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Economics of Management and Innovation

MARTINELLI Module

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Approach Preview

I based everything I wrote on the slides' material, in-slides sources and the recommended 'support material'. For intra-text citations, I relied on the classic author-date format, and set a bibliography (at the end) to reference the precise articles/lectures I used while answering[1]. The lectures' bibliography voices and citations are of course less formal in their typing. Regarding the remaining (personal) editorial criterias I've followed, the main ones are:

- the double apex (") is used for direct quotes, which are considered terms, expressions, or sentences directly taken from a certain source and pasted as they were in it;
- the single apex (') may emphasize a content, flag a term as 'particular', or indicate an expression to which has been given a slightly (sometimes very slightly) different meaning (connotation) compared to its standard denotation;
- *Italics* formatting serves to emphasize further the term, expression or sentence to which it has been applied (merely aesthetic/preference purpose).

Besides this approach introduction, I tried to stick to an impersonal tone while writing, although from time to time it felt necessary to switch to the opposite. It may lower a bit the formality of the document in some of its parts, but I saw it as viable in the end and left it like that.

[1] In-text cits are also all bookmarked, so that clicking on one leads to the precise bibliography voice it refers to.

Exam Contents

Question 1:

"Empirical approaches to mapping technological change inevitably simplify high-level theoretical concepts".
Critically examine this statement with reference to technological paradigms, trajectories, and technological space. Compare at least two empirical approaches presented in the course and rigorously assess the specific dimensions of technological change they do or do not capture.

Answer 1:

The concept of a Technological Paradigm, as defined by Dosi (1982), is inherently multidimensional. It includes not just the physical artifacts (products), but also the specific 'knowledge base', the 'heuristics' (directions of search), and the social institutions that support them. Consequently, any attempt to measure this empirically requires a reduction of complexity: a projection of a multi-dimensional phenomenon onto a measurable plane. This simplification is necessary, but comes at the cost of losing information, mainly about the cognitive and organizational drivers of innovation.

In order to assess this trade-off, we must first define what it entails to refer to '*technological space*'. In the theoretical literature, and specifically in the framework proposed by Saviotti and Metcalfe (1984), 'technological space' does not imply a single dimension of meaning. It is in fact the bridge between the internal structure of a technology (how it is made) and the external environment (how it is used). A '*Technological Trajectory*' is therefore defined as the pattern of 'normal problem solving' activity moving through this space, improving trade-offs among relevant characteristics (Dosi, 1982).

However, capturing this 'movement' empirically is quite difficult. We can compare two distinct approaches presented in the course: the *Product Characteristics* approach (Saviotti and Metcalfe, 1984) and the *Patent Citation Network* approach (Martinelli, 2012). Both successfully map trajectories, but they capture entirely different 'slices' of the technological reality.

Starting with the Product Characteristics approach, Saviotti and Metcalfe's (1984) work structures the technological space by decomposing a product into Three distinct sets of vectors:

- *Technical Characteristics*: The 'internal engineering' dimensions (e.g., the dimensions of a combustion engine, the material of a pipe…).
- *Process Characteristics*: The inputs and methods of production.
- *Service Characteristics*: The performance attributes valued by the user (e.g., speed, safety, durability…).

In this view, innovation is a *dynamic mapping* process. Firms manipulate Technical and Process characteristics, to then improve Service characteristics[2]. A technological trajectory is

[2] Clarifying further: a 'technically' better or tailored product is of course expected to have better performance attributes and a conversely higher value for the user.

observed when we see a consistent movement over time in this multivariate space, for example, aircraft consistently becoming faster and more fuel-efficient over decades.

The critique we can make is linked to the strength of this approach. In fact, it is excellent at capturing the market realization of a trajectory[3], but it completely simplifies the 'upstream', the cognitive process laying behind: specifically, It treats the R&D process as a black box… hence, we see the *result* (better performance) but we do not see the *knowledge* flows, or the heuristics, exc., that led the people having engineered what we are looking at to 'that' particular solution. If we want to make it coincise: it measures the 'what' part, not the 'how'.

In contrast, the network approach used by Martinelli (2012) in the telecommunications switching industry moves the analysis from the 'product space' exactly to the 'knowledge space'. Here, the technological trajectory is not a line on a performance graph, but a path of *knowledge accumulation*. By using patents as nodes and citations as links, this method reconstructs the 'network'/flow of ideas. Martinelli (2012) demonstrates that by analyzing the topology of these networks[4], we can identify the core 'skeleton' of a trajectory. A paradigm shift is not just a change in performance, but a structural break in the *citation network*: a moment where the knowledge base shifts from one cluster of patents to another (e.g., from electromechanical switches to digital ones).

However, the issue could be that while this captures the cumulativeness and the direction of search (heuristics) that Saviotti misses, it suffers from its own simplification. As noted in the lecture slides (intro/trajectories slides), *a patent does not always equal a product*. This approach maps the flow of information but seems to disconnect it from economic value. A trajectory might look robust in a citation network (lots of R&D activity) while then failing to produce a commercially viable product (service characteristics); this appears as a logical consequence to the 'limitations' we explored.

