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# The Agenda for Evolutionary Economics: Results, Dead Ends, and Challenges Ahead.

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# The Agenda for Evolutionary Economics: Results, Dead Ends, and Challenges Ahead.

Is there an "evolutionary paradigm", in the first place? And if yes, what is it?

I do believe *there is one indeed*, even if, unfortunately, many current practitioners invoking it seem to have forgot what it is.

It is useful to start from the basics (for much more detailed accounts of what follows, see Dosi and Roventini, 2019; Dosi and Virgillito, 2021; Dosi, 2023).

In brief, in such a paradigm, the economy is interpreted as a *complex evolving system*. In that, a wide set of techno-economic phenomena are understood as *emergent properties* – outcomes of *far-from-equilibrium interactions among heterogeneous agents* – characterized by endogenous preferences, most often "boundedly rational" – but always capable of learning, adapting, and innovating with respect to their understandings of the world in which they operate, the technologies they master, their organizational forms, and their behavioral repertoires.

I use here the most minimalist notion of "complexity", which stand at the very least for the fact that the economy is composed by multiple interacting actors. As H. Simon, also cited in Kirman (2016), puts it:

> *"Roughly by a complex system I mean one made up of a large number of parts that interact in a non-simple way. In such systems, the whole is more than the sum of the parts, not in an ultimate metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole" (Simon, 1962, p.468).*

Indeed, the "properties of the whole" are generally *emergent properties*, that is collective properties stemming from the local interaction among multiple agents, which however cannot be attributed to the intentionality of any agents or collection of them (more in Prigogine and Nicolis, 1977; Lane, 1993; Camazine et al., 2001). Note that complexity and emergence do not prevent at all the search for possible laws of motion of any system, but they do rule out any "antropomorphization" of the interpretation of whatever dynamics, so familiar in contemporary theory.

All that involves some crucial properties.

*First*, if the entities are genuinely evolving, new elements, new sub-entities, new morphologies are bound to appear along the course of evolution. Biological ecologies are a straightforward example: the very emergence of life, and then cellular organisms all the way to mammals have been unfolding over time in processes whose unique invariant feature is probably the increasing complexity of the entities and the ensuing environments… Socio-economic evolution is at least equally striking, with its impressive sequence of emergence of new technologies and new organizational forms. The economist trying to reduce all of it to some invariant "production function" entirely misses the point. And so does the physicist lent to social sciences or to biology, trying to reduce evolution to "changes in temperatures and energy states".

*Second*, evolution is a *multi-scale phenomenon*. This is a fundamental property of biological evolution (Gould, 1980): the evolution of, e.g., *taxa* is nested – and indeed is coupled with – the evolution of ecologies, species, phenotypes, genes… And even more so is the evolution of economies and whole societies, nested in different institutions – possibly evolving at different paces, and coupled with technological and organizational changes.

*Third*, but relatedly, economies are *complex interactive systems*. Interaction generally implies *emergence*. There is no isomorphism between macroscopic phenomena, say, the dynamics of industries, markets, and whole economies, on the one hand, and the behaviours of individual entities, on the other. *More is different* (Anderson, 1972). The dynamic of a beehive can hardly be reduced to that of a "representative bee", as the behaviour of a gas can be reduced to that of a "representative molecule".

*Fourth*, complexity is intimately linked with *non-linearities*, and thus multiple possible dynamical paths. *History counts*. And this, even more so, in socio-economic environments characterized by knowledge accumulation. Knowledge builds upon itself, thus involving what economists in their jargon call *dynamic increasing returns*. That is, in the physicists' parlance, they are "non conservative systems". But this is not because they "dissipate" energy to the outside, but because they "create energy" *ex nihilo* from within – something clearly in violation of physical laws, but not of socio-economic evolution.

Note that if evolution implies complexity and non-linearities, the opposite is not true. When you go home to eat and you say, "I cook a plate of spaghetti", you plan a highly non-linear activity, with major phase transitions, from the cold water to the boiling one, to the cooked spaghetti… However, you do not say "I go home to evolve a plate of spaghetti", for the simple reason that everything is there from the start, the spaghetti, the water, the fire… But this is not so when a multi-cellular entity appears, the steam engine is invented, the DNA is discovered…

And another fundamental qualification that must be repeated is that "evolutionary" does not mean "gradualist", i.e., "anti-revolutionary". There have been *punctuated equilibria* intermingled with major discontinuities in biological history, and even more so in the socio-economic ones.

My mentors Chris Freeman, Dick Nelson, Sid Winter as well as many of the co-authors/co-editors of the 1988 book (Dosi *et al.*, 1988), including myself, thought that the analysis of innovation as an evolutionary process was a great place to start. And I still think so.

Indeed, a lot of progress has been made since the '80s, sometimes in serendipitous ways, building on contributions which would not call themselves as "evolutionary". I try to integrate the state-of-the-art on the foundations of the analysis of the economy as a complex evolving system in my forthcoming *Manual* (Dosi, 2023) to which the reader is warmly referred for all details.

There have been also some worrying setbacks.

Quite a few of us – not me, I must say – equated "evolutionary economics" with the "economics of innovation", forgetting, at least in my interpretation, that that was only part of a greater re-foundational design, which, on the contrary, got progressively forgotten even by many of the early "subversive" contributors to the economics of innovation as a nascent discipline. So even if originally "economics of innovation" primarily meant "evolutionary analysis of innovation", nowadays it is a sub-discipline of economics like many other ones, such as "industrial economics" or "macroeconomics". But one can address the latter as Maynard Keynes or as Milton Friedman: the subject matter does not qualify for the interpretative perspective.

