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Abstract

Schumpeter persistently sought to reconcile innovation with general equilibrium to explain economic evolution. In essence, he was interested in innovatory discontinuities that upset equilibrium and generate a transitional dynamics converging to a different state of technology. There are two central approaches to the analysis of economic evolution which revolve around the Schumpeterian vision: the evolutionary approach as originated in the landmark book by Nelson and Winter *An Evolutionary Theory of Economic Change* and the neoclassical approach emerging from Romer's seminal paper "Endogenous Technological Change" Neither of these approaches is able to explain economic evolution in an economy where both general equilibrium and innovatory discontinuities can happen. In this paper I formalize the notion of innovatory discontinuity using the concept of 'ideas production function' and present an appreciative model of economic evolution involving equilibrium, innovation and innovatory discontinuities. This (hybrid) model sheds some light on the answer to the question: is economic evolution continuous or discontinuous?

Keywords: General equilibrium, economic evolution, neoclassical approach, evolutionary economics, mega-invention, innovatory discontinuities, Schumpeterian view
JEL classifications: 030 and 031

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1. INTRODUCTION

It is generally agreed that the work of Joseph A. Schumpeter provided much of the basis for the following axiom: to understand economic evolution it is necessary to think carefully about business innovation. It is also generally agreed that the ultimate end of the Schumpeterian vision of economic evolution is to understand fully the rules that govern a creative economy.[1]

Schumpeter persistently sought to reconcile innovation with general equilibrium. In essence, he was interested in innovatory discontinuities that upset equilibrium and generate a transitional dynamics converging to a different state of technology. Apparently, the origin of this insight harks back to Leon Walras. In fact, the following paragraph from *Elements of Pure Economics* suggests that it is not unreasonable to conjecture that Schumpeter found inspiration in Walras:

> Such is the continuous market, which is perpetually tending towards equilibrium without ever actually attaining it, because the market has no other way of approaching equilibrium except by groping, and, before the goal is reached, it has to renew its efforts and start over again…Viewed in this way, the market is like a lake agitated by the wind, where the water is incessantly seeking its level without ever reaching it. But whereas there are days when the surface of a lake is almost smooth, there never is a day when the effective demand for products and services equal their effective supply and when the selling price of the products equals the cost of the productive services used in making them…For just as a lake is, at times, stirred to its very depths by a storm, so also the market is sometimes thrown into violent confusion by *crises*, which are sudden and general disturbances of equilibrium. Walras (1954, p. 380-381) [*Italics in original*]

There are two central approaches to the analysis of economic evolution which revolve around the Schumpeterian vision: the *evolutionary* approach as originated in the book by Nelson and Winter (1982) and the *neoclassical* approach emerging from Romer (1990b). Although these approaches discuss similar economic issues concerning the creative economy, they see the innovation process with quite different lenses. It is logically impossible to reconcile these approaches because the key assumptions in the neoclassical approach are rejected by the evolutionary approach, and vice versa. Moreover, neither of these approaches is able to explain economic evolution in a creative economy where both general equilibrium and innovatory discontinuities can happen.

In this paper I formalize the notion of innovatory discontinuity using the concept of 'ideas production function' and present an appreciative model of economic evolution involving equilibrium, innovation and innovatory discontinuities. This (hybrid) model sheds some light on the answer to the question: is economic evolution continuous or discontinuous?

[1] In this paper the term 'creative economy' means a market-guided economy where the increase in the standard of living of its residents is primarily based on the production of profitable new ideas.

The remainder of the paper is organized as follows. Section 2 briefly outlines the conceptual framework of the mathematical models of a creative economy with particular regard to the ideas production function. Section 3 formalizes the notion of innovatory discontinuity. Section 4 brings into sharp focus the difference between neoclassical and evolutionary theorizing. Section 5 presents an appreciative model of Schumpeterian evolution. The paper ends in Section 6 with a brief summary and some concluding comments.

2. IDEAS PRODUCTION FUNCTION

The centrality of technological innovation in economic growth has been clearly recognized by many economists ranging from Smith (1776) to Abramovitz (1952) and Solow (1956). However, it is only in the recent past that technological change has been mathematically treated as an endogenous variable in a general equilibrium model capturing important aspects of the Schumpeterian vision of economic change. This line of research was initiated by Paul M. Romer -somewhat roughly in Romer (1990a) (1990b)- and provoked an explosion of articles on innovation and economic growth.

