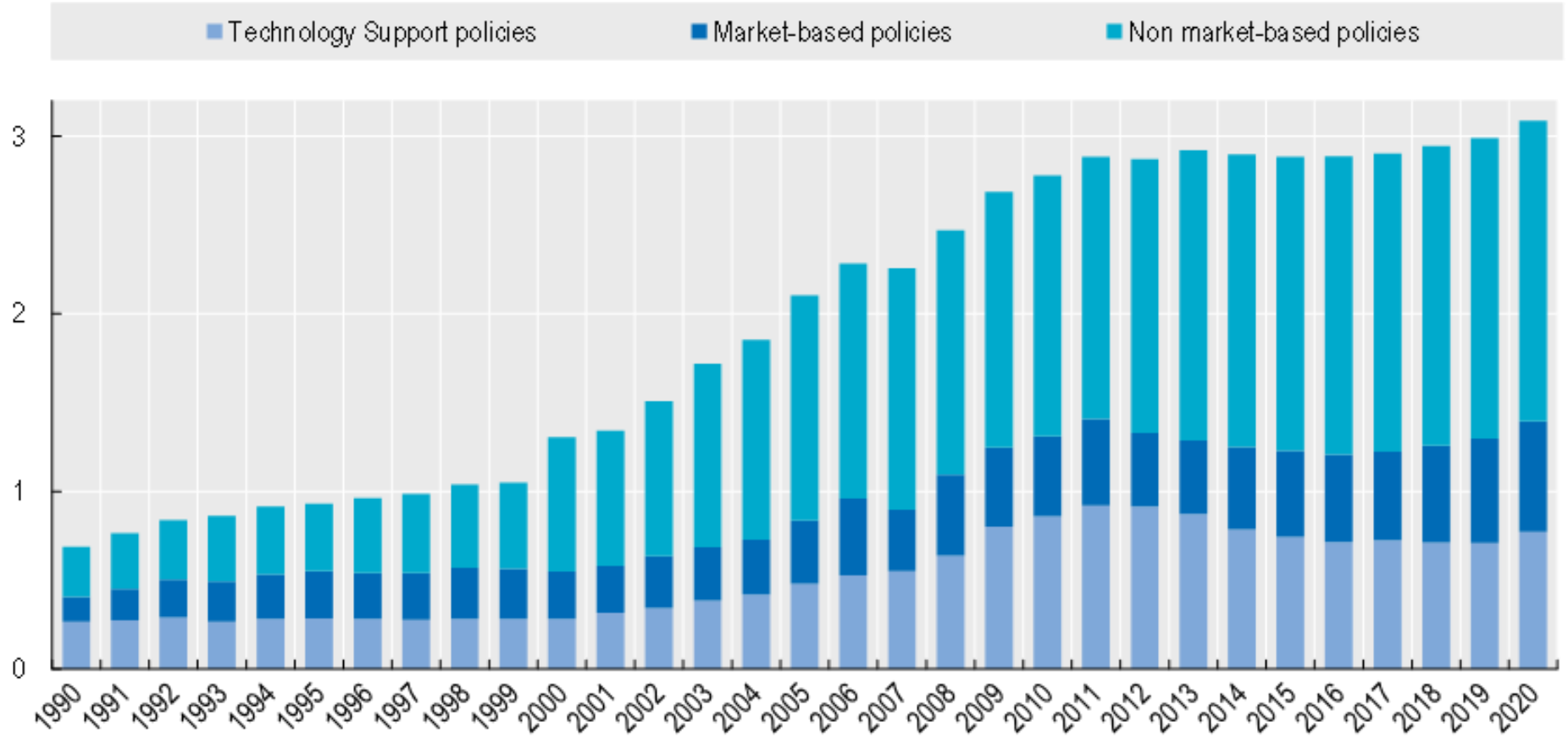
- Why this sudden downturn? Possible explanations
  - Oil price drop: Acemoglu et al. (2019), Popp et al. (2020), Probst et al. (2021), Cervantes et al. (2023)
  - Weaker regulatory support: Popp et al. (2020), Cervantes et al. (2023)

Oil price vs green patents



Share of « green » patents vs oil price, 1970-2020 (Probst et al. (2021))

Slowdown in growth of climate policy stringency



Climate policy stringency in OECD countries, 1990-2020

Source: Cervantes et al. (2023) OECD

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In line with the **path dependence** result, all these explanations for the downturn are **exogenous**. We would like to propose **endogenous** explanations

We propose two other possible explanations

1. **Insufficient progress in energy storage.** We focus on the energy sector and show that the path dependency result from AABH no longer holds when renewables intermittency is taken into account
   - **Chapter 1.** Energy storage and the direction of technical change, *Economics Bulletin*, 2022.

2. **Imperfect competition.** We focus on the photovoltaics sector and propose an explanation based on imperfect competition: a consequence of China's state-subsidized solar PV production expansion.
   - **Chapter 2.** Green innovation downturn: The role of imperfect competition, w. René Aïd and Anna Creti, *Energy Economics*, 2023

Urban organization, air quality and carbon emissions

Map of median annual salary revenues (in euros) in Paris and Parisian suburbs.

Urban organization, air quality and carbon emissions

- There exists a relationship between urban air pollution and economic activity: economic activity generates pollution, for instance through heating and transportation; in turn, pollution spreads around and generates economic disutility.
  - Housing values are negatively affected by air pollution: e.g. Fontenla et al. (2019)

- As air quality can affect the economic activity of the city, it may have also an impact on carbon emissions.

- In **Chapter 3**, we couple a urban economics model with an atmospheric dispersion model.
  - ➢ An equilibrium model of city with atmospheric pollution dispersion, w. Quentin Petit, *Journal of Mathematical Economics*, R&R, 2023

Chapters 1 and 2

Chapter 1

Energy storage and the direction of technical change

Accepted in: *Economics Bulletin*, 2022
Presented at: GCET 24 (Paris, France)

Model

- An extension of AABH schumpeterian growth model
- A unique final good is produced by fossil and renewable technologies
- Renewable technologies are assumed to be intermittent and need to be backed up by fossil technologies or storage
- We characterize the Laissez-Faire Equilibrium and the Social Optimal Allocation

Results

- We show that path dependency no longer holds when renewable technologies' intermittency is taken into account
  - As long as storage is expensive, renewables must be backed up by fossil fuels, which end up capturing all the innovation.

