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Theorem of not independence of any technological innovation

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Abstract. The theorem of *not* independence of *any* technological innovation states that in the long run, the behavior and evolution of *any* technological innovation is *not* independent from the behavior and evolution of the other technological innovations. In particular, *any* technological innovation does not function as an independent system *per se*, but each innovation depends on the other technological innovations to form a complex system of parts that interact and coevolve in a non-simple way. The theorem of *not* independence of *any* technological innovation can explain and generalize, whenever possible, one of the characteristics of the evolution of technology that generates technological and economic change in human society.
Keywords. Evolution of technology, Technological innovation, Technological evolution, Radical innovations, Technological systems, Technological dependence, Fundamental interaction, Complex systems, Technological change.
JEL. C00, O30, O33.

1. Introduction

In analogy with some concepts from systems science (Ackoff, 1971, p. 661ff; *cf.*, Churchman & Ackoff, 1950; Oppenheimer, 1958; Rosenblueth *et al.,* 1943), suppose that: Technological innovation[i] is defined an entity (system) that is composed of at least two components and a relation that holds between each of its components and at least one other element in the set. Each of a technological innovation's components is connected to every other component, directly or indirectly. No subset of components in a technology is unrelated to any other subset.

Remark: a component of technology is an element of its system that can be abstract or concrete. Abstract components of technology are concepts, such as in computer programming, a string. Concrete (tangible) components of technology are objects, such as electronic and/or mechanical parts of artifacts (cf., Ackoff, 1971).

In this context, the technology has fundamental interactions between components (sub-systems) and other associated systems (technological innovations) in a complex system; these fundamental interactions are reciprocal movement of information/resources/energy and other physical phenomena directed to satisfy needs, achieve goals and/or solve problems of human society. The fundamental interaction in technological domains is strong between intra-component linkages (sub-systems) and weak between inter-component linkages of one or more technological innovations (Simon, 1962). The environment of a technological innovation is a set of elements and factors that can affect its state. The state of a technological innovation "at a moment of time is the set of relevant properties which that system has at that time" (Ackoff, 1971). For instance,

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environments of technology are the markets (competition, oligopoly, monopolistic competition, contestable, etc.) that can drive technological advances with a reciprocal influence between innovations in order to achieve and/or support goals and competitive advantage of subjects (competition-driven innovation).

Some characteristics of technological innovations are:

1. A technological innovation can be a state-maintaining system: "is one that (1) can react in only one way to any one external or internal event but (2) it reacts differently to different external or internal events, and (3) these different reactions produce the same external or internal state (outcome). Such a system …must be able to *discriminate* between different internal or external states to changes in which it reacts". These technological innovations: "are not capable of learning because they cannot choose their behavior. They cannot improve with experience." (e.g., compass; Ackoff, 1971, p.665, original italics).
2. A goal-seeking technological innovation is a system:"that can respond differently to one or more different external or internal events in one or more different external or internal states and that can respond differently to a particular event in an unchanging environment until it produces a particular state (outcome)…Thus such a system has a *choice* of behavior… Under constant conditions a goal-seeking system may be able to accomplish the same thing in different ways and it may be able to do so under different conditions. If it has memory, it can increase its efficiency over time in producing the outcome that is its goal ...for example, an electronic maze-solving rat.... Systems with automatic 'pilots' are goal-seeking." (Ackoff, 1971, pp.665-666, original emphasis).
3. A multi-goal-seeking technological innovation isa system: "that is goal-seeking in each of two or more different (initial) external or internal states, and which seeks different goals in at least two different states, the goal being determined by the initial state" (Ackoff, 1971, pp.666).
4. A purposive technological innovation: "is a multi-goal-seeking system the different goals of which have a common property. These types of system can pursue different goals but they do not select the goal to be pursued.... A computer which is programmed to play more than one game ...is multi-goal-seeking. What game it plays is not a matter of its choice, however; it is usually determined by an instruction from an external source. Such a system is also purposive because 'game winning' is a common property of the different goals which it seeks" (Ackoff, 1971, pp.666). In short, by combining two or more goal-seeking components, it is possible to construct a multi-goal-seeking (and hence a purposive) system.
5. A purposeful system, instead, is: "one which can produce the same outcome in different ways in the same (internal or external) state and can produce different outcomes in the same and different states. Thus a purposeful system is one which can change its goals under constant conditions; it selects ends as well as means and thus displays *will*. Human beings are the most familiar examples of such systems …The goal of a purposeful system in a particular situation is a preferred outcome that can be obtained within a specified time period. The objective of a purposeful system in a particular situation is a preferred outcome that... can be obtained over a longer time period." (Ackoff, 1971, pp.666-667, original italics).
6. A technological innovation can be state-maintaining, goal-seeking, multi-goal-seeking, or purposive; but not a purposeful system.

