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ARTICLE

Schumpeter's business cycle theory and the diversification argument

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Abstract
Schumpeter's business cycle theory can be divided into three component parts: entrepreneurs produce innovations, innovations generate local plan failures, and local plan failures at times grow sufficiently large to generate global recessions. The third component of Schumpeter's theory is susceptible to the diversification argument, i.e. small micro-changes tend to average out in a large economy thereby generating little macro-fluctuation. While Schumpeter was cognizant of this problem, he did not develop an explicit mechanism to nullify the averaging out of micro-changes. We argue that the network dynamics generated by Schumpeterian innovations is the missing link in his theory. More specifically, innovations change the production network by prodding firms to seek new suppliers of inputs and new buyers of output. These production network dynamics ensure that micro-changes are not independent of each other, rather micro-changes occur in response to each other, thereby nullifying the diversification argument. Production network dynamics are capable of transforming micro-flux into macro-turbulence.

Keywords Schumpeter · Business cycles · Production network

JEL Classification E10 · E30 · B30

1 Introduction

One of the long-standing problems of economic theory is explaining the temporal fluctuations in aggregate variables. Over the years, a wide variety of theories have been proposed to resolve the problem. These theories differ in the sources of their impulse and the mechanisms by which the impulses change economic variables. Despite their differences, most theories concur in viewing the fluctuations in

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aggregate variables as emanating from forces outside the ordinary workings of the market economy. In 1939, Schumpeter proposed a somewhat different solution to the problem of macroeconomic fluctuations. He argued that fluctuations in aggregate variables emerge from micro-innovations, which themselves reflect rivalrous competition between firms. Schumpeter's theory did not depend on exogenous fiscal-monetary shocks, unexpected changes in aggregate productivity, or unforeseeable changes in investor sentiments. In other words, Schumpeter thought macro-variables moved not because of collective forces that act upon all agents in the economy but because of micro-forces through which firms act upon each other.

Schumpeter's theory of macroeconomic turbulence has three components: entrepreneurs produce innovations, innovations create local plan failures, and local plan failures occasionally generate recessions. Schumpeter wrote flamboyantly on the first component explaining the motivations of entrepreneurs and the battles these peculiar species of men fight to produce innovations. He was, however, somewhat less explicit when it came to the second component and largely silent on the third. Schumpeter (1939, p. 87) observed that capitalism can be extremely sensitive to small micro-changes but did not develop a process that generates this sensitivity. Schumpeter's theory, therefore, remains without an explicit mechanism to nullify the diversification argument. Where by the 'diversification argument', we mean the proposition that idiosyncratic micro-changes average out in a large economy thereby generating little aggregate volatility. The third and the most 'macro' component of Schumpeter's business cycle theory, therefore, remains its weakest.

Schumpeter was cognisant of this weakness of his theory. For instance, Schumpeter (1935, p. 10) says "...the phenomenon of the cycle cannot be defined and understood as a sort of average between independent changes in individual industries". This is a significant assertion for it is precisely the independence of micro-changes that allows the Central Limit Theorem to guarantee the averaging out of small micro-changes. Schumpeter's writings on why micro-changes are not independent is however scant and dispersed. So much so that later day economists came to see this weakness of the third component as a fatal flaw in Schumpeter's business cycle theory. As Goodwin (1991, p. 91) put it, the macro-fluctuations that emerge from Schumpeterian micro-innovations would be "nearly invisible" in a large economy. Under the sway of the diversification argument, economists by and large abandoned attempts to develop a Schumpeterian macroeconomics. Those with an interest in Schumpeterian micro-processes appended these with Keynesian features like aggregate demand shocks to generate macroeconomic volatility Dosi et al. (2010). The Schumpeterian idea that the ordinary workings of the market economy is capable of generating sizeable macro-turbulence was lost.

In this essay, we begin from an old fork in the development of Schumpeter's business cycle theory, i.e. from the 1939 book on Business Cycles. We believe there is little reason to forgo Schumpeter's idea of developing a business cycle theory founded on perennial micro-flux. Schumpeterian micro-innovation when placed within a network setting is capable of generating sizeable macro-dynamics. Micro-changes do not 'average out' because one firm's action affects the plans of it output buyers, input sellers, and competitors. Firms may change the proportions in which they combine inputs and the prices they charge for output. These changes in microeconomic demands and supplies may prod some firms to seek alternate providers of inputs or buyers of output. In other words, microeconomic innovations are capable of generating changes in the topology of the production network itself. Where by a ‘production network’, we mean the buyer–seller relations between firms in an economy. We argue that the missing element of Schumpeter’s business cycle theory is production network dynamics. It is network dynamics which transforms perennial micro-flux into occasional recessions in market economies. We, therefore, present a motivation for pursuing Schumpeterian macroeconomics as a means to go from micro to macro via dynamic production networks. Our development of Schumpeter’s ideas on business cycle points to a path very different from that sketched by Minsky (1986), who thought Schumpeterian innovations are sterile by themselves and have macro consequences only within a Keynesian world.

