TECHNO-ECONOMIC PARADIGMS AND LATECOMER INDUSTRIALIZATION

Conceição, Pedro and Heitor, Manuel V.
Instituto Superior Técnico, Lisbon, Portugal

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Contents

Summary

The interaction between the emergence of new technologies and the larger economic and social patterns of behavior are explored. After presenting a broad overview of theoretical concepts associated with technological innovation and economic progress, a description of the major techno-economic paradigms is described. The country specific paths within the broader context provided by the evolution of techno-economic paradigms are analyzed. After this general discussion, the focus moves to a specific techno-economic paradigm: the information technologies and telecommunications era, which was the dominant techno-economic paradigm at the end of the 20th century. Finally, a more speculative argument is developed around the idea that the emergence of knowledge-based economies and the importance of social capital provides a more profound change than previous techno-economic paradigm shifts.

1. Ideas and Concepts

The interaction between the emergence of new technologies and the larger economic and social patterns of behavior can be understood, following Schumpeter, as a process of creative destruction. At a first approximation, this statement is obvious: new technologies disrupt and often replace older ones. Thus, the steam engine technology replaced animal powered means of land transportation and sailboats. At a higher level of analysis, the implications of new technologies are broader. The impact is often felt not only as a replacement of older for new technologies, but brings with it opportunities for new firms and difficulties for existing firms, the obsolescence of some occupations and shifts in the structure of employment, changes in the terms of trade between regions and countries. In other words, new technologies bring with them the conditions for the establishment of new economic conditions. On the other hand, it is clear that not all advances in technology are disruptive to the point of creating substantial changes in economic and social conditions. In fact, most technological advances and innovations make their impact felt in a relatively smooth way, when analyzed from a macro perspective.

One way to conceptualize the interaction between technological change and shifts in economic conditions is the idea of techno-economic paradigms. A techno-economic paradigm embodies a relatively stable cluster of core technologies, around which innovation and economic activity take place. The core technologies have a strong impact in the economy and society, being defined as core given their potential for generalization and penetration across a wide number of products and processes, across all sectors of economic, and often human, activity. Within a paradigm, the core technologies are virtually unchanged over time, but this does not mean that there is not economic and technological progress. On the contrary, these core technologies provide a positive heuristic that defines the knowledge and incentives for innovation and economic activity to occur. At the same time, this progress in inherently limited by the conditions set by the interaction of the core technologies with the dominant modes of economic activity, from the organization of firms, to the distribution of employment. Therefore, progress exists within a certain techno-economic paradigm, but occurs within a framework defined by a set of core technologies and modes of organizing economic activity.

Thus, within a paradigm, innovation occurs namely as the core technologies become more and more pervasive and influence ever more wider realms of production and distribution of products and services. For example, the steam engine influenced not only transportation (by land, with the railroad, and by sea), as is well known, but equally all modes of industrial production and manufacturing. Later, a new core technology, electricity, became crucial in manufacturing, but also in transportation once again, in telecommunications and, indeed, in the way it expanded the overall possibilities of hours available for production through the diffusion of electric light, to say nothing about the changes in day-to-day life.

When a major technological advance occurs, disrupting the existing core technologies and modes of economic operation, then a new techno-economic paradigm emerges. The displacement of the core technologies of the old paradigm creates a new wave of invention and innovation and is no longer tied to the previous paradigm core technologies. The examples of the previous paragraph illustrate the shift from one to a newer paradigm. While the steam engine provided the core technology for using energy in production and transportation, the emergence of electricity progressively displaced the steam engine as the preferred mode of energy provision. Note that the impact associated with the emergence of a new techno-economic paradigm is not only associated with the shift in the usage of the old by the new core technologies. In other words, it is not only the fact that factories started using electric motors and machines instead of steam engine powered instruments of production. The emergence of a new core technology requires, and creates the opportunity for, an entire new set of small and incremental innovations that permit the widespread usage of the new core technologies. Thus, when a shift in techno-economic paradigm occurs, we have not only a "substitution effect", but also an expansion of the creative frontier that allows the emergence of new technologies and enables, in the end, a shift to yet another techno-economic paradigm.

Additionally, beyond the technological and purely economic factors, the social and institutional frameworks that fit a certain techno-economic paradigm may not be adequate for a new one. Indeed, the process of emergence of a new techno-economic paradigm results from the interaction of the technological, economic, institutional and social spheres. Just having a new technology coming in may not have any effect if a set of changes in the other dimensions does not accompany the technological novelty. A certain set of institutions and social features may provide sufficient context for innovation within a certain paradigm; in other words, it is not necessarily needed to create institutions and social rules at the same pace as technological innovation progresses, but when there is a shift in techno-economic paradigm, a new institutional framework may be needed.