Romer (1990b) developed the first general equilibrium model of a creative economy (henceforth Romer model). The basic concepts in Romer's conceptual framework are 'profitable new idea' exhibiting two attributes (non-rivalry and at least partial excludability) and ‘human capital’ with the properties of a private good. Ideas with economic value and human capital are the driving force of the creative economy. These two concepts are related to each other through an *ideas production function* involving two explanatory variables (the number of researchers and the stock of ideas available to these 'ideas workers') and a single dependent variable, defined as the rate of new ideas creation.

Insights

The most important achievement of the Romer model is the *integration* of the following five insights into a coherent conceptual framework:

- Schumpeter’s insight (New ideas): The act of innovation consists of *reconfiguring* old ideas in new ways to produce new ideas. Schumpeter (1934, p. 68)
- Schmookler’s insight (Profit motive and new ideas): Innovation is essentially an *economic* phenomenon, or at least explicable in economic terms. Schmookler (1966, p. 208)
- Nelson’s insight (Proprietary aspects of new ideas): The act of human innovation is typically *imperfectly* appropriable. Nelson (1982, p. 467)
- Romer’s insight a (Ideas and Increasing returns): The existence of intangible inputs renders *increasing returns* inevitable. Romer (1990a, p. 97)
- Romer’s insight b (Ideas and Human Capital): Ideas and human capital are inherently *different* economic products. Romer (1990b, pp. S74-S75).

General equilibrium growth models revolving around these insights are called *Schumpeterian growth models*.[2]

Romer's model also indicates that innovations only occur in the ideas-producing sector completely described by the ideas production function. There is a one-to-one correspondence between innovations and profitable new ideas. Innovations are largely stimulated by the profit motive (Schmookler's insight) and the corresponding new ideas are at least partially excludable due to the existence of intellectual property rights (Nelson's insight). Consequently, private investment in innovation occurs in an imperfectly competitive environment.

The logic of the existence of increasing returns (Romer's insight a) is as follows. A new idea is non-rival in the sense that its use in one activity does not prevent its use elsewhere. Moreover, any new idea needs only to be created once, so that an innovation only entails fixed costs, given by the one-time costs of creating the idea. Consequently, a creative economy displays increasing returns to scale.[3]

Definition

It is a basic premise of the Schumpeterian growth models that the ideas production function reflects the innovation process in a creative economy. The general expression of the ideas production function (briefly, IPF) can be written as the differential equation

$$\dot{A}(t) = F(L_A,\ A)], \tag{1}$$

where $\dot{A}(t)$ represents the rate of new ideas creation at time t, and L_A and A denote, respectively, the number of researchers and the stock of ideas. Romer (1990b) was the first economist to make the ideas production function explicit and concrete.

A pictorial description of the IPF can be presented as the source-target picture shown in Fig.1. The IPF turns out to be a mapping from a point in a two-dimensional space into a point in a one-dimensional space: in correspondence with each ordered pair $[L_A(t),\ A(t)]$ there is one and only one instantaneous rate of new ideas creation $\dot{A}(t)$. This function, while a valuable analytical device, remains silent about the varieties and complexities inherent to the innovation process. In this regard, the IPF is a black box.

[2] These models constitute the core of what Richard Nelson calls the 'new formal neoclassical growth theories.' Nelson (1994, p. 319). It is for this reason that in the present paper the expressions 'Schumpeterian growth models' and 'neoclassical approach' are used interchangeably.

[3] Intuitively, an increase of 1% in all inputs results in an increase in output by more than 1% because, by definition, non-rival inputs can be used over and over again simultaneously by many people.