The paper is organized as follows. Section 2 develops the first and the second component of Schumpeter’s business cycle theory. We use a network setting to explain the local miscoordination that emerges from innovation and the process of adaptation to innovation. Section 3 presents the problems associated with the third component of Schumpeter’s business cycle theory, i.e. the step from local miscoordination to global miscoordination. We note Schumpeter’s recognition of the problem and his proposed solutions. Section 4 places Schumpeterian innovations within a dynamic production network. It develops the mechanisms through which innovations generate changes in the network of relations between firms. We argue that these changes break the basic assumptions necessary for small micro-changes to average out in a large economy. Section 5 presents concluding thoughts.

2 Entrepreneurial innovation and local miscoordination

Schumpeter begins Business Cycles with a description of the circular flow. Imagine an economic system as a production network, with firms as nodes and the linkages between firms indicating their buyer–seller relations. Some firms produce goods used as intermediate inputs by other firms, some firms produce for final consumers, yet other firms produce goods used both for consumption and as intermediate inputs. The preferences of consumers, technological possibilities of firms, and the network of buyer–seller relations between economic agents define the general equilibrium of such an economy. Note that such a general equilibrium is characterized not only by a set of prices and quantities but also a flow of intermediate inputs between firms consistent with the economy’s primitives. Schumpeter calls such a ‘flow general equilibrium’ as ‘the circular flow economy’. Within the circular flow, the same goods are produced day after day, in the same ways, and at the same costs. It is within this serene picture that Schumpeter introduces entrepreneurial innovation.

Entrepreneurs have little respect for tradition within the economic sphere of life. The entrepreneur is a leader willing to command others beyond the rigmarole of routine. Entrepreneurs create new products, discover new ways of doing things, and find new markets. Schumpeter (1939, p. 85) calls these activities “innovations” and distinguishes them from novel scientific discoveries. Most societies have an abundance of scientific discoveries sitting on the shelf waiting to be put into economic use. Water mills, for example, were common in eleventh century France, however it was only centuries latter that they were put to wide industrial use Baumol (1996). Note also that an innovation is not merely a change in the technique of production of the kind that occurs when firms move along their production possibility planes in response to changes in the relative price of inputs. An innovation involves the creation of new production possibility sets and new cost curves.

The dynamics set about by an innovation begins with the effect of the innovation on competitors. The innovating entrepreneur operates on a new lower cost curve or produces altogether new products, and thereby upsets the economic plans of his competitors. Those hurt by an innovation may be competitors not only in the product market but also in the input market. An innovating firm by operating on a lower cost curve may draw more resources by outbidding existing users of those inputs. The innovating entrepreneur therefore hurts the economic interests of existing players in the market. Note that these players may be willing and able to fight the entrepreneur through economic and political means. This is what Schumpeter calls "positive resistance" to innovation. Such positive resistance is matched by a equally problematic "passive resistance". Often enough the raw material for new goods and production processes must be created from scratch, whereas materials for the old ways of doing things are available with great ease. The passive resistance to innovation on the supply side has its counterpart on the demand side. Consumers are held by an inertia of sorts within their old patterns of purchase. They may be reluctant to try new goods. Consumers must, therefore, be trained to leave the old and embrace the new (Schumpeter 1939, p. 73).

An entrepreneur must fight many battles to make an innovation work. Entrepreneurship therefore "is a feat not of intellect, but of will" (Schumpeter 1928, p. 379). Entrepreneurs are willing to fight battles others cannot imagine, let alone fight. For Schumpeter, it is precisely such unique personal qualities that make an entrepreneur who he is, i.e. place him in a rivalrous position vis-a-vis old ways of doing things. And the uniqueness of the personality of entrepreneurs has economic consequences. Not the least of which is the fact that ordinary competitors cannot instantaneously replicate the actions of the innovating firm. The innovating firm, therefore, operates on a new cost curve or produces altogether new products, while competitors continue to operate on old cost curves or produce old products. And this difference generates entrepreneurial profits.

