Multi-scale approach to the emergence of technological innovation waves: the case of hydraulic turbines during the Spanish industrialization

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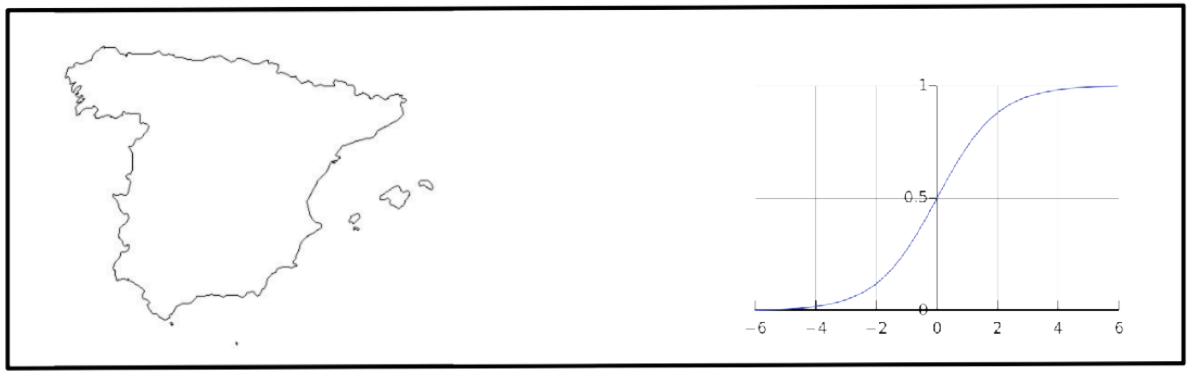
Innovación individual y olas de cambio técnico: particularidades de la mecanización de la primera industria española

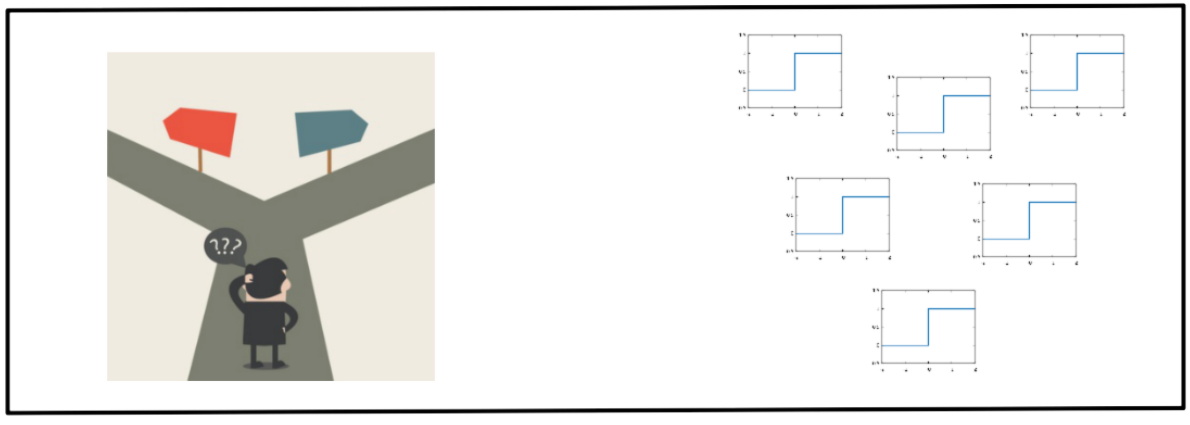
Individual innovation and waves of technical change: Particularities of mechanization at the first Spanish industry

Introduction

- **Motivation**:Technological change as a key ingredient of economic development
- **Focus**: Spatio-temporal diffusion (waves of change)
- **Case study**: Adoption of hydraulic turbines during second half of 19th century in Spain
  - an efficient alternative to coal during the Spanish early-industrialization
  - Few Spanish producers and negligible imports $\Rightarrow$ controlled scenario

