PASTEUR'S HOPE: THE DECONSTRUCTION OF A POLARIZED DISCOURSE IN SCIENCE AND TECHNOLOGY AND THE NEW HORIZONS FOR ACADEMIC ENTREPRENEURSHIP

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ABSTRACT

The present study is a theoretical review on the distance between research and academic entrepreneurship. The objective is to contextualize the construction of the discourse in which basic science and applied science were polarized, and from this explanation, to deconstruct the polarity and present new possibilities. Journals considered to be significant in the area of technological innovation were analyzed in order to present studies that address new ways to generate spillovers from universities to the market through academic entrepreneurship. The contextualization goes through the work of Stokes' Pasteur's quadrant and the contributions are given by presenting new modalities of incentive for academic entrepreneurship, references to existing mechanisms around the world, and academic studies that have explored such modalities. The review presents itself as a provocative reflection that allows the horizons to be expanded on higher education management related to innovation and social improvement through research being spilling over within technology.

Keywords: Academic entrepreneurship, Technological innovation, Academic spillover, Entrepreneurial universities, Science and Technology (S&T).

INTRODUCTION

The present review begins by breaking with ideological polarities: in a "*Mises x Marx*" view (Liberalism *versus* Marxism), entrepreneurship can be well liked by both-depending only on the way in which it is observed. On the liberalism side, the traditional victory of the "*self-made man*" in the figure of the entrepreneur speaks for itself. In Marxism, his ideas are reinforced by one of the main theorists who support the arguments of research in entrepreneurship and innovation: Joseph Schumpeter. In his book "*Capitalism, Socialism, and Democracy*", Schumpeter (1943)-perhaps the main academic basis used by researchers in entrepreneurship and innovation-structures his thought, which first occurs with the exposition of Marx's thoughts. In his work, Schumpeter defended the need for the deconstruction of oligopolistic capital structures, with entrepreneurship and innovation being ways of reinventing such structures from a creative destruction. Echoing Marx's thoughts, Schumpeter held the view that the fight was not between individuals, but rather over structures that emerge from the capitalist system, as can be identified here in a reading on Marx's socialist thought: *"None of the usual slogans about bargaining power and cheating satisfied him. What he wanted to prove was that exploitation did not arise from individual situations occasionally and accidentally; but that it resulted from the very logic of the capitalist system, unavoidably and quite independently of any individual intention"* (Schumpeter, 2013).

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However, the present review deals with another polarization: that of pure science versus applied science. Supported by Schumpeter's thinking, the present study carries the following premises: (i) entrepreneurship and innovation become important by renewing existing structures, ensuring economic development, and promoting social well-being from the generation of jobs and improvement of products/services available for consumption (Acs et al., 2008; Fagerberg et al., 2013; Audretsch, 2014); (ii) in a systemic view, universities play a central role in the advancement of technological entrepreneurship (Rice et al., 2014; Guerrero et al., 2016; Ribeiro et al., 2018); and (iii) there is an institutional logic that distances students from the protagonism that they could have as entrepreneurs (Sauermann & Stephan, 2011; Simeone et al., 2018).

The academic protagonism for entrepreneurship reinforced here becomes, therefore, a key characteristic to achieve Schumpeter's creative destruction, which *"incessantly revolutionizes an economic structure from within, incessantly destroying the old one, incessantly creating a new one."* The construction of the present review follows: (i) themes and objective of the review; (ii) reflections: constructing and deconstructing polarized thinking with Pasteur's quadrant; (iii) discussions: translation mechanisms as agents of empowerment of academics; and (iv) conclusion.

INSTRUMENTS AND METHODS

The subject of the present study revolves around the polarity and distance between basic research and applied research, specifically in the search for a greater understanding of what universities and research environments have done to minimize polarity and allow academic research to materialize in the form of technologies appropriate for society. The first step towards this resolution is a reflection on how the polarized discourse between basic and applied research was constructed. From this step, the main journals worldwide which deal with science and technology (S&T) were analyzed, in order to identify best practices for minimizing gaps and to generate greater research spillover. Publications in the journals Technovation, Research Policy, and the Journal of Technology Transfer were especially considered, selected according to the ranking proposed by (Ratinho et al., 2015). Having introduced the main approaches, the present review seeks to point out relevant conclusions that contribute to the theory and practice of research environment management in the search for greater generation of technology and its appropriation by society. Since it is a theoretical review, no empirical research or systematic data collection was carried out, being more a reflective textual production on the practical and academic advances in the area.