In the circular flow, firms do not make economic profits. But once innovation succeeds, the innovating firm makes profits while competitors make economic losses. Some competitors die or exit the market because losses become unsustainable. Others are forced to find new ways of doing things. Competitors cannot continue with routine behavior, because it becomes difficult to sell the same old product in the same old way. Firms affected by the innovation have little choice but to adapt to the new economic environment. The adaption involves numerous changes in the production network of the economy. Some firms will be forced to find new buyers of their products. Others will have to find new suppliers of inputs, particularly as they attempt to replicate the innovating firm. The production network, therefore, rewires amidst the process of adaption to innovation.

The rewiring occurs not only because firms are forced to seek new buyers and sellers, but also because some firms exit the production network. Some competitors of the innovating firm may simply close business. The suppliers of these competitors lose buyers. Firms that have only a handful of buyers will be adversely affected by such a shock. In the limit, if a firm loses its only buyer, the firm must halt production until it finds another buyer. The ease of finding another buyer will depend on a variety of factors including the specificity of product and market conditions. Some industrial products are specific and have few buyers. Consider for instance the production network of publicly traded firms in the United States Atalay et al. (2011). While firms like General Motors have more than 40 major suppliers, the average firm has one or two major suppliers. In such a setting, if a firm loses one of its buyers, the decline in demand may sufficiently raise the cost of production to adversely affect its other buyers. The upstream impact of the process of adaptation to innovation can be sizeable.

In a system without innovation, i.e. within the circular flow, firms do not ponder over the question of 'what to produce', 'for whom to produce', and 'from whom to purchase inputs'. These questions were settled yesterday. Firms know whom to buy inputs from, what to produce, and whom to sell from knowledge of what has worked in the past. This means that within the circular flow, mutual adjustments to exogenous shocks happen in a foreseeable manner as firms are aware of the reaction functions of their buyers and sellers. Firms coordinate with each other by making adjustments within the price–quantity dimension. Innovation however widens the horizon of decision-making beyond the price–quantity dimension. The product becomes an economic variable, so does the structure of relations between firms. Firms do not respond to innovation simply by changing prices or quantities of their products, but tend to change the way they do things. It is difficult to predict the response of a firm that has gone into making losses due to the innovation of another firm. The firm hurt by innovation may go out of business or respond creatively by making new products, and finding new buyers of its output and new sellers of inputs.

The widening of the horizon of decision-making produced by innovation, i.e. the new behaviors that emerge in response to the new environment, make it difficult for one firm to forecast the behavior of others on whom its own plans depend. In the circular flow, firms face the problem of determining what to do given their own reaction functions and what they know of the reaction function of others from long experience. Once the process of adaptation to innovation begins, firms face the problem of creating their reaction functions, knowing well that others are doing the same. In the midst of adaptation to innovation, firms do not face the problem computing solutions to well defined problem but of imagining the future Shackle (1972). The very nature of economic relations between firms and production processes within firms remain to be imagined, created, and adapted to each other. All this means that the risk of failure of new plans is greatly increased. After all the success of a plan depends on one's ability to forecast the actions of those making competitive and complementary plans (Schumpeter 1939, p. 135). Innovation, therefore, creates an environment in which a great number of plans fail.

3 Global miscoordination and the diversification problem

We have so far discussed the micro- and meso-dynamics that emerge from entrepreneurial innovations, i.e. changes in industries, sectors, and firms related to the innovating firm. What makes Schumpeter's theory truly 'macro' is the claim that the afore discussed micro-processes of innovation and adaptation to innovation are capable of generating sizeable fluctuations in aggregate variables. And it is here that the theory encounters the diversification argument. But before we get to the diversification argument, it is important to note that Schumpeter was not building a theory that depended on a few exceptional cases of large innovations. The foundation of his macroeconomics was perennial microeconomic innovations none large relative to the size of the economy. In Schumpeter's (1939, p. 99) words:

> The ability to decide in favor of untried possibilities or to choose not only between tried but also between tried and untried ones, may, however, be distributed in the population according to the Guassian—though more plausibly a skew—law, and should not be thought of as confined to a few exceptional cases.

Schumpeter was ambitious for no one before him had travelled from micro to macro. But this ambition made his theory vulnerable to the diversification argument. The diversification argument says sizeable macroeconomic volatility cannot emerge from microeconomic innovations, because micro-changes average out in a large economy. More specifically, according to the Central Limit Theorem in an economy with n firms, each of which produces independent innovations, aggregate volatility is proportional to $n^{\frac{1}{2}}$. In the United States, there are more than six millions firms with employees Axtell (2001). Firm volatility is on the order of 10%. The Central Limit Theorem, therefore, implies aggregate volatility will be on the order of 0.001% Gabaix (2011). In reality, aggregate volatility is on the order of 1%. Therefore, according to the diversification argument, micro-innovations explain an insignificant portion of macroeconomic volatility. In Lucas's (1977, p. 20) words, the cancelling of small changes in a large system is "the most important reason why one cannot seek an explanation of the general movements we call business cycle in the mere presence, per se, of unpredictability of conditions in individual markets". The diversification argument presents a serious challenge to Schumpeter's theory. If firm innovations average out in a large economy, then micro-flux cannot generate much macro-movement. As Goodwin (1991, p. 30) put it:

> Innovations are many and different as to timing and duration of integration into the economy. Consequently, for Schumpeter's theory, the innovative 'swarms' would be so many, so disparate in timing, amplitude and duration, that his cycle would tend to be nearly invisible.