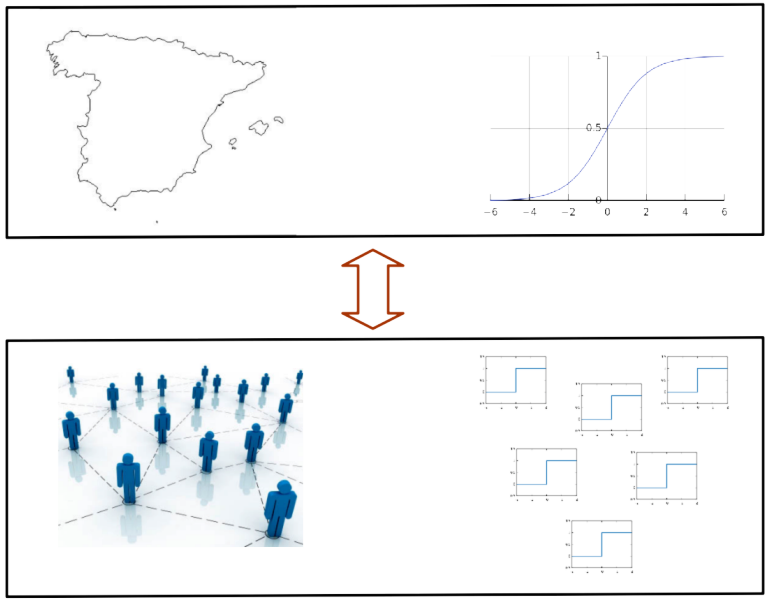
Common approaches in Economic History





Objective

To integrate these two approaches by addressing the case study as an **emergent phenomenon**.