Theoretical Background: from Bush to Stokes-Constructing and Deconstructing a Polarized Discourse

In addition to the frequently commented great events that marked the Second World War, such as the rise and fall of Adolf Hitler or the end of the war with nuclear bombs in Japan, another phenomenon occurred transversely to the events: the dominance of the United States of America in science (Cockburn & Stern, 2010). Beyond this, the end of the war brought the understanding in which scientific hegemony guaranteed the political hegemony of a nation. Aware of the history unfolding before his eyes, the then American president, Franklin Delano Roosevelt, asked one of his chief advisers, Vannevar Bush, for recommendations on the future of the nation in terms of science and technology after the end of the war.

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According to Bush's report (1945), Roosevelt, understanding the role of scientific development in World War II (which was not limited to atomic bombs, but also to penicillin, computational advances, and so many other inventions), had questions about (i) the continuity in advances in public health and the fight against diseases; (ii) the future of the role of government and private institutions in supporting research activities; and (iii) the maintenance and increase of the mass of researchers in the country from the American youth.

Bush's response is still considered one of the most important texts of the twentieth century. In it, the former director of MIT (Massachusetts Institute of Technology) presented the pillars of a paradigm on science and technology that are present in the speech of many leaders until today. Recognized studies in the field of S&T refer to Bush's work in the construction of their arguments, such as the title of the article that coined the concept of Triple Helix in academic research (Etzkowitz & Leydesdorff, 2000): "*Introduction: From the endless frontier to an endless transition"*.

The arguments defended the importance of the American budget being directed towards scientific research, reinforcing the need for non-discontinuity of investments, the autonomy of scientific structures in relation to the military, and the need to strengthen scientific education from the base of the American system in order to guarantee a mass of talents for the advancement of national research. However, in the midst of building his argument, Bush structured what came to be one of the main points criticized in his thinking: the linear model of innovation. In his document, the importance of investing in basic research in the search for a fundamental knowledge of things was presented-research that was diametrically separated from applied research, which would take this knowledge into practice and give completeness to the answers necessary for industrial development. For Vannevar Bush, science was a spectrum of two mutually exclusive elements: basic and applied research. Deepening in his official report, the need for support for both modalities is reinforced and especially the importance of investment in basic research for the long-term development of industry and other technological advances.

Among the criticisms of the documentary framework created by Bush, the one that opened the debate for other discussions and clearly established the impacts generated was the one presented in the book "*Pasteur's Quadrant*", by Stokes (2011). His defense unfolded in five points:

1. Contextualization of the post-war paradigm, in which the author discusses the development of linear thinking for innovation and presents his first arguments against Bush.
2. Emergence and institutionalization of polarization in modern thought, in which there is a discussion in terms of the philosophy of science, presenting the construction of dichotomous thinking and its roots since Classical Antiquity. Here Stokes even draws upon Aristotle's texts when he cites the pursuit of "*science as an aim of knowing, and not for any utilitarian end*" (Stokes, 2005).
3. Presentation of a new model of thinking, in which Stokes presents his quadrant structure (to be explored further) and reflects on its implications in public policies.
4. The renewal of the pact between science and government, a moment in which the tensions generated after a certain period of investment in pure science are highlighted, tensions that are characteristic of expectations that are often frustrated (due to the nature of risk involved in pure science) that bring with them discourses of denial of research and a consequent budget reduction for such purposes.
5. An analysis of the impact of linear thinking on specific policies and programs in the United States of America, such as the difficulty in evaluating projects by the dichotomy of the applied social role *versus* pure scientific advancement; the conflicting polarized mentality within public bodies; and variations in the volume of funding according to the profile of the leaders or politicians involved.