Interestingly enough, Schumpeter was cognizant of this problem with his business cycle theory as the following passages illustrate:

> ... it cannot be said that whilst all this applies to individual firms, the development of whole industries might still be looked at as a *continuous process*,

> a comprehensive view *'ironing out'* the discontinuities which occur in every single case (Schumpeter 1928, p. 382, emphasis ours)

> If, in a given, year, one industry makes 100 millions and another loses 100 million, these two figures do not add up to zero or, to put it less paradoxically, the course of subsequent events generated by this situation is not the same as that which would follow if both had made zero profits (1946, p. 5)

One can find two tentative solutions to the diversification problem within Schumpeter's own writing, with the second solution being proposed nearly 2 decades after the first. The first of these solutions may be called the 'entrepreneur-leader and herd-followers' dynamics. In the early years, Schumpeter (1934) argued that a step in a new direction is difficult, however, once the step is taken it becomes easy to follow. As Schumpeter (1927, p. 298) puts it, "the first success draws other people in its wake and finally crowds of them". It is worth noting that the crowds of people who follow the entrepreneur need not be from the same industry. Schumpeter (1927, p. 298) believed entrepreneurial action has a 'public good' quality, which is revealed to all upon its successful completion.

> ... [once] new things have been successfully done by some, others can, on one hand, copy their behaviour in the same line—whence prominence of one industry at the time—and on the other hand, get the courage to do similar things in other lines, the spell being broken and many details of the behaviour of the first leaders being applicable outside their own field of action.

In the latter years, Schumpeter developed a wholly different argument as to why micro-innovations do not average out. He appears to have moved from emphasizing the 'personality' of the entrepreneur to more causal-mechanistic lines of reasoning Hagemann (2003). Schumpeter (1946, p. 5) says that profits and loses of different firms does not simply cancel out because they impinge "upon different sectors of the economy in entirely different ways". Here, he appears to hint at the interactions between firms and sectors as the force that magnifies micro-flux. Yet he says little more in the paper. In the next section, we develop this line of reasoning, i.e. the role of sectoral interlinkages or more generally the production network in nullifying the diversification argument.

4 From local to global miscoordination via dynamic critical networks

Dynamic production networks—particularly those that tend towards criticality—is one way to solve the diversification problem within the context for Schumpeter's business cycle theory. More specifically, systems—physical, biological, or economic—can be in one of three states: sub-critical, critical, or super-critical. A system is said to be in a sub-critical state when small changes in parts produce small changes in the properties of the system. In a sub-critical state, large micro-changes are necessary to produce large macro-changes. A system is in a super-critical state when small changes in parts produce large changes in the properties of the system.

A system is in a critical state when small changes in parts produce changes of all scales at the system level, i.e. most micro-changes produce small macro-changes but some produce large macro-changes. Often external tuning of parameters is necessary to hold a system in a critical state. However, for some systems, the critical state is an attractor, i.e. they self-organize into a state of criticality without external tuning of parameters. A prototypical example of a critical system is a sand pile, as the following passage explains:

> When the slope of the pile is nowhere too steep, dropping on additional grains of sand at randomly chosen sites has no macroscopic effects, as at most small numbers of grains will shift position in each case. However, randomly dropping on additional sand will eventually result in the slope of the pile increasing to a critical slope, at which point large avalanches can occur in response to the dropping of a single additional grain of sand. A sand pile with a slope that is initially greater than the critical slope also evolves toward it. In this case through an immediate large avalanche that collapses the pile. Thus while the existence of macroscopic instability without large external shocks depend upon a particular critical slope, the system endogenously evolves toward exactly that state (Scheinkman and Woodford 1994, pp. 417–418).