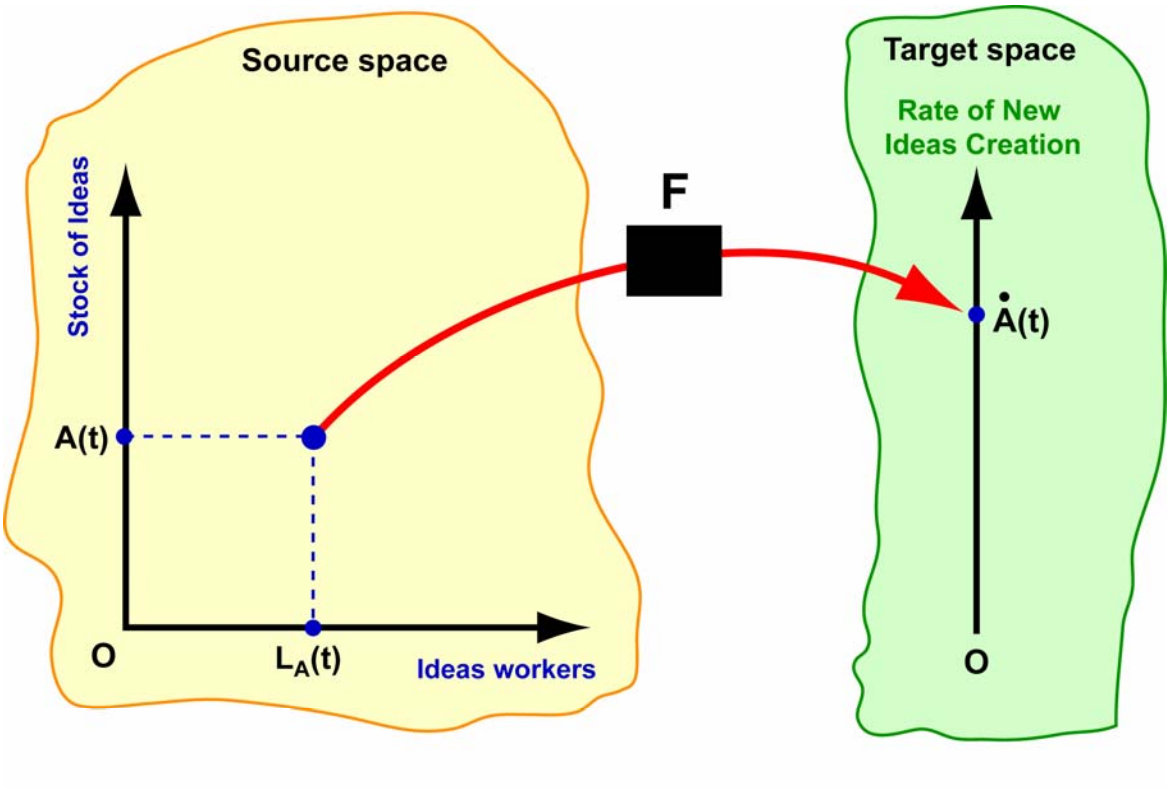

Figure 1

An immediate implication of the existence of the IPF should be emphasized. The specification of the right hand side of (1) would allow us to obtain a function A(t) that reconstructs the past and predicts the future number of ideas in the creative economy. Indeed, a particular solution to the differential equation (1) would give a whole function A(t) describing the state of knowledge at any particular time t.[4] It is assumed that this function condenses or summarizes the existing *state of technology*.

One basic question immediately suggests itself. Can we dispose of the concept of an ideas production function and still have a formal Schumpeterian model? The short answer is no because the elimination of the IPF would imply a return to the Solow (1956) model. Consequently, the strategic assumption in the neoclassical approach to economic evolution is the existence of the IPF.

The IPF revolves around three tacit assumptions. First, all innovations are equally important for economic growth (e.g. the economic impact of a new satellite technology is indistinguishable from that of a new can opener). Second, all innovations occur in one sector only (the ideas-producing sector). Last but not least, there are no innovatory discontinuities. These assumptions will be referred to as (1) *equipollent innovation,* (2) *confined innovation*, and (3) *unruffled innovation*, respectively.[5]

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[4] Given the number of ideas workers, that is, once the form of the function $L_A(t)$ is *specified*, a differential equation like (1) usually has a *general* solution that depends on one constant that can be uniquely determined. For example, assuming that the stock of ideas is historically known at the initial time t = 0, say $A(0) = A_0$, the *particular* solution of equation (1) can be determined.