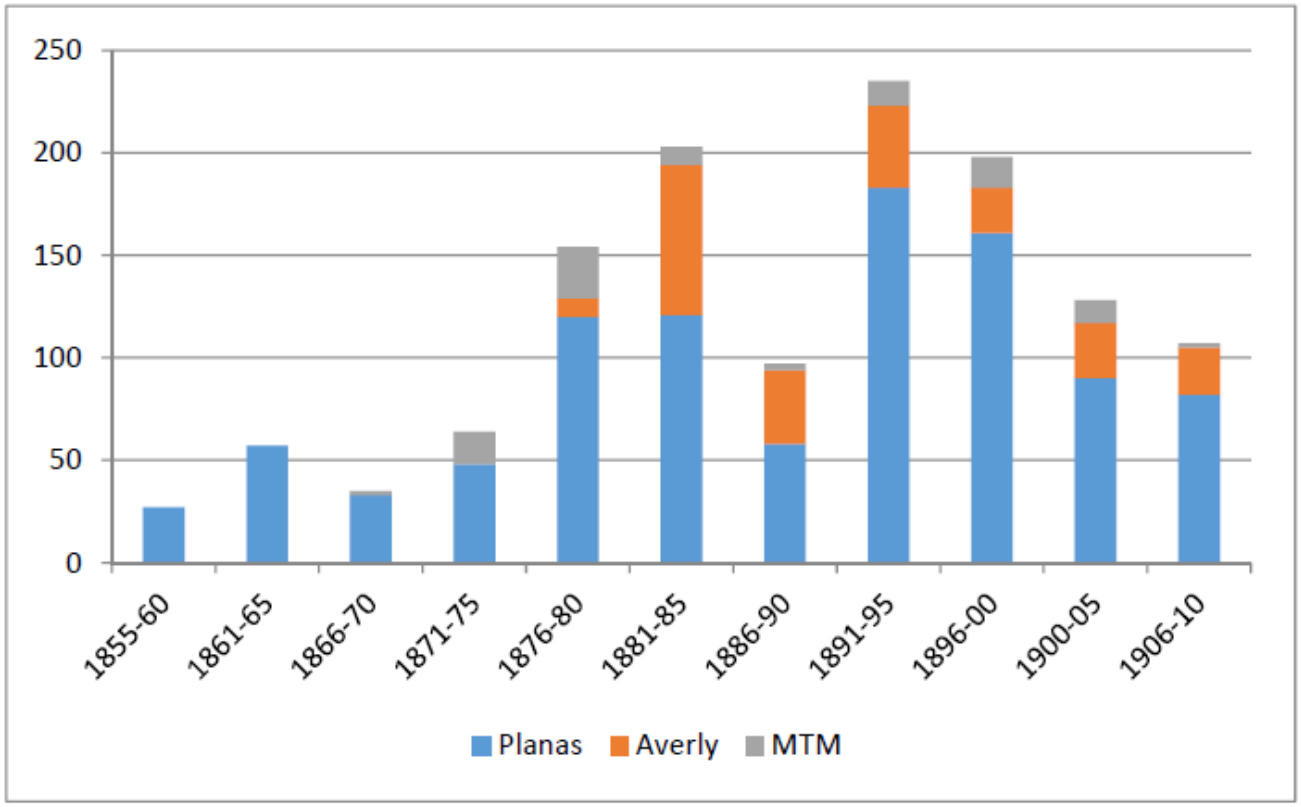


Data

- **Temporal window**: From first 'Spanish' turbine (1858) to 1st World War.
- **Main dataset**: Selling list (Jordi Nadal). We GOT all machines sorted temporally, including: Buyer, power, location (place and province) and economic sector. For several engines we DID NOT get the year of acquisition $\Rightarrow$ Local History research and Industrial Archaeology

Number of turbines

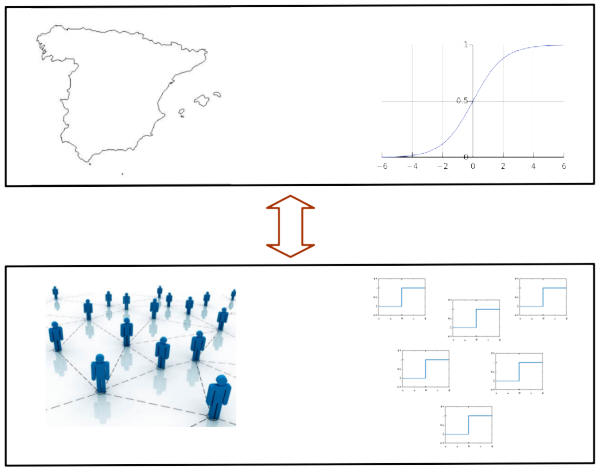
Figura 3 – Número de turbinas hidráulicas construidas por "Plans y Cia.", "Averly" y "MTM", excluyendo las turbinas destinadas a la producción de electricidad



Fuente: Elaboración propia a partir de (Nadal, 1992, 2003) combinando multitud de fuentes complementarias (véase apéndice).

Our approach: Micro - macro link

1. A macroscopic description of the phenomenon
2. Analyze local factors influencing turbine installation
3. Computational experiments to better understand the micro-macro link



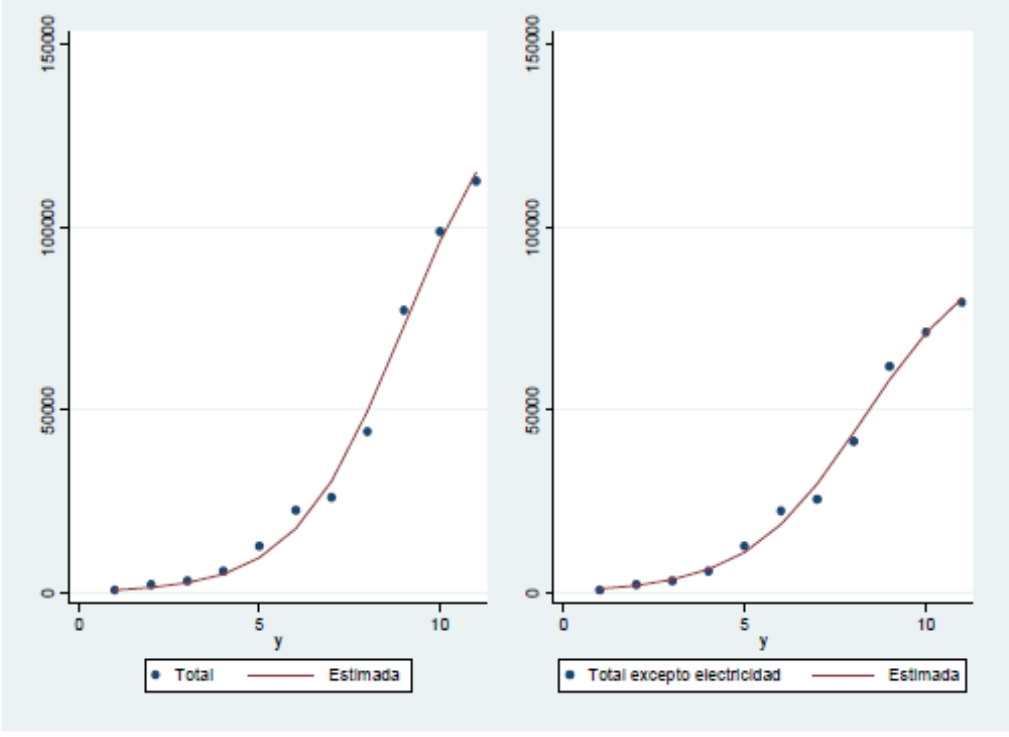
Macro description: Fitting a logistic function

