

TECHNOLOGICAL CAPABILITIES OF FIRMS

Relatedness, complexity, divergence and stagnation

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- The global technology map: tracking patterns of related and unrelated technological invention by multinational firms.
 - Recombination of existing knowledge
 - Related versus unrelated diversification
- Technological innovation and the productivity paradox
 - How does the global knowledge base condition the opportunities for invention/innovation?



TECHNOLOGICAL INNOVATION

- Innovation is what drives competitive advantage of firms, and productivity growth in the economy as a whole.
- Firms draw on the globally available stock of technological knowledge to innovate. To remain competitive, firms have to keep developing and acquiring new knowledge.







PRODUCTIVITY PARADOX



- However, since the late 1990s the productivity growth has slowed markedly for many of the world's largest economies.
- While there are many more researchers and engineers, in more locations around the world than ever before, and much more money is spent on technological research, the pace of innovation, the production of new knowledge that will teed the pipeline of future progress, appears to be slowing (OECD Compendium of Productivity Indicators 2016, 2016).
- Much work before now has found that slower technology growth is the main driver of this productivity paradox (Brynjolfsson, 1993; Cowen, 2011; Gordon, 2016).



FRONTIER FIRMS

Frontier and non-frontier growth

Manufacturing and business services, excluding the financial sector



Note: 2001 = 1 (log points), average across 24 OECD countries and 22 manufacturing and 27 market services industries. Global frontier has two definitions here (see two series on figures). Global frontier is defined as the 100 most productive firms within each industry and is defined as the 5% most productive firms within each industry. by each year.

Source: OECD preliminary results based on Andrews, D., C. Criscuolo and P. N. Gal (2016), "The Global Productivity Slowdown, Technology, Divergence and Public Policy: A Firm Level Perspective", forthcoming, OECD Publishing, Paris.

Data Source: Orbis database of Bureau van Dijk.

- However, (Andrews, Criscuolo, & Gal, 2016) showed that the top ("frontier") firms in OECD member countries have continued seeing productivity increases while the others (the "laggards") haven't, contributing to a growing productivity divergence between the top and the bottom.
- The study also suggests that differences in the ability of firms to develop new technological knowledge is an important reason for this pattern of divergence.
- However, the study did not identify the firms at the head of its productivity frontier, nor did it study the knowledge base of the firms, which could provide information about how the changing technological portfolio of firms drives performance.



AIMS

- In this paper, we address the question how the characteristics of the technological knowledge base of firms might explain the innovative performance of firms over time.
- For the period 2000-2010, we first establish how the composition of the global patent portfolio of the world's top 2000 R&D performing companies can explain patterns of entry and exit of new technology domains for these firms.
- Second, we explore how patterns of divergence among firms can be explained by the diversity, complexity and growth of the technological knowledge base of firms. Furthermore, we investigate how different sectors, general purpose technologies and countries of origin contribute to the performance of frontier firms



GAP

- The starting point of our analysis is that technological progress is reliant on recombinant innovation (Arthur, 2007; Malerba & Orsenigo, 1996), the recombination of existing technologies where firms combine prior art with their own ideas to form new patentable technologies now more than ever (Wuchty, Jones, & Uzzi, 2007).
- While the global stock of available technological knowledge keeps on expanding, it has been suggested that all the 'low hanging fruit' has been picked (Cowen, 2011). It is increasingly complex to develop new technological knowledge and to bring together the necessary skills and capabilities required to bring about new technological combinations (Chesbrough, 2003; Jones, 2009).
- It is remarkable how little is actually known about the characteristics of innovative firms that operate at the technological frontier. In this paper, we wish to address this gap in our understanding.



THEORY

- Schumpeter claimed that he had set himself three goals in life: to be the greatest economist in the world, to be the best horseman in all of Austria and the greatest lover in all of Vienna.
- He said he had reached two of his goals, but he never said which two, although he is reported to have said that there were too many fine horsemen in Austria for him to succeed in all his aspirations.