Together, the dialogues with other streams of the "sciences of complexity" also progressively shrank. And so did the dialogue with genuine economic historians (as such a specie on the verge of extinction).

And the "economics of innovation" has become increasingly a tolerated niche or even welcomed as a source of insights in a newly normalized paradigmatic panorama. To push the metaphor, a sort of equivalent to the Trent Council of the Catholic Church answering the Reformation, with many more Ptolemaic epicycles to account for innovative activities, dressed up in sophisticated econometrics, addressing relatively trivial "research questions" – indeed only those which could be handled by the technical instruments at hand.

And all that in the face of two major macroeconomic crises, challenging at its foundations a "standard" intellectual paradigm supporting the view that we have been, are, and will always be living in the best of all possible worlds ( except , possibly , for some "market failures" … )

# The state-of-the-art: technologies, firms, markets, and industrial dynamics

## 1. Technology and innovation

Since the '80s, major advances have been made concerning technology, innovation and technological change. They concern the analysis of sources, procedures, and microeconomic effects of innovation. It starts from the basics – i.e., what is technology –, in terms of problem-solving *knowledge*, *procedures*, *recipes*, *routines* and ensuing *artifacts*. Together, one has explored the structure and dynamics of such knowledge in terms of *technological paradigms*[1], and the implications in terms *trajectories*[2] of technological change.

There are few features which the generality of paradigms has in common, and others which differentiate them in terms of richness of *opportunities* of innovation and their sources; *tacitness* of the underlying knowledge bases; *cumulativeness* in the processes of innovative advances; *appropriability* of the economic benefits from innovation itself. Different paradigms map into different sectoral regimes of innovation and industrial dynamics, of which one can build illuminating taxonomies (for some examples, see Dosi, 2023, and below).

The economic impact of innovations depends on their diffusion. Thus, it is crucial to understand if they diffuse at all, and the determinants of the rates and patterns of diffusion themselves. A lot of progress has been made on that, even if, worryingly, not much in the new millennium ( most likely , because , with the mainstream lenses , it is hard to see diffusion as an “equilibrium “ phenomenon , except for quite baroque assumptions … )

## 2. Capability-based theories of the firm

In modern capitalism, business firms are a central locus of *applied* technological advances, employ most new technologies, produce, and market new products, operate new production processes.

Modern firms operate in environments that are changing over time, in ways that cannot be predicted in any detail. Technological advances are one of the primary forces causing permanent *uncertainty* , in any rigorous Knightian sense , ruling out any agency-theoretic theory of firm .

Relatedly, a capability-based theory of the firm has emerged, seeing firms as *problem-solving entities* characterized by distinct internal distributions of knowledge and power and patterns of division of labour, and, in that perspective, analyze “what firms do”, and “how well they do it”. Distinctive organizational capabilities bear their importance also in that they persistently shape the destiny of individual firms—in terms of, e.g., profitability, growth, probability of survival. All this links with a broad *Simonesque* general interpretation

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1Each technology can to be understood as comprising (i) a specific body of practices (processes for achieving particular ends) together with an ensemble of artifacts on the “input side”; (ii) some notion of a design of a desired “output”; and (iii) a specific body of understanding (much of it shared among professionals in a field). All these elements, *together*, can be considered as constituent parts of a *technological paradigm* (somewhat in analogy with Kuhn’s scientific paradigm – Kuhn, 1962). Generally, technological paradigms can be understood also as “cognitive frames” shared by technological professionals in a field that orient what they think they can do to advance a technology, identify the operative constraints on prevailing best practices as well as the *problem-solving heuristics* deemed promising for pushing back those constraints. Examples among many are the semiconductor paradigm and the internal combustion engine paradigm (more in Dosi, 1982 and Dosi, 2023).

2 Trajectories may be understood in terms of the progressive refinements and improvements (made by many different agents) in the exploration of the *innovative opportunities* entailed by each paradigm . A growing number of examples of trajectories include aircrafts, helicopters, various kinds of agricultural equipment, and automobiles (again more in Dosi, 2023).

of the behaviour of agents in complex evolving environments, in terms of *routines*, *heuristics* and higher-level rules apt to change the former.

More recently, knowledge-based theories of the firm have met another, fundamental but mostly neglected, dimension of organizations, namely *power* (Dosi and Marengo, 2015; Dosi, Marengo and Virgillito, 2020 and 2021): indeed, this is a major frontier ahead, concerning the distribution of knowledge and power within organizations and their effects upon performances and income distribution.

## 3. Modeling learning processes

Related modelling efforts have progressed too, addressing the dynamics of learning, innovation, and diffusion.

A *first* ensemble of models, with their roots in the seminal contributions of Herbert Simon, attempts to formally grasp the *procedural aspects* of knowledge together with the combinatorial nature of organizational activities and learning. Many models of organizational "cognition", memory, adaptation, and learning refine on the formalism of so-called "NK models", while others build on "Classifier Systems" (see again Dosi, 2023).

A *second*, more black boxed, but lower dimensional, approach to technological knowledge, represents learning in the space of input-output relations, generally as stochastic dynamics, made possible by expensive search efforts and with uncertain probabilities of success, depending also on the nature of innovative opportunities.

Finally, *third*, one has developed models of innovation diffusion, along paths often characterized by various forms of increasing returns, network externalities, social adaptation, co-evolution between the features of supplied goods and demand, path-dependencies.

## 4. Toward an evolutionary theory of production

Modifications and refinements of procedures and designs are "where the action is", but they result into changes in input/output relations as the outcome of successful attempts to achieve effective procedures and designs with certain performances, and to change them in the desired directions.

In that, *first*, each organization knows only one or very few of them.