- The regulator can counteract this effect and reach the social optimum by implementing a carbon tax and subsidizing the research in renewable AND storage technologies.

- If the objective is to minimize the transition period during which fossil energy is used, then innovation should always be directed towards the less advanced sector between renewable energy and storage.

Policy recommendations

- In 2021 (Lazard (2021a), Lazard (2021b)):
  - CCGT: between 45$ and 74$/MWh
  - Solar PV: between 28$ and 37$/MWh
  - Storage: between 165$ and 296$/MWh

- Governments should now prioritize supporting research in the storage sector

- Supporting research and innovation in energy storage (particularly in long-term storage) is part of the European Commission recommendations on energy storage published in March 2023

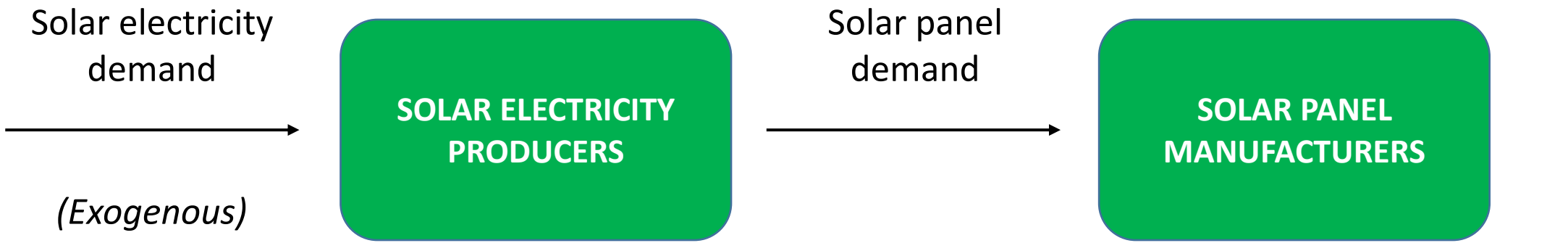
Chapter 2

Green innovation downturn: The role of imperfect competition

Published in: *Energy Economics*, jww René Aïd and Anna Creti, 2023
Presented at: EAERE 2022 (Rimini, Italy), PET 2022 (Marseille, France)

Model

- A dynamic game model, inspired by Pillai & McLaughlin (2013)



Competitive market

Duopoly: a European one (**E**) *and a Chinese one* (**C**)

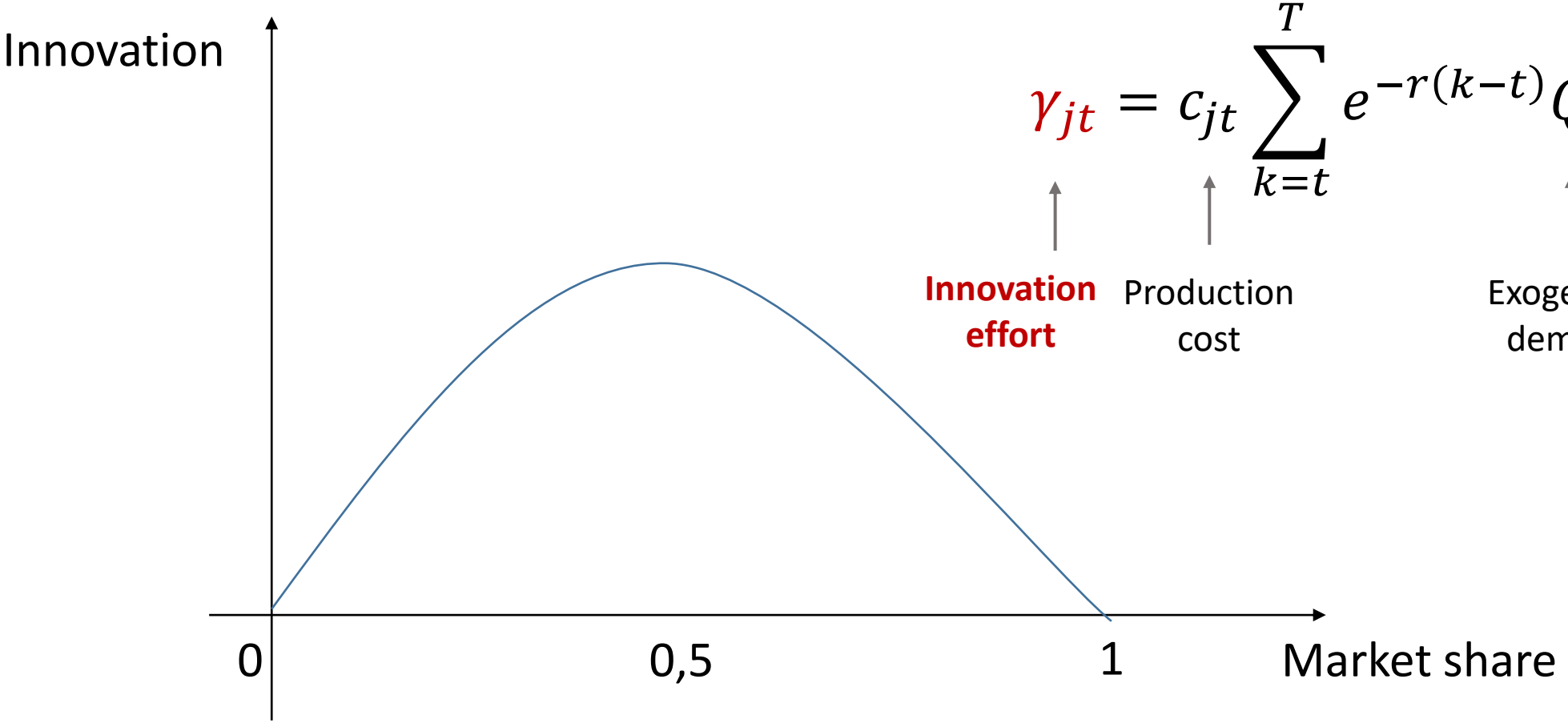
- *Price competition*
- *Cost-reducing R&D*
- *Chinese manufacturer is state-subsidized*