But does an economic system, like a sand pile, exhibit macro-movements of all scales in response to small micro-changes? Mandelbrot (1997) finds many economic time series have fractal-like qualities. Macroeconomic times series like stock indices are more like a coastline than a razor blade. A microscopic view of a razor blade shows many irregularities and much roughness. However, as we zoom up, the irregularities begin to even-out and disappear, till finally one sees a straight sharp edge. A coastline is a very different object. A view of a coastline from a cliff shows an irregular boundary with many curves, these irregularities however do not disappear as we view the coastline from higher and higher altitudes. Rather, at higher altitudes, new irregularities are injected, smoothness is never found. Some macroeconomic time series, like output and employment, are not measured at frequent enough intervals to subject them to fractal analysis. However, many series that are measured with high frequency show fractal-like properties. For instance, the S&P 500 Index at scales of an hour, day, year and decade looks very similar to the naked eye. The irregularities and roughness in economic time series do not disappear with an increase in the time scale; rather new irregularities are injected at every time scale. There are recessions of all scales: hourly, daily, weekly, yearly, and over a century.

The existence of perpetual micro-economic flux as indicated by labor dynamics and firm dynamics on the one hand (Axtell et al. 2019), and the fractal-like nature of economic time series on the other hand, suggest economic systems may be in a critical state. In a critical state, small micro-changes like the discovery of new products, new markets, new ways of doing things, are capable of producing recessions and depressions. Though most entrepreneurial actions will register little change in macroeconomic variables, some actions will produce cascades that grow into recessions. As to which entrepreneurial actions generate recessions is difficult to predict, because the attributes of the actions themselves are not sufficient to answer the question. Whether an action generates a large cascade depends on the state of different parts of the system, their inter-relations, and where the entrepreneurial action originates. The macro-consequences of a micro change depends not only on the magnitude of the micro-change itself but the state of the system and interconnection between parts of the system when the micro-change occurs.

4.1 The NKC model as a way to understand Schumpeterian dynamics

Little is known about why an economy may self-organize into a state of criticality. There are no economic models linking up entrepreneurial actions with the criticality of an economic system. There is, however, a model of biological evolution which comes precariously close to developing a relation between innovation and macro-turbulence. Kauffman and Johnsen (1991) present the NKC model of biological evolution. The NKC model is an extension of Kauffman's NK model. In the NK model, each organism is characterized by *N* attributes. Organisms evolve by searching for better traits along *N* dimensions. However, the attributes are not independent of each other, the influence of an attribute on overall fitness depends on the presence or absence of complementary attributes. Needless to say, the nature and degree of complementarities can be quite intricate. Kauffman cuts the Gordian knot by assuming that the influence of each of the *N* traits on overall fitness depends on *K* other traits. The greater the *K* relative to *N*, the more rugged the fitness landscape of the organism, with many local maxima. The NKC model extends the NK model by allowing the fitness landscapes of different organisms to be related to each other. The contribution of an attribute of an organism to its fitness depends on *C* attributes of related organisms. When a butterfly develops slippery feet, it becomes profitable for the frog to develop sticky tongue. The NKC model of biological evolution self-organizes into a critical state under certain parametric conditions.

As the reader may have observed, the NKC model can be readily adapted to study Schumpeterian dynamics. The fitness landscapes of firms in an economic system depend on the attributes of related firms. More specifically, the profitability of the product developed by one firm depends on products that are sold by other firms. These 'other' firms include competitors, suppliers of complementary products, and suppliers of inputs. Each firm encounters rivalrous relations with its competitors, while sharing symbiotic relations with the suppliers of complementary products and suppliers of inputs. Naturally then, each firm's opportunity landscape (profit landscape) is influenced by the products generated by other firms with whom it shares symbiotic and rivalrous relations. The profitability—or even the very ability—of making a product depends on the availability and the cost of inputs. Similarly, the profitability of making a product depends on the closeness of the product to those made by rival firms, with the closeness being in part measured by the elasticity of substitution. All this means that the economic system is much like the NKC world. One firm's decision to move along its opportunity landscape changes the topology of the opportunity landscape of other firms. Put differently, one firm's innovation changes the opportunities available to other firms. When Apple Inc. develops a new laptop, Apple's innovation changes the opportunities available to Microsoft. Apple's innovation influences not only particular decisions of Microsoft but changes the payoffs associated with all possible decisions, i.e. it alters the topology of Microsoft's profit landscape. The economic system therefore much like the NKC model embeds an ecology of "dancing landscapes", whereby each agent's steps along its own landscape perturbs the landscape of other agents.

The mutual perturbations within an economic system are likely to be more complex than in biological system. One reason for the greater complexity is the fact that firms periodically form new symbiotic and rivalrous relations, thereby altering the relations by which different opportunities are tied together. Economic systems unlike biological systems are not characterized by somewhat stable relations between organisms, rather economic systems exhibit rapid changes in the relations between firms that seek lower cost providers of inputs and more profitable buyers of output. The economic network is not static entity, it evolves in response to decisions of firms.