A number of authors, working together and independently, developed the theory of techno-economic paradigms. The most influential author is, naturally, Schumpeter, who argued that the expectations of profits would drive the "entrepreneur" to innovate. The entrepreneurs drive towards innovation is motivated by the temporary monopolistic position from which the innovator would benefit. He regarded this position as temporary because the advantages from this privileged position would eventually "perish in the vortex of the competition which streams after them", since other firms would copy the innovator. Schumpeter called this process 'creative destruction'. Therefore, for him, innovation appears at the forefront of economic progress, driving prosperity. In a later version of these same fundamental ideas, Schumpeter refined this earlier simplistic version of an entrepreneur in a perfect market composed by a multitude of competing firms that destroy any persistent market advantage. In his final work, Schumpeter acknowledged that some large corporations could sustain a market advantage by an institutionalization of the effort to innovate through the establishment of large R&D facilities.

The reinterpretation of Schumpeter's fundamental ideas of innovation as a process of disequilibrium in the broader context of techno-economic paradigm is due primarily to Christopher Freeman and his co-authors. Often called a "neo-Schumpeterian" approach, this perspective is articulated by Freeman, Clark and Soete , and by Freeman and Perez, and in Giovanni Dosi , to cite a few representative examples (see Bibliography). Freeman and his co-authors generalized the concept of Schumpeterian innovation to the national level, making an analogy between innovation at the firm level and a change in a techno-economic paradigm at the country level. A new techno-economic paradigm is, according to Freeman:

"...a combination of interrelated product and process, technical, organizational, and managerial innovations, permitting a quantum jump in potential productivity for all or most of the economy and opening an unusually wide range of *new* investment and profit opportunities." Freeman (1988).

This macroeconomic definition of innovation corresponds to what is, at the firm level, a radical innovation. Under this extreme, there are milder types of innovation, like incremental innovations, that correspond, at the micro level, to improvements in existing products and processes. Freeman builds a similar hierarchy for his macro analysis of innovation, leading to a conceptual framework that has some similarity to the evolutionary perspective of Nelson and Winter.

The perspective of looking at the relationship between technological change and economic growth through the concept of techno-economic paradigms is starkly different from the neoclassical approach, which, in the late 19th century, developed the idea of a production function. Capital (machines) and labor are the side-by-side ingredients of production. Labor and capital interact in a process of production of wealth that is limited by the current level of technology. In the neoclassical literature, the accumulation of physical capital in the form of machinery and "industrial capacity" was regarded as the main driver of economic growth, and this perspective still informs many of the current policies.

At the aggregate level, Solow showed that the pure accumulation of physical capital and labor was not sufficient to account for all the observed growth in the US for long historical periods. Solow's model assumed constant positive returns to scale, diminishing returns to each input and positive finite substitution elasticity between the two inputs. A final assumption was that technology change was exogenous. The two main conclusions of this model were, first, that without technological change per capita growth would cease, and, second, that a conditional convergence would occur. This second conclusion means that countries with a lower per capita GDP would grow faster than the richer countries, a direct consequence of the diminishing returns. The major shortcoming of this model was, obviously, that technological change, the main factor responsible for growth in the long run, was outside the model. He attributed the component of growth that went beyond the accumulation of physical capital and labor to technological change. This is an equilibrium perspective, in which resource allocation is mediated in free markets by pricing in a competitive environment.

Denison enhanced the Solow framework, arriving at similar conclusions. He analyzed long-term series of national accounts in the US, and included different potential growth drivers, in order to circumscribe what was then called the Residual Factor, the unexplainable growth of the total economy in the light of strictly traditional production factors, to its minimum size. Still, the residual, when equated with technological change, remained large, although smaller than the initial Solow estimates.

Up to the 1970s, there were several efforts to improve the treatment of technological change in Solow's model. As Barro and Sala-i-Martin refer:

"The inclusion of a theory of technological change in the neoclassical framework is difficult, because the standard competitive assumptions cannot be maintained. Technological advance involves the creation of new ideas, which are partially nonrival and therefore have aspects of public goods." Barro and Sala-i-Martin (1995)

As we saw, the work of Solow showed that the accumulation of physical assets was insufficient to account for even a small part of the observed growth. The introduction of factors such as human capital and technology to the equations attempting to account for economic growth was largely motivated by that deficiency. Denison, as we mentioned before, used even more sophisticated techniques to try to circumscribe the "unexplained" component of growth. But the fundamental issue is that the roles of human capital, technology, and of the other factors proposed by Denison in promoting growth were ill understood, and the way in which these factors were introduced into models of growth reflected these deficiencies. In particular, formal models failed to incorporate the dynamics of innovation conceptualized and described by Schumpeter.