*Second*, even for apparently similar recipes, any two organizations might master them with very different degrees of effectiveness. *Heterogeneity* across firms is, thus, the rule, even in presence of identical relative prices.

*Third*, in general, there is at any point in time one or very few best-practice techniques which dominate the others irrespectively of relative prices. Different firms are likely to be characterized by persistently diverse (better and worse) techniques.

*Fourth*, over time the observed aggregate dynamics of technical coefficients in each particular activity is the joint outcome of the process of imitation/diffusion of existing best-practice techniques, of the search for new ones, of the death of some others and of the changing shares of the firm carrying them over the total.

The analysis of all that, of course, require to *entirely dispose of notions such as production functions, and with that, also of all links between technological conditions, relative prices, and input demand (in primis demand of labour)*.

## 5. The evolution of consumption patterns

The evolutionary perspective is less developed concerning consumption, and, in my view, for good reasons. Its groundings on the institutional embeddedness of individual and organizational behaviors distances it enormously from any notion of "consumer sovereignty" and, more generally, of "methodological individualism." However, one may still want to identify some general empirical properties of consumption acts and their evolution. In Dosi (2023), we present a simple model, based on earlier works , which tries to capture—albeit in a quite rudimentary form— phenomena like the existence of recognizably different 'lifestyles,' lexicographic orders on consumption acts, (limited) path-dependency of individual and collective consumption patterns, innovation, and social imitation. It turns out that, despite its simplicity, the model generates emerging aggregate patterns of consumption with statistical properties quite in tune with empirically observed regularities, such as S-shaped diffusion of new commodities, and Engel-type dynamics of budget shares. It is also able to generate, under quite a few micro-parametrizations, distributions of consumption coefficients yielding, in the aggregate, *notional* downward sloping demand curves, even if, emphatically, *there is no demand curve*, neither in the head of the people, nor in the very processes of aggregate adjustment.

## 6. How markets work

Of all economic institutions the market is probably the most ancient and the most historically documented. And, as all the others, it is a 'socially constructed one in which the behavior of traders is suspended in a web of customs, norms, and structures of control'. Phenomena like incomplete and asymmetric information are ubiquitous. However, the sole acknowledgement of them is largely insufficient to characterize how markets work. We study different forms of market organizations and the ways different institutional architectures, distributions of behavioral rules and mechanisms of interaction affect collective outcomes. In Dosi (2023) , in the chapter written together with Alan Kirman , we also present the analyses of learning processes within them. Generically, the aggregate relationship is *not* the sum of many similar individual relationships but has characteristics resulting from the ensemble of interactions themselves. In order to study "how markets work", one must study how they behave out of equilibrium and the characteristics of the states through which it passes, or to which it settles, if at all.

## 7. Industrial evolution

Differences in products and in processes of production – and, as a consequence, costs and prices – are central features of the competitive process by which heterogeneous firms get selected – with some firms growing, some declining, some going out of business, some new ones always entering on the belief that they can be successful in this competition. Such processes of competition and selection are continuously fueled by the activities of innovation, adaptation, imitation by incumbent firms and by entrants. The competitive process involves *selection across firms*. But underlying that, rests *learning* on *techniques*, organizational practices, and product attributes *within the firms themselves*. Ultimately, *learning*, and *competitive selection* are the two central drivers of changing industry structures and industrial demographics.

Indeed, one has made a lot of progress on the evidence concerning some general features of (i) *firms' characteristics, and industrial structures and dynamics*, broadly understood to cover variables such as size, productivity, innovativeness, age, and their intra-industry distributions; and (ii) *performances*—including individual profitabilities, growth profiles, market turbulence and survival probabilities, together, again, with their aggregate distributions.

Major developments also involved different families of models apt to account for the foregoing "stylized facts" as *emergent properties* of industrial evolution.

## The risks and the challenges

On the whole state-of-the-art from technologies to firms to markets to industries, I must refer the reader to the *Manual* (Dosi, 2023).

Even in these domains, progress has been significantly uneven, and, to repeat again , often due to communities which would not call themselves "evolutionary", while many students of innovation, albeit rooted in the evolutionary tradition, seem to have accepted a good deal of the conventional assumptions and methodologies. It is not possible to discuss here in detail the implications of such acceptances. However, some warnings are necessary.

### *On risks and pathologies, first…*

Evolutionary worlds typically entail *co-evolutionary dynamics*, *complementarities*, and diverse forms of *heterogeneity*. In turn, these properties have major implications in terms of methodology by which we analyze them. However, in contemporary applied analyses, there is almost obsessive quest for "causality", and together, the almost exclusive focus on whatever is measurable even if not relevant at the cost of neglecting whatever is interesting but not measurable (this is a paraphrase of an Einstein quote…).

### *Dynamic coupling*

*Co-evolution* and even simpler *dynamically coupled processes*, imply an intrinsic "bi-directional causation" which is impossible to get rid of. Go and ask biologists whether it is the gazelles which "cause" the lions, or the lions which "cause" the gazelles. They will simply reply that you are drunk! Of course, one may fruitfully try to parametrize the predator-prey dynamics (i.e., some form of Lotka-Volterra system), but no biologist in the right state of mind would rationalize the issue in terms of "supply and demand curves" of lions and gazelles, trying to disentangle the dynamics by distinguishing between movements *along* the curves and movements *of* the curve. (Recall that the attempt to “identify” a causal effect by finding the appropriate “instruments” boils down to that).

There are many analogs in economics: a simple one is the so-called cob-web dynamics of price and quantities of e.g., corn and pigs fed with corn. A straightforward way to account for it is to write a relatively simple dynamical system, without any need of imaginary supply and demand curves and identification requirements. But, then why such a widespread obsession with the latter?