Overall Schumpeterian innovations when conceived within a dynamic and critical network entail processes that do not meet the assumptions necessary for the diversification argument to hold. The first of these processes is the way in which one firm's decision influences other firms by altering their opportunity landscape. The second is the changes in buyer–seller and competitive relations between firms as they look for new buyers of output and new sellers of inputs in the process of adaptation to innovation. These two dynamics imply that the decisions of different firms are not independent of each other, rather they depend on each other in complex ways. The diversification argument necessitates the independence of firm decisions, and therefore, does not hold within a Schumpeterian setting. If the two aforenoted mechanisms are capable of taking the economic system to a critical state, then Schumpeterian micro-process may generate recessions at all scales from the hourly changes in stock indices to the yearly changes in aggregate output.

4.2 The MIT production network model and Schumpeterian dynamics

At this juncture it is worth noting some of the similarities and differences between the dynamic critical network approach discussed so far and recent work on production networks as typified by Acemoglu et al. (2012) and reviewed in Carvalho (2014). We call this class of models as the "MIT Network Model" due to the affiliation of its leading contributor. In some senses, recent work on production networks echoes Schumpeter's idea that sizeable macro-instability can emerge from distributed microeconomic actions. Acemoglu et al. (2012) and Barrot and Sauvagnat (2016), among others, have shown that the buyer–seller relation between firms nullifies the independence assumption necessary for the diversification argument to hold. The literature on production networks also finds support for two rather profound but cryptic of Schumpeter's claims. The first claim is that the macro-effects of an innovation "is independent either of the size of the innovating firm or firms or of the importance of the immediate effects their action would in itself entail" (Schumpeter 1939, p. 101). Theorems 2 and 3 in Acemoglu et al. (2012) echo Schumpeter's claim about the loose relation (perhaps not independence) between micro-innovation and macro-volatility. Theorem 2 shows that the relation between micro-innovations and macro-volatility depends not only on the first-degree distribution of the production network but also on the second-degree distribution. The first-degree distribution marks the number of buyers (or sellers) of different firms. The second-degree distribution marks the number of buyers (or sellers) of the buyers (or sellers) of different firms. While the immediate effects of a firm's innovation depends on the number of its buyers and sellers, the macro-effects depend also on the number of buyers–sellers of its buyers–sellers. Therefore, the macro-effects can be different from the immediate effects.

Theorem 3 in Acemoglu et al. (2012) presents a different reason for the wedge between the immediate and the macro-effects of a firm's innovation. Theorem 3 establishes a relation between interconnections of high degree micro-entities and aggregate volatility. A firm has a high degree if it has a large number of buyers or sellers. Highly connected firms are interconnected if they share a common seller of input or buyer of output. Dense connections between high degree micro-entities can amplify the macro-effects of micro-innovations. If firms with many buyers–sellers share a common buyer or seller, innovations of that common buyer or seller can have significant macro-effects. Furthermore, the common buyer or seller—though small—can propagate significant innovations from one high degree firm to another. The positions of firms in the production network and the structure of the network itself matters in how micro-flux becomes macro-volatility. Schumpeter was quite right in saying there may be a considerable difference between the 'immediate effects' and the 'macro effects' of a firm's innovation. The difference between the 'immediate effects' and the 'macro effects' of an innovation is attributable to a firm's position in the production network.

The second of Schumpeter's profound but cryptic claims for which the recent literature on production networks finds support is that relatively small micro-innovations can produce large macro-events. Schumpeter (1939, p. 87) notes the "extreme sensitiveness" of capitalism to disturbances. And Schumpeter (1939, p. 101) says some innovations produce "big" macro-changes by disrupting the entire economic system. Acemoglu et al. (2017) show micro-innovations can produce extreme macro-events if some firms are of far greater significance than others in terms of their number of buyers and sellers. Highly connected firms are central to the propagation of the micro-innovations.

Despite these thematic similarities, there are profound methodological difference between Schumpeter and the aforenoted work on production networks. Not the least of which is that much of the recent work has an equilibrium orientation. The literature sparked by Acemoglu et al. (2012) uses the production network as an amplification mechanism to transform exogenous idiosyncratic productivity shocks to macroeconomic volatility (Kirman 2016, p. 14). Their notion of macroeconomic volatility measures the changes in GDP as an economy jumps from one equilibrium to another in response to idiosyncratic productivity shocks. To better understand the notion of 'equilibrium volatility', consider a ball hanging from the ceiling via a rope. Suppose the point from which the rope hangs is moved. The ball will tend to swing on the rope in response to the shock. With the passing of sufficient time, the ball comes to rest in its new position. Equilibrium volatility measures the magnitude of changes in the position of the ball when the position of the rope on the ceiling is periodically