$$y_{it} = \frac{\beta_{i,1}}{1 + e^{-\beta_{i2}(t-\beta_{i3})}}$$

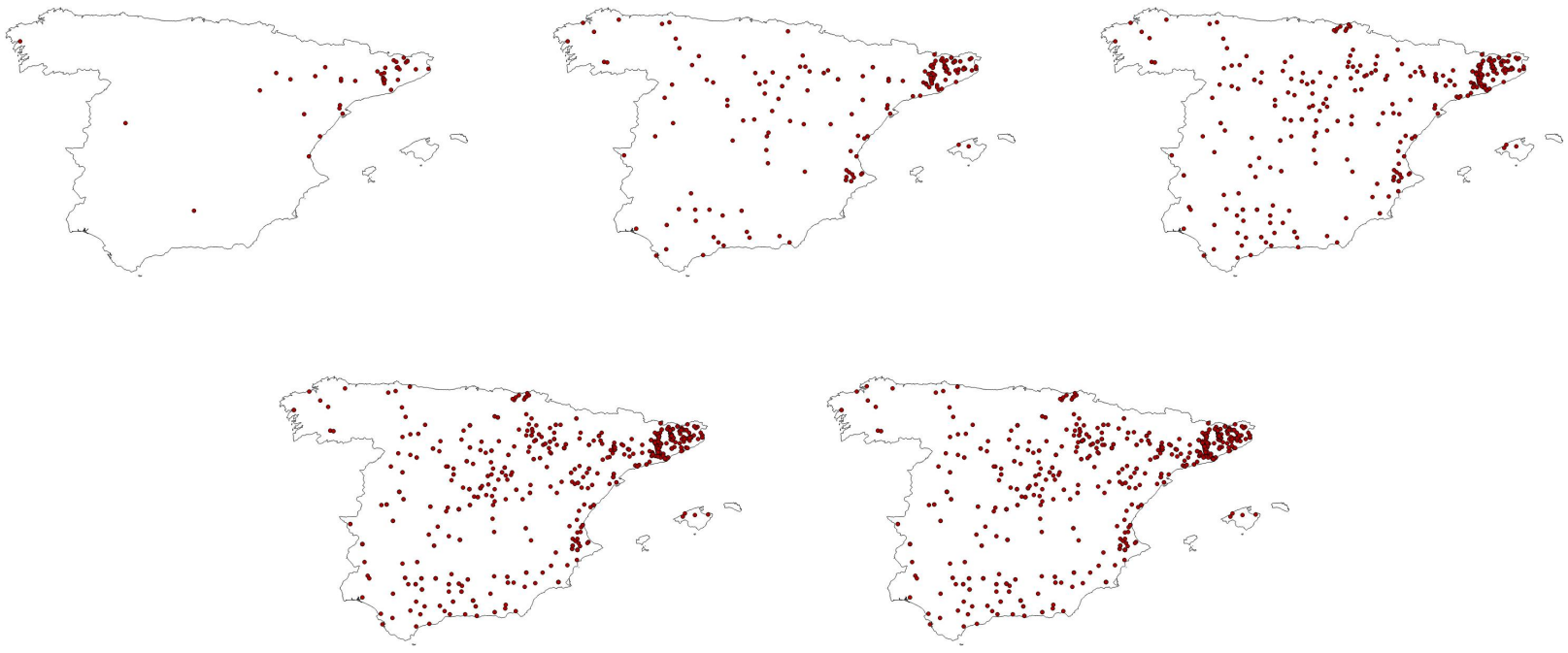
- Y_{it} is the level of adoption of a technology for a sector or region i, t is the period considered
- β_{ik} are the fitted parameters of the logistic function (with economic significance).
  - β_{i1} is the saturation value around the year when the adoption of technology stabilizes
  - β_{i3} is the year when 50 % of the adoption is adopted.