The answer is pathetically simple. Because, for the majority of our profession, it is very hard to get rid of the ideas that, first, observations at times 1, 2, … t *are equilibrium observations*, and second, that behind them, at least in principle, *there is a “structural model” of equally imaginary agents who maximize something*, yielding the foregoing imaginary curves. Of course, if this were the case, and if something changed from time 1 to time 2, it must have been due to a “shock” somewhere. And here come the efforts of the brightest students to find the most far-fetched “instruments”, which correlate with changes in lions and not in the gazelles, or vice versa. Needless to say, it is not surprising that more conventional applied economists would follow this methodology. But the drama is that also quite a few of the young scholars that *we* train follow it unquestioningly. It is humanly understandable, even if not ethically praisable, that they follow this path as it makes publications much easier. It is a major sin of omission that *we* – those with a certain age and supposed wisdom – do not warn them or, better, try to vaccinate them.

### ***Complementarities***

All socio-economic processes involve ubiquitous *complementaries*, from the very micro to broad historical processes.

Think of technologies. As I teach my students and argue at much greater depth in Dosi (2023) in a chapter written with Dick Nelson , would any cook try separate the contribution to the “goodness of a cake” of the sugar, butter, flour, eggs, etc? Or, even worse, try to estimate the “marginal rate of substitution” among the former ingredients, holding the “goodness of the cake”, whatever that means, constant?

However, this is what *innocently* most of the profession does, concerning, e.g., production functions, indeed one of the most poisonous constructions of our profession.

And it applies this same methodology at all levels of observations from technologies to firms, to industries, to whole economies and historical periods. So, one is trained to estimate separate “contributions” from sugar and eggs, from labor and capital, from R&D and tangible investments, from rules of law and culture… all the way, to genetic traits!

The dominant heuristic is roughly the following: put something on the left-hand side of the estimate and then plug on the right-hand side a long Kamasutra of variables (possibly with some interaction terms, plus “fixed effects”, but more below…). Watch the p-values (r-squares are nowadays considered Jurassic relics) and the paper is done.

However, *in a world of complementarities, all this does not hold*.

Sugar and eggs must combine as the (partly tacit) heuristics of cooks prescribe in rather fixed and idiosyncratic combinations. So do labour and capital inputs in firm-specific production routines which evolve along proximate paradigm-driven trajectories of change. And so major historical discontinuities, such as the Industrial Revolution, emerge as the effect of the congruent complementarities among multiple technological, economic, institutional, and cultural factors (see the seminal Freeman, 2019).

In such a world of complementarities, how should then properly conduct the analysis?

First, most obviously, one should try to identify them, and, together, the conditions of "congruence" or "mismatching" among the different variables and processes. This applies to:

- the identification of specific paradigms and trajectories in the technological domain,
- different organizational "types" entailing distinct capabilities, in the domains of firms;
- different mappings between the features of knowledge and the features of industries which generate/use it, in the domain of sectoral systems of production and innovation.

All the way to:

- different profiles of congruence/mismatching between the prevailing technological paradigms, the 'economic machine' of income generation and distribution, and the modes of socio-economic governance, in the macro-economic / macro-social domain.

Inevitably, one is bound to develop *categories* and *taxonomies*. A famous and highly fruitful one is Pavitt (1984) on the sectoral patterns of innovation. However, the exercise is insightful and indeed necessary in all the other foregoing domains. So, for example Costa et al. (2021) identify by means of cluster analysis different "types" of firms embodying different organizational capabilities as revealed by distinctly different combinations of organizational processes and routines.

At macro level, exercises like those on "variety of capitalisms" and "regimes of regulation" have the same nature.

In all that, also the empirical evidence and its treatment differ a lot. In some cases, such as Costa et al. (2021), taxonomies are built on the grounds of hundreds of dimensions regarding hundreds of thousands of firms. At the opposite extreme an entire, indeed quite insightful, theory of the firm in modern American capitalism – Chandler's (Chandler, 1962 and 1993) – is mainly built on *two* observations. I repeat, two! , Dupont and General Motors. Indeed, in all our history-grounded disciplines intelligent analyses must be prepared to *learn from samples of one or fewer*, paraphrasing March, Sproull and Tamuz (1991).

### *Taxonomies and structural heterogeneities*

The development of taxonomies crucially helps also in meaningfully handling heterogeneities of different sorts.

Turn again to the biological example. Darwin's *Origin of the Species*, could not have even been conceived without Linneus' species, families, taxa, etc.

Imagine on the contrary, a Darwin skillful statistician but unaware of all discrete morphologies. He might have run some estimates over “all animals”, from warms to birds to fishes to mammals – bunching together turtles and Achilles - , with some measure of performance on the left-hand side and, on the right, variables like intake of food, weight, length, number of legs, etc. together with a series of dummies (does it have hair? feathers? a tail? etc.), and obviously “fixed effects”. Does it sound familiar?

In this “night in which all cows are black”, the capital methodological mistakes are to suppose that all entities (i) do not structurally differ; (ii) are basically nested in the same generating stochastic process, no matter how complex, with the typical associated assumptions (iii) on normality of the distributions, stationarity in first moments or log differences, etc. This does not obviously apply to biology but does not even apply to the medicine of humans in general, because even among us humans the heterogeneity is too high (see the germane discussions on “randomized control trials” and their striking limits by Deaton, 2020, and Deaton and Cartwright, 2018).