An inv-U relationship between innovation and market share

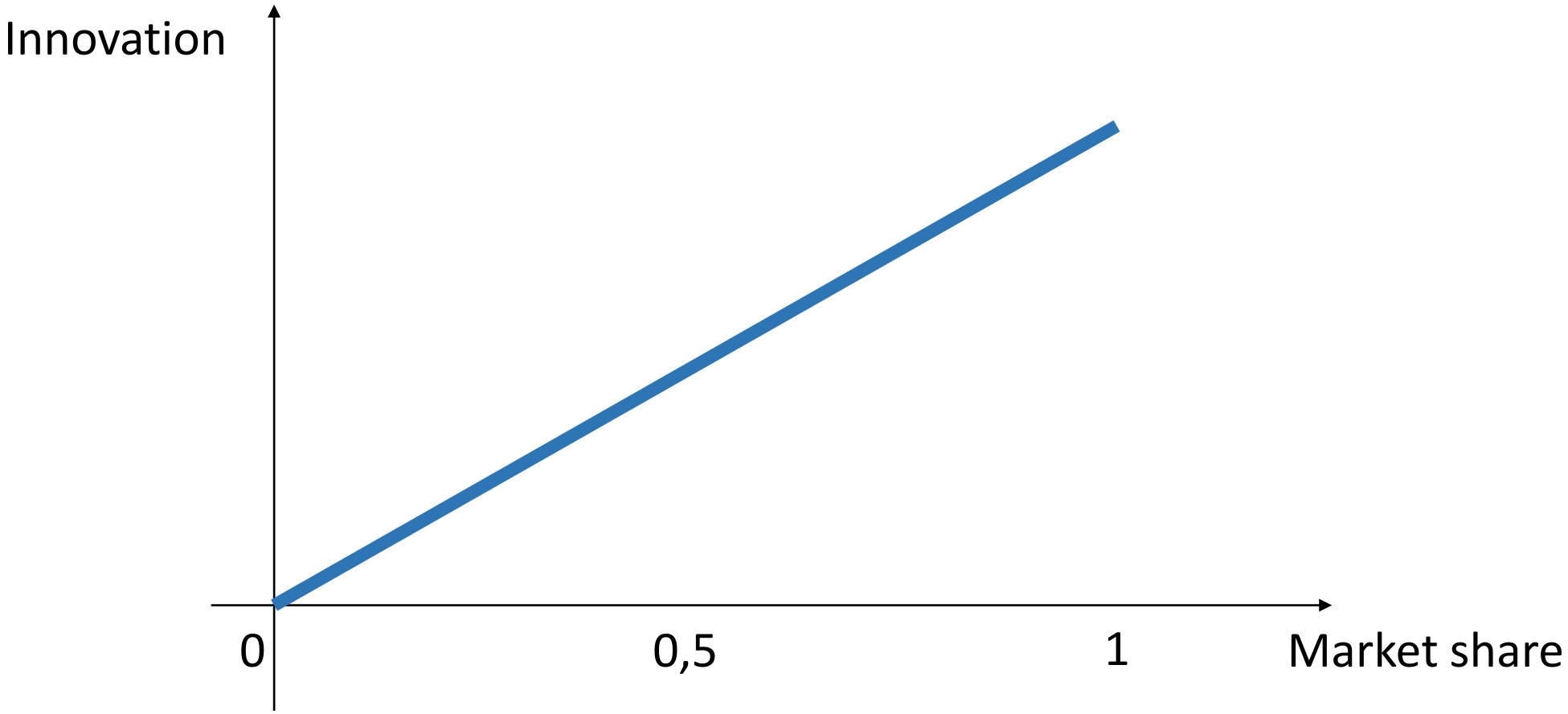
For **L** and **F**, at the Nash equilibrium

