Green innovation downturn: The role of imperfect competition

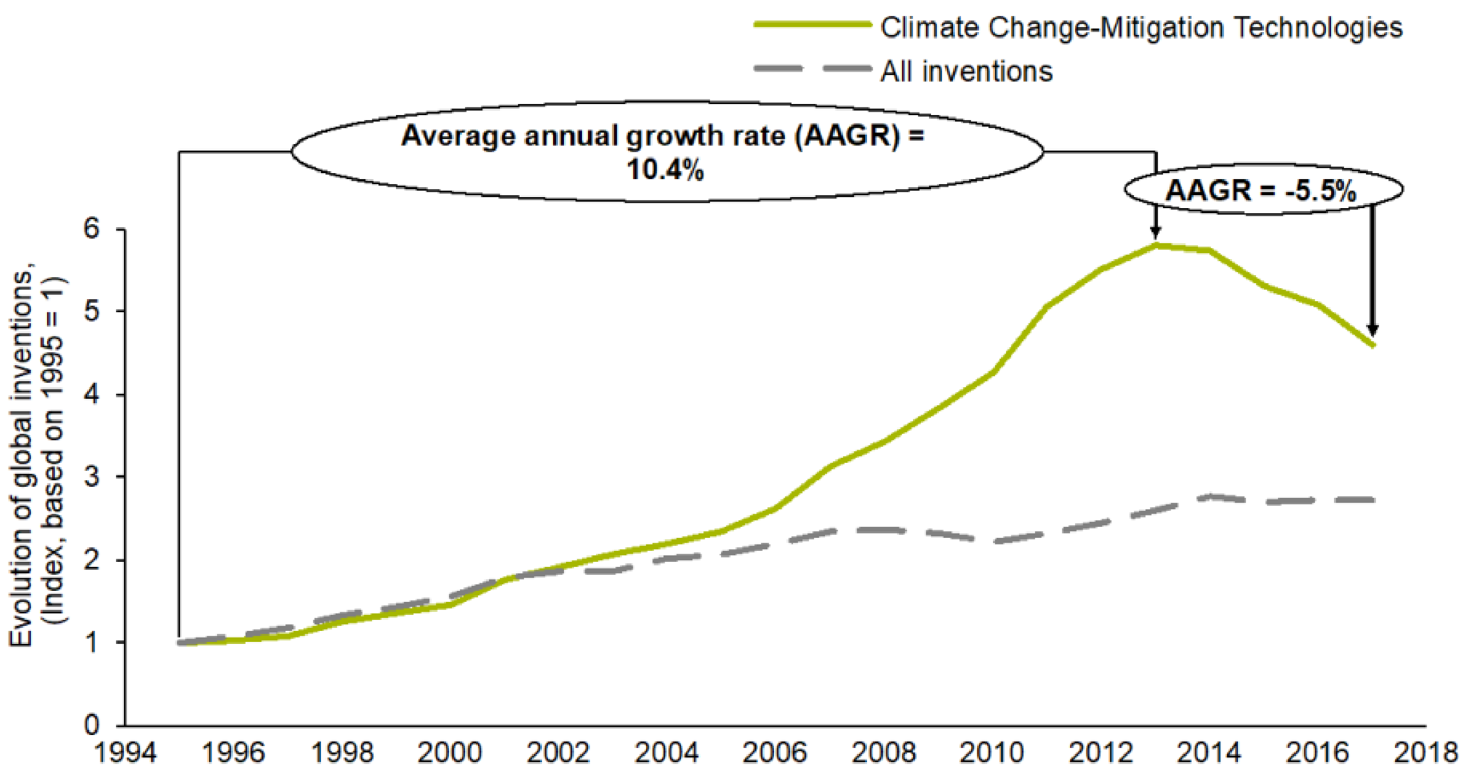
René AÏD (Université Paris Dauphine)

Mohamed BAHLALI (Université Paris Dauphine)

Anna CRETI (Université Paris Dauphine)

Introduction

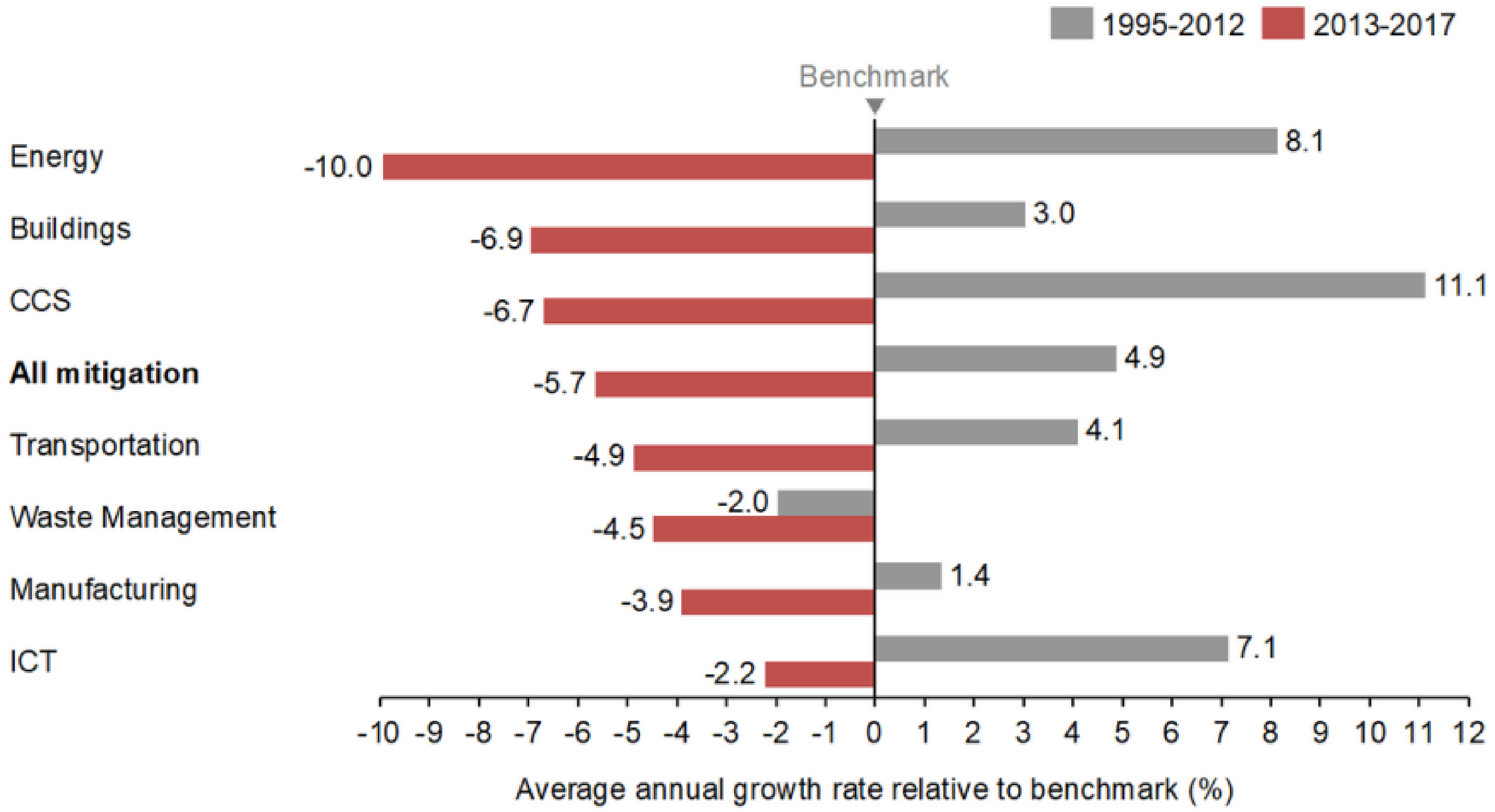
The pace of low-carbon innovations has slowed



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

Probst et al. (2021)

The pace of low-carbon innovations has slowed



Average annual growth of climate change mitigation innovations by sector

Probst et al. (2021)

Literature

- Acemoglu et al. (2012): « The Environment and Directed Technical Change »
  - Production of a unique final good from two substituable inputs, a clean one and a dirty one
  - There exists a « virtuous path dependence » of environmental technical change:

    More green innovation today leads to even more green innovation in the future

    (A high-level of green technologies today implies a larger market for green technologies, which leads to a larger market for green innovations, which leads to more green innovation)
  - Sustainable growth can be achieved with temporary taxes/subsidies aiming at redirecting innovation from dirty toward green technologies

    Once green technologies become cheaper than dirty technologies, green innovation would increase by itself indefinitely