Of course, this is not to say that we should not do “normal science” – which in this case “normal” basically means “prevalent” –, but is an invitation to do it with a keen awareness of the methodological limits of an art-form which is quite far from the core questions of the evolutionary program. When the question is very very simple, and one talks about, e.g., shocks over a subset of populations, *which we know* ex-ante to be quite homogeneous, and the “shock” is well defined, then standard methodologies are quite welcome. Talking about evolution, or just multi-dimensional shocks like, e.g., the Covid-19 pandemic is a totally different matter.

## The big challenges

No matter what, one of the biggest challenges ahead concerns major *macro* issues. Its almost total absence has in fact been one of the major faults of the contemporary evolutionary community since the start, which has been far too much “supply-sider”, as it has been far too “Schumpeterian”. Schumpeter, with all his merits in putting innovation at the center of his analysis, at the same time has been totally blind to the notions that (i) the rates of growth of the economic system are crucially dependent on aggregate demand, and (ii) supply and demand process interact at all time scales. Suffice to read Schumpeter’s review of Keynes’ *General Theory* (Schumpeter, 1936): it could have been written by a not-too-bright Chicago Ph.D. student.

But even in the seminal Nelson and Winter (1982), one finds too much Schumpeter and too little Keynes. The models therein, together with their path-breaking merits in formalizing endogenous uncertainty-ridden technological search, are, from the macroeconomic point of view, *equilibrium models:* the labour market clears and so does the product market. A central reference of them is Solow's growth model. The related quest is for much more reasonable (indeed, evolutionary!) foundations to Solow’s (equilibrium ) macro patterns . In that, they fall short of Keynesian economics, which – as Paul Krugman puts it, and I fully agree – is “essentially about the refutation of Say's Law, about the possibility of a general shortfall in demand". And in that view, one finds “it easiest to think about demand failures in terms of quasi-equilibria models in which some things, including wages and the state of long-term expectations in Keynes' sense, are held fixed, while other adjust toward a conditional equilibrium of sorts" (Krugman, 2011, p. 3).

Indeed, as Kaldor (1983) sharply points out in his 50-years assessment of the *General Theory*, generic multiplicity of *non-Say quasi-equilibria* is the rule. Let me refine a bit on this, citing again Kaldor:

> *The originality in Keynes's conception of effective demand lies in the division of demand into two components, an endogenous component and an exogenous component. It is the endogenous component which reflects production, for much the same reasons as those given by Ricardo, Mill or Say - the difference is only that in a money economy (i.e. in an economy where things are not directly exchanged, but only through the intermediation of money) aggregate demand can be a function of aggregate supply (both measured in money terms) without being equal to it - the one can be some fraction of the other.*
>
> *To make the two equal requires the addition of the exogenous component (which could be one of a number of things, of which capital expenditure -"investment" - is only one) the value of which is extraneously determined. Given the relationship between aggregate output and the endogenous demand generated by it (where the latter can be assumed to be a monotonic function of the former), there is only one level of output at which output (or employment) is in "equilibrium" - that particular level at which the amount of exogenous demand is just equal to the difference between the value of output and the value of the endogenous demand generated by it. If the relationship between output and endogenous demand (which Keynes called "the propensity to consume") is taken as given, It is the value of exogenous demand which determines what total production and employment will be. A rise in exogenous demand, for whatever reasons, will cause an increase in production which will be some multiple of the former, since the increase in production thus caused will cause a consequential increase in endogenous demand, by a "multiplier" process. How large this secondary increase will be will depend on a lot of things such as the retribution of the additional output between wages and profits, and the change in productivity (or in costs per unit of output) associated with the increase in production, etc. [...] A capitalist economy ... is not "self-adjusting" in the sense that an increase in potential output will automatically induce a corresponding growth of actual output. This will only be the case if exogenous demand expands at the same time to the required degree; and as this cannot be taken for granted, the maintenance of full employment in a growing economy requires a deliberate policy of demand management.*
>
> *[...]*
>
> *Keynes was no student of Walras. However, there was enough in Marshall (particularly in Book v, the short period theory of value) to raise the same kind of qualms - why don't all markets behave in such a way to compel the full*

*utilisation of resources? Marshall's own theory suggested that saving provide the supply of "loanable funds" which, given an efficient capital market which equates supply and demand, governs the amount of capital expenditure incurred. This amounts to a denial of the whole idea of an exogenous source of demand - the latter notion presupposes that the supply and demand for savings are brought into equality by changes in income and employment and not by the "price" of savings in the capital market, which is the rate of interest. In order to explain why the market for loans is not "market-clearing" in the same sense as other markets, Keynes introduced the liquidity-preference theory of interest - which, as is evident from his own later writings, was added more or less as an afterthought.* (Kaldor, 1983, 172-175).

With respect to Keynes and Keynesianism, one may remind that also on this side of the Atlantic, one of my mentors and founder of modern evolutionary economics, Chris Freeman, heavily criticized the Keynesian policy framework (cf. Freeman's critique of the so-called McCracken report – McCracken et al., 1970 – in Freeman, 1977). But the advocacy there was to go *beyond* Keynes, fully taking on board the properties of technological change, *not to regress to pre-keynesian times* (as unfortunately the so-called "new classical" economics actually did).

Indeed, a crucial challenge for any theory rests on its ability to account for broad macroeconomic phenomena, on different scales. We discuss them in the historical introduction to the Manual (Dosi, 2023). Here a litmus test are deep crises, including the recent ones. Their very arrival and their sheer size are as near as one can get in social sciences to a falsifying "crucial experiment": as the "Dahlem Manifesto" puts it, the crisis highlights a systemic failure of the economic profession (Colander *et al.*, 2009).

Of course, one cannot demand economists to predict precise dates or modes of occurrence of any crisis, but what is astonishing is that the mainstream paradigm was unable to allow the very possibility of a crisis, and, even more astonishingly, "evolutionary" theorists have been almost silent on all that.