[5] Clearly, assumptions (1) and (2) are at odds with the empirical evidence. This is not intended to be a criticism of the type "This equation is so simplistic, and the real world of innovation is so complicated." I

Disaggregation

The correlation between new ideas and their economic impact is not perfect. The importance of distinguishing innovations in terms of the magnitude of their economic impact goes back to Kuznets (1929). He formulated an innovation law that can be condensed as follows: the introduction of a major technological innovation in a given sector leads to a phase of *rapid* sectoral growth and gradually generates a set of forces leading to a *deceleration* in the rate of growth of the sector in question.[6]

As Pavitt (1984) has shown, sectors *differ* in important innovation aspects. His classificatory scheme emphasized innovation linkages between sectors and that technological change occurs differently across industries. One way of dealing with innovation linkages consists of separating 'enabling sectors' and 'recipient sectors.' An economic sector is said to be *enabling* if the innovations originated in that sector are efficiency-enhancing in the same sector or in other sectors. The sectors receiving the beneficial innovation flows are called *recipient* sectors. We have introduced these concepts elsewhere to design an innovation-based typology of economic sectors. Pol et al. (2002). As will become apparent in a moment, the notions of enabling and recipient sectors are also useful to relax assumptions (1) and (2).

A glance at Fig.1 shows that the formulation of the innovation process implied by the IPF is extremely condensed, not including many important aspects such as possible distinctions between 'big' ideas and 'small' ideas, sectoral patterns of innovation, etc. The relaxation of the assumptions of equipollent innovation and confined innovation requires that we enter the black box of the IPF and design a stylized scheme of innovation production to capture the following three facts: (a) innovations differ in terms of their economic impact; (b) innovation occurs differently across sectors; and (c) there are enabling and recipient sectors.

Consider two ideas-producing sectors, Sector 1 (*enabling* sector) and Sector 2 (*recipient* sector). At any time t the state of technology A(t) is decomposed into ideas generated in the enabling sector A_1 plus ideas originated in the recipient sector A_2

$$A(t) = A_1(t) + A_2(t) \quad (2)$$

Assuming that new ideas emerging from the enabling sector have a multiplier effect in the recipient sector, but the new ideas created in the recipient sector do not have a perceptible influence on the generation of new ideas in Sector 1, the ideas production functions for Sectors 1 and 2 can be written, respectively, as

$$\dot{A}_1(t) = F_1[L_1(t), A_1(t)] \quad (3)$$

$$\dot{A}_2(t) = F_2[L_2(t), A_1(t), A_2(t)], \quad (4)$$

believe that there is nothing wrong in assuming the existence of an IPF, provided that the limitations of using such a concept are realized.

[6] Some 40 years after the formulation of the law of retardation of sectoral growth, Kuznets wrote an illuminating paper on the impact of major innovations (Kuznets, 1972). For a detailed analysis of the Kuznets law on innovation, see (Pol and Carroll, 2004).

where $L_1(t)$ and $L_2(t)$ denote the amount of labour allocated to producing ideas in Sectors 1 and 2, respectively. For lack of a better expression we call the system of differential equations (3)-(4) together with the identity (2) the *innovation regime*.

The preceding formalization of the innovation regime has the advantage of mathematical simplicity.[7] However, the interaction between enabling and recipient sectors may be more complicated than the foregoing analytical representation. For example, recipient sectors may feedback into the enabling sector and shape future innovation in the latter. As will become apparent, the appreciative model developed in the following sections does not depend on this restrictive formalization.

3. MEGA-INVENTIONS AND INNOVATORY DISCONTINUITIES

Mega-inventions are those inventions that constitute a platform for future inventions and imply major technological shocks for the entire economy or that significantly contribute to changes in its performance. Mega-inventions always induce *mini-inventions*, that is, subsequent individually small inventions that help to make the mega-inventions operational or small inventions that are conducive to gradual improvements in the technology already in use. For example, we can say that the mega-invention of the xerography occurred in 1938, but required lots of subsequent improvements (mini-inventions) before the era of photocopying began in 1959.