More recently, the work of a generation of economists and other social scientists has fought the tendency to oversimplify the impact of new skills and ideas on development, and the conceptual framework proposed by Schumpeter has been a constant guide for theorizing about growth. The body of work of these scholars has provided sophisticated conceptual insights into the way that technology is related to economic growth. The "new growth theories" are a prime example of the effort to introduce some of those insights into the formal economic modeling framework inherited from Solow. Romer provides a non-technical overview of the main existing variants. According to Paul Romer, this effort, clearly neo-Schumpeterian, can close the gap between the formal and appreciative theorists:

"The first round of endogenous growth model relied on Marshalian external increasing returns and avoided explicit recognition of monopoly power. A second round of growth models subsequently made the leap to equilibrium models of monopolistic competition. [...] These second round or 'neo-Schumpeterian' models of growth with monopoly power may help bridge part of the gap between the mainstream theorists and appreciative theorists." Romer (1995).

Nelson and Solow provide critical assessments of new growth theories from opposing perspectives. While Nelson criticizes these theoretical efforts on the basis that they do not add anything significantly new to scholarship in the area, Solow claims that new growth theory almost provides a distraction from the fundamental aspects of economic growth, which should not be concerned with modeling technological change.

Regardless of the validity of the new growth theories, which is very much under dispute in the specialized literature, we want to stress that there is an increased effort to incorporate the analysis of Schumpeter and many other social scientists in a coherent framework that stresses the ability to learn as the main driver of long-term growth. The origins of these efforts date back to the work of Arrow, which is praised and cited as the origin of formalized efforts to account for "the ability to learn" in the context of economic development. Other examples include the work of Pasinetti, that uses a modeling framework inherited from Ricardo. However, his main point is to investigate the economic consequences of human learning. The concept of economic learning also reflects the idea that some economies are able to prosper in a changing environment, whether the origin of change is in new technology or in shifting preferences.

Coming back to the concept of the techno-economic paradigm, it is important to stress that two important dimensions of the techno-economic paradigm theory are "time and space". Time is, indeed, crucial, as we saw, since the process of technological change and its economic and social impact is seen as a progress, more stable within a certain techno-economic paradigm, and very different across techno-economic paradigms, which differ over time. Space is equally important, since it is not clear that a certain techno-economic paradigm will not affect all the regions of the world similarly. Certainly there will be different rates of adoption of new core technologies when there is a paradigm shift, or even, within a paradigm, different ways in which specific innovations and modes of economic organization develop in different countries and different regions. Some countries may originate or lead the development of a new techno-economic paradigm, and others may lag behind, or even stay closer to the older, rather than the newer techno-economic paradigm.

An important idea joining the time and space dimensions of the techno-economic paradigm theory is that of technological trajectories within national innovation systems. The idea of trajectories in national innovation systems (developed, with a comparative analysis across countries, by Nelson, for example) relates to the fact that each country follows its own developmental path, within the general framework of the existing techno-economic paradigm, but also – and this is crucially important – influenced by the past history and specific conditions of the local context.

This brings to the discussion the idea of latecomer industrialization, which, in essence, refers to the concept that some economies do catch up with the latest techno-economic paradigm later than in the countries that led or originated the new techno-economic paradigm. The asymmetries in country performance cannot be understood merely by looking at the neoclassical models of growth. More recently, economic growth has been understood in a way that incorporates the teachings of the techno-economic paradigm concept. According to this emerging view, economic progress and technological change are understood as being dependent on what we could call, with generality, the knowledge accumulated through “learning” processes.

Conceptually, the foundations for the relationship between learning and economic growth are well established in the recent literature (see Bibliography), and stem from a combination of the pure Solownian perspective, with the Schumpeterian view. Learning is reflected in improved skills in people and in the generation, diffusion, and usage of new ideas. Likewise, organizational learning reflects social processes driven by collective cultures and appropriate management attitudes. The ability to continuously generate skills and ideas (which is to say, to accumulate knowledge through learning) is the ultimate driver of an economy which has long-term prospects.