Let me cite from the "Manifesto":

*"The implicit view behind standard models is that markets and economies are inherently stable and that they only temporarily get off track. The majority of economists thus failed to warn policy makers about the threatening system crisis and ignored the work of those who did. … The confinement of macroeconomics to models of stable states that are perturbed by limited external shocks and that neglect the intrinsic recurrent boom-and-bust dynamics of our economic system is remarkable. … The failure [of the economic discipline] has deep methodological roots. The often-heard definition of economics – that it concerned with the 'allocation of resources' – is short-sighted and misleading. It reduces economics to the study of optimal decisions in well-specified choice problems. Such research generally loses track of the inherent dynamics of economic systems and the instability that accompanies its complex dynamics. (Colander et al., 2009, pp. 2-3)*

Can the mainstream paradigm be saved by appropriate modifications?

I do not think it can, precisely because its massive interpretative failure is connected to its core building blocks (forward looking rationality, equilibrium, etc.).

In fact, the evolutionary paradigm precisely addresses the properties of endogenously changing multi-agent systems.

The basic micro and "meso" building blocks are there: I must refer again to Dosi (2023). One of the biggest challenges is to connect them to the eminently *macro levels*.

In order to do that, one has to focus on the relationships between technology, productivity and growth. Technological progress is one of the core drivers of economic growth.

Since the Industrial Revolution, which saw the massive introduction of mechanization in industrial production, machines have helped human activity improve the quantity (and also the quality) of production (Freeman, 2019; Dosi, 1984, and 2023, and the citations therein). In turn, technological innovation has been *roughly* translated into productivity, and the latter into economic growth. But this is just a first, and indeed quite rough, approximation.

To see this, consider the identity:

$y = \pi + n$.

From an accounting point of view, this is just an identity that tells us that the growth rate of aggregate income $y$ is given by the sum of the growth rate of productivity $\pi$, and the growth rate of the working population n. From the point of view of the theory of growth, however, things are much more complicated.

In order to say that it is the growth of productivity and demography that *directly* drives GDP growth, it must of necessity be assumed that: (a) the initial conditions are equilibrium ones; (b) the rate of growth of the working population corresponds to the rate of growth of the labor supply – i.e. the system is in equilibrium at least in the long-run, with no involuntary unemployment and no endogenous changes in the participation rates; and (c) productivity growth is exogenous, or, if endogenous, does not involve feedback between income growth rates and productivity growth (hence, e.g., no Smith-Young-Kaldor dynamic increasing returns).

Here, however, I advocate a quite different story (more in Dosi and Virgillito, 2021). It is a fundamental property of modern economic systems that there are forces at work that hold them together and make them grow despite rapid and profound modifications of their industrial structures, social relations, production techniques and consumption patterns. We must better understand these forces in order to explain possible structural causes of instability and/or cyclicity in performance variables.

In that, it is useful to start from a more explicit definition of "dynamic stability" and "homoeostasis". We probably live in the first social structure where technological, social, and economic changes are fundamental features of how that same system functions. For the first time, what we call the "bicycle postulate" applies: in order to stay up, you have to keep pedaling (Dosi and Virgillito, 2021). It is the system's very growth and development that yields the conditions of its (imperfect) coordination. However, change and transformation are by nature "disequilibrating" forces. Thus, there must be other factors that maintain relatively ordered configurations of the system and allow broad consistency between the conditions of material reproduction (including income distribution, accumulation, available techniques, patterns of consumption) and the web of social relations. In a loose thermodynamic analogy, this is what some French authors call "regulation". The problem of long-term discontinuities or waves of innovation, which might result in changes to macroeconomic activity rates, pertains precisely to this level of analysis: are there structural features that produce crises in regulation set-ups?

We can distinguish three main domains in the overall socio-economic fabric, namely,

- the system of technologies;
- the economic machine; and,
- the system of social relations and institutions.

These three domains clearly interact with one another. However, despite powerful interactions, each of these three domains has rules of its own that shape and constrain every inducement and adjustment mechanism between them.

In that,

- There is a limited number of ways in which these three domains can be configured so as to be relatively well regulated and smoothly consistent.
- Unbalanced or crisis configurations do not necessarily embody the need to transition to another "better" configuration. So, persistent depressions, episodes of international divergence, explosive mechanisms of income polarization cannot be ruled out. On the contrary, they are recurrent and persistent features of contemporary economies which must be integral part of the interpretation.[3]

Needless to say, all this is lightyears away from conventional macroeconomics, which, I must confess, does not seem only a pie-in-the-sky, but is also, in my view, utterly boring!

In the alternative, one is bound to pursue the investigation of *coordination with evolution* also on the ground of higher dimensional, phenomenologically much richer *Agent Based Models*.

We have begun to do it, developing the family of "Schumpeter meeting Keynes" *(K + S)* models (Dosi *et al*. 2010, 2013, 2015, 2017, 2018, 2022), but the exploration is far from over.

Such family of models clearly meet Solow's (2008) pleads for microheterogeneity: a multiplicity of agents interact without any ex-ante commitment to the reciprocal consistency of their actions.[4]

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3 Of course, there is the standard objection to this argument according to which the standard theory works "most of the time " ( that is basically whenever tomorrow looks like today plus or minus something ) . To that, I would reply with my friend Alan Kirman: what would you make of a political theory according to which "in the twentieth century Germany has been a peaceful country most of the time" ? ! ?

4For germane ABMs, Delli Gatti et al (2005), (2010) and (2011), Russo et al (2007), Dawid *et al*. (2008) and (2011), Ashraf, Gershman and Howitt (2017), and with both some Keynesian and Schumpeterian elements see, Verspagen (2002), Saviotti and Pyka (2008), Ciarli *et al.* (2010) and the discussion in Silverberg and Verspagen (2005).