The « virtuous path dependence » in AABH

Literature

- So, why this sudden downturn? Possible explanations

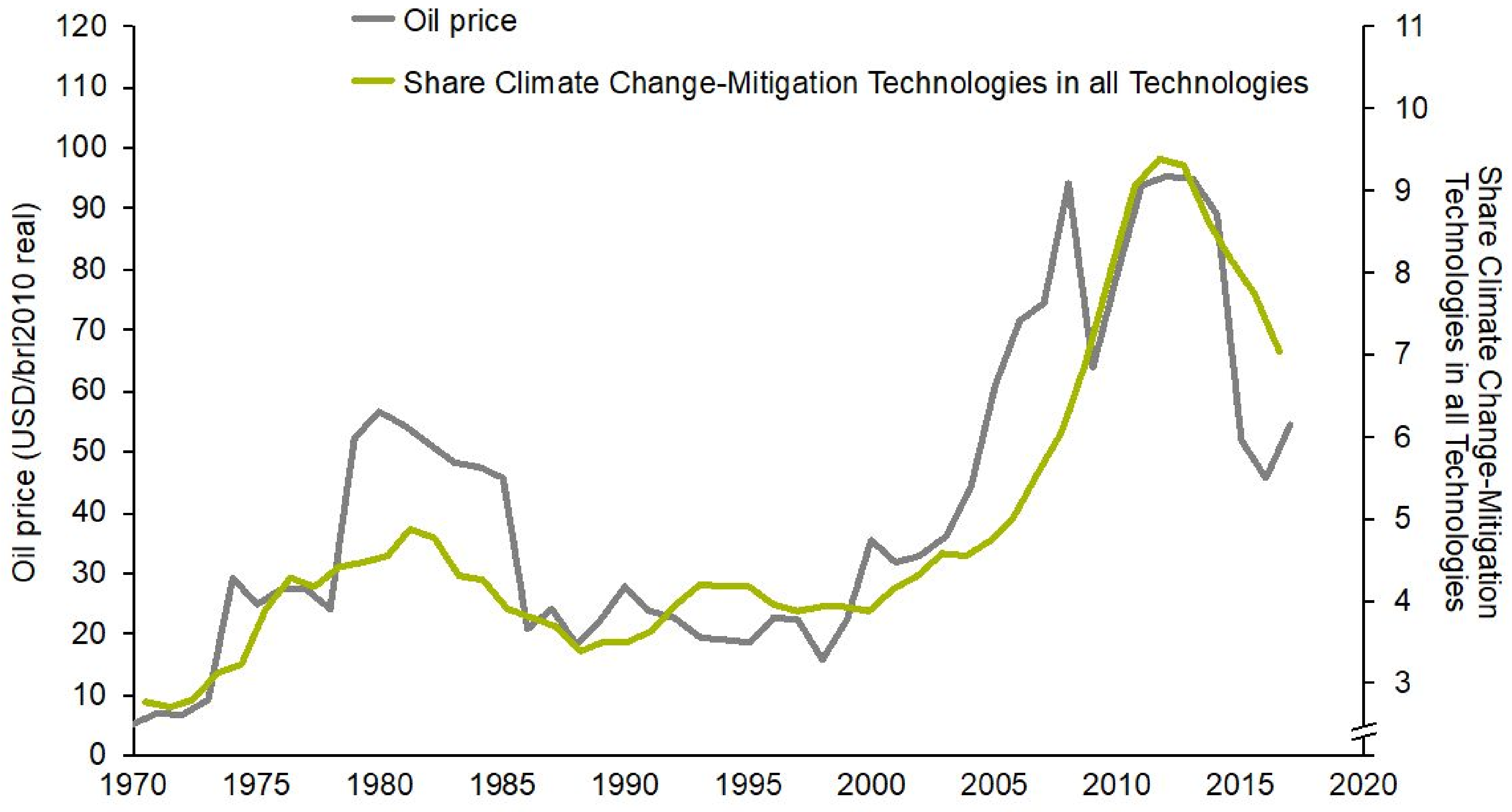
    Acemoglu et al. (2019), Popp et al. (2020): the US shale gas boom

    Popp et al. (2020), Probst et al. (2021): oil price drop

    - in line with the Induced Innovation Hypothesis (Popp (2000))

    Popp et al. (2020): weaker and uncertain regulatory support

Literature



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

Literature

- So, why this sudden downturn? Possible explanations

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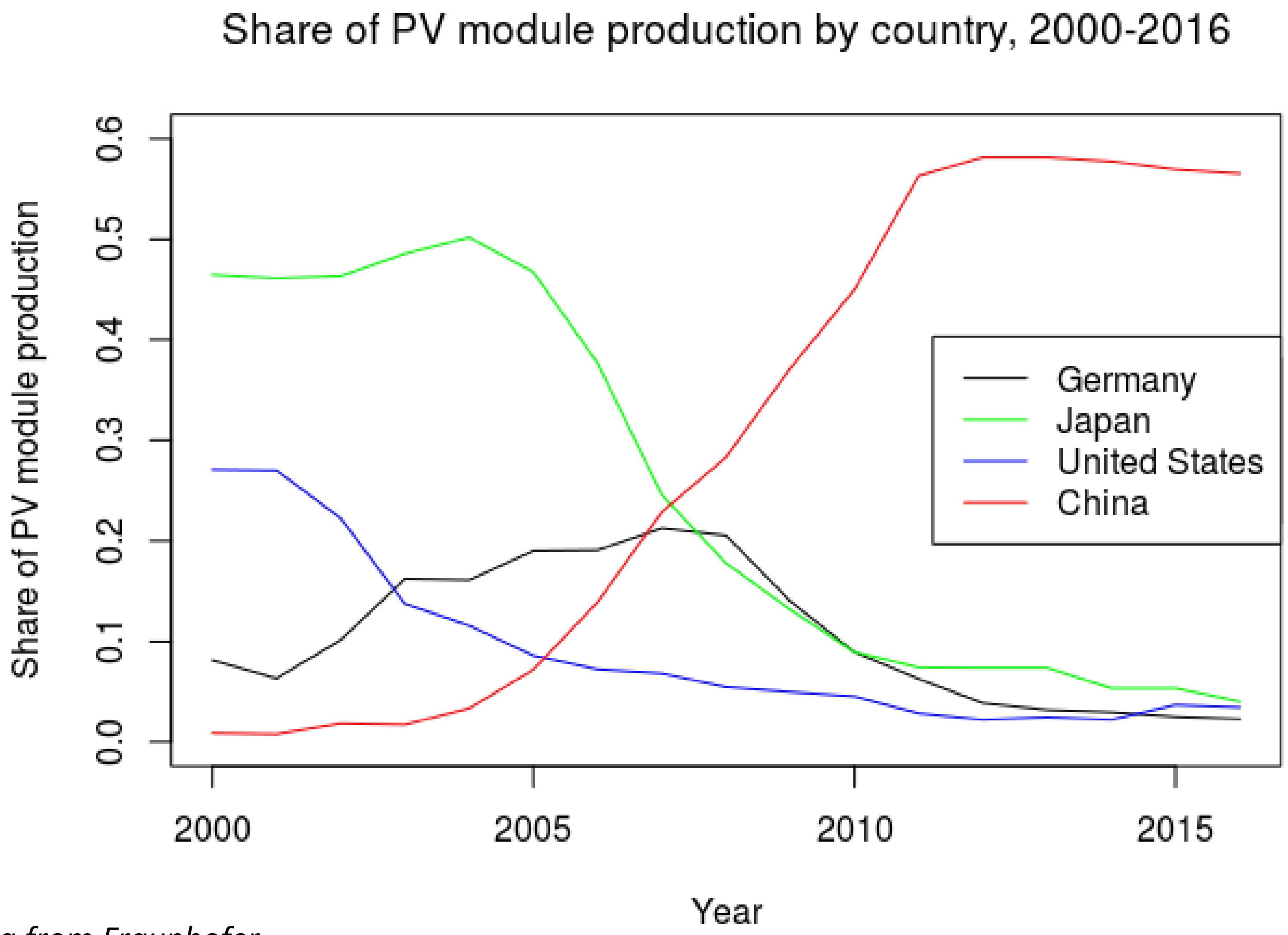
In line with the **path dependence** result, all these explanations for the downturn are **exogenous**. We would like to propose **endogenous** explanations

Our approach

- We propose an endogenous interpretation of this downturn, based on imperfect competition: a consequence of China's state-subsidized solar PV production surge.
  - An interpretation already suggested (in a think-tank paper) by Hart (2020)
  - The expansion of state-subsidized Chinese solar panel manufacturers has induced significant cost reduction, but also weakened the global industry to the point of undermining innovation.

