LED there be light The evolution in LED technology and dynamics of entry into the LED lighting market

Summary

This PhD thesis contributes to the literature about the role of technology in the economy, by providing new evidence on how technological change takes place, and the relationship between technological change and the emergence of new markets. Emphasis is put on understanding the evolutionary dynamics of a multi-purpose technology that develops by spanning several domains and generating different innovations and novel recombination in each domain. The dynamic interplay between different technology domains and their contribution to driving the overall technological trajectory are examined. Furthermore, the firms' decisions to develop capabilities in particular technology domains are examined, and the relationship between their technological investments and strategic decision to enter into a new technology-based industry is studied.

The theoretical framework builds on previous literature from evolutionary economics and strategic management. The LED technology and its application in the LED lighting devices industry are chosen as the field of research. This is a multi-purpose technology, which found application in several domains over its long development process, and had an enormous transformative power on the lighting industry.

In Chapter 2, we provide an overview of LED technology from both a technical and historical perspective. This chapter explains the key components of the technology, the main steps from the initial invention to the subsequent experimentations across the multiple generations of technology improvements and applications, the challenges encountered in developing functioning and high-quality LEDs, and the advantages of LED over alternative light sources. This chapter lays down background information about the technology and its development, useful to frame the subsequent empirical analysis.

Chapter 3 uses patent data on LED and shows the application of community detection algorithms applied to the patent technology classes to identify the different technology domains associated with LED. The unsupervised and automated classification method proved suitable for detecting the different technological sub-fields related to a multi-purpose technology such as LED, which evolved over a long time and across several multiple directions. The identified LED technology domains are used for an in-depth study of the technology evolution, which is carried out in the next chapter.

In Chapter 4, we analyse the patent citation network to map the LED technological trajectory. Not only the single main path of the overall LED trajectory is identified, but the main paths followed by each LED technology domain are also traced. The

network of the technology-specific main paths is built with the aim to investigate the interlinkages between different domains and their specific contribution to the overall LED technology development. We found that patents in electrical components, semiconductors, vehicles lighting, and general lighting devices more directly and significantly contributed to driving the technological trajectory, each one in particular periods. Other LED technological domains, both large, such as LED for displays, and small, such as LED for medical applications or agriculture, had a much more limited role in determining technological advancement. Instead, they followed distinct development paths, diverging away from the main trajectory.

In Chapter 5, we analyse how the firms' participation on the main paths of particular technological domains influenced their decision to enter (or not) the LED lighting devices market, i.e. the largest application market of LED emerged since the late 1990s. A sample of 313 firms and their technology portfolios are considered. Econometric models are developed to study the probability of developing core technologies relevant to the emerging LED lighting market and the likelihood of entry into the LED lighting devices market conditional to the set of capabilities and complementary assets owned by firms. Interviews with some of the most important market players are used to complement and better interpret the findings from the quantitative analysis. The results show that possessing core technological capabilities and complementary assets facilitates market entry; in turn, core technological capabilities are more likely to be developed if the firms have technical capabilities in closely related fields. Firms that chose to invest in other less related LED application domains found themselves on a path leading to different technological and market opportunities, which were less likely to converge towards the LED lighting devices market.

Overall, the theoretical framework and the results of this research contribute to the extant literature, by informing on the relationship between technological change, market dynamics, firm decision-making, and the direct and indirect links between the development of technical capabilities and the decision to enter an emerging technology-based market. Also, this thesis highlights the advantages of combining theories and methods from different disciplines to gain a richer view of technological evolution and the factors determining the firms' behaviour under uncertain and evolving market conditions.