These models bridge Keynesian theories of demand generation and Schumpeterian theories of technology-fuelled economic growth. Agents always face opportunities of innovations and imitation, which they try to tap with expensive search efforts, under conditions of genuine uncertainty (so they are unable to form any accurate expectations on the relation between search investment and probabilities of successful outcomes). Hence (endogenous) technological shocks (the innovations themselves) are unpredictable and idiosyncratic.

This family of models builds on evolutionary roots and is also in tune with several insights from the "economics of information" (see Stiglitz and Greenwald, 2014) and from "good New Keynesianism" (cf. for example Stiglitz, 1994). It tries to explore the feedbacks between the factors influencing aggregate demand and those driving technological change. By doing that it begins to offer a unified framework jointly accounting for long-term dynamics and higher frequencies fluctuations.

The models are "structural" in the sense that they explicitly build on a representation of what agents do, how they adjust, etc. In that, our commitment is to "phenomenologically" describe micro-behaviours as close as one can get to available micro evidence. Simon (2009) and Akerlof (2002) advocacy of a "behavioural microeconomics" builds on that notion. In fact, this is our first fundamental disciplining device. A second, complementary discipline involves the ability of the model to generate jointly, as emergent properties, a wide ensemble of stylized facts regarding both "micro/meso" phenomena with genuinely macro "stylized facts". In the case of the mentioned model they include (i) endogenous growth; (ii) persistent fluctuations; (iii) recurrent involuntary unemployment; (iv) pro-cyclical consumption, investment, productivity, employment and changes in inventories; (v) fat-tailed distributions of aggregate growth rates; together with (persistent asymmetries in productivity across firms; (vi) "spiky" investment patterns; (vii) skewed firm size distributions; (viii) fat-tailed firm growth rates, and, (ix) on the labour market side, Beveridge, Wage (or Phillips), and Okun curves (or lack of them). To repeat the foregoing robust statistical regularities and relatively stable relations amongst aggregate variables do indeed emerge out of turbulent, disequilibrium, microeconomic interactions.

This however is only the beginning. Explorations and refinements upon models of the *K + S* type or similar ones are fundamental in undertaking thought experiments, counterfactual exercises and virtual policy checks *concerning complex evolving systems*, in which, let me repeat again and again, it is just futile looking for "ultimate causes", as complementarities and emergent phenomena are ubiquitous. But this must go together with empirical analyses of different genres (see also the short discussion above).

As I see it, there are four major urgent challenges ahead, among many others.

A *first* one concerns the relations between the labour-saving and demand-creation effects of technical change. After all, technical change is ultimately about two things: either producing existing commodities or services with fewer inputs (i.e., more efficiently), or producing new commodities and new services. In practice, product innovations of one sector are often process innovations for other sectors which are using them. The distinction, nonetheless, is theoretically fruitful. Process innovations necessarily involve some input saving. More precisely, in capitalist economies where conflict over labor processes, income distribution and power are structural features, labor saving is one of the fundamental dimensions of most technological trajectories. Moreover, any labor-saving upstream, i.e., in the production of inputs required by other commodities, represents an input-saving change, in value terms, downstream. Developed industrial systems are functionally characterized, in normal conditions, by reproducibility and not scarcity, demand-pulled in terms of macroeconomic activity, and balance of payment constrained. Under these conditions, paramount importance must be attributed to the broad duality of technical change which on the one hand continuously saves labor and, on the other hand, creates new markets or expands existing ones by means of changing costs and prices of commodities and services. The balance between demand creation and labor displacement defines the endogenously generated rates of macroeconomic activities and utilizations of the labor force. How is this balance affected nowadays by the prevailing patterns of technological change? This was a question central to the interests of Chris Freeman (cf. Freeman, Clark and Soete, 1982; and Freeman, 1987) and long forgotten thereafter. We address formally the same question in Dosi et al. (2022), but a lot more must be explored also empirically from a general *disequilibrium* perspective.

*Second*, one has witnessed over the last four decades a dramatic rise in functional and personal income inequality, with an explosion of profits, and especially financial profits and other rents; polarization even among wage earners; weakening of bargaining institutions like unions; the growing penetration of market forms of organization in domains like health, education, and research; and together the weakening of the redistributive role of fiscal policies. All these phenomena tend to go together. In my view , in order to interpret them one requires the evolutionary perspective to meet a genuine political economy, i.e., far away from what nowadays comes under that label but in fact is just a "production function on institutional steroids". For sure, to repeat , it is time to *radically delink the theory of production*, *factors demands*, *and the theory of income distribution*. This is one of the major implications of the whole interpretative framework presented in Dosi (2023). If standard "production functions" go, as they should, with that goes also all theories of "skill biases" (and also "routine biases") in technical change and the related interpretation of the dynamics on income shares. In turn, this open the way to novel investigations of the role of institutional and policy factors – including of course unions, forms of organization of the product and labour markets, and changing taxation regimes (an insightful historical analysis in is Mishel, 2022; we tackle germane issues on the grounds of the *K + S* model in Dosi et al., 2021 and 2022).

*Third*, it is time that evolutionary theory face head-on the issues which one finds at the center of standard macro texts. Some are just silly, and we better forget them (e.g., "ricardian equivalences", "menu costs" and other futile "frictions", etc.). Others are outrageous but require an answer given the dismal state of the discipline (e.g., DSGE and related *virtuosos*). A few are quite important, such as the transmission mechanisms from the financial to the real domains; the determinants of distributive shares ; the role of expectations; the impact of monetary policies; their difference *vis-à-vis* fiscal policies; some crucial properties of the international ( and more generally "geography-nested" ) economy such as the drivers of trade flows and the location of production ; among others.