$$\gamma_{jt} = c_{jt} \sum_{k=t}^{T} e^{-r(k-t)} Q_k s_{jk}(1 - s_{jk})$$

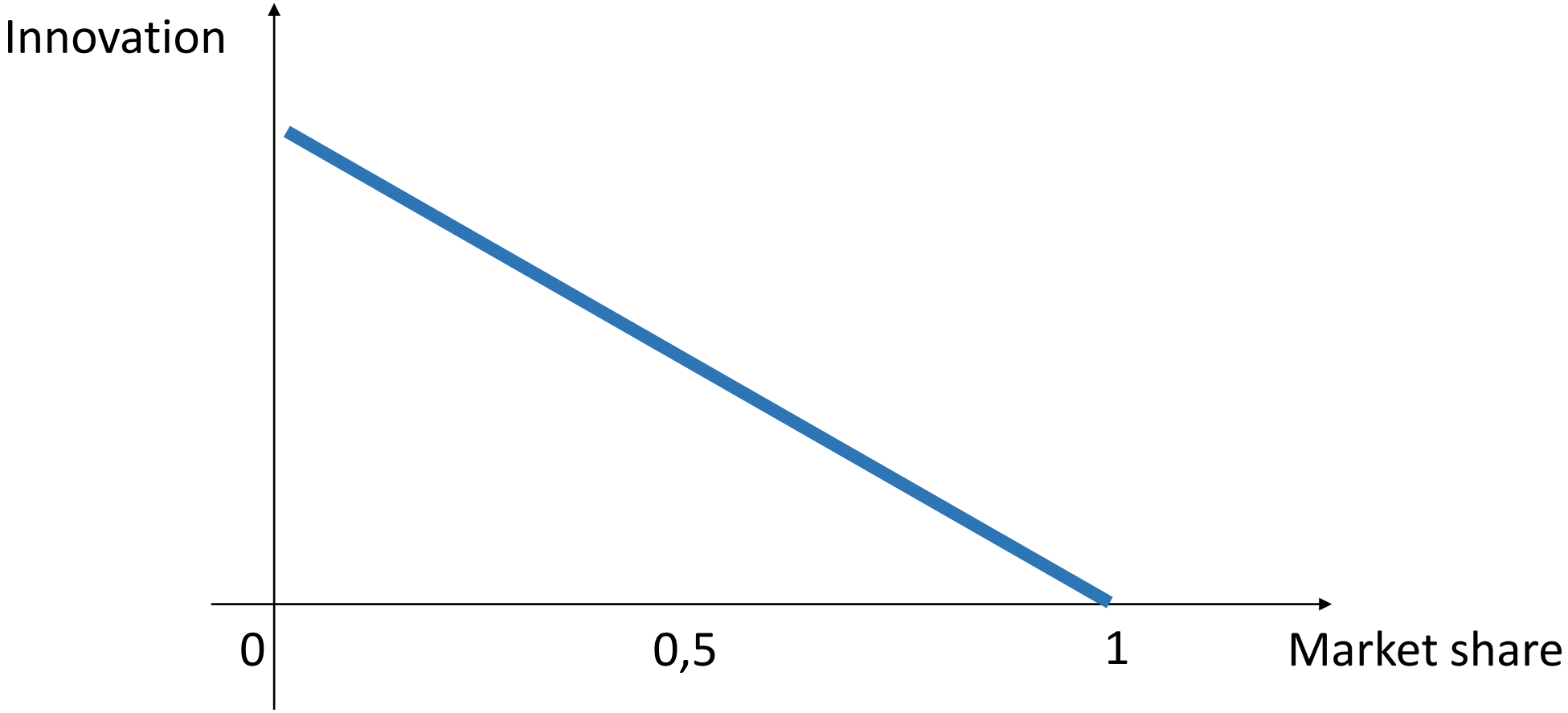
Innovation effort | Production cost | Exogenous demand | **Market share**



The Schumpeterian view (1949)



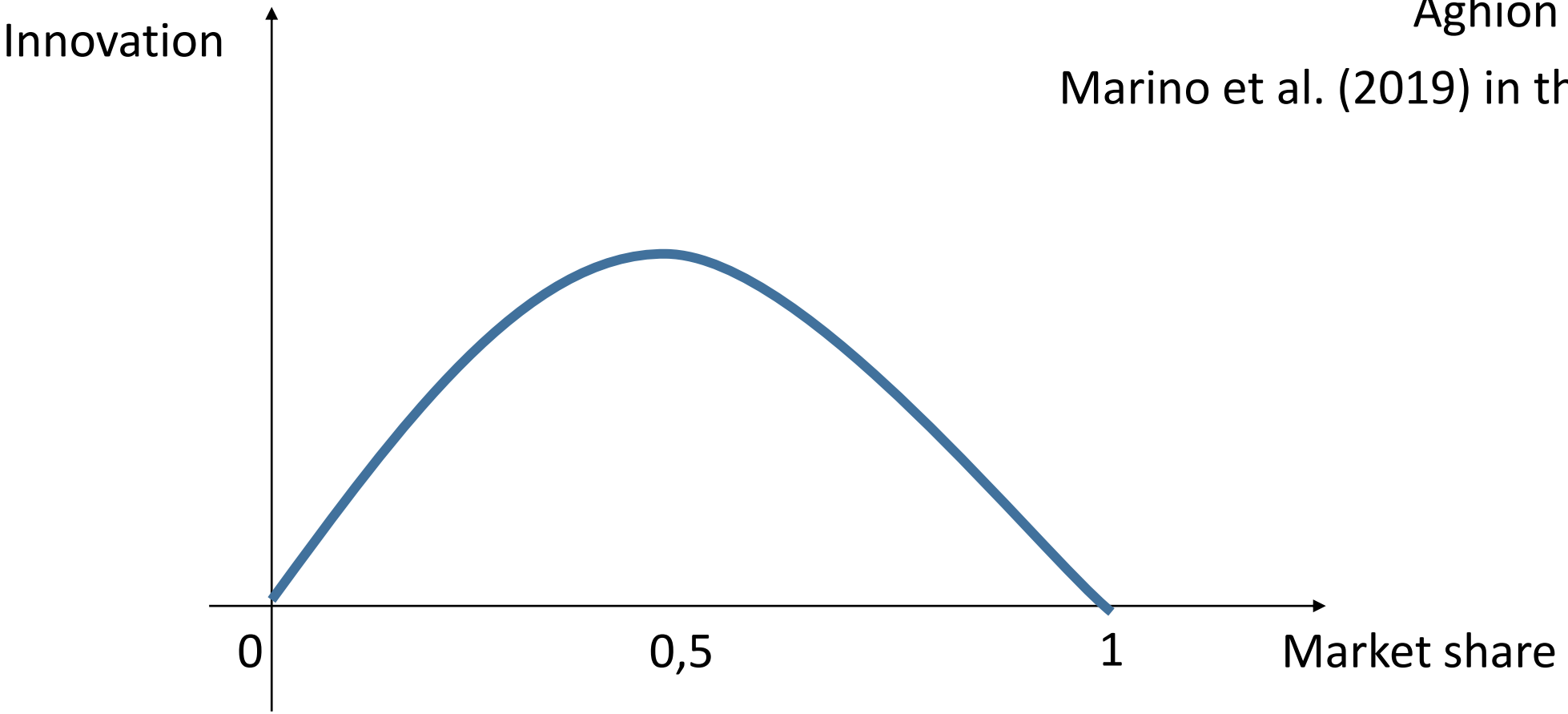
The Arrowian view (1962)