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Dialoguing with Stokes' proposals, the authors Narayanamurti et al. (2013) sought, based on a study of Nobel Prizes in Physics related to information technology (1956, 1964, 1985, 1998, 2000, and 2009), to prove the lack of dichotomy between basic and applied research. In their study, the authors show that research characterized as applied was fundamental for advances in basic research (technologies that allowed in-depth studies, for example), many of which were in the middle of a spectrum between invention and scientific discovery. Other authors who stood out for their denial of Bush's linear model were Kline & Rosenberg (1986), paying attention to the phasing of the linear model of innovation (research-development-production-marketing) and proposing a new structure with phases that dialogue in a more complex way (nonlinear and sequential) and at different levels.

One of the main aspects reinforced by Stokes and other authors lies in the polarization of discourse, which has consequences such as interdepartmental conflicts in public bodies; inefficiency of devices to promote technological development; academic research distancing from its potential applications; and construction of an elitist mentality in relation to the purity of scientific knowledge and it becoming tainted when in contact with private structures. Although many works have been produced to deconstruct the idea of polarization between basic and applied research, the idea that there is an untouchable distance between the two universes of basic and applied research is still common in the collective imagination. As Harari (2014) points out, societies are composed of their shared myths and beliefs and the rise of the European empire from 1850 onwards was due to a different social construction in understanding the role of science as a promoter of technological advances and national expansion through its appropriation. According to the author, the fact that such a view was not shared by the Asian empires was the fundamental factor for European domination and the loss of Eastern power during the seventeenth and eighteenth centuries.

For Stokes (2011), the old structure of the linear model-being a spectrum with basic and applied research at both extremes-becomes a quadrant model with two axes: (i) are there considerations of use? (yes or no); (ii) does it seek a fundamental understanding? (yes or no). It is understood here that when using a question that generates binary answers (positive *vs* negative), Stokes may have made a mistake that leads to the entanglement of researchers in the quadrants-the interpretation of the present study argues that few researchers would feel comfortable being in any quadrants where there is a denial of important questions about the reality of research, regardless of its characteristic. Based on this, a proposed adaptation to the quadrant model of scientific research would be the use of four characteristics of research: (i) Seeks to stress the foundations of science; (ii) use of two existing foundations of science-what Stokes presents as the use of "*the science at hand*"; (iii) born from a scientific curiosity; and (iv) born from a pre-identified problem of society.

Adapting the quadrants to the model already proposed by Stokes, we have:

Table 1
ADAPTATION OF STOKES' QUADRANTS OF SCIENTIFIC RESEARCH

	Born from a scientific curiosity	**Born from a pre-identified societal problem**
Stresses the boundary of the foundations	**Bohr's quadrant:** pure basic research, such as the Bohr's atomic model, which is born out of *"a pure voyage of discovery, regardless of the*	**Pasteur's quadrant:** research oriented towards pre-identified societal problems, but which at the same time generates spillover by stressing the frontier of the foundations of science. Pasteur was chosen due to his

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of science	*extent to which his ideas later remade the world".*	discoveries, which revolutionized microbiology, which came from research contracted by industrialists to solve specific problems such as quality deterioration in the production of vinegar and beer.
It uses existing foundations (science at hand)	Quadrant for the exploration of particular phenomena, with a more descriptive character. Here, Stokes does not reference anybody in particular, but points out that such research can build foundations that nourish work in the Bohr or Edison quadrants.	**Edison's quadrant**: applied goal-oriented research using the science at hand. Edison was an example due to the fact that he prevented the laboratory from advancing in the scientific implications of the discoveries that occurred, concentrating only on the inventive process of immediate application.

Source: adapted from Stokes (2011)

Why is it necessary to reinterpret the linear model? Because, as pointed out by Stokes and others already cited, the polarized vision is limiting. In addition to the arguments already mentioned, it is important to reinforce that the isolation of the scientific community not only harms society, but also harms scientists, who lose ambition for the possible advances of their studies. The most harmful of the consequences of polarization is the negligence regarding the possible advance when attacking applied problems, when dialoguing with industry demands that also contribute to the advance in the fundamentals of science, either by direct spillover in the findings arising from this research, or by the use of solutions created to advance science (as in the case of the Nobel prize winning in information technology). It should be noted that, within the scope of public policies, Stokes defends the plurality of investments-ensuring the progress of all quadrants, allowing greater consistency, and better design of promotion strategies.

