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

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Introduction

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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
To integrate these two approaches by addressing the case study as an emergent phenomenon.
Data & Methods

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 ⇒ Local History research and Industrial Archaeology
Figura 3 – Número de turbinas hidráulicas construidas por “Plans y Cia.”, “Averly” y “MTM”, excluyendo las turbinas destinadas a la producción de electricidad.

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

\[ y_{it} = \frac{\beta_{i1}}{1 + e^{-\beta_{i2}(t-\beta_{i3})}} \]

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

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 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**

<table>
<thead>
<tr>
<th>Province</th>
<th>Early adopters (%)</th>
<th>Majority (%)</th>
<th>Laggards (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alicante</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Barcelona</td>
<td>58.70</td>
<td>36.96</td>
<td>4.35</td>
</tr>
<tr>
<td>Burgos</td>
<td>13.33</td>
<td>80</td>
<td>6.67</td>
</tr>
<tr>
<td>Córdoba</td>
<td>8.33</td>
<td>75</td>
<td>16.67</td>
</tr>
<tr>
<td>Girona</td>
<td>14.29</td>
<td>57.14</td>
<td>28.57</td>
</tr>
<tr>
<td>Granada</td>
<td>0</td>
<td>81.25</td>
<td>18.75</td>
</tr>
<tr>
<td>Guadalajara</td>
<td>0</td>
<td>73.33</td>
<td>26.67</td>
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<tr>
<td>Guipúzcoa</td>
<td>0</td>
<td>66.67</td>
<td>33.33</td>
</tr>
<tr>
<td>Huesca</td>
<td>35.71</td>
<td>28.57</td>
<td>35.71</td>
</tr>
<tr>
<td>Jaén</td>
<td>0</td>
<td>66.67</td>
<td>33.33</td>
</tr>
<tr>
<td>Lleida</td>
<td>28.57</td>
<td>28.57</td>
<td>42.86</td>
</tr>
<tr>
<td>Madrid</td>
<td>22.22</td>
<td>66.67</td>
<td>11.11</td>
</tr>
<tr>
<td>Málaga</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Teruel</td>
<td>13.04</td>
<td>56.52</td>
<td>30.43</td>
</tr>
<tr>
<td>Valencia</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Zaragoza</td>
<td>15.56</td>
<td>71.11</td>
<td>13.33</td>
</tr>
</tbody>
</table>
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, \( \tau_i \) 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**

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

  Where \( \sigma \) 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:
Summary

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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