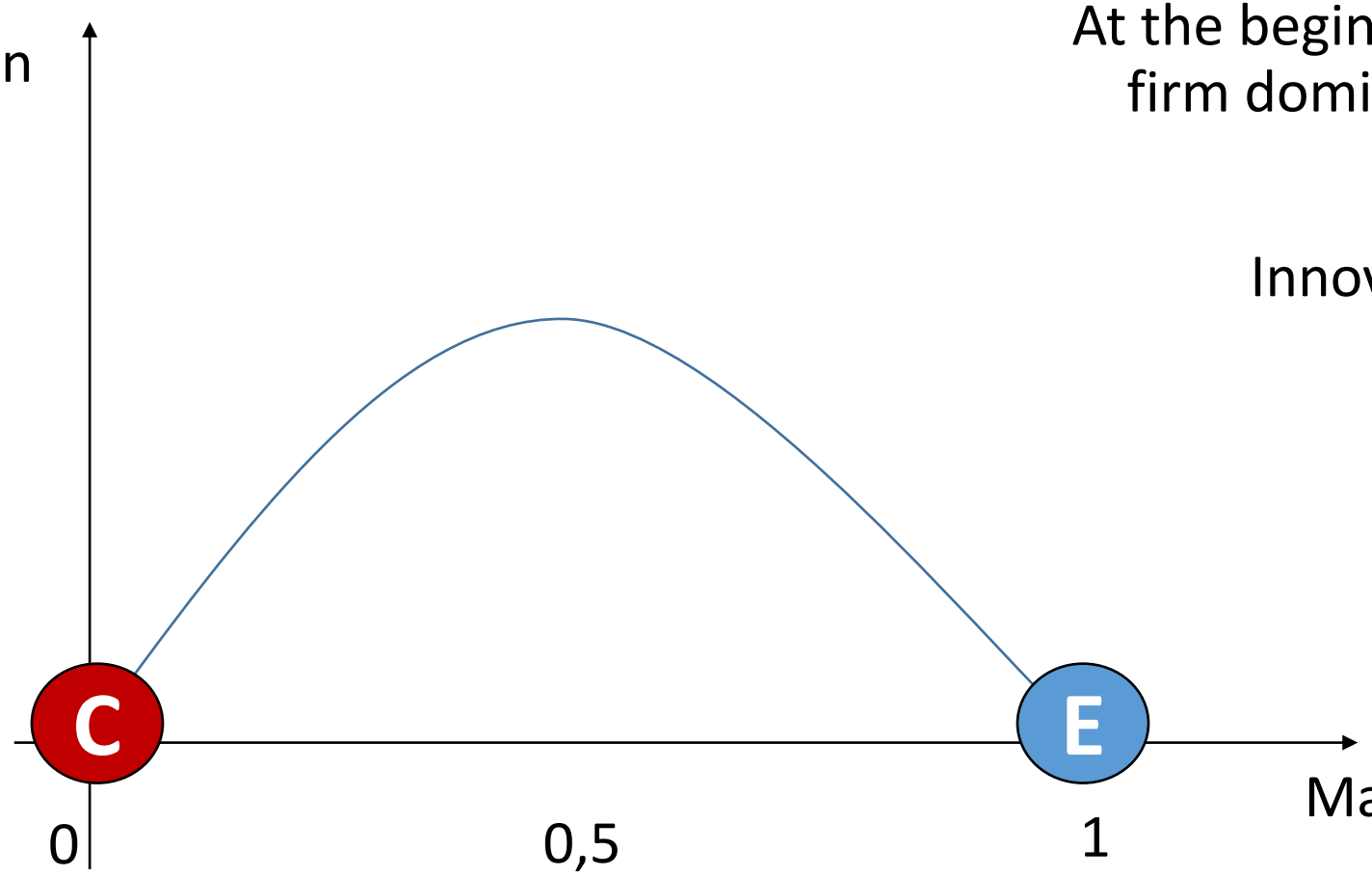
An inv-U relationship between innovation and market share

Aghion et al. (2005)