Therefore, it is understood that, with the review of the discussions on research models, the deconstruction of polarized discourse proposed by Stokes is a key piece to ensure protagonism of academic research in the technological development of nations, a leading role that is today undermined by institutional logics that isolate science from the generation of structures that revolutionize society through academic entrepreneurship (Sauermann & Stephan, 2011).

RESULTS AND DISCUSSIONS

Translation Mechanisms in Universities as a Hope for the Technological Development of Pasteur's Quadrant

The conflicting institutional logics presented by Sauermann & Stephan (2011) have behavioral consequences, according to the authors, in two main aspects. The first, presents companies highly focused on results being applied to solving concrete problems, while the academic environment gives greater attention to the contribution of research to the frontiers of human knowledge. Such an approach often reflects on the demand for results and the timescale of responses-with industry more attentive to the short term, and academia not necessarily valuing this temporal restriction. The second would be the work environment, in which academic researchers have relative freedom to choose their research, projects, and their priorities in relation to relevance to science. In contrast, the business environment is characterized by having

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its direction defined by the organization's strategic objectives, forcing the researchers to submit, to a large extent, to what is established by top management.

Hatchuel et al. (2001) corroborate the aspects of conflicting logics presenting an existing paradox in the development of relations between companies and academia: academic research "*is responsible for its methods, not its results*", while it is expected that advances in technological development have their attention focused on results, regardless of the methods. Faced with this configuration of often opposing logics, Simeone et al. (2018) highlight the need for translation mechanisms that can bring these different universes closer together and solve issues involving vocabulary, mentality, expectations, values, and objectives.

The argument of the present study is, therefore, not to deny the existence of conflicts of mentality, objectives, temporality, and others, but to reinforce the harmful effect of polarized discourse in the construction of a great barrier that prevents a search for alignment between Bohr's quadrant and Edison's quadrant-alignment that occurs in the works carried out within Pasteur's quadrant. Here lies the central question of the present theoretical review: How have universities acted to dissolve these barriers in science and technology? More specifically, dialoguing with the need to reinvent economies from the creation of new businesses, what are the best practices to stimulate the spillover of their research through academic entrepreneurship?`

The advance in these practices may lead to more cases such as the Quartet Medicine, whose steps progress in the search for innovation and development in biotechnology brought more solidness to the scientific foundations in the development of some drugs, being considered a "*successful failure*":

"Yes, we and our co-investors lost all of our invested capital, and that hurts. But it was 'successful' because we stayed disciplined to the investment thesis and focused on revealing the scientific truth. In the end, the team determined the probability of making a new medicine on this mechanism was now too remote, and so we closed the book on the final chapter of a well-executed story" (Booth, 2017).

From this context, the various mechanisms for bringing researchers closer to the business sphere are born, and vice versa. Since the purpose of this article is to identify concrete answers, it is considered important to detail the main ones, which are:

TTOs: Technology Transfer Offices, whose main inspiration is the international technology transfer offices, aim to support the management of intellectual property generated at universities. Therefore, its efforts are focused on guiding researchers whose research results have potential for application in the market-either by creating a company or transferring the technology to some well-established organization in a variety of possible contracts. TICs track the filing of the patent, negotiations with companies, improvement of the technology, and legal details related to the distribution of the rights involved.

Strategies for approaching institutional logics: meetings with companies; lectures and activities to disseminate the culture of entrepreneurship and innovation; active prospecting of potential stakeholders; and participation in innovation networks.

Relevant academic work in the field: One of the most recognized academic works on the effectiveness of TICs was produced by Siegel et al. (2003), with the reading of the practical work presented by the Council (2014) also recommended. A recent academic debate revolves around the awareness that there are different models and stages of maturity for these organizations, with the works of Baglieri et al. (2018); Secundo et al. (2016) being good sources for deeper reading.