General

Figura 7 - Nivel de adopción de la potencia instalada (CV) del total de las turbinas instaladas y el total de las turbinas no destinadas al sector eléctrico y el ajuste de la función logística (1855-1910)



Spatial distribution (by decades)



From turbines location to individual adoption decisions.

- **Hypothesis**: Besides the dependence on geographic constraints and economic determinants, there was an underlying process of influence ('contagion') among innovators.
- Following previous literature on diffusion of innovations and social contagion, we focused on three aspects:
  - Individual adoption thresholds and their distribution within population (Rogers, 1955; Hägerstrand, 1968; Granovetter, 1978)
  - Social networks linking decision-makers (Valente, 1995; VandenBulte2001)
  - Individual vs. environmental (*mass-media*) influence

Computational experiments

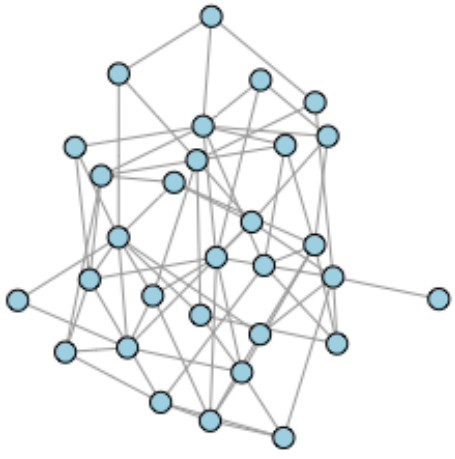
- Computational experiments **combining Agent-Based Modelling and network analysis** to reproduce macroscopical trends.
- 3 aspects:
  - **Individual adoption thresholds**: Homogeneous or heterogeneous scenarios based on provinces' 'type of adopters'(i.e. *early adopter*, *majority & laggard*).
  - **Social networks**: 2 network models (Erdös-Renyi and Spatially-dependent graphs)
  - **Individual vs. environmental influence**: Simulated decision procedure based on neighbours' state

Adoption thresholds

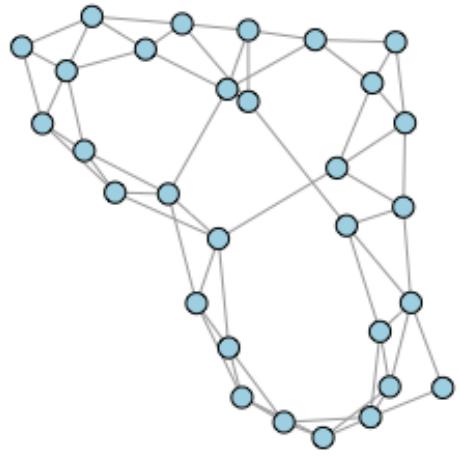
Tabla 6 – Proporción de tipos de adoptantes en función del momento de compra de la primera turbina, por provincias

	Early adopters (%)	Majority (%)	Laggards (%)
Alicante	0	0	100
Barcelona	58,70	36,96	4,35
Burgos	13,33	80	6,67
Córdoba	8,33	75	16,67
Girona	14,29	57,14	28,57
Granada	0	81,25	18,75
Guadalajara	0	73,33	26,67
Guipúzcoa	0	66,67	33,33
Huesca	35,71	28,57	35,71
Jaén	0	66,67	33,33
Lleida	28,57	28,57	42,86
Madrid	22,22	66,67	11,11
Málaga	0	100	0
Teruel	13,04	56,52	30,43
Valencia	0	0	100
Zaragoza	15,56	71,11	13,33