> The term 'mega-invention' is related but not identical with the concept of 'macroinvention' introduced by Joel Mokyr in *The Level of Riches*:
>
> (…) I define *microinventions* as the small, incremental steps that improve, adapt, and streamline existing techniques already in use, reducing costs, improving form and function, increasing durability, and reducing energy and raw material requirements. *Macroinventions*, on the other hand, are those inventions in which a radical new idea, without clear precedent, emerges more or less ab nihilo. In terms of sheer numbers, microinventions are far more frequent and account for most gains in productivity. Macroinventions, however, are equally crucial in technological history. Mokyr (1990, p.13) [Italics in original]

The occurrence of a macroinvention does not necessarily have a noticeable effect on the economy. For example, ballooning is considered as one of the greatest macroinventions of all times but it is not a mega-invention because its economic impact was negligible. In Mokyr's own words: "Ballooning must be regarded as one of the most radical new ideas of all times, yet its direct impact on economic welfare was small." Mokyr (1990, p. 294)

From the viewpoint of economic evolution, what matters is the concept of mega-invention: a big invention is not 'big' merely by virtue of its intellectual novelty. It has to have significant economic impact. Typically, mega-inventions are technologies

[7] Specifically, it is possible to solve the system in two steps. First, we solve equation (3) for $A_1(t)$, and then, we obtain $A_2(t)$ from equation (4). The addition of these two functions provides an explicit specification of the state of technology A(t). It can be easily shown that with this choice for A(t) all the results in the Romer model remain intact.

that could *not* have evolved through incremental improvements in existing technologies that they challenged in regard to some particular use. For example, electricity could *not* have evolved out of steam. Less frequently, mega-inventions are radical new insights emerging more or less without a clear precedent as in the cases of X-rays, penicillin and radio astronomy.[8]

The emphasis on 'innovatory discontinuities' harks back to Schumpeter himself. He was quite explicit about the discontinuous nature of mega-inventions, although he did not use the term mega-invention in his writings. Schumpeter articulated the view that long cycles are caused by innovation.[9] His analysis in *Business Cycles* was intended to apply only to innovations of a kind that implied a significant shift of the state of technology. In Schumpeter's own words,

> (…) We shall impose a restriction on our concept of innovation and henceforth understand by an innovation *a change in some production function which is of the first and not of the second or a still higher order of magnitude*. A number of the propositions which will be read in this book are true only of innovation in this restricted sense.Schumpeter (1939, p. 94) [*Italics in original*]

One of the distinguishing features of an innovation is that it can always be understood *ex post*, but it can never be fully understood *ex ante* applying the ordinary rules of inference to the existing facts. Innovation is by definition an uncertain phenomenon. However, for analytical purposes the difference between a mega-invention and a mini-invention is that mega-inventions are shrouded in *Knightian* uncertainty (*sensu stricto* uncertainty) while mini-inventions are susceptible of calculable uncertainty (*risk* in Knight's sense). This approximation is in line with the history of technological innovation. Mokyr (1990, esp. p. 295).

In the Schumpeterian growth models, the state of technology A(t) presupposes that all mega-inventions have *already* occurred and that technological change consists of a continuous sequence of minor innovations, including mini-inventions. By definition, a mega-invention (e.g. the invention of the electricity) substantially alters the prevailing state of technology, and thereby provokes a *change* in the current innovation regime.

After a mega-invention has occurred the *new* innovation regime can be mathematically described as follows

$$\dot{B}_1(t) = G_1[L_1(t), B_1(t)] \tag{5}$$

$$\dot{B}_2(t) = G_2[L_2(t), B_1(t), B_2(t)], \tag{6}$$

---

[8] The concept of 'mega-invention' is also similar to the notion of *general-purpose technologies*. For a detailed explanation of the concept of 'general purpose technology', see (Lipsey et al., 1998, pp. 14-54). This paper (implicitly) explains the difference between a macroinvention and a general purpose technology.

[9] Kondratiev's ideas about the existence of long cycles or long waves of economic growth were brought to the attention of the English-speaking economists through Schumpeter's treatise *Business Cycles*.

where the state of technology is now

$$B(t) = B_1(t) + B_2(t) \quad (7)$$

In brief, when a mega-invention occurs the state of technology changes from A(t) to B(t).

Mega-inventions can be thought of as random innovation shocks affecting the whole creative economy. An innovation shock entails a *discontinuity* in the following sense: the state of technology changes from B(t) to A(t). Specifically, an *innovatory discontinuity* is said to occur when a mega-invention provokes a selective replacement of the state of technology. An innovatory discontinuity is not necessarily a 'jump' discontinuity but rather, and perhaps more typically, a gradual change from one state of technology to another.