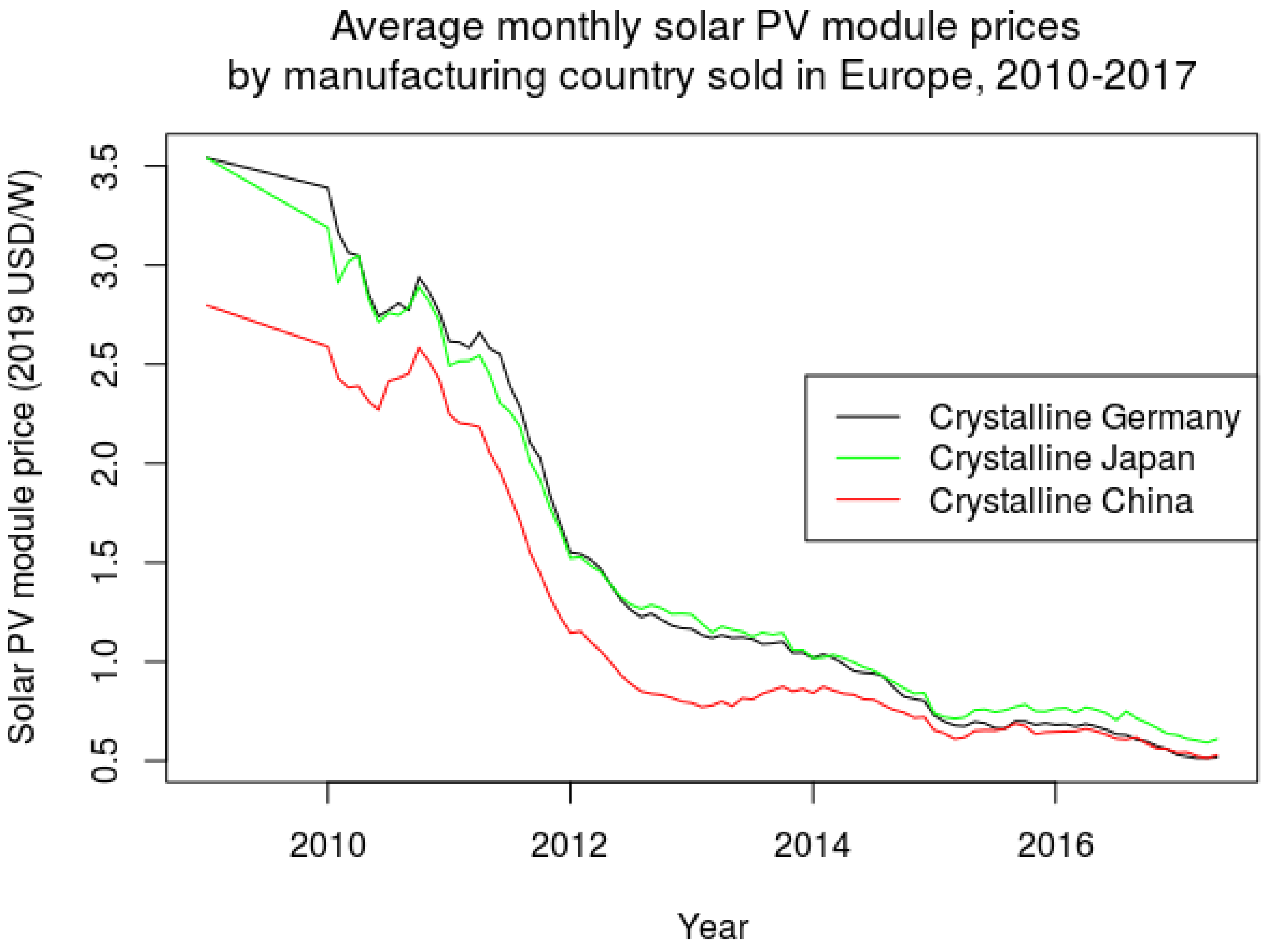
- We develop a dynamic game model that puts the following three facts in relationship:
  - Fact 1: China has become the dominant global player in PV manufacturing,
  - Fact 2: Global PV module prices have fallen,
  - Fact 3: Global solar PV innovation has peaked in 2010.

Fact 1: China has become the dominant global player in PV manufacturing



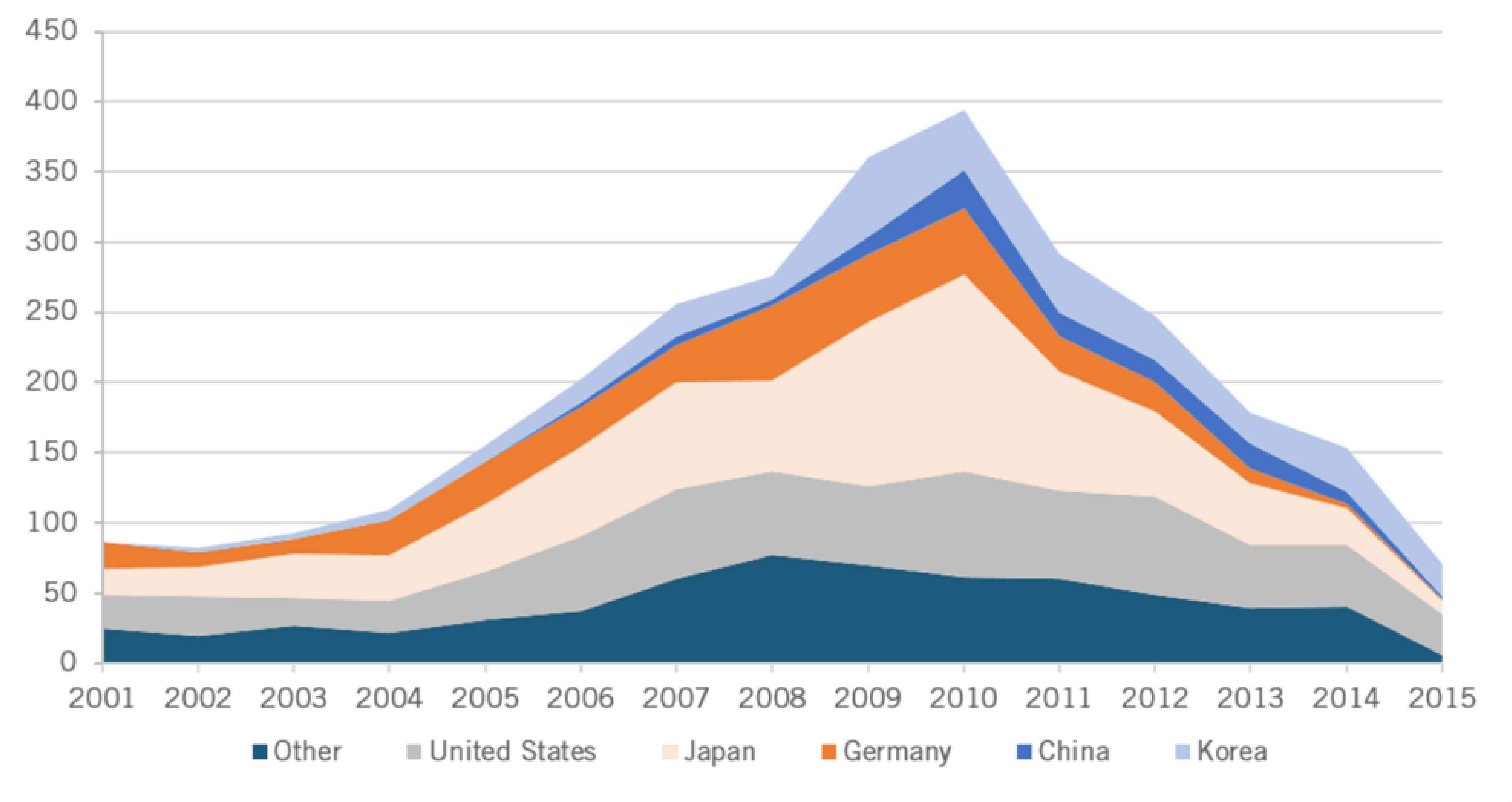
Author's graph based on data from Fraunhofer Institute for Solar Energy Systems (2020)

Fact 2: Global PV module prices have fallen



Author's graph based on data from IRENA (2020)

Fact 3: Global solar PV innovation has peaked in 2010

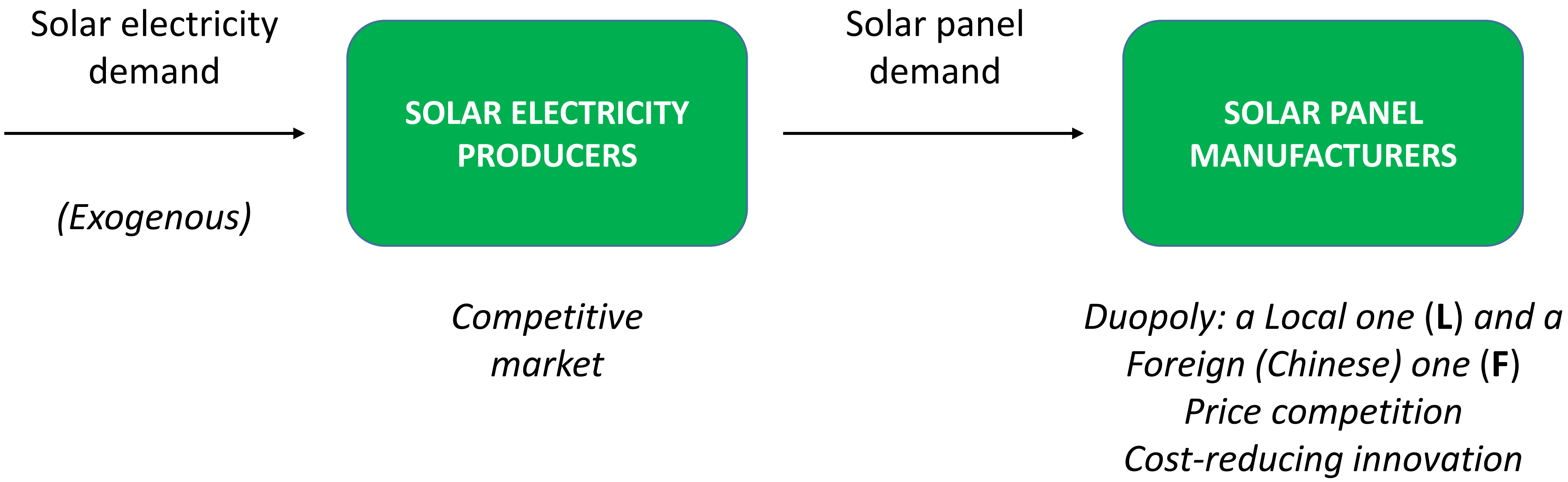


Hart (2020)

