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# Driving forces of technological change in medicine: Radical innovations induced by side effects and their impact on society and healthcare☆

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ABSTRACT

Technological change in medicine has complex interactions driven by demand- and supply side determinants. The epistemological position of this paper is that scientific research generates in medicine vital radical innovations (new drugs/therapies) that are associated, *a posteriori*, to moderate and/or severe side effects. These side effects spur feedback mechanisms, which support a co-evolution of innovation in parallel technological pathways: 1) incremental innovations with lower side effects and higher efficacy; 2) emergence of new radical innovations induced from severe side effects. Empiricist-positivist arguments support this stance and show the main role of society and healthcare in the patterns of technological innovation in medicine. Critical evidences are the foundation to state main inductive theoretical implications between observed facts.



## 1. Epistemological position

The analysis of the underlying driving forces of technological innovation in medicine is a complex task but important, very important to understand and support drug discovery industry ([26]; p. 30ff; [2]; p. 188ff; cf. also [12,14] for efficient political economy of R&D across countries; [11] for the vital role of democratization to support economic and technological change; [8,9] for an accurate description of technometric approaches to evaluate the impact of technological innovations on geo-economic systems). Dynamics of technological change in medicine are different from electronics, mechanics, and other scientific fields, and within the broad medical field, patterns of technological innovation in pharmaceuticals are different from biotechnologies and health technologies (cf. [67]; p.4ff). In addition, the linear model of technological innovation does not capture all determinants of technological innovations in medicine since technological change is driven by complex demand- and supply-side factors that can act simultaneously in specific

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spatial-temporal contexts. Several works have provided many valuable insights into the origin and diffusion of technological innovation in medicine (*e.g.* [67]), however some driving forces of the technological change are not been accurately explored and/or are under-researched.

This paper, in order to analyze how medical innovations occur, claims the following epistemological position:

> Scientific research generates in medicine vital radical innovations (*e.g.* a new drug A) that are associated, *a posteriori*, to moderate and/or severe side effects. These side effects spur feedback mechanisms for technological change that generates parallel pathways represented, respectively by: a co-evolution of the innovation A (incremental innovations with lower side effects and higher efficacy) and a possible new technological paradigm (emergence of new radical innovations to treat severe side effects, called adverse effect-induced innovations).

The study here provides empiricist-positivist arguments to support this stance. The analysis focuses on patterns of innovation in fertility control drugs in order to understand some driving forces of technological innovation in medicine and to analyze the effects on society and healthcare. Main findings of this study can be generalized to understand driving forces of patterns of technological innovation in medicine.

## 2. Scientific background and related works

Patterns of technological innovation in medicine are often characterized by new technological paradigms. Dosi ([19]; p. 152, original emphasis) states that a technological paradigm is a: " 'model' and 'pattern' of solution of *selected* technological problems, based on *selected* principles derived from the natural science and on *selected* material technologies". The technological paradigm in a specific research field can spur several incremental and radical innovations that drive new technological and scientific trajectories. Sahal ([70]; p. 70, original emphasis) argues that: "the origin of *revolutionary innovations* lies in certain *metaevolutionary* processes involving a combination of two or more *symbiotic* technologies whereby the structure of the integrated system is drastically simplified". In general, technological paradigms are generated and driven by new scientific paradigms, although there can be an interval between scientific breakthrough, invention and innovation that in some cases is more than 50 years (*cf.* [66]; p. 198ff). New technological paradigms in medicine co-evolve with the general process of technological change, leading to innovative drugs for longer, better and healthier living (*cf.* [13,33]). According to Shine ([74]; p. 137): "Technology has revolutionized healthcare over the past 50 years" and some important medical innovations are proton pump inhibitors, serotonin reuptake inhibitors (SSRIs), etc. (p. 138). The medical innovations represent main technological advances but they are also associated to adverse effects (see Refs. [75,48]).

Laubach ([46]; p. 212) argues that breakthroughs in biomedical sciences are based on continuous small scientific advances and interaction between clinical research and clinical practice.[1] Gelijns and Rosenberg ([27]; pp. 8–9) describe the technological pathway of contraceptive pill that, after the introduction in clinical practice (around 1960s), has been associated to an increased risk for thromboembolic disorders. The accumulation of clinical experience by feedback information of users and medical staff has played a key role for scientific research to find out that high concentration of estrogen in contraceptive pills might be cause of these defects. Subsequent versions of contraceptive pills have decreased estrogen level with the main effect of a huge reduction of some serious pathologies (such as those linked to cardiovascular system). Current technological change in medicine has a fast pace driven mainly by scientific advances in molecular and cell biology that focus on causes of diseases to produce innovative treatments [13]. Perpich [60] shows the "astonishing" (p. 405) progress of genetics and human stem cells that has been driving scientific advances in understanding the genetic basis of diseases for supporting cancer therapies and bio-regenerative medicine of hard and soft tissues (*cf.* also [50]; pp. xxx–xxxiii; [35]; pp.5–8). In particular, new drugs have specificity for some diseases and target a single type of receptor to reduce undesirable side effects in comparison to traditional agents that act in general way ([72]; p. 71). The patterns of technological innovation in medicine are complex and cannot be described with simple linear models of R&D (cf. [69,67]). Radical innovations in medicine are basic technological breakthroughs, often with several shortcomings[2]; feedback mechanisms by users and medical staff (in clinical practice) play a key role in R&D to spur the evolutionary change in new generations of drugs with incremental innovations in terms of higher efficacy and/or lower adverse effects and costs for healthcare ([26]; p. 32ff). In fact, Gelijns and Rosenberg ([28]; p. 91ff) argue that medical profession and clinicians have an active role in the development of innovation in medicine that is often "user dominated". There is a vast literature in the economics of innovation that analyzes these main topics, however some driving forces of technological change in medicine are under-researched but they play a vital role in the insurgence of new technological paradigms. In order to analyze these critical determinants for the technological change and progress in medicine, next section describes the research strategy to support the epistemological position of radical innovations induced by adverse effects of oral contraceptive pill (*e.g.* breast cancer).

## 3. Sources and research method

The study here analyzes a main case study based on the development of the radical innovation of oral contraceptive pill that has driven an interesting technological change in medicine. This case-study is the foundation of empiricist-positivist arguments to support the epistemological position. The starting point is a rational meta-analysis of the scientific literature to investigate the scientific chronicle of

[1] An interesting example of fruitful technological development is the endoscope described by Refs. [26,28].

[2] Cf. Ref. [10] for negative effects of other typologies of technological innovations.