Incubators: Incubators arise with the mission of offering a safer environment for the high-risk conditions related to a nascent technology-based company. Among the resources

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offered by incubators are physical spaces at more affordable costs, consulting and specific services, laboratory infrastructure (either within the incubator or in its surroundings, with the incubator usually being inserted nearby or within universities), network of contacts, and access to public instruments to promote entrepreneurship.

Strategies for approaching institutional logics: use of physical infrastructure to hold events; large companies offering benefits and support for incubated companies; dissemination of materials and content among companies; and specific processes for approaching companies through methodologies linked to entrepreneurship and innovation, such as customer development and design thinking.

Relevant academic work in the field: Good references can be found in the work of Phan et al. (2005), as well as in the review of the current state of the theory carried out by (Mian et al., 2016).

Technology parks: Technology parks aim to increase the concentration of participants of a technology ecosystem in a particular region-usually by settling in regions with a high density of academic research. The parks are responsible for attracting large companies (anchor companies), startups, research and development laboratories, and research centers so that, through the density of interested people, there are "*serendipitous collisions*" that usually characterize innovation processes.

Strategies for approaching institutional logics: thematic events; collision-oriented structures (cafeterias, shared dining rooms, common spaces, and others); technological showcases; and agents connected to the technology park specifically allocated in efforts to approximate and translate institutional logics.

Relevant academic work in the field: The work of Phan et al. (2016) also discusses technology parks. The theme has been well developed in Asian regions, with recognized references on Chinese technology parks (Lai & Shyu, 2005; Hobbs et al., 2017).

Capillary efforts: In addition to the well-established mechanisms, other more dispersed efforts are present in universities and research centers whose intention is to bring the academic and business universes closer together. These mechanisms include thematic events; networking and connections carried out individually; specific laboratories with an emphasis on spillovers to the market; graduate courses oriented to entrepreneurship and innovation; undergraduate courses focused on product development; student-led organizations; and workshops and training programs in entrepreneurship and innovation. Other agents and their specific performances can be found in the works of (Rasmussen & Wright 2015; Tornatzky et al., 2014).

More recently, new mechanisms have emerged for the support and translation of research for the encouragement of academic spillover in a general way. Some of the highlights are:

Accelerators: While incubators are born with the mission of cushioning the impact of the external environment, accelerators "*in contrast, are designed to increase the speed of interactions with the market to help nascent businesses to quickly adapt and learn*" (Cohen & Hochberg, 2014). They also differ from incubators by the duration of the programs (shorter, usually a maximum of six months), the presence of initial investment, and intense involvement with external mentors (Ribeiro et al., 2015).

Best practices: Y Combinator (USA); Harvard Blavatnik Biomedical Accelerator (USA); and Hax Accelerator (China).

Relevant academic work: Pauwels et al. (2016) produced an extensive analysis of the emergence of the accelerator phenomenon, which can be complemented by the less academic,

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but quite complete production of Miller & Bound (2011). The study by Dempwolf et al. (2014) also comprehensively covers the topic.

Translational programs: More intensely present in research areas related to medicine, translational programs arise to eliminate communication barriers between clinicians and academics, in order to ensure that institutional logics, especially related to vocabulary and practical routines, are overcome to accelerate the development of concrete solutions for the medical field (Woolf, 2008; Zerhouni & Alving, 2006). Currently, translational programs work in various spheres of research environments, such as engineering and design (Simeone et al., 2018).

Best practices: Translational Research and Applied Medicine (Stanford, USA) and MIT Translational Fellows Program (MIT, USA).

Relevant academic work: Reynolds et al. (2016) provide a breakdown of MIT's translation efforts, with explicit processes and activities, being a technical complement to the academic article by Simeone et al. (2018) on Harvard's translational program.

Proof of Concept Centers: One of the most recent mechanisms, POCCs aim to develop technology-based companies from scientific research using a development mechanism based on goals. As project funding is made available based on the achievement of goals, the barrier to entry is reduced and the proposal becomes more attractive to a greater number of researchers-which guarantees a filtering process of greater amplitude. Studies show increases in the rate of emergence of companies within universities of more than 200% in specific situations (Sergey et al., 2015).