Marino et al. (2019) in the electricity sector



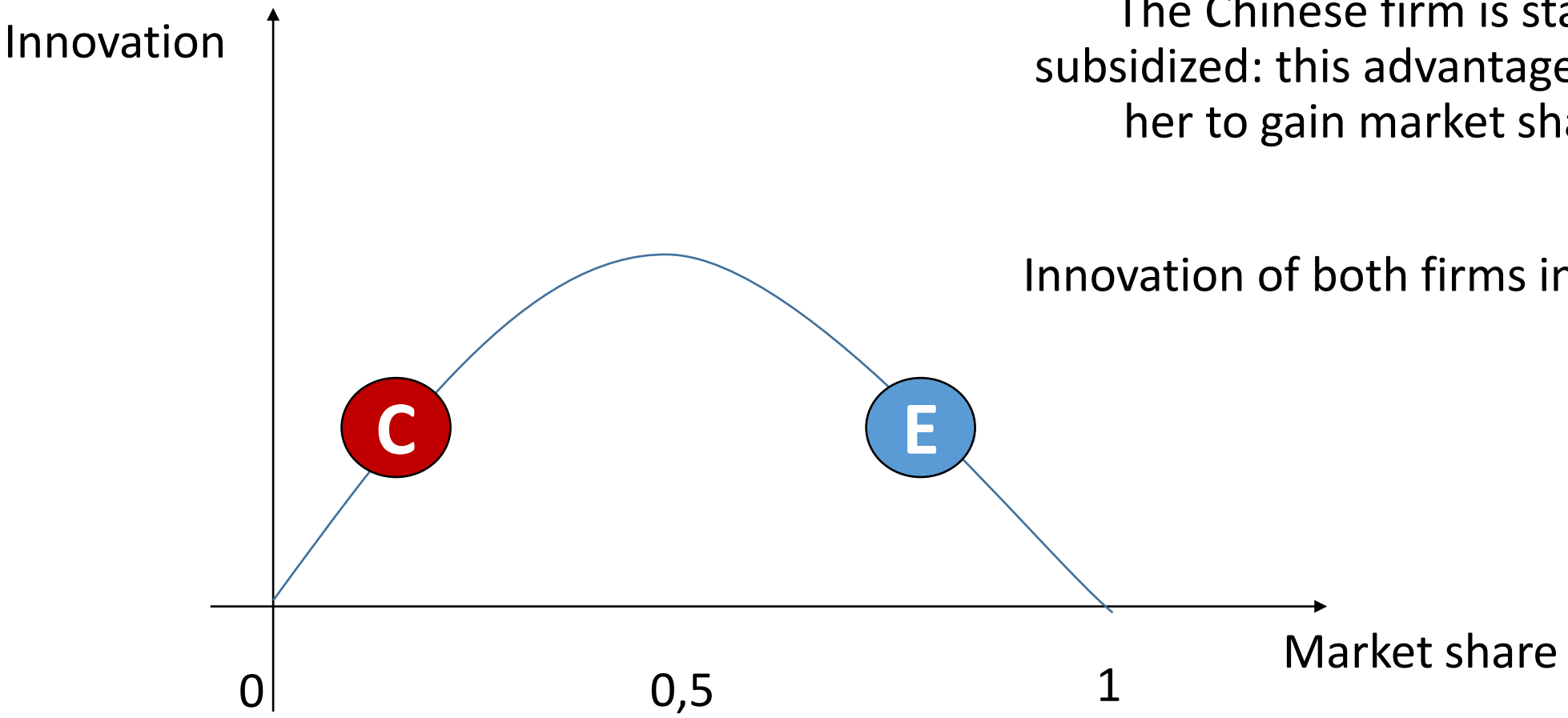
Results



At the beginning, the European firm dominates the market

Innovation is low

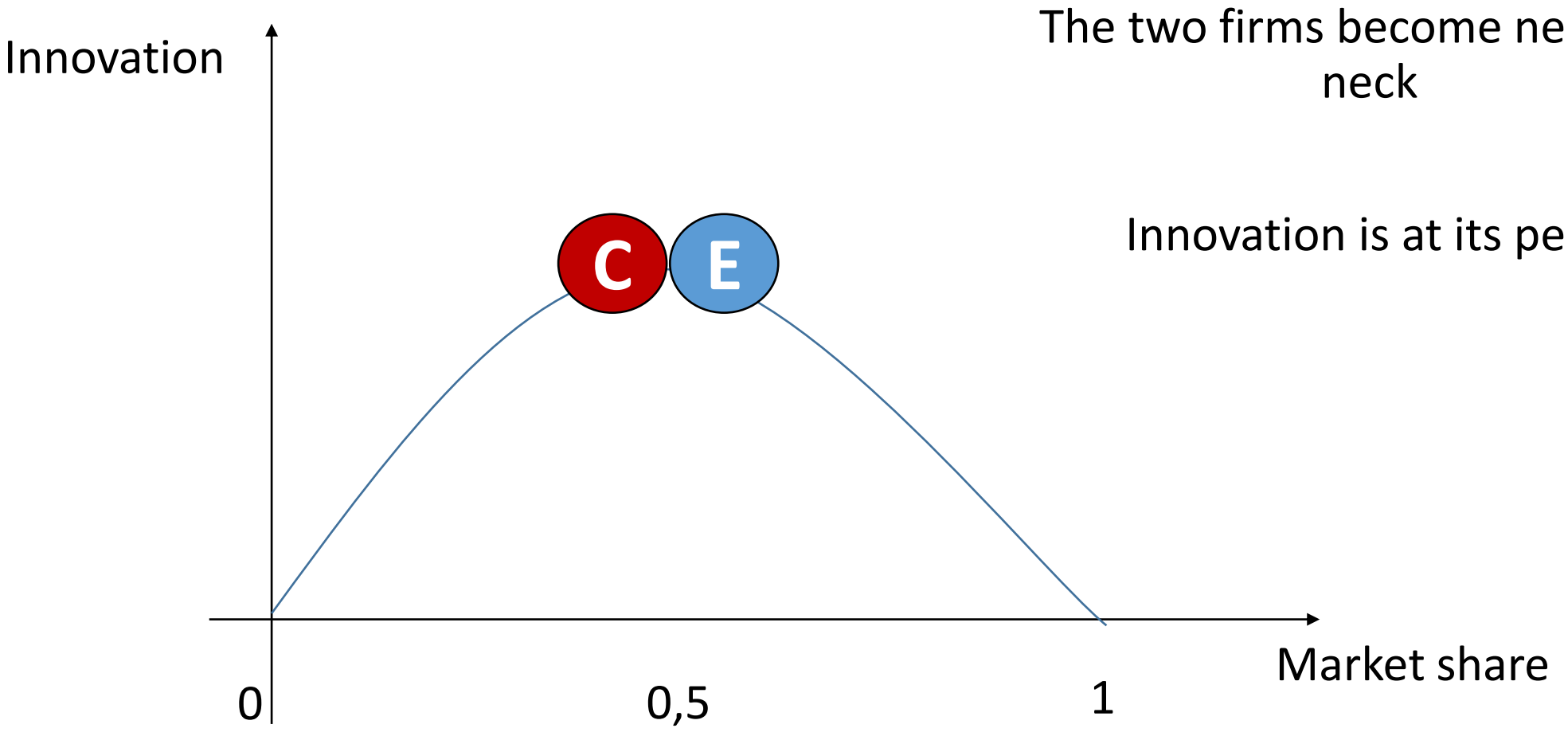
Results



The Chinese firm is state-subsidized: this advantage allows her to gain market share