Triadic patents for PV inventions by country, 2001-2015

Model

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

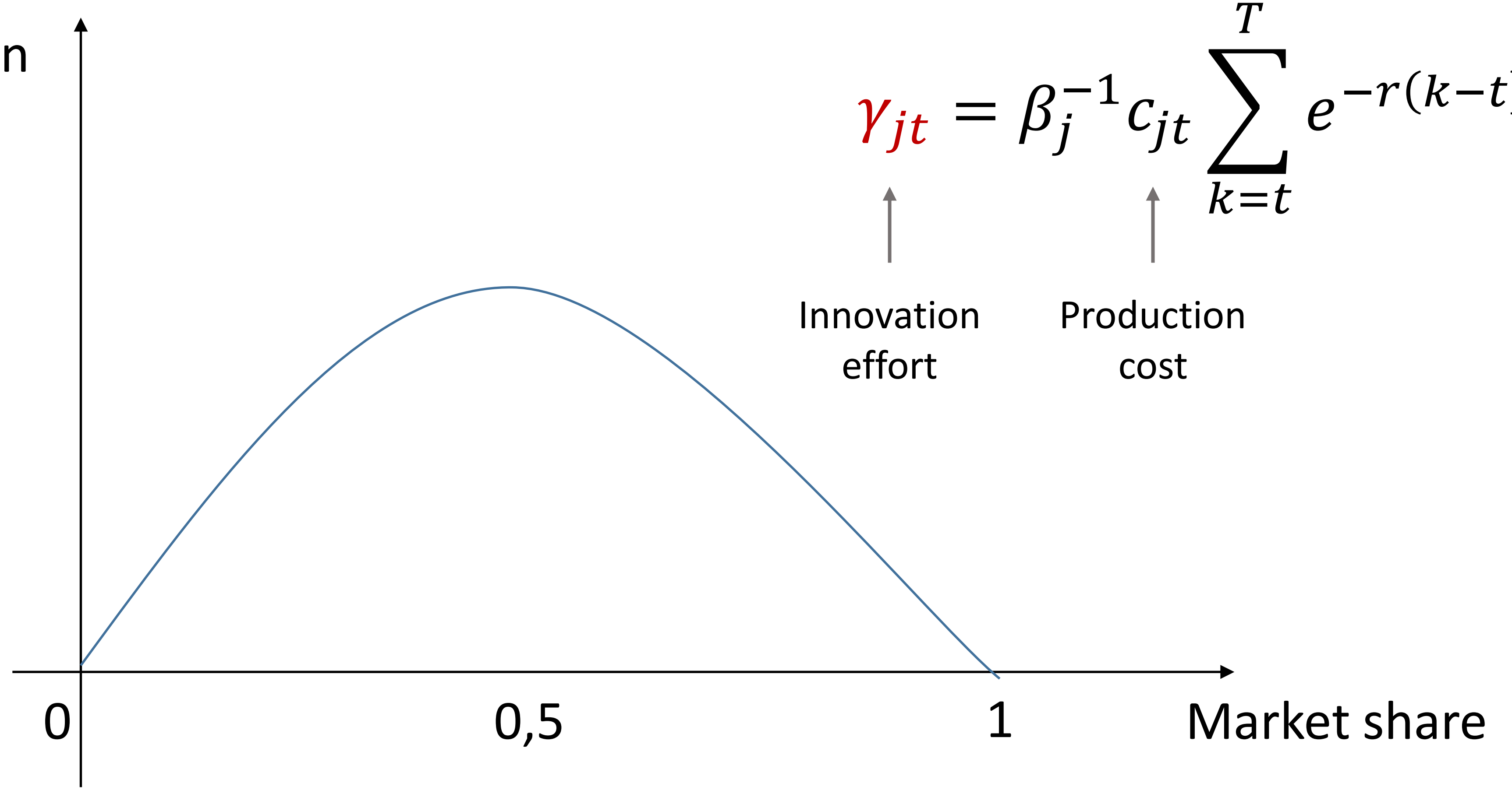


Assumptions

- The Foreign (Chinese) firm (F) has initially a lower market share than the Local one (L)

- The Foreign firm faces lower R&D costs than the Local one

An inv-U relationship between innovation and market share



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

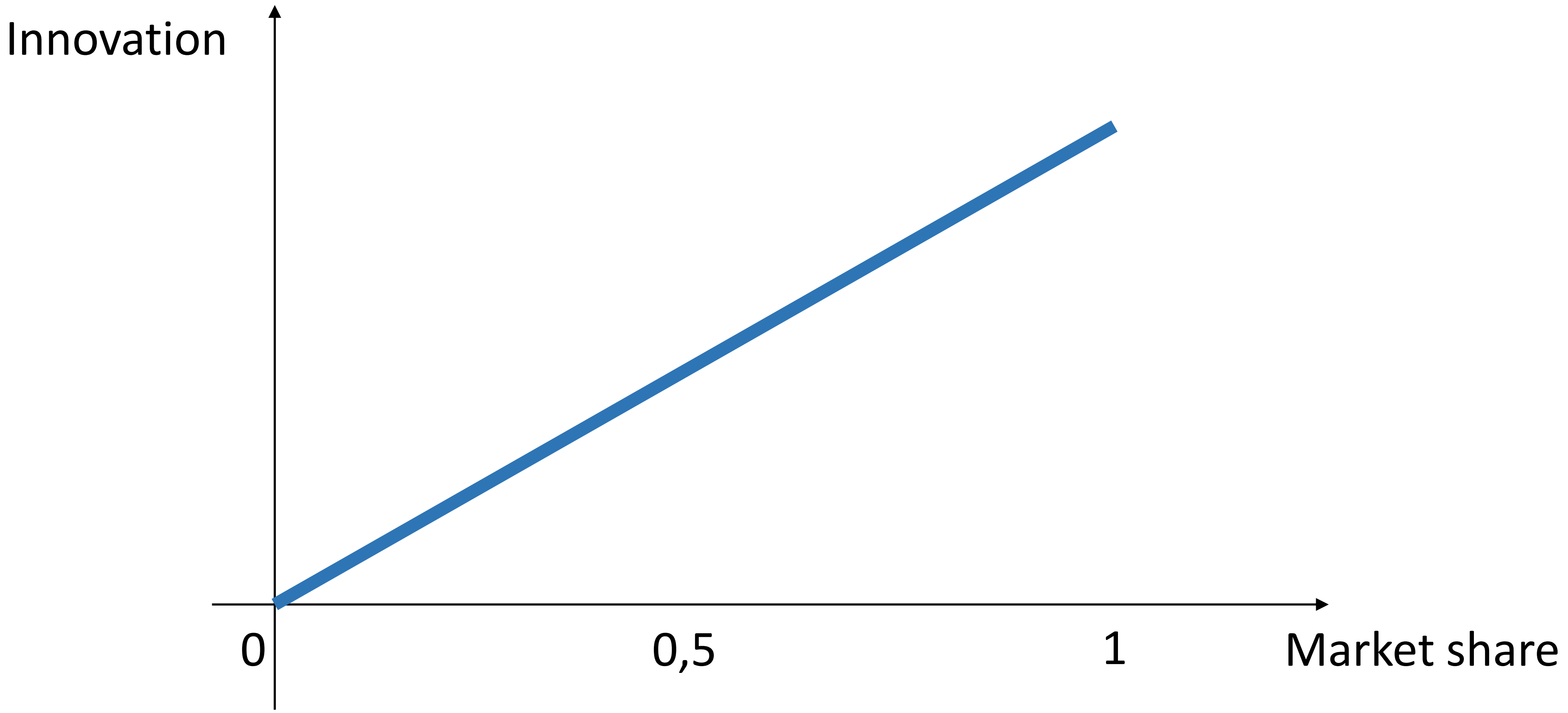
$$\gamma_{jt} = \beta_j^{-1} c_{jt} \sum_{k=t}^{T} e^{-r(k-t)} Q_k s_{jk}(1 - s_{jk})$$