Best practices: MIT Deshpande Center (USA) and University of Colorado Proof of Concept Program (USA).

Relevant academic work: Analyses can be found in the works of Hayter & Link (2015); Gulbranson & Audretsch (2008). It should be noted that some studies relate POCCs with technology accelerators, such as Byrd et al. (2017).

Innovation and rapid prototyping laboratories: The existence of innovation laboratories and rapid prototyping means the availability of an infrastructure from which researchers can build prototypes and experiments at low cost in order to accelerate testing and process learning. In addition to the availability of rapid prototyping machinery (3D printers, laser cutting printers, steel molding machines, and other computer-controlled devices from 3D models), such laboratories are generally marked by inter disciplinarily, collaboration with companies, easily adaptable environments, and a culture of experimentation which is explicit when analyzing in speeches and communications. Collaboration with companies occurs not only in shared projects, but also in the sponsorship of rooms, equipment, and in the organization of events.

Best practices: Design factory network (worldwide); MIT Media Lab (USA); and Aalto Fablab (Finland).

Relevant academic work: The research around innovation laboratories focuses a lot on their role in creating a culture of inventiveness in students, being the works generally related to education, as present in that of Feisel & Rosa (2005). In addition, the work of Stacey (2014) presents a comprehensive coverage of best practices in Fab Labs.

The present theoretical review sought to create a resource for empowerment. Initially, the giants under whom the argument was based, Schumpeter and Marx, were presented to defend the need for greater academic protagonist in the creation of companies, in order to reinvent economic systems by breaking oligopolistic structures. The central element of the article focused

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on Stokes (2011) argument for a diagnosis of how a polarized discourse was constructed and responsible for undermining the impetus of universities in relation to entrepreneurship originating from science. The answer to the diagnosis of this polarization was found in Pasteur's quadrant-the search for the resolution of predetermined social problems generating not only the impact of scientific application on technological development, but also bringing progress in the foundations of science with such an undertaking. Finally, the present study aimed to present the mechanisms for bringing academics closer to the business world and practical problems to be solved, residing here the hope for universities to position themselves more within Pasteur's quadrant.

It is important to pay attention to the concept of "*conflicting institutional logics*" (Sauermann & Stephan, 2011), which argues that many of the challenges between the pure academic universe and the applied one (either by academic entrepreneurship or acting in R&D laboratories) happen through different ways of thinking. In the mechanisms found and presented here, there is even the term "*translation*" (translational program), who's premise makes sense: to bring together and build a common language-or translation efforts-for universes that have been polarized by a narrative rooted in society. It is understood, in the present review, that the ideal scenario is when such mechanisms are no longer necessary. In this utopia, Pasteur's quadrant will be internalized in many academics, which will begin to treat entrepreneurship and innovation as a possible trajectory for their research, without any demerit or negative impact on their work as a scientist.

CONCLUSION

The conclusion, therefore, is structured in three main points. The first of them is the reality of the occurrence of economic crises all over the world and the disastrous consequences of budgetary restrictions on scientific advances, often left aside in countries that do not understand it's obvious relationship with the development and recovery of an economy. Such budgetary limitations reinforce the need to create new revenue generation mechanisms for a university, with technology transfer being a mechanism that when observed in Pasteur's quadrant, can offer good resources without hindering the advancement of science. The second one relates to the growing emergence of new mechanisms of approximation between concrete problems of society to be solved, and researchers willing to develop solutions based on academic research. This horizon opens up fields for more elaborate organizational studies, seeking to better understand the practices and the most successful elements for the management of research aimed at promoting academic entrepreneurship. Finally, the impact on the feedback behavior of entrepreneurship an ecosystem is reinforced by awakening the creation of new businesses based on academic research. Such movement strengthens the culture of entrepreneurship of a university by showing new possibilities, triggering a positive spiral that advances research, society, and capital structures, now better distributed.

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