The empirical intuition behind the notion of innovatory discontinuity can be illustrated by using the examples of the electricity and IT eras. Electrification arrived in the 1890s (the start-up of the electricity era is often taken as the construction of the first hydro-electric facility at Niagara Falls in 1894) and from the viewpoint of technology adoption attained a plateau in 1929. The IT era started in 1971 when Intel's invention of the key component of the personal computer occurred (namely, the "4004 computer chip") and still underway.

4. NEOCLASSICAL VERSUS EVOLUTIONARY THEORIZING

Few economists would deny that the very notion of 'evolution' is sometimes vague and at other times imprecise. For example, sometimes the term is associated with the Darwinian theory of natural selection and at other times the word is used in opposition to 'revolution.' As emphasized by Hodgson (1993, p. 38): "Nothing is more guaranteed to generate confusion and stultify intellectual progress than to raise such a muddled term [evolution] to the centrepiece of economic research, while simultaneously suggesting that a clear and well-defined approach to scientific enquiry is implied. The term can be used to describe a varied group of approaches in economics, perhaps in contrast to the exclusive focus on equilibrium in neoclassical theory, but it does not indicate a well-defined type of analysis. (…)"

Notwithstanding, there are notorious exceptions to the alluded lack of terminological discipline. Schumpeter, for example, gave a clear definition of the term 'evolution'. For Schumpeter (1954, p. 435) *evolution* means a process characterized by incessant and irreversible change. Furthermore, the defining characteristic of evolutionary *analysis* in any field consists of making evolution "the pivot of one's thought and the guiding principle of one's method." Schumpeter (1954, p. 436). The striking implication of this definition is that the new generation of formal models of a creative economy (including the Romer model) falls into the category of evolutionary analysis.

What is distinctive about the so-called evolutionary theorizing is the following two postulates: (a) a creative economy involves disequilibrium in a fundamental way; and (b) both the occurrence and development of mega-inventions are inherently uncertain. Specific interests and approaches shared by evolutionary economists include sympathy with the inductive method; emphasis that history matters, and the role of government. This broad characterization of evolutionary theorizing can consistently accommodate the wave of evolutionary models that started in the 1980s with the work of Nelson and Winter (1982).

According to evolutionary scholars, the new generation of formal growth models represents a desirable convergence of formal theory with appreciative theory. They combine important aspects of reality (such as innovation, imperfect competition, proprietary aspects of technology, and increasing returns to scale) within a general equilibrium framework. Nelson (1994, p. 309). However, evolutionary theorists believe that the neoclassical formulation emerging from the Romer model is inconsistent with the Schumpeterian argument that a creative economy had to be understood as a process inextricably linked to *disequilibrium*. Specifically, the evolutionary approach entails the throwing away of both the equilibrium and optimizing notions that constitute the unifying threads of the new neoclassical growth models. More specifically, this approach emphasizes uncertainty in the Knightian sense and focuses on the nature of *routines* that guide the behaviour of firms and how better routines get created and spread. Nelson and Winter (2002, esp. pp. 39-40).

If technological change is path dependent (somewhat roughly, an evolutionary process taking place under uncertainty in the strict sense) one implication is that it is virtually impossible to predict technological developments. In particular, the production of new ideas seems to depend on the random history of the creative economy. There can be no well-defined ideas production function.

Although the central focus of both neoclassical and evolutionary theorizing is economic evolution, these approaches concentrate on two different meanings of the word 'evolution.' Indeed, while the Schumpeterian growth models indicate that economic growth and technological change are predictable and continuous, evolutionary theorizing stresses the unpredictability of economic evolution due to trial and error, learning by doing, nature of the process. Or, to put it differently, neoclassical and evolutionary theorizing constitute antagonistic approaches. It should be emphasized, however, that both approaches are mute regarding innovatory discontinuities.

5. APPRECIATIVE MODEL

Schumpeter's conceptual grasp yielded the central concepts for the analysis of economic evolution: innovation, entrepreneurship and creative destruction. Both approaches (evolutionary and neoclassical) are *extensions* of Schumpeter's insights. Neither of them can capture his scientific desire of constructing a theoretical system involving both equilibrium and innovatory discontinuities.

The extended analytical framework developed in Section 3 and 4 can be used to build an appreciative model of the Schumpeterian vision of economic evolution. If we assume that the creative economy is operating with the state of technology represented by the function $A(t)$ and that a mega-invention occurs at a particular point in time t^*, then how does the creative economy move from one state of technology to another? There is no obvious answer. The propagation mechanisms are difficult, if not impossible to decipher *ex ante* because technologies never move in a predictable fashion. For example, formerly unconnected technologies (such as lasers and fibre optics) may turn out to be complementary.