THEORY

- A century ago, the economist and political scientist Joseph Schumpeter argued that the central virtue of a market economy was its capacity to innovate. Economists' traditional focus on competitive markets was misplaced; what mattered was competition for the market, not competition in the market.
- Economy as an evolving complex adaptive system
 - Firms interact, process information, create emergent structures
 - Recombinations of ideas



THEORY AND HYPOTHESES

- Firms are positioned with respect to the global knowledge base (Boschma, Heimeriks, & Balland, 2014; Cohen & Levinthal, 1990; Cohen & Levinthal, 1989; Heimeriks & Boschma, 2014).
 Technological knowledge is differentiated among firms, given that it is specific to the context in which it is created. Creating new knowledge does not occur in abstraction from current abilities. Rather, new learning, such as innovations, are products of a firm's combinative capabilities to generate new applications from existing knowledge (Kogut & Zander, 1993).
- Hypothesis 1: Relatedness drives patterns of entry and exit



- Many observers fear we experience a productivity paradox of slower technological development. Wuchty et al. (2007) and Jones (2009) emphasise that incremental recombinant innovation is growing in relevance due to the growing burden of knowledge, which requires greater investments in human capital and team work and a greater reliance on reusing existing ideas in new ways.
- Hypothesis 2: technological progress of the global knowledge base is slowing as shown by a relative increase in incremental recombinant innovation



- At the same time, the potential for innovation is increasing rapidly. More technological building blocks become available. Technological development applies positive feedback since successful inventions resulting from one stage of evolutionary progress can potentially be used to create the next stage
- Hypothesis 3: Increasing diversity of the knowledge base of firms



METHODS

- This paper relies on a unique database, the Corporate Invention Board (CIB). The CIB combines patent data from the PATSTAT database with financial data from the ORBIS database about the 2033 companies with the largest R&D investments (Alkemade et al., 2015).
- The distance between areas of technology is based on the analysis of the co-occurrence of IPC codes assigned to individual patent documents. The more often a code is assigned to patent documents within one area together with codes from another area, the stronger the relationship between those codes and the shorter the (technological) distance between the technological areas to which these codes belong. The global technology map thus provides a "bottom up" measure of the technological distance between different technological fields.



THE CORPORATE INVENTION BOARD





GLOBAL MAP OF TECHNOLOGY

- Starting from WIPO technological fields
- Expand to 387 subfields
- Concordance table IPC TF
- Technological distance based upon co-occurrence of IPC/TF codes on priority patents
- Follow Hidalgo et al. to create map
 - Maximum spanning tree
 - Add strong links (> 1000 co-occurrences)



Universiteit Utrecht A GLOBAL MAP OF TECHNOLOGY

BASED ON IPC COOCCURRENCES IN PRIORITY PATENTS APPLIED FOR WORLDWIDE BETWEEN 2000 AND 2005



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RELATEDNESS AND TECHNOLOGICAL CHANGE IN CIB CORPORATIONS.

- The rate of entry of new technological fields MNCs is strongly related to the diversity of the existing knowledgebase
- Average density is the average percentage of related technological fields for the MNC.





RESULTS

• A (small but significant) increase in the diversity of the knowledge base of MNCs can be observed





CONCLUSION

- Relatedness drives patterns of entry and exit of the technological domains of firms
- Technological progress of the global knowledge base is slowing as indicated by a relative increase in incremental recombinant innovation?
- Increasing complexity and diversity of the knowledge base of firms



- ICTs are associated with unleashing a phenomenon of "winner-take-most" markets thanks to a combination of low marginal costs (which allow first movers to expand quickly) and network effects (which make popularity its own, profitable, reward). The OECD notes that the informationtechnology industry is producing a class of super-frontier firms: the productivity of the top 2% of IT companies has risen relative to that of other elite firms (Andrews et al., 2016).
- Hypothesis : ICT sector shows a distinct pattern; GPT



Thanks