The statement in the prompt[5] is then verified by the following comparison. The 'technological space' is theoretically composed of both the knowledge dynamics (Martinelli) and the performance outcomes (Saviotti). Saviotti and Metcalfe capture the economic selection environment. They show if a trajectory is actually meeting user needs (practically, the 'SWOT' of the technology), but they fail to capture the paradigm itself: the underlying knowledge recipe. Martinelli captures the technological paradigm (the cognitive exclusion of other directions), so we see the 'shoulders of giants' effect clearly (cumulative innovation: building upon prior knowledge), but it partially fails to capture the economic weight of the trajectory: as backed by Hall et al. (2001), citation is a proxy for knowledge flow, not necessarily for economic success.

Therefore, "empirical approaches inevitably simplify high-level (theoretical) concepts" because they force a choice between measuring the input/process (knowledge networks) or the

[3] Since, like stated before, it measures the output of innovation in terms of efficiency and user utility.

[4] The methodology employed to do so is attributed to a 1989 work of Hummon and Doreian, which weights the citations using traversal counts, specifically the "Search Path Link Count" (SPLC) and the "Search Path Node Pair" (SPNP; Martinelli, 2012). These indicators measure the probability that a specific link is used in the flow of knowledge from start-points to end-points. The "Main Path" is subsequently identified by selecting the links with the highest SPLC or SPNP values, thus filtering out minor flows to reveal the cumulative path of knowledge (Martinelli, 2012).

[5] Recalling it, from the question itself: "Empirical approaches to mapping technological change inevitably simplify high-level theoretical concepts.".

output/outcome (product characteristics). Neither method can fully encapsulate the Dosi (1982) definition of a trajectory as a co-evolution of both economic and technological factors. They are complementary projections, but not complete pictures.

Question 2:

"Designing intellectual property rights involves balancing dynamic efficiency against static inefficiency".
Discuss this statement by referring to the economic theory of patents presented in the course. In your answer, explain how patent length and breadth affect innovation incentives and social welfare, and illustrate your argument with at least one concrete sectoral or technological example.

Answer 2:

The question captures the fundamental economic dilemma inherent in the production of knowledge. As outlined in the course material (IPR slides), knowledge is a public good characterized by non-rivalry and non-excludability. In a competitive market, this leads to a market failure: since the marginal cost of reproducing information is near zero, competition drives prices down, preventing the innovator from recovering the fixed, sunk costs of R&D. To correct this, the patent system imposes a '*static inefficiency*' (a legal monopoly that restricts output and raises prices) to generate the '*dynamic efficiency*' (future innovation) required for long-term growth (Arrow, 1962).

The design of this system relies on two main policy levers: patent *length*, defining the monopoly's duration, and patent *breadth*, establishing the protection scope against imitation. As discussed in Belleflamme and Peitz (2015), the regulator faces a maximization problem: ensuring the firm recovers R&D costs while minimizing static deadweight loss. The optimal composition of these levers is conditional rather than fixed. Gilbert and Shapiro (1990) argue that breadth is socially costlier than length, as broad patents maximize deadweight loss in every period; they advocate for '*narrow and long*' patents to allow imperfect substitutes and lower prices. Conversely, alternate frameworks (e.g., Gallini, 1992) suggest that '*broad and short*' patents are preferable when narrow protection encourages socially wasteful imitation costs. Therefore, theory suggests that the optimal mix is not universal, but depends on whether breadth or length is the more efficient instrument for generating profit relative to the social cost[6].

This theoretical balance is heavily dependent on the sectoral context, particularly the distinction between discrete and complex technologies: in discrete sectors like pharmaceuticals in fact, where the relationship between a product and a patent is often one-to-one, strong protection is vital (Hall and Ziedonis, 2001; IPR slides). Grabowski (2002) notes that without robust patents, the low cost of imitation would destroy incentives for high-cost R&D. Conversely, in complex industries like semiconductors, innovation is cumulative and a single product may rely on hundreds of patented components. Here, broad patents can create patent "thickets" (Hall and Ziedonis, 2001) that hinder development. Hall and Ziedonis (2001) also document and revisit a "patent paradox" in this sector, where firms patent aggressively not just to exclude competitors, but to amass portfolios of "bargaining chips" (Hall and Ziedonis, 2001; IPR slides) for cross-licensing. In such cumulative environments, excessive breadth exacerbates the

[6] Equations demonstrating this claim are not reported here, but from Belleflamme and Peitz (2015) we can see how it can be 'reduced' to grasping if the first derivative of the "social return on innovative effort" variable with respect to the breadth variable is positive (breadth improves social welfare) or negative (breadth reduces social welfare).

risk of *hold-up*, suggesting that the optimal design must account for the strategic and structural differences between industries.