Network models



Erdös-Renyi (null case)



Spatially dependent

Simulated decision dynamics

- Direct influence

$$s_i = \begin{cases} 1, & \text{if } \tau_i > \frac{\sum_{j \in N_n} s_j}{|N_n|} \\ 0, & \text{otherwise} \end{cases}$$

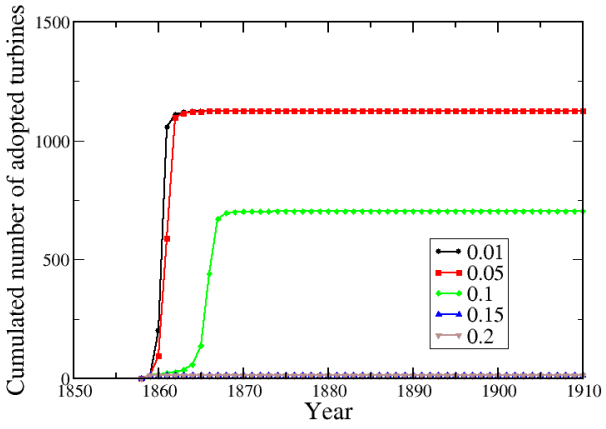
Where i is the agent making the decision, τ_i is its adoption threshold, N_n is the set of direct neighbours it has in the network, and s_j takes value 1 when agent's j state is ADOPTED.

- Indirect influence

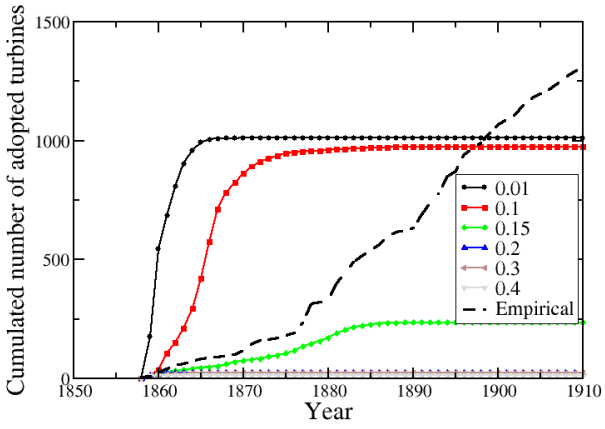
$$s_i = \begin{cases} 1, & \text{with probability } p_{media} = \sigma \frac{\sum_{j \in N} s_j}{|N|} \\ 0, & \text{with probability } 1 - p_{media} \end{cases}$$

Where σ is the sensibility of any agent to the environmental (media) pressure, and its value range is $[0, 1]$.