After the occurrence of a mega-invention there is a *transitional dynamics* converging to the new state of technology B(t). There exists an interval (not just a point) of discontinuity t** - t* where the transition from the old to the new state of technology takes place. What is involved in this transitional dynamics is an extensive process of technological cross-pollination, redesign, modification, and innumerable small improvements occurring after the introduction of a mega-invention. This means that the convergence to the new state of technology B(t) will take a lengthy period of time (technologies move slowly from the first mega-invention) and the transitional dynamics is, at least in part, intrinsically intractable.

Figure 2 is an appreciative model of economic evolution as envisaged by Schumpeter: the creative economy evolves gradually for long periods of time until one or more mega-inventions provoke an innovatory discontinuity.

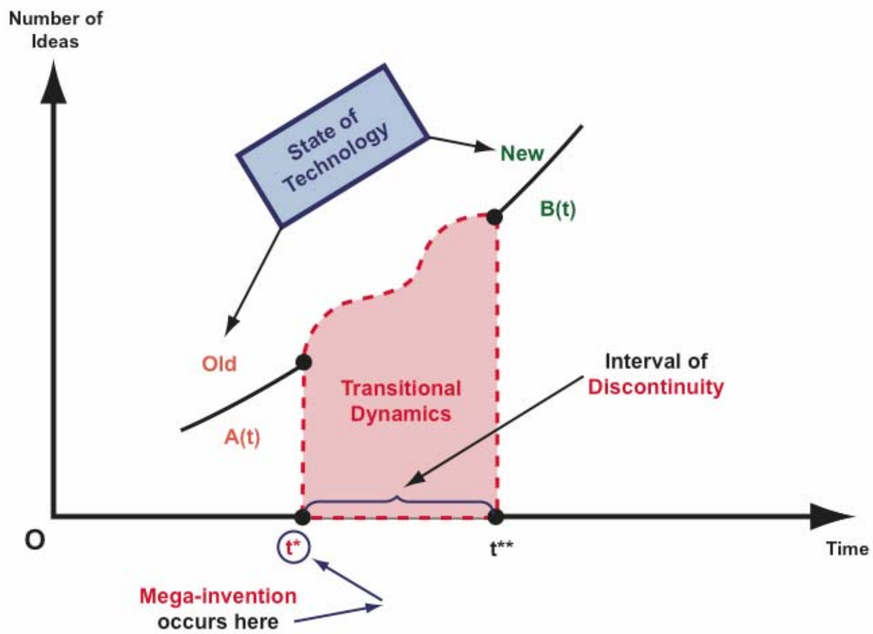

Figure 2

This figure also highlights the intuition behind the antagonistic approaches. The neoclassical approach assumes gradual predictable evolution as represented by the states of technology A(t) or B(t). The Schumpeterian growth models concentrate on evolution in the first sense and ignore the transitional dynamics. Evolutionary theorists tend to focus on stochastic evolution characterized by Knightian uncertainty and disequilibrium conditions. For them the transitional dynamics is essential.

6. SUMMARY AND CONCLUDING COMMENTS

In economics, we are prone to having superstar-figures. In the analysis of economic evolution, Schumpeter continues to reign as the undisputed superstar. Like other (non-mathematical) pioneers, Schumpeter did not write with the utmost precision.

The lack of clarity in Schumpeter's writings is most conspicuous in the field of economic evolution associated with innovatory discontinuities.

The past twenty five years have been marked by a number of important developments in the analysis of a creative economy. Schumpeterian growth models have articulated five insights in a general equilibrium context emerging from optimizing behaviour, namely: that innovation has a recombinant nature, that innovation is pursued for gain, that new ideas are at least partially excludable, that innovation generates increasing returns to scale, and that ideas and human capital are products with different economic attributes.

In the simplified world of the Schumpeterian growth models technological innovations come from an *ideas-producing sector* which operates according to the ideas production function. Furthermore, technological change is viewed as a cumulation of small, individually minor innovations. The assumption that there exists an ideas production function is the *sine qua non* of the Schumpeterian growth models. Although the analytical meaning of such a production function is simple and clear, troublesome questions arise when one wants to introduce the notion of innovation heterogeneity into these formal models.