Innovation effort (↑ γ_{jt})

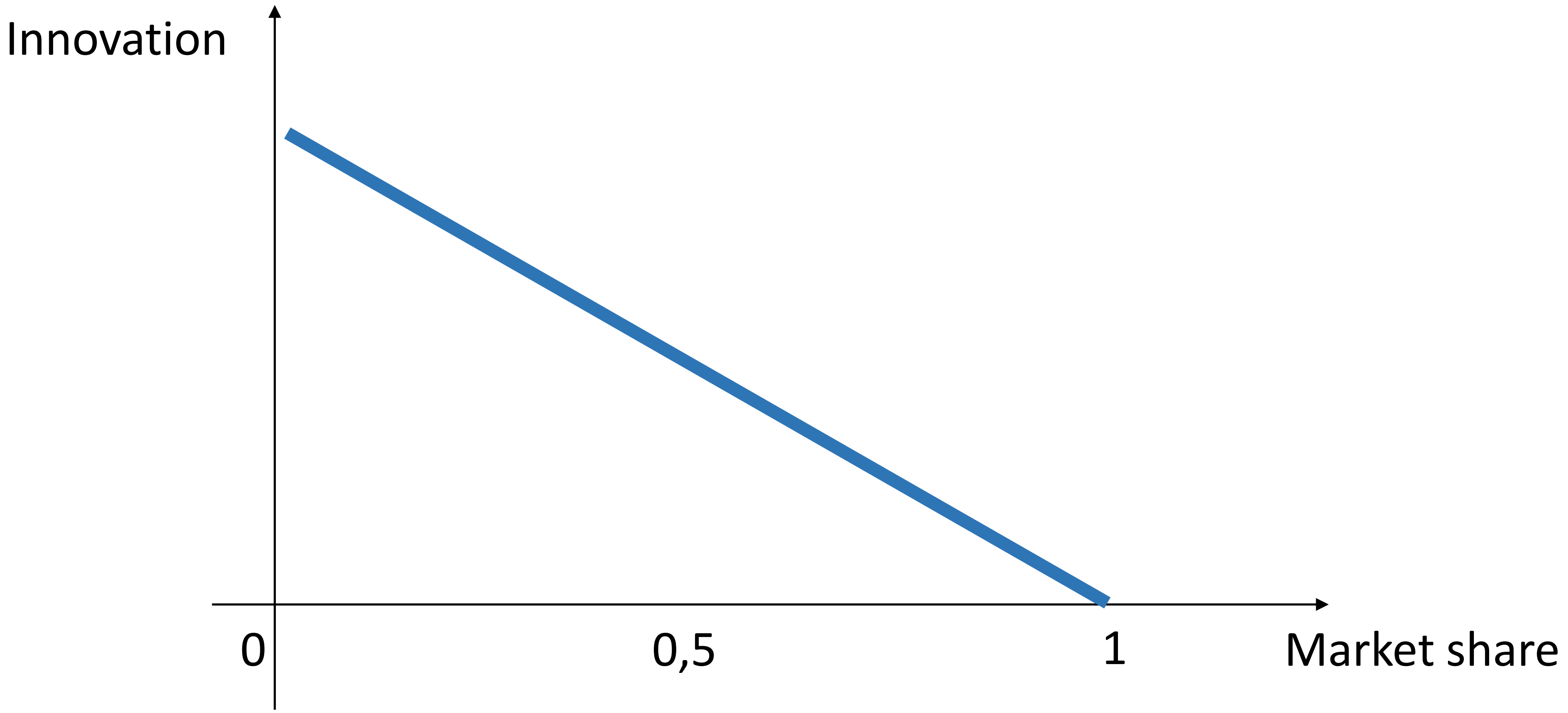
Production cost (↑ c_{jt})

Market share (↑ s_{jk})

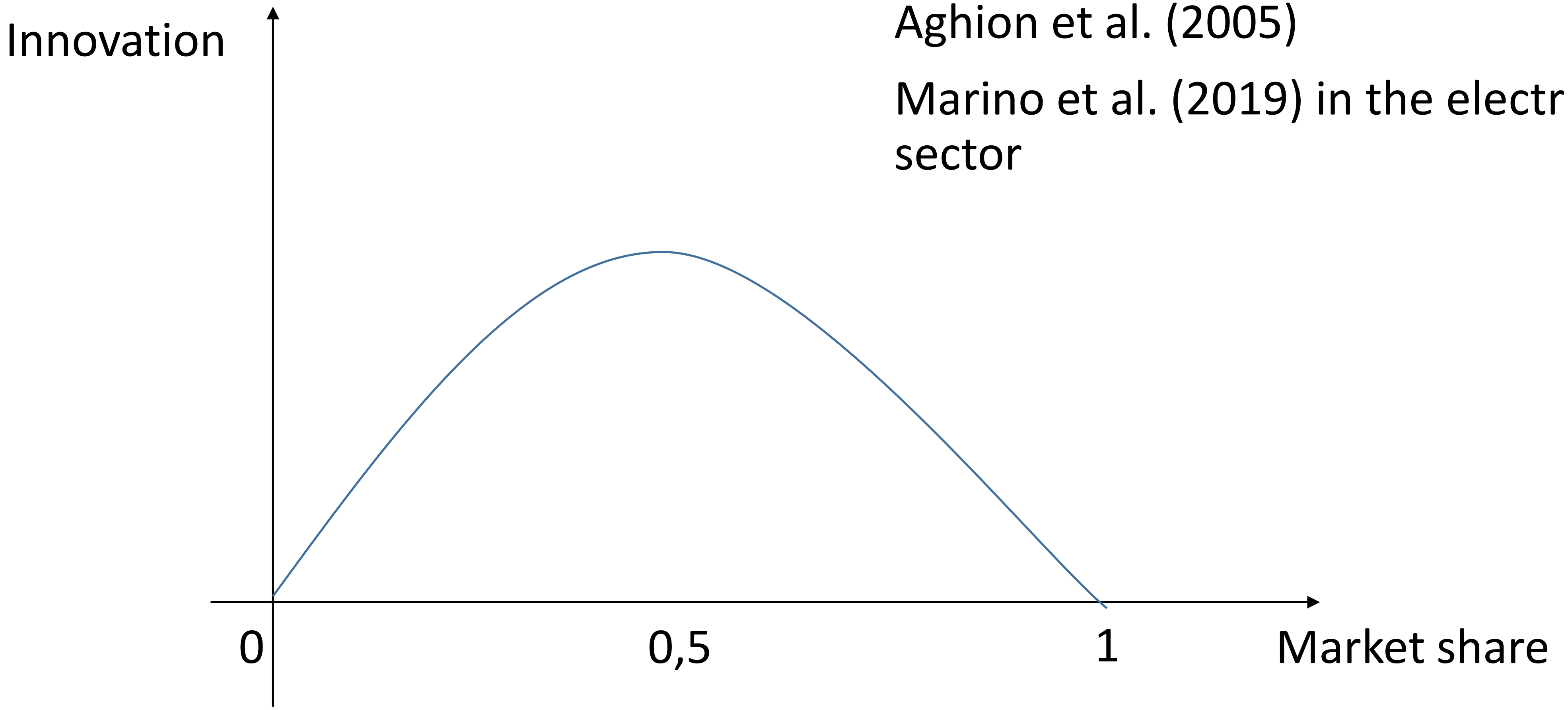
The Schumpeterian view (1949)



The Arrowian view (1962)