All being said, we can confidently say the statement quoted in the question is correct: patent design is a second-best solution that accepts static waste to buy dynamic progress. However, as the comparison between Grabowski (Pharma) and Hall & Ziedonis (Semiconductors) demonstrates, the optimal balance is sector-specific, and I would say that is a very important remark to be underlined (a policy that provides necessary protection for a discrete pharmaceutical drug may create quite onerous transaction costs for a cumulative semiconductor technology).

Question 3:

> *"Differences in innovation patterns across industries cannot be fully explained by firm-level characteristics alone".*
> *Discuss this statement by referring to the sectoral approach to innovation. In your answer, explain which sector-specific factors matter for innovation dynamics and assess the analytical value and limits of a sectoral perspective.*

Answer 3:

The assertion that firm-level characteristics are insufficient to explain innovation patterns challenges the traditional industrial organization perspective, which long sought to identify a universal market structure conducive to technical change. As outlined in the lectures topics, the original "*Schumpeterian hypotheses*" (Breschi et al., 2000; Sector slides) posited that the size of the firm and its degree of market power were the primary determinants of innovative activity. The underlying assumption was that large, *monopolistic* firms were the most powerful engines of progress due to their superior ability to internalize risks and finance R&D. However, empirical evidence has consistently demonstrated that this relationship is neither linear nor universal: a monopoly in the textile industry behaves fundamentally differently from a monopoly in the software industry. To understand these disparities, we must look beyond the individual firm and analyze the structural context in which it operates: the *sector*.

The structural 'rules of the game' that differentiate industries are captured by the concept of the *technological regime*. As elaborated by Breschi et al. (2000), a technological regime is defined by the specific combination of four fundamental dimensions: *opportunity conditions*, *appropriability conditions*, *cumulativeness*, and the *nature of the knowledge base*. These dimensions constrain the behavior of firms and ultimately shape the "*Schumpeterian patterns*" of innovation (Breschi et al., 2000; Sector slides). A regime characterized by high opportunities, low appropriability and cumulativeness, and a knowledge base more related to applied sciences typically results in a "*Schumpeter Mark I*" pattern (or "*widening*"), dominated by a turbulent population of new entrants; Conversely, sectors with high opportunities, but coupled with high cumulativeness and appropriability, and a knowledge base more related to 'basic' science, lead to a "*Schumpeter Mark II*" pattern (or "*deepening*"), where a stable oligopoly of large incumbents dominates technical change (Breschi et al., 2000; Sector slides).

The analytical value of this perspective lies in its ability to systematize heterogeneity. Pavitt (1984) provided a robust taxonomy demonstrating that the *sources* (focus of his quoted work) and directions of technical change vary predictably across categories. For instance, in '*science-based*'[7] sectors like biotechnology, innovation is driven by exogenous opportunities stemming from university research, and firms rely heavily on patents for appropriability. In contrast, in '*supplier-dominated*' sectors like textiles or agriculture, opportunities are scarcer and typically enter the firm through the purchase of advanced machinery rather than internal discovery. This structural variance explains why the 'optimal' firm organization is not constant

[7] Even if it is a category actually used and named in Pavitt (1984), I preferred to keep it as a "particular term/concept" (see Approach preview section) from the editorial-norms p.o.v. instead of a direct quote, that is the reason i used the single apex (') instead of the double ("), since it is also a common expression (i applied this same reasoning also elsewhere, but this was the instance where i preferred to insert a clarification).

across the economy; policies that encourage the formation of large champions might succeed in the automotive sector (a '*scale-intensive*' industry) but fail in the specialised instruments sector[8], where maybe lower entry barriers and a reliance on niche performance might[9] favor a more rapid turnover of small, innovative firms.

However, the sectoral approach is not without critical limits. While it successfully explains inter-industry variance, it risks simplifying too much intra-industry heterogeneity. As argued by Srholec and Verspagen (2012), there is significant diversity even within the same statistical sector. Their analysis, framed as a "*Voyage of the Beagle*" into innovation data, suggests that firms often adopt innovation strategies that cut across established sectoral boundaries (Srholec and Verspagen, 2012). For instance, a firm classified in a 'low-tech' sector might actually adopt a 'science-based strategy', investing heavily in R&D and interacting with public research institutes. Therefore, while the sector defines the broad technological regime, it does not automatically dictate the strategy of every single agent by itself. A comprehensive understanding requires acknowledging that while the sector sets the stage, the actors still possess the agency to *improvise*, leading to a more diverse landscape where firm-level characteristics and sectoral constraints evolve together.

[8] I made the example inspiring to the "instrument engineering" sector discussions in Pavitt (1984).

[9] Note that the 'excessive' use of "maybe", "might", is related to the examples and claims made in this part being mainly based on a 1984 paper (sectoral assertions could differ the more one wants to ground them in the present context, which was not the central scope in there).

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