In their evolutionary alternative to the neoclassical approach Nelson and Winter (1982) represent technology as routines followed within firms. Most (if not all) evolutionary economists object the existence of an ideas production function on the basis that it is simplistic and the real world is much more complicated. Surely, the rate of new ideas creation depends on factors such as culture, social capital and the nature of the innovation environment.

It is generally recognized that the neoclassical and the evolutionary approaches to the study of economic evolution are irreconcilable. In the context of the Schumpeterian growth models evolution means gradual predictable change devoid of discontinuities. For the evolutionary theorists, the word evolution refers to the unfolding of a fundamentally unknown future where there is change based on mutation and selection.

Evolutionary scholars believe that the economics profession will ultimately be driven to adopt their non-equilibrium approach, if economists attach high priority to characterizing and modelling unforeseen economic change induced by technological shocks. Mainstream economists seem to believe that the style of modelling used by the neoclassical economists is appropriate because the equilibrium concept is flexible enough to encompass a time path along which the salient variables change in a predictable manner (moving equilibrium). Recent generations of neoclassical growth theorists reject the representation of technology as routines.

The Schumpeterian view has significant influence on contemporary thinking. The antagonistic approaches tend to represent what economists *thought* Schumpeter meant. Faced with the choice between neoclassical and evolutionary theory, what should we do? There is no generally accepted answer to this question. The appreciative model of Schumpeterian evolution suggests that to capture the Schumpeterian view one has to use the 'parallelogram law' (see Fig.3). The antagonist approaches can be thought of as the sides of a parallelogram and the Schumpeterian view is the diagonal of the parallelogram (or ‘sum’ of the parallelogram sides). Fig.3 also suggests that one need not choose one extreme or the other.

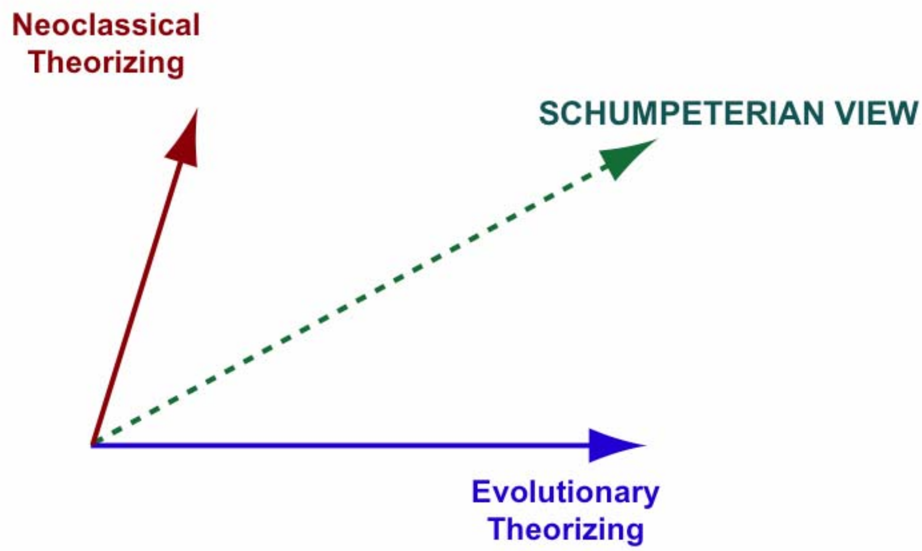

Figure 3

A large proportion of the total growth in productivity takes the form of minor innovations, including mini-inventions. However, there have been large and spectacular changes in technology leading to economically significant changes as illustrated by the electricity and IT eras. Thus, the empirical evidence appears to support the view that there can be non-incremental technological changes and technological shocks to the economy. The concept of innovatory discontinuity it is intended to these events.

Scientists have debating for a long time whether the past demonstrates that change is gradual or not. In economics, this debate was originated by two great thinkers, Marshall and Schumpeter. Alfred Marshall and Joseph Alois Schumpeter were (and still are) extremely influential economists. Both of them were quite explicit in the answers they gave. Marshall argued that economic evolution does *not* make leaps. Schumpeter argued that, at least from time to time, economic evolution *does* make leaps. The appreciative model is biased toward Schumpeter.

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