Table 1 Schumpeterian attributes of two classes of network models

Schumpeterian attributes	NKC model	MIT network model
Local connections between agents	Yes	Yes
Endogenous generation of novelty	Yes	No
Rivalrous competition	Yes	No
Coordination	No	Yes
Non-equilibrium dynamics	Yes	No
Prices	No	Yes
Price discovery process	No	No
Self-organized criticality	Yes	No
Forward-looking behavior	No	Somewhat
Direct agent interactions	Yes	No

changed (shocked) but enough time passes between each shock so as to let the ball settle in the equilibrium defined by the new configuration. Schumpeter did not view macroeconomic fluctuations as jumps from one equilibrium to another. His procedure of studying business cycle dynamics involved considering a circular flow economy in the early chapters of Business Cycles, into which he introduced innovations as a disruptive force that generates non-equilibrium dynamics.

Within a Schumpeterian schema, the topology of the production network and so-called 'idiosyncratic productivity shocks' are endogenous. In so far as firms respond to innovations by seeking new buyers of inputs and new sellers of output, the topology of the production network itself is shaped by the process of adaption to innovation. Furthermore, in so far as 'idiosyncratic productivity shocks' are measured by changes in sales of firms, these changes reflect firms' responses to each other in midst of adaptation to innovation. Therefore, neither the structure of the production network nor the magnitude of firm level changes can be taken as a given. Both the structure of the production network and firm-level changes co-emerge amidst the process of innovation and adaption to innovation. In fact, Schumpeter (2010, p. 112) says that in studying macro-dynamics, we must "avoid the assumption of uncreated and unchangeable structures". The production network is indeed one such structure. A Schumpeterian way of looking at the economic system therefore points to the richer problem of the co-emergence of micro and structural variables in a way consistent with the empirically observed fluctuations in aggregate variables.

4.3 Schumpeterian attributes in the NKC model and the MIT network model

In some senses, the NKC Model and the MIT Network Model contain ingredients with which to build a truly Schumpertian model that does not depend on Keynesian features to generate macro-dynamics. We, therefore, list (see Table 1) some essentially attributes of a Schumpeterian macro-model and discuss their presence or absence in the two classes of models. (Note that the attributes listed in Table 1 are meant to be neither mutually exclusive nor collectively exhaustive). In what follows, we compare the two models along each of the ten attributes.

First, both the NKC Model and the MIT Network Model involve local connections between agents, i.e. they study the outcome of systems in which not all agents are connected to all other agents. Second, the NKC Model involves the endogenous generation of novelty, while the MIT Network Model depends on exogenous idiosyncratic productivity shocks. More specifically, in the NKC Model, agents respond to other agents by developing new capabilities and behaviors. No such creative response occurs in the MIT Network Model: no agent responds to idiosyncratic productivity changes of other agents by developing new technologies. Third, the NKC Model ingrains rivalrous competition between agents, whereby an improvement in the position of one agent comes at the expense of the worsening of the position of another. This feature is entirely absent in the MIT Network Model. Fourth, the NKC Model does not contain a notion of coordination between agents, the MIT Model defines equilibrium as a coordinated state. Note that having some notion of coordination is important because ultimately Schumpeter's business cycle theory is a story of how innovation generates sizeable miscoordination in the economic system. Fifth, the NKC Model involves non-equilibrium dynamics, whereby the system shows no tendency of converging towards an absorbing state. The MIT Network model does not generate non-equilibrium or disequilibrium dynamics. Sixth and seventh, the NKC setting being a model of biological evolution does not contain prices or a process by which prices are discovered. The MIT Network model does contain a definition of equilibrium prices but no description of a decentralized process through which prices are discovered. Eight, the NKC Model generates system dynamics that tends towards a state of self-organized criticality, no one has so far shown that the MIT Network Model is capable of generating criticality. Rather, the MIT Network model involves static jumps from one equilibrium to another. The rich meso- and macro-dynamics that occur at the edge of chaos are simply absent in the MIT Network Model. Ninth, the NKC Model does not contain agents who exhibit significant forward-looking behavior. Agents within the NKC setting respond to the present behaviors of their immediate neighbors without considering of the behavior of other agents or the potential responses of other agents to the changes in one's own behavior. The MIT Network Model in some sense entails rationality consistent with the standard equilibrium setting, i.e. no agent has an incentive to deviate from its present decision. It does not, however, involve agents reasoning about future plans using limited information about the plans of other agents on whom their own plans depend. Tenth, the NKC model entails direct interaction between agents, while in the MIT Network Model, agent influence each other only through equilibrium prices. Overall, while neither the NKC Model nor the MIT Network Model incorporate all Schumpeterian attributes listed in Table 1, they contain elements that can be combined to develop a Schumpeterian macro-model. More specifically, the MIT Network Model contains some economic-aspects of agent decision-making that must be introduced into the NKC Model for it to be of value to macroeconomists.