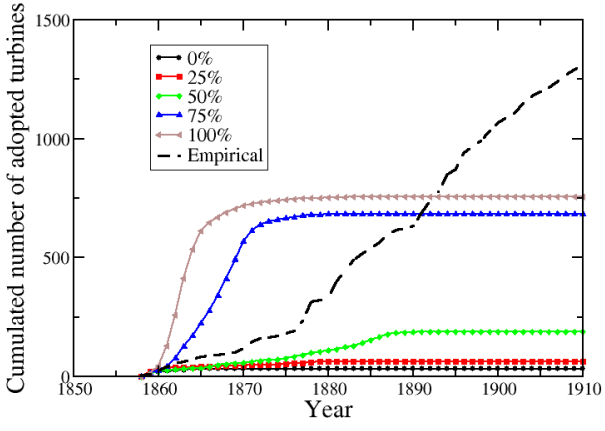
Intermediate results



Random network + homogeneous population



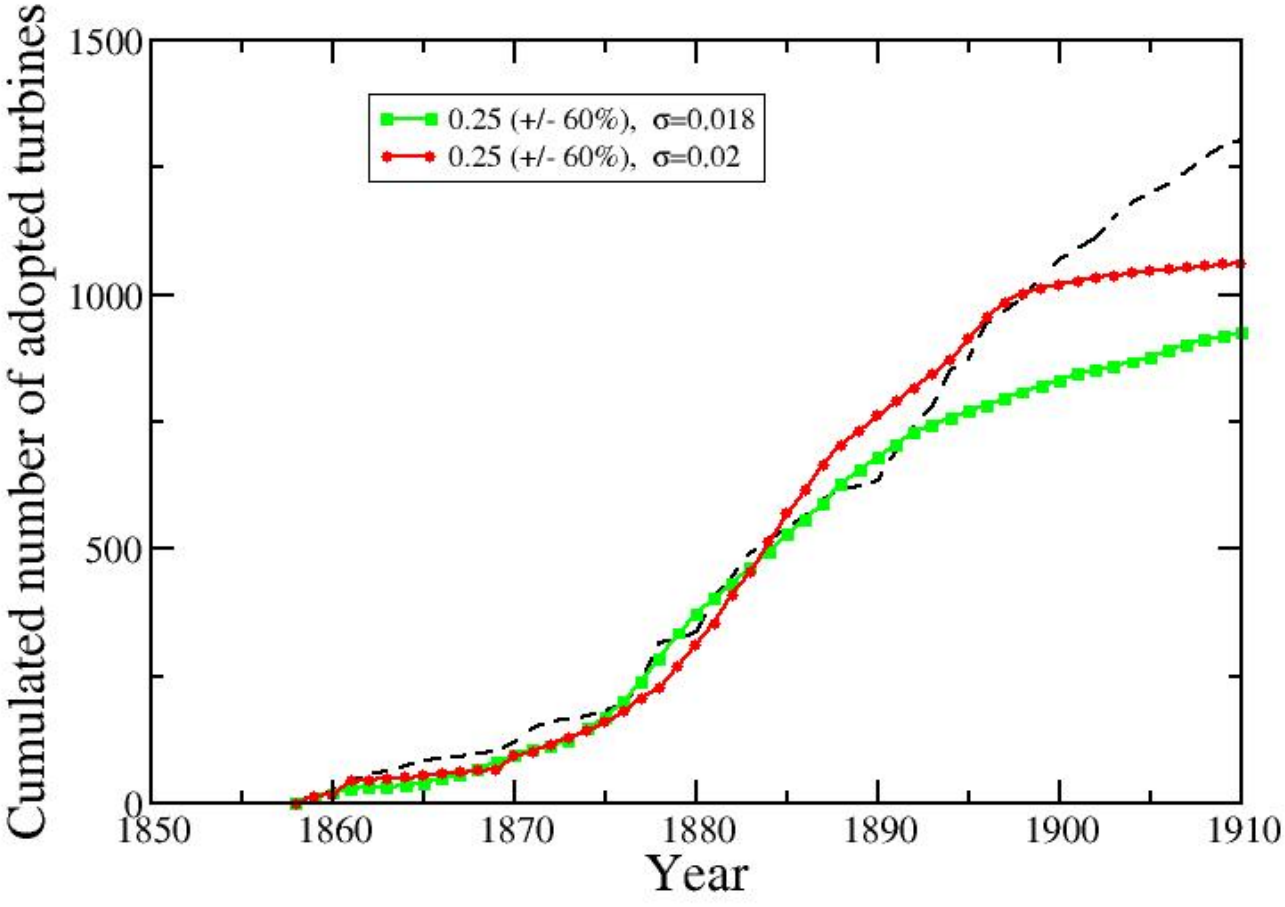
Spatial network + homogeneous population



Spatial network + heterogeneous population

Preliminary fitting to empirical data

Combining all the previous mechanisms and adding some sensitivity to the media influence:



Sumarizing..

- Diffusion of hydraulic turbines in Spanish early Industrialization as an emergent phenomenon
- A combination of macroscopic description, microscopic analysis and multiagent model (micro-macro link)
- Already interesting results from computational experiments (but still working on it..).

Thank you !

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