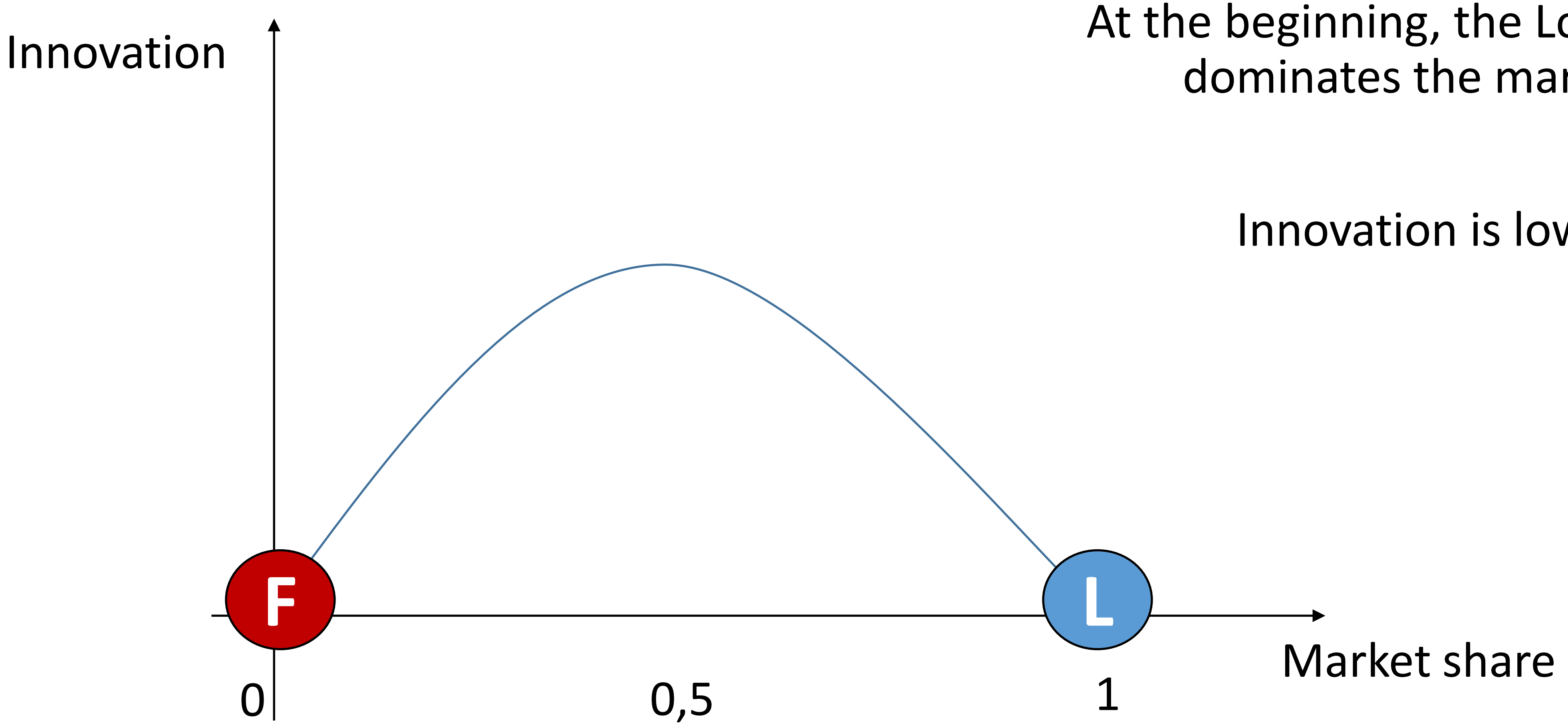
The contemporary view



Aghion et al. (2005)