5 Concluding thoughts

We began this paper by noting that Schumpeter sketched a somewhat unique solution to the problem of macroeconomic fluctuations. He argued that the observed turbulence in aggregate variables is a natural outgrowth of the ordinary workings of the market economy. One of the stumbling blocks in going from micro to macro is the tendency for small micro-changes to average out in a large economy. We have argued that Schumpeterian micro-process engrain a dependency between firms decisions that nullifies the diversification argument. The changes in the plans of one firm can spark changes in the plans of other firms, and under certain circumstances such changes can generate avalanches sufficiently large to register changes in aggregate variables. These dynamics are intimately related to the evolving relations between firms as buyers and sellers of intermediate inputs. Production network is the missing link in Schumpeter's business cycle theory.

Schumpeter had in essence developed a theory which does not postulate stability as the normal course of life within a market economy. Such an analytical overture is not without philosophical underpinning. And like so much in 'Western thought[1]' (as caricatured by Whitehead's popular remark), the underpinning derives from Plato. In the Republic, Plato tells the story of men living in a cave, with their necks and legs fettered, able to see only in front of them. The source of light is a long way up behind their backs. At the entrance to the cave, there are objects of all kinds placed on a low wall like that of puppeteers. The men in the cave, only seeing shadows of the objects, come to believe the shadows to be the real thing. As the sun rises in the morning and sets in the evening, the shadows change size and shape, though the real things remain unchanged. One of the cave dwellers is released from his fetters and taken to the entrance. He comes to see the objects whose shadows he has seen all his life. After which, he comes back to cave to meet his fellows still tied to their fetters.

Many macroeconomists theorize from the position of the man who left Plato' cave and happened to see the unchanging stable reality. The modern way out of the cave is the econometric technique of filtering trends from aggregate time series. Ultimately, most business cycle theories are founded on the presumption that a well-functioning economic system engrains stability, and therefore, instability occurs due to shocks from outside the system. Macroeconomic analysis therefore seeks to identify the mechanisms that produce a difference between the world of change and the changeless. And macroeconomic policy attempts to shape our world along the contours of the eternal, to dampen macroeconomic turbulence so that economic time series look more like the trend.

The perspective of the man who left Plato's cave is not the only position from which one can theorize. The twin facts of microeconomic flux and macroeconomic turbulence can be taken as the real, for that is all we know about reality. There is no sense in which one can speak of the world outside the window as the pale reflection of something else, for the ordinary course of human experience is all we know, it

[1] In so far as thought can be thought to be contained with geographical or historical boundaries.

is all we must work with Lovejoy (1936). As Schumpeter (2010, p. 112) put it, we must not interpret "change from a line of development that has not been derived in an empirical way". From an empirical point of view, perennial micro-flux and occasional macro-instability are the truly real. In the United States, every year, tens of thousands of new firms are created and millions of individuals change jobs (Axtell et al. 2019). In a typical year, nearly a third of those employed move from one firm to another (Fallick and Fleischman 2004). And about a third of those employed move from employment to the unemployment pool, and a comparable number move in and out of the labor pool. All this means that the US labor force churns over more than once in a single year. Furthermore, there is great variety within the flux. Some workers change jobs frequently, others retain jobs for decades. Some firms die prematurely, others live long lives (Phillips and Kirchhoff 1989). Some products are greeted with joy, others rejected without consideration. Change not constancy characterizes the day to day workings of an economic system.

In some senses, microeconomic flux emerges from men's desire for change, sometimes for its own sake. As Shackle (1972, p. 238) says, the world of the circular flow is so boring that "Not even the Economic Man could endure to live in such a prison without wrecking". One man's desire for change necessarily wrecks another man's peaceful stability, for the economic plans of different individuals are related through a production network. There is no reason to presume economic actors make plans with the intention of dovetailing with the plans of others. It is indeed true that we all like to play in a concert, but it equally true that far too many of us want to be the first violin (Wagner 2010). Competition is a rivalrous process Hayek (1948). Disharmony of interests is the very modus operandi of economic dynamics (Wagner 2020, pp. 97–126). Sun Tzu's Art of War is as much a book on economic life as Frederic Bastiat's Economic Harmonies. The harmony, discord, and change in microeconomic plans are seeds of macroeconomic turbulence. We have attempted to argue that dynamic production networks may be the way these seeds grow into macroeconomic turbulence.

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