Innovation of both firms increases

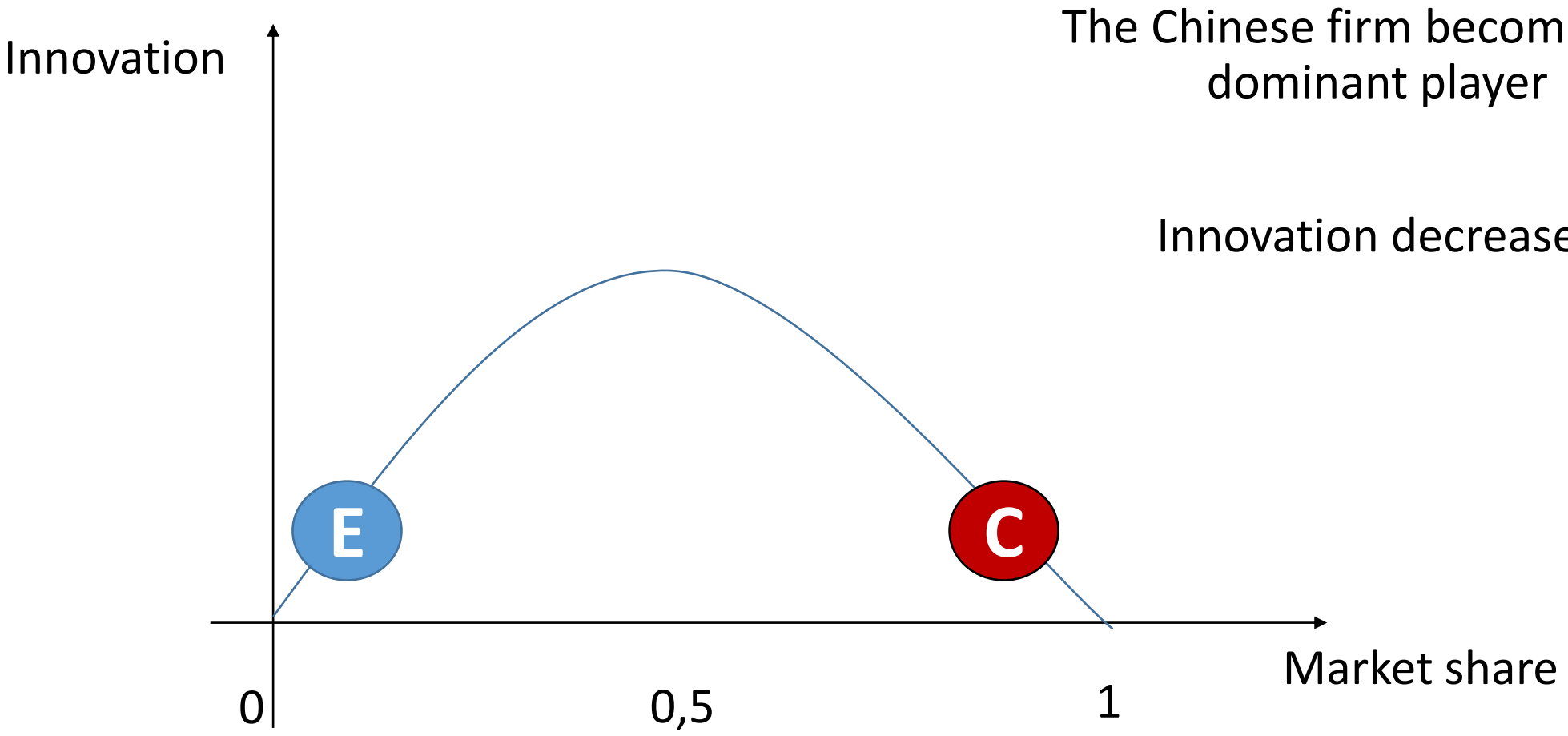
Results



The two firms become neck and neck

Innovation is at its peak

Results



The Chinese firm becomes the dominant player

Innovation decreases

Results

- The Nash equilibrium shows an inverted-U relationship between innovation and market share
- This relationship translates into an inverted-U trajectory of innovation over time
- National technology push policies, such as R&D subsidy, can affect cross-border innovation not only by spillover effects, but also by changing the structure of global competition