2. Theorem of *Not* independence of *Any* technological innovation

In the long run, the behavior and evolution of *any* technological innovation$\varphi_i$is *not* independent from the behavior and evolution of the other technological innovations$\lambda_j \forall i = 1, \dots, n \text{ and } j = 1, \dots, m$

Proof

Assume the statement of the theorem above (called P) to be false.

Suppose that $\neg P$ (the negation of the theorem) is true: ∃ a technological innovation$\varphi_i$such that (s.t.)$\varphi_i$is independent from the other technological innovationsλ_j

⇒∃a technological innovationφ_is.t.it is a purposeful system that can change its goals, select ends as well as means and displays will.

However, *any* technological innovation cannot be a purposeful system per definition.

The statement $\neg P$ implies a contradictory assertion (an *argumentum ad absurdum*: reduction to absurdity).

Therefore, ∴ the statement P (theorem) is true (QED).

Corollary

- ∄*any* technological innovation φ_I that has a long-run behavior and evolution independent from the other technological innovations λ_j.
- The theoretical implications of this theorem are fundamental interactions between systems of technologies that generate dependence and interdependence between two or more associated technologies in human society.

3. Theoretical and practical implications of the theorem

The concept system, applied here, plays a critical role in science and technology (Ackoff, 1971). The systems approach focuses on systems taken as a whole, not on their parts taken separately and is an appropriate theoretical framework to analyze the patterns and evolution of technological innovation (Coccia, 2017). The theoretical implication of this theorem is that:

1. in the long run, the behavior and evolution of any one of the technological innovations interact and depend on the behavior and evolution of the other technological innovations;
2. in the short-run, the behavior and evolution of technological innovations may be approximately independent of the short-run behavior and evolution of the other technological innovations (cf., Simon, 1962).

The theorem here can explain and generalize, whenever possible the existence of fundamental interactions, between *any* technological innovations and at least one other technological innovations in complex and inter-related systems. The not independence of any technology is an important property of the evolution of technology inhuman societies.

Overall, then, this theory here suggests that in the long run, *any* technological innovation does not function as independent system *per se*, but technological innovations depend on the other technological innovations to form elements of complex systems that interact and coevolve in a non-simple way. Technology has an intrinsic nature to progress with fundamental interactions with the other technological innovations and human societies (human-technology interactions) to satisfy needs, achieve goals and/or solve problems. Future technological and scientific progress may generate, with the artificial intelligence (AI), new technology similar to purposeful systems, but the similarity will not be an identity and a completely independence of AI technology is hard to be conceived.

To conclude, the proposed theorem here may form a groundwork for development of more sophisticated theoretical framework sto explain the evolution of technology in the long run. However, we know that other things are often not equal over time and space in the domain of technology. There is need for much more detailed research to shed further theoretical and empirical light on patterns of technological innovation to explain evolution of technology, technological and economic change in human society.

Notes

[i] For studies about technological innovation see Coccia, 2001, 2003, 2004, 2005, 2005a, 2005b, 2005c, 2006, 2006a, 2007, 2008, 2008a, 2008b, 2009, 2009a, 2010, 2010a, 2010b, 2010c, 2010d, 2010e, 2011, 2012, 2012a, 2012b, 2012c, 2012d, 2013, 2013a, 2014, 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2014g, 2015, 2015a, 2015b, 2015c, 2015d, 2016, 2016a, 2016b, 2016c, 2017, 2017a, 2017b, 2017c, 2017d, 2018, Coccia & Bozeman, 2016; Coccia & Finardi, 2012, 2013; Coccia & Wang, 2015, 2016.

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