2. Empirics: Techno-Economic Paradigms and Country-Specific Trajectories

The fact that countries have different levels of income is clearly self-evident. Therefore, it is equally obvious that each country has followed its own trajectory, within the context of an existing techno-economic paradigm and the specific innovation system of the nation. We look here at some evidence for the translation of different paths in the economic performance of countries. But we begin with an interpretation of the major techno-economic paradigms, illustrated in Table 1..

Approximate Period	Description	Key Sectors	Economic Organization
1770s to 1840s	Early Mechanization	Textiles, Canals, Turnpike Roads	Individual entrepreneurs and small firms; local capital and individual wealth
1830s to 1890s	Steam Power and Railway	Steam Engines, Railway, World Shipping	Small firm competition, but emergence of large firms with unprecedented size; limited liability corporations and joint stock ownership
1880s to 1940s	Electrical and Heavy Engineering	Electrical Engineering, Chemical Process Industries, Steel ships, Heavy armaments	Giant firms, cartels, trusts; mergers and acquisitions; state regulation and enforcement of anti-trust; professional management teams
1930s to 1980s	Fordist Mass Production	Automobiles, Aircraft, Consumer Durables, Synthetic Materials	Oligopolistic competition; emergence of multinational corporations; rise of foreign direct investment; vertical integration; technocratic management styles and approaches
1970s to …	Information and Communication	Computers, Software, Telecommunications, Digital Technologies	Networks of large and small firms based increasingly on computer networks; wave of entrepreneurial activity associated with new technologies; strong regional clusters of innovative and entrepreneurial firms

Source: Adapted from Freeman and Soete (1997: Table 3.5).

Table 1. Major techno-economic paradigms and their features

The table shows five important techno-economic paradigms. The first techno-economic paradigm corresponds to the emergence of the Industrial Revolution, as mechanization was increasingly incorporated in manufacturing, especially in some industries, such as textiles. However, the technologies used within this paradigm presented some important limitations for the increase of the scale and output of the productive activity. Most firms remained small and local. Process control was poor and hand operated machines did not allow for output of reliable quality. Advances in steam engine technologies and machinery were already taking place, but it took a long time until they were ready for fruition. When these important technologies matured to the level that made their economic utilization possible, they became the core technologies of the second techno-economic paradigm. The new techno-economic paradigm based on steam engine and on machinery ameliorated some of the previous limitations, and created in itself the germ for new types of economic organization, as the table details.

If we cross the techno-economic paradigms with geography, then we start joining together the ideas of technological trajectories and national innovation systems. The two first techno-economic paradigms were led by Britain. In this context, the US and Germany, for example, were “latecomers”. Still, they became leaders in the third techno-economic paradigm, with Japan also leading in the fourth and the US arguably retaining the lead alone in the fifth, although we will be looking at this claim in more detail below. Therefore, the concept of latecomer industrialization is, in itself, relative and mutable.

Still, the manifestations of the current differences in the paths followed by different countries are dramatic. Even taking a set of relatively homogeneous countries, such as the OECD, shows great disparities in income per capita and productivity. Productivity, in a way, is probably the best indicator of the extent to which a nation is taking full advantage of the conditions provided by the existing techno-economic paradigm. A recent study by Ark and McGuckin tackles international comparisons of productivity and income in a particularly careful way, especially in finding comparable measures across countries. They also link labor productivity with output per capita following a common decomposition procedure. While the relationship between these two variables may seem obvious, in fact there are many subtleties involved. For example, a country that is very productive but where workers engage in productive activities for fewer hours than a less productive country can result in a higher output per capita in the second country. Table 2 shows the results presented in this work. Column (1) indicates labor productivity and column (8) provides the level of GDP per capita.