In all this , a fundamental challenge concerns the thorough development of a price theory , without which of course also the analysis of income distribution , inequality etc. is bound to be incomplete . Some steps have been made . As mentioned in Dosi (2023) , refining on Kirman ( 2010 ) , we analyze "how markets work" . And the whole K+S family of models runs on pricing behaviours driven a heuristics of variable mark-ups , adjusting to the relative success of individual firms in the markets in which they operate . Still , general price theories must entail also interactions between the micro - i.e. the agents who make, or contribute to make, the prices - , and the macro – e.g. the conditions of the labour markets , the levels of social conflict , the exchange rate, etc . Here is also where expectations *might* play a role . Personally, I believe that the role of expectations has been largely overestimated ( for reasons that we discuss in Dosi et al , 2020 ) . My conjecture is that in some markets where the object of transaction is not immediately reproducible under condition of non-decreasing returns they might be very important ( e.g. natural resources ) . Otherwise , they might be negligeable ( i.e., in general, industrial goods ) . For sure , I do not buy ideas like "expectations drive the dynamics of inflation" . But much more investigation by non-believers must go into it .

In tackling the foregoing issues, a major methodological issue concerns the status of "reduced form" non-microfounded models. I must say that I am utterly skeptical about the use of models based on totally imaginary relations, such as IS, LM, aggregate supply and aggregate demand curves. On the contrary, I am quite hopeful about the use (complementary to ABM) of reduced form models based on aggregate relations which are in principle emergent properties of the agent-based dynamics, including "accelerators", "multipliers", "Goodwin-type" wage-profit dynamics; Verdoorn-Kaldor dynamics, etc. Needless to say, this under the caveat that such relations must be borne by both the statistical empirics and the ABM simulations.

*Fourth*, but not least, the evolutionary perspective must urgently address the co-evolutionary dynamics between the economy and the environment. Too often, many of us have shared a sort of Schumpeterian optimism on the socially positive role of innovation and the merits of "creative destruction", while neglecting the dramatic importance of "destructive creation" associated with capitalist (or for that matter "socialist") development.[5]

As some might recall, the first spur in such debate occurred in the early seventies around the "Club of Rome" manifesto in turn grounded in forecast of the simulation exercise by Forrester and colleagues at MIT (Meadows et al., 1972). Within that discussion the major emphasis was on the limit to growth related to resource availability coupled with rapid population growth and after 1973, by the rising trend in oil prices and declining growth in

5 In Lamperti et al. (2018) and subsequent developments we explore the properties of a "dystopian" K+S model where technological progress and economic growth are coupled with an explicit environmental dynamic (from Sterman et al., 2012), yielding 'dirty' environmental trajectories. I think it is an important advancement. Still, I believe we are short of a satisfactory account of the disastrous impact of, e.g., climate change in so far as one keeps the representation of the effects in the narrow confines of GDP measures. If a family gets the house wiped out by a flood, with some member injured, it is totally misleading to think of the damage just in terms of the costs of reconstruction of the house and the hospital costs. It is urgent to go beyond such measures of social welfare.

output in many industrialized countries. Those who stood on the pessimists' side, argued that, on the basis of the MIT models, disaster could be avoided only by zero population growth and zero economic growth from year 2000 on. Optimists – which at the time included Chris Freeman and collaborators at the Science Policy Research Unit at Sussex – argued that growth could continue, provided that the two following conditions were to be met: (i) a combination of institutional changes that led to a different path of world development (with more emphasis on sustainability) and (ii) a re-orientation of world R&D so that environmental objectives could be given higher priority (see Freeman, 1992). The scenario drawn by the Club of Rome turned out be overpessimistic in assessing the importance of natural resources shortage in constraining economic growth. At the same time the scenario was heavily optimistically biased in relation to the environmental impact of pollutant emissions into the environment in general and the impact of energy use on climate in particular. As Brock and Taylor (2005) vividly put it: "Recently it has become clear that limits to growth may not only arise from nature's finite source of raw materials, but instead from nature's limited ability to act as a sink for human wastes."

Indeed, we are very near, if not beyond, the point of no return in the carrying capacity of nature a free sink. To be on the hopeful side, we are now at a turning point in what some scholars have called the *Anthropocene* era with a very serious possibility of (i) massive reduction in biodiversity and the frequent occurrence of pandemics threatening the very survival of human civilization. It has been convincingly argued that pandemics and the emergence of the Anthropocene era are closely linked[6] . Moreover, (ii) the nonlinear growth of earth temperature causes massive worldwide damages in human living conditions, mortality, and access to food and shelter. Finally, (iii) the damages that we made to the very life on the planet by massively distributing nearly non degradable poisons is still there to be estimated but is likely to be beyond our worst guesses. Trying to squeeze all this within some "production function with some inputs with a negative sign", frankly is just pathetic if not worse, even when awarded with Nobel Prizes. On the contrary, the most pertinent interpretations might be those involving, *ceteris paribus*, the "evolution toward collapse" brilliantly described by Diamond (2005) in several occurrences of "suicidal civilizations" from the past.

I realize that the outlined agenda ahead is an extremely ambitious one. It is however fully in line also with the broader social concerns of founding fathers like Chris Freeman and Dick Nelson. Of course, nowadays, following their steps is much less acceptable in the scholarly community controlling the gates to publications – in a general drive to the trivialization of any question –, but this is not a good reason to give up. If the house is burning, one cannot focus on the size and aesthetic of the water pump.

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6 See amongst others Coriat (2020) and the