Marino et al. (2019) in the electricity sector

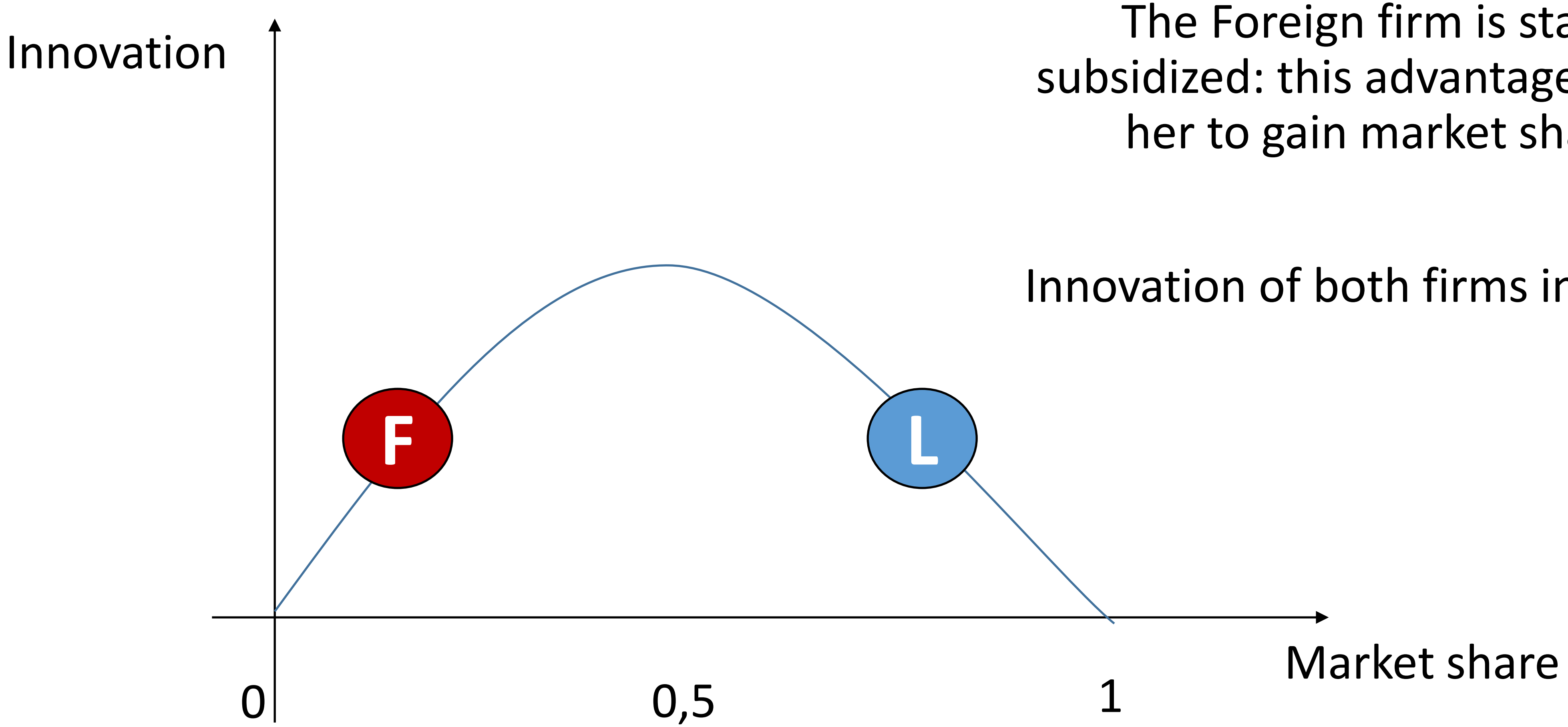
The dynamics



At the beginning, the Local firm dominates the market

Innovation is low

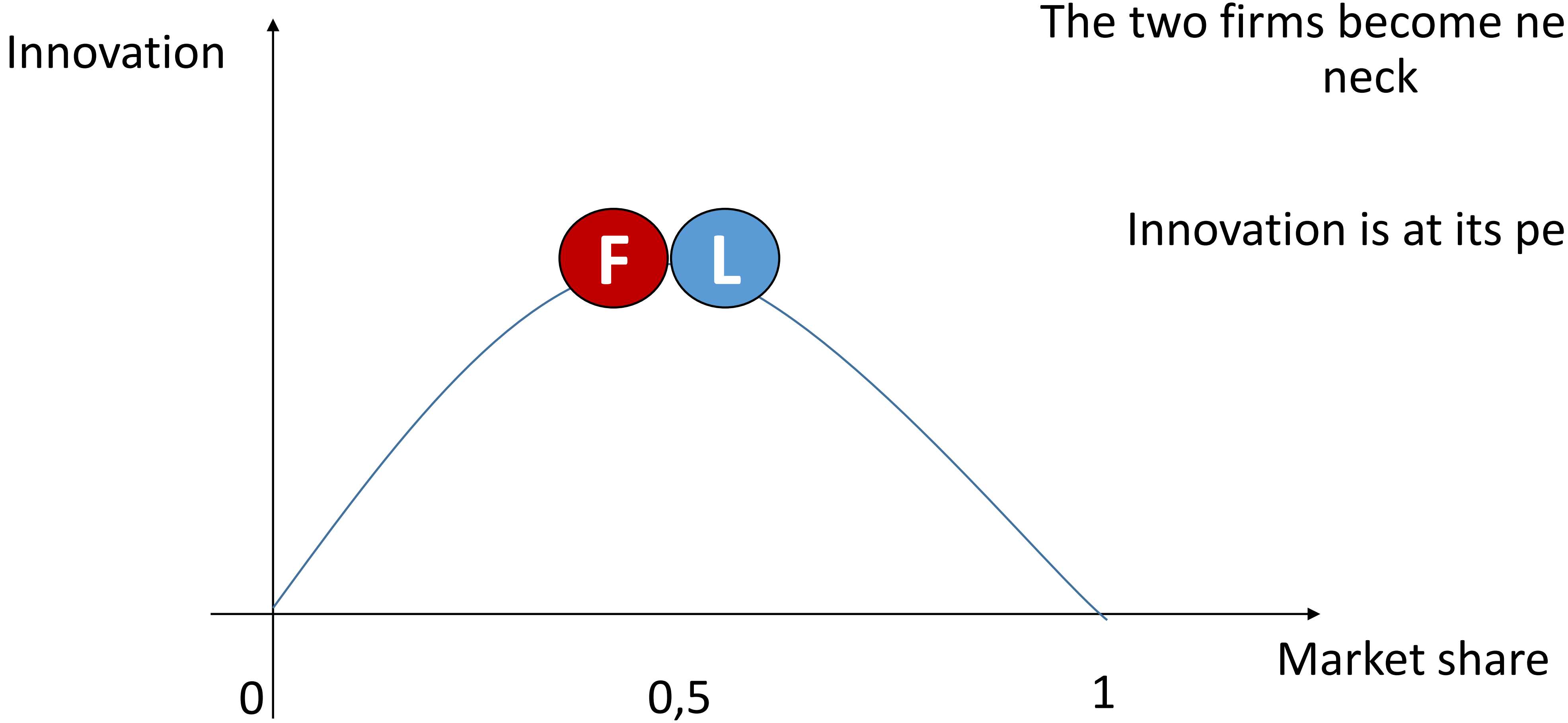
The dynamics



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

Innovation of both firms increases

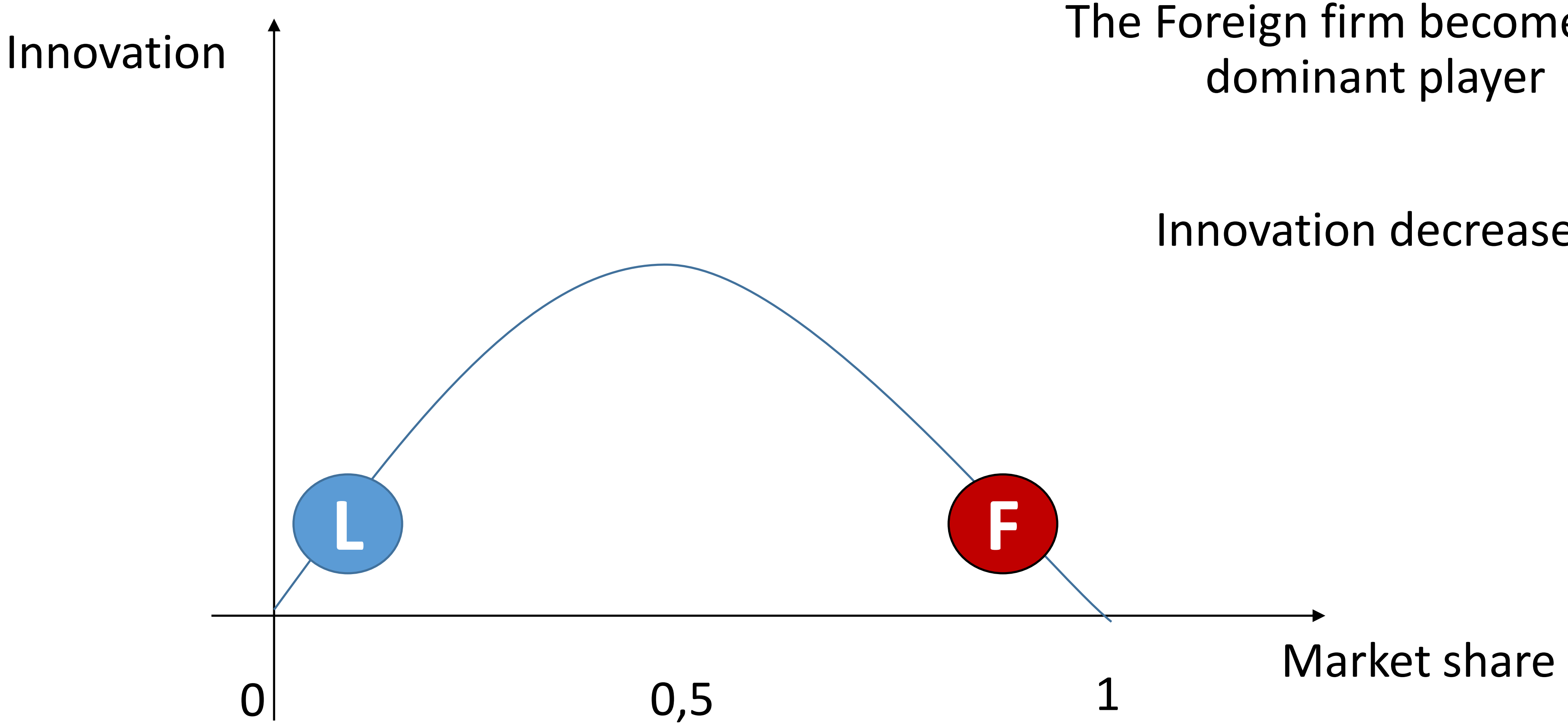
The dynamics



The two firms become neck and neck

Innovation is at its peak

The dynamics



The Foreign firm becomes the dominant player

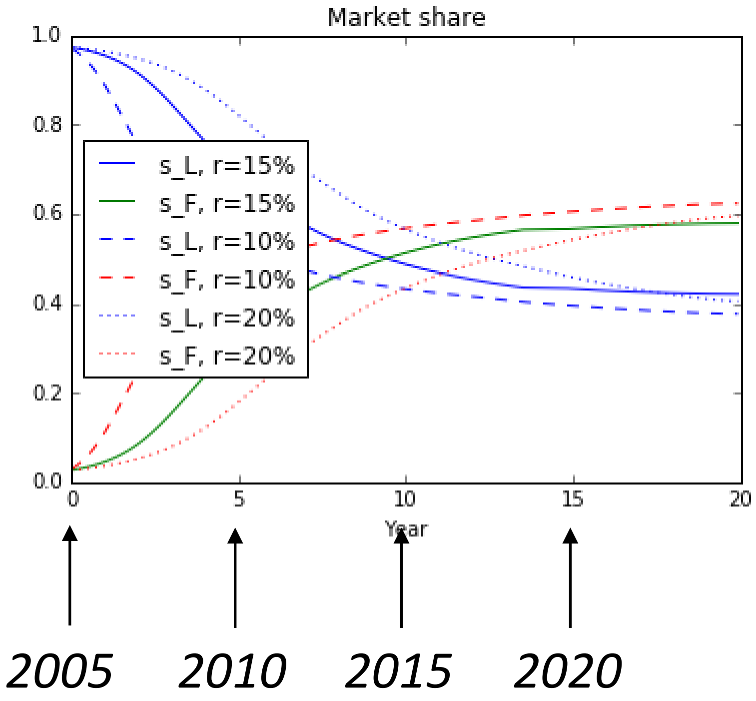
Innovation decreases

Numerics

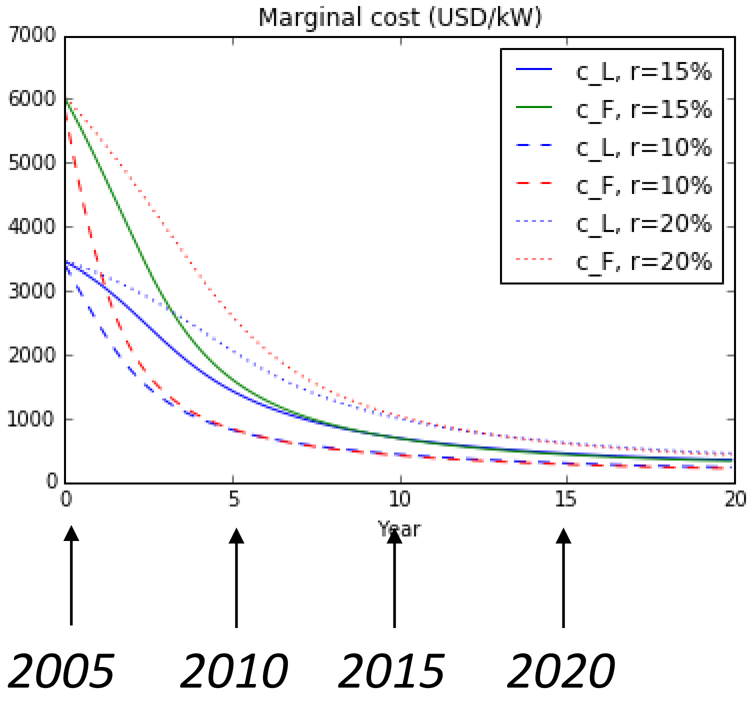
Table 1: Calibration choices.