	GDP **per hour worked** as a % of the OECD Average	Effect of working hours	GDP **per person employed** as a % of the OECD Average	Effect of unemploy-ment	Effect of labor force as a % of the working age population	Effect of working age population as a % of the total population	Total effect of labor force participation	GDP **per person** as a % of the OECD Average
	(1)	(2)	(3)=(1)+(2)	(4)	(5)	(6)	(7)=(4)+(5)+(6)	(8)=(3)+(7)
Australia	**96**	0	**96**	-1	2	0	1	**97**
Austria	**102**	-4	**98**	3	-2	1	2	**100**
Belgium	**128**	-5	**123**	-3	-19	-1	-22	**101**
Canada	**97**	2	**98**	-2	2	2	2	**100**
Denmark	**92**	0	**92**	1	9	1	11	**103**
Finland	**93**	0	**94**	-7	2	0	-5	**88**
France	**123**	-9	**113**	-6	-9	-2	-17	**97**
Germany	**105**	-5	**100**	-3	-4	2	-4	**96**
Greece	**75**	-4	**71**	-2	-11	1	-12	**58**
Ireland	**108**	5	**113**	-4	-12	-3	-18	**95**
Italy	**106**	-11	**96**	-5	-1	2	-5	**91**
Japan	**82**	10	**92**	4	6	4	14	**106**
The Netherlands	**121**	-26	**95**	2	-4	2	0	**96**
New Zealand	**69**	8	**77**	1	3	-1	2	**79**
Norway	**126**	-17	**109**	4	12	-4	12	**122**
Portugal	**56**	2	**58**	0	1	1	2	**60**
Spain	**84**	13	**97**	-14	-13	2	-26	**71**
Sweden	**93**	-3	**89**	-3	6	-4	-1	**88**
Switzerland	**94**	0	**94**	3	12	1	17	**111**
Turkey	**36**	2	**38**	0	-8	-1	-9	**29**
United Kingdom	**100**	-9	**91**	0	3	-2	0	**92**
United States	**120**	-1	**118**	3	9	-2	10	**128**
EU-14	**103**	-5	**98**	-4	-4	0	-8	**90**

Source: Ark and McGuckin (1999). Summations may not add exactly due to rounding errors.

Table 2. Decomposition of GDP per Hour Worked into Effects of Working Hours, Labor Force Participation and GDP Per Capita, in 1997

Portugal and Turkey have the lowest hourly labor productivity rate of the OECD. Portuguese hourly productivity is about half of the OECD average. Productivity in Greece is 19 points above Portugals, and Spains productivity is 28 points above the Portuguese hourly labor productivity. When one looks at column (8) Greeces GDP per capita is actually lower than Portugals by two points, and Spains GDP is only 11 points above Portugals.

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Biographical Sketches

Pedro Conceição is Senior Policy Advisor and Deputy to the Director of the Office of Development Studies, United Nations Development Program. Previously he was an Assistant Professor at the Technical University of Lisbon and a researcher at the Center for Innovation, Technology and Policy Research, the Instituto Superior Técnico (IST)-Technical University of Lisbon. He is also a researcher at The University of Texas Inequality Project (UTIP), at The University of Texas, Austin, USA. He has co-authored two books in Portuguese (*New Ideas for the University*, IST Press, Lisbon; *Innovation in Portugal*, Celta Editora, Lisbon), has co-edited Science, Technology, and Innovation Policy Opportunities and Challenges for the 21st Century (Quorum Books, 2000) and has contributed to *Inequality and Industrial Change: A Global View* (Cambridge University Press, 2001), and to *The Globalizing Learning Economy* (Oxford University Press, 2001). He has written more than fifteen papers in journals, on economics, and in the fields of science and technology policy and management. He can be contacted at the following e-mail address: pedroc@uts.cc.utexas.edu

Manuel V. Heitor is Full Professor at the Department of Mechanical Engineering, the Instituto Superior Técnico (IST, Technical University of Lisbon). Heitor has also served as the Deputy-President of IST for the period 1993-1998. He is the director of the IST´s M.Sc. Program on *Engineering Policy and Management of Technology*, which he launched in 1998. He is co-founder and current director of the IST´s *Center for Innovation, Technology and Policy Research*. In 1999, he was appointed as the *National Coordinator of the Evaluation of Research Units* by the Portuguese Ministry of Science and Technology, and coordinated the evaluation of the Mechanical Engineering panel in 1996.

He is co-editor of several books (*Combusting Flow Diagnostics*, published in 1992 by Kluwer Academic, and *Unsteady Combustion*, published by Kluwer Academic in 1996) and is the author of several scientific papers in the area of experimental combustion and related energy aspects. Since 1986, he has been a member of the Organizing Committee of the International Conferences on *Applications of Laser Techniques to Fluid Mechanics*. He is co-author of *New Ideas for the University* (in Portuguese), published in 1998 by IST Press. He is also co-editor of *Science, Technology and Innovation Policy: Opportunities and Challenges for the 21st Century*, published in 1999 by QUORUM Publishing.

His current interests include the management of technology and the development of engineering and innovation policies. Since 1995, he has been a Research Fellow of the *IC2 Institute, Innovation, Creativity and Capital*, at the University of Texas, Austin, USA, and has also been a member of the Advisory Board of *Technological Forecasting and Social Change*. He has co-ordinated the Organizing Committee of the series of International Conferences on *Technology Policy and Innovation*, which have been organized annually since 1997. He can be reached at the address given at the beginning of this article. His e-mail address is: mheitor@dem.ist.utl.pt