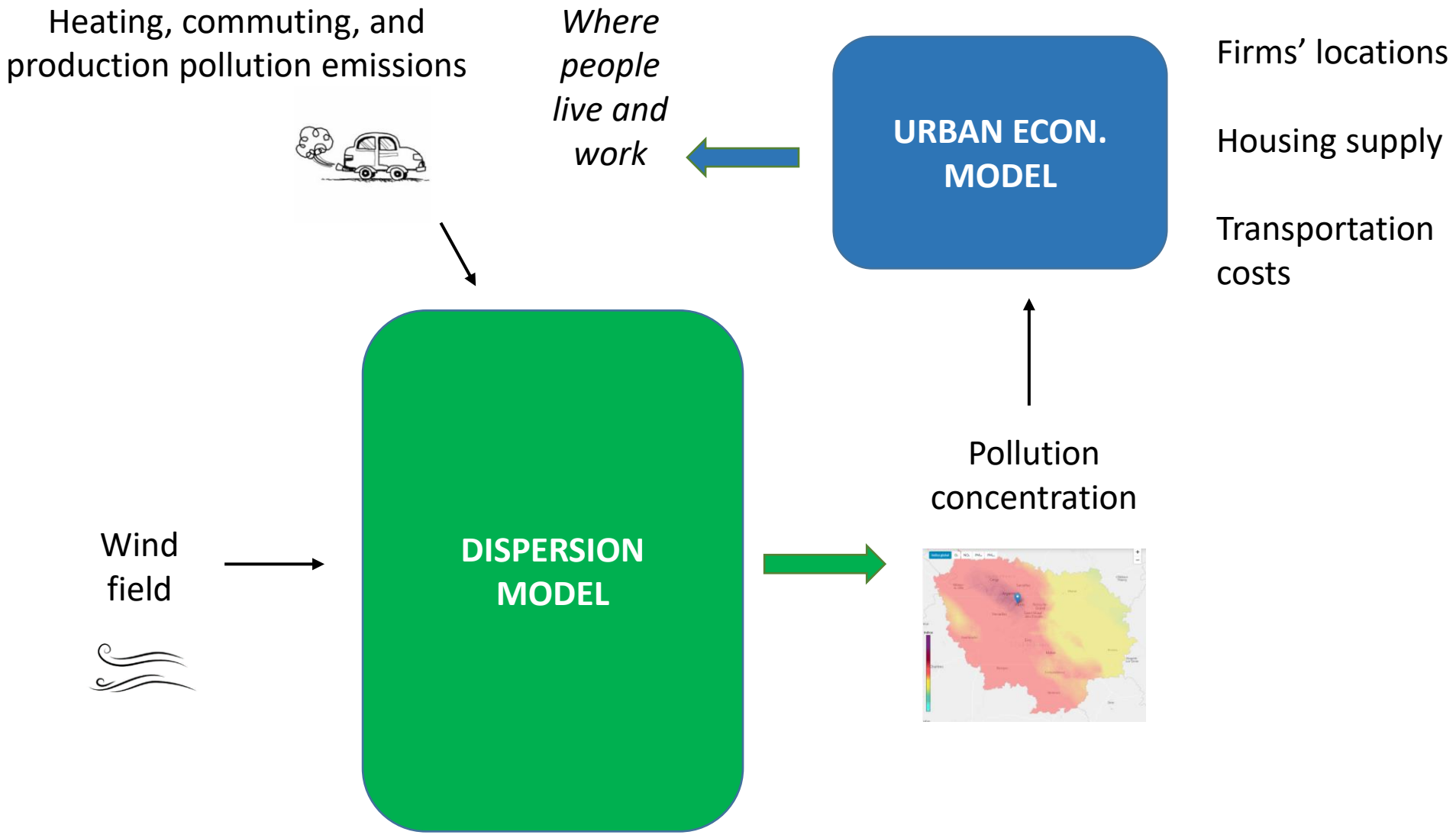
Chapter 3

Chapter 3

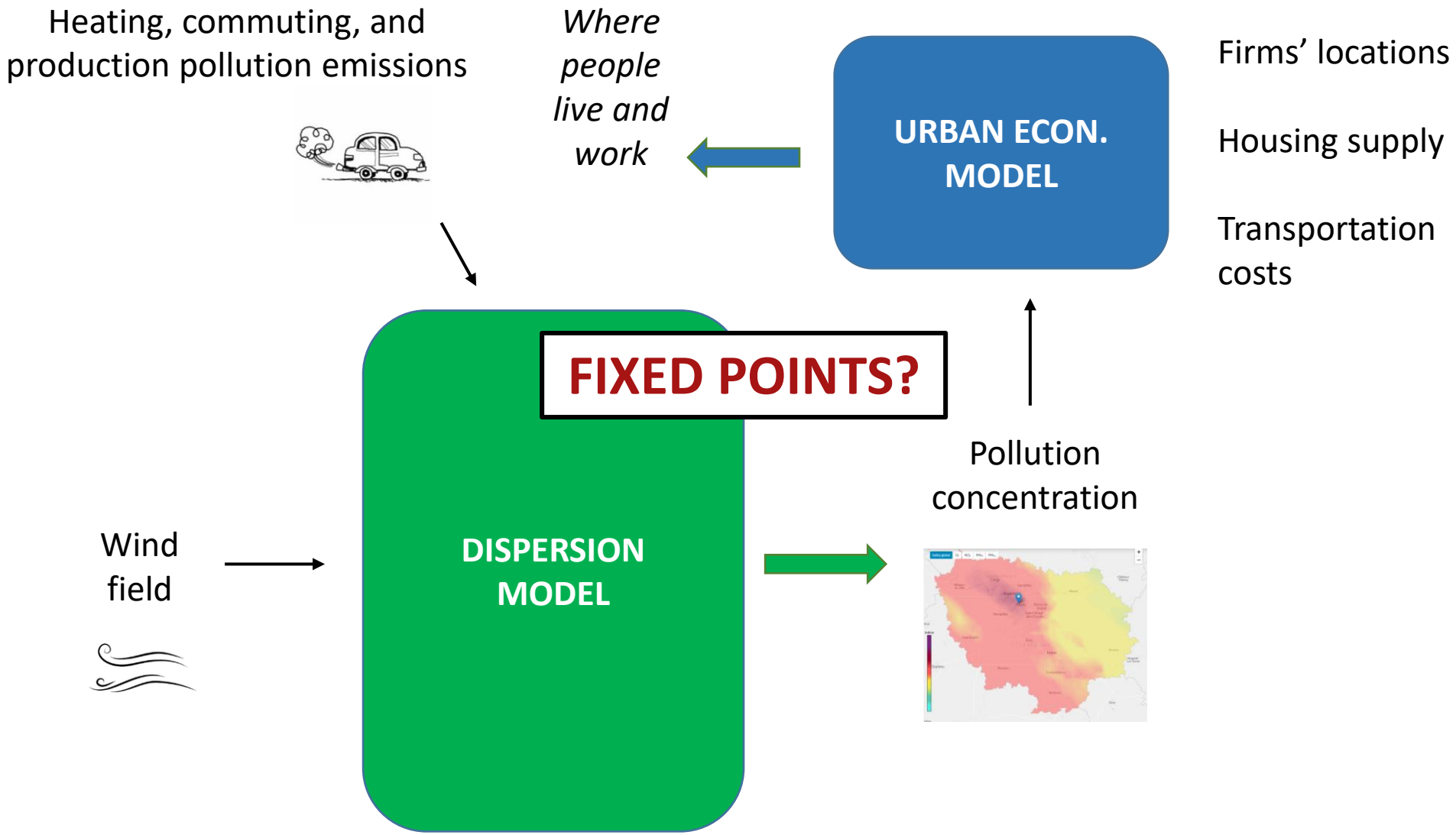
An equilibrium model of city with atmospheric pollution dispersion

In revision for: *Journal of Mathematical Economics*, jww Quentin Petit (EDF R&D)
Presented at: BSDE 2022 (Annecy, France), UEA 2023 (Milan, Italy), AFES 2023 (Nairobi, Kenya), LAGV 2023 (Marseille, France)

Model


Heating, commuting, and production pollution emissions
Where people live and work
URBAN ECON. MODEL
Firms' locations
Housing supply
Transportation costs
Wind field
DISPERSION MODEL
Pollution concentration

Model


Heating, commuting, and production pollution emissions
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URBAN ECON. MODEL
Firms' locations
Housing supply
Transportation costs
FIXED POINTS?
Pollution concentration
Wind field
DISPERSION MODEL

Results

- We prove existence and uniqueness of equilibria

- The model is currently used to assess the impact of the Low Emission Zone regulation in Paris region (ongoing work with Anna Creti and Eva Gossiaux)

Thank you for your attention