Parameter	**Symbol**	**Value**	**Source**
Solar panel demand	Q_t	2 GW per month in average	BP (2021)
Initial production costs	$c_{L,2005}$ and $c_{F,2005}$	$c_{L,2005} = 3500$ USD/kW $c_{F,2005} = 6100$ USD/kW	Authors' estimations based on Taghizadeh-Hesary et al. (2018)
R&D costs	β_L and β_F	$\beta_L = 300$ G.USD $\beta_F = 270$ G.USD	Authors' estimations
Elasticity of substitution	ρ	7.5	Authors' estimation
Discount rate	r	15%	Moore et al. (2007)
Time horizon	T	20 years	Arbitrary

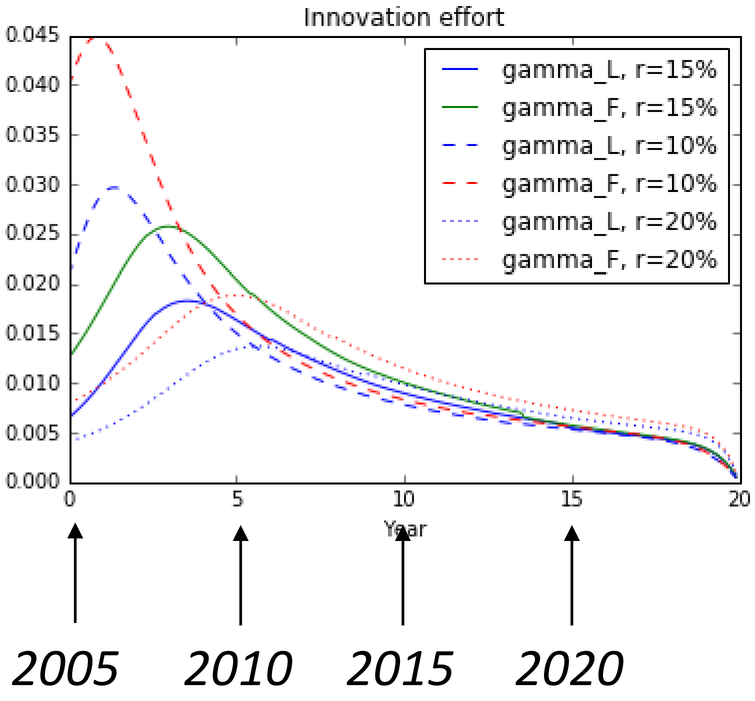
Numerics



Market share
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
Year
s_L, r=15%
s_F, r=15%
s_L, r=10%
s_F, r=10%
s_L, r=20%
s_F, r=20%
2005
2010
2015
2020

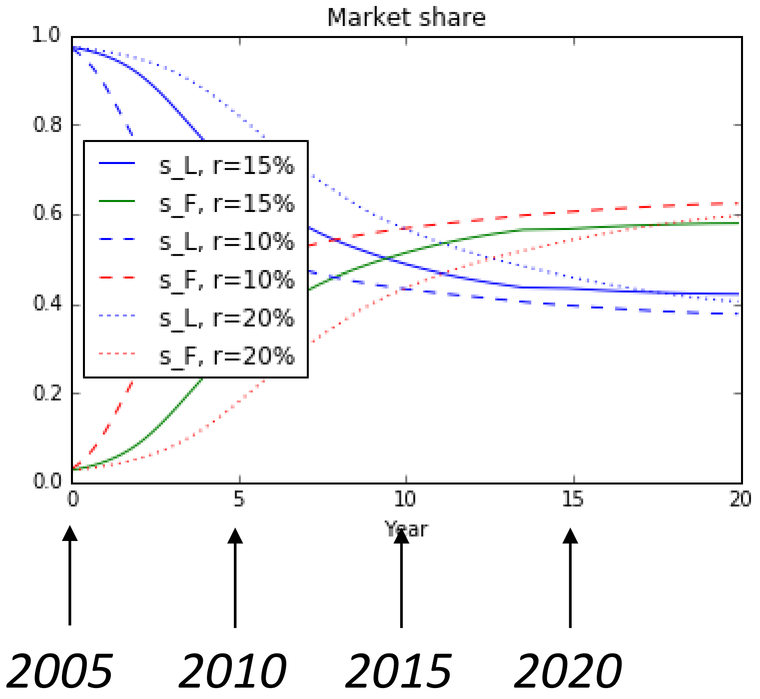


Marginal cost (USD/kW)
7000
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
Year
c_L, r=15%
c_F, r=15%
c_L, r=10%
c_F, r=10%
c_L, r=20%
c_F, r=20%
2005
2010
2015
2020



Innovation effort
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
5
10
15
20
Year
gamma_L, r=15%
gamma_F, r=15%
gamma_L, r=10%
gamma_F, r=10%
gamma_L, r=20%
gamma_F, r=20%
2005
2010
2015
2020

Numerics



Market share
1.0
0.8
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5
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15
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Year
s_L, r=15%
s_F, r=15%
s_L, r=10%
s_F, r=10%
s_L, r=20%
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2005
2010
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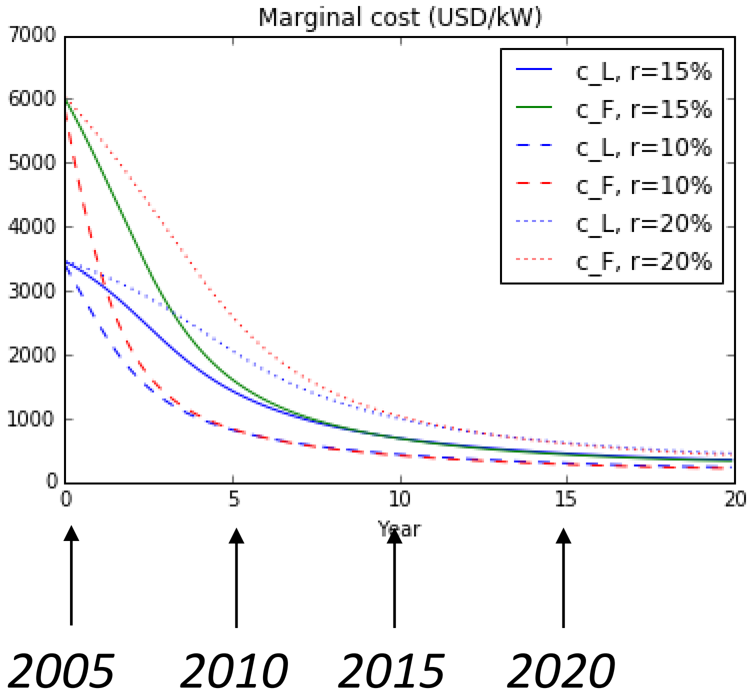
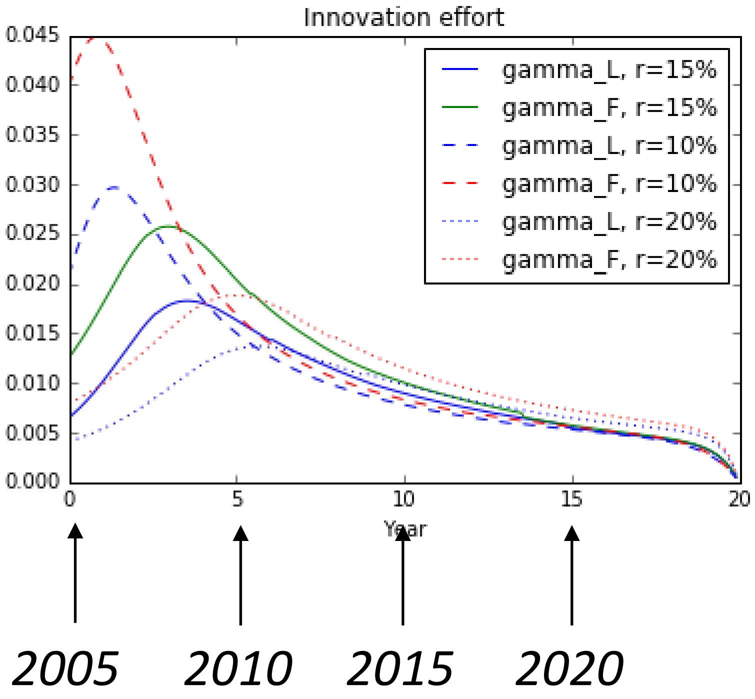
2020



Marginal cost (USD/kW)
7000
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
Year
c_L, r=15%
c_F, r=15%
c_L, r=10%
c_F, r=10%
c_L, r=20%
c_F, r=20%
2005
2010
2015
2020



Innovation effort
0.045
0.040
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0.030
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0.015
0.010
0.005
0.000
0
5
10
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20
Year
gamma_L, r=15%
gamma_F, r=15%
gamma_L, r=10%
gamma_F, r=10%
gamma_L, r=20%
gamma_F, r=20%
2005
2010
2015
2020

Conclusion

- Our model is able to replicate the three stylized facts given in the introduction

- It shows that national technology-push policies, such as national R&D subsidies, can have an impact on foreign R&D, by changing the structure of global competition

Thank you

Energy storage and the direction of technical change

Model

- An extension of AABH with clean input intermittency and storage technologies

AABH

$$Y_t = \left(Y_{ct}^{\frac{\varepsilon-1}{\varepsilon}} + Y_{dt}^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\varepsilon/(\varepsilon-1)}$$

Clean and dirty are substitutes ($\varepsilon > 1$)

Our model

$$Y_t = (Y_{ct} + Y_{dt})^{\kappa}$$

$$Y_{ct} \leq \alpha_d Y_{dt} + \alpha_s Y_{st}$$

(Intermittency constraint)

Clean and dirty are complements

In our model, **if storage is too costly**