FORMATIVE PHASE AND SPATIAL DIFFUSION OF ENERGY TECHNOLOGIES

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(1) Overview

Two moments are particularly relevant in the diffusion of energy innovations: the formative phase and the transition to new regions. The former prepares the technology for widespread growth, while the latter enlarges its impact on the market. The objective of this research is to identify historical patterns in the formative phases of energy technologies in the core, as well as in the spatial diffusion to subsequent areas.

A recent research on the historical scaling of energy technologies has suggested that diffusion evolutes in a three-stages process (Wilson, 2012; Wilson and Grubler, 2011; Wilson, 2009): a formative phase (when a large number of units are produced and several designs are tested); an up-scaling phase (characterized by the production of units of a bigger size); and, finally, the growth phase (mass-commercialization of large scale units).

The formative phase prepares the conditions to scale-up the technology. It may take some time until a particular design becomes dominant and the main technical problems are identified and solved in the core. However, this phase may generate spillovers that enable a faster diffusion in other areas. This would in part explain the empirical finding by which diffusion accelerates when it reaches new areas, though with lower levels of penetration (Wilson and Grubler, 2011).

In the last decade the diffusion of new renewable energy, such as wind technologies, has rapidly attained impressive results in Portugal. This rapid development has contributed for the progress of the technology, and gives an interesting field of study of the factors that can accelerate the spatial diffusion of innovations.

A better understanding of the dynamics of technological diffusion, in particular during the formative phase and the spatial diffusion, would allow the design of more theoretically and empirically grounded policies to promote the dissemination of the next wave of sustainable energy innovations (e.g., solar, wave).

(2) Methods

The historical diffusion of several energy technologies is studied, and their evolution is compared in the core and in subcenter areas.

A sample of energy technologies is used which includes both supply-side (e.g. wind power plans, natural gas, coal) and end-use (e.g. cars production, motorcycles) technologies. The actual data (expressed in cumulative unit numbers or megawatts) is fitted with logistic functions to reveal the parameters of the diffusion (cf. Wilson, 2009): rate of diffusion (Δt); saturation (k); and inflection point (to).

The formative phase is defined as the period corresponding to the early stage of diffusion before technology up-scaling at unit level (cf. Wilson, 2012). The operational criterion adopted in this study considers that the formative phase ends at 10% of maximum cumulative number of units (k).

Finally, it is compared the patterns (and parameters) of growth in the different geographic areas in order to reveal tendencies in spatial diffusion. The study of the growth in a specific case (Portugal) allows the discussion about the role of the institutional context and policies to support technology diffusion.

(3) Results

Table 1 presents the main features of the formative phase of several energy technologies in the core.

Table 1. Formative phase of energy technologies (in core)

Technology		Core Market	First Commercial Capacity Installed	10% of Max. Cumulative Total Numbers of Units	Formative Phase: Number of Years	Formative Phase: Number of Units	10% of Max. Cumulative Total Capacity (MW)	Δt (10-90% max. MW)
Supply-side	Nuclear Power	OECD	1950s (1940s)[a]	1966	10-20	41	1973	20
	Coal Power	OECD	1900s	1940	40	386	1957	33
	Natural Gas Power	OECD	1900s	1949	45-50	456	1955	28
	Wind Power	Denmark	1970s (1880s)[a]	1985	15-100	769	1991	11
	Refineries [b]	*US*	*1860s-1870s*	.	*80-90*	*>500**	*1948*	*41*
GPT [c]	Steamships	UK, US	1807	1880	73	24,022	1890	72
	Steam locomotives	UK, US	1825	1880	55	59,234	1900	63
	Stationary steam	UK, US	1710s	1861	150	157,939	1880	61
	All steam	UK	1710s	1870	160	229,738	1900	67
Transport	Jet aircraft	US	1958	1969	11	1,791	1973	49
	Motorcycles	West Europe	1900	1949	49	>12 million	1956	64
	E-bikes	China	1997	2005	8	>17 million	2005	8
	Cars	US	1890s-1900s	1937	40	>57 million	1955	67
Residential	Washing machines	US	1920	1951	31	>56 million	1962	54
	CFLs	OECD	1990	1994	4	>372 million	1994	15
	Cellphones	Nordic, Japan	1979	2001	22	>872 million	2002	17

[a] First nuclear installations on submarines date to 1940s; first wind power generators date to 1880s, but from 1970s in their modern form.

[b] Refineries data are indicative only because it is measured in installed capacity, not cumulative. Saturation capacity measured in terms of average rather than maximum capacities; * number of units are rough estimate.

[c] General Purpose Technology.

In many technologies, the length of the formative phase follows closely the rate of diffusion (Δt). This result may signify that longer transitions require more time to prepare for innovation up-scaling and growth. In the case of more complex and interrelated technologies, such as the GPT, it is necessary to wait for the invention of other technologies to fulfill all their potential, thus elongating the duration of the formative phase. In addition, it appears that the formative phase is longer for energy supply-side technologies than for transport and residential innovations. However, end-use technologies require the production of many units (frequently millions) to progress in the diffusion.

(4) Conclusions

The formative phase of technologies is the period over which the main technological, institutional and market challenges are addressed, allowing the innovation to up-scale and progress in the market. The experience gained during the formative phase in the core may generate spillovers that foster the growth in subsequent areas. The next step of this research analyzes the relation between the length of the formative phase in the core and the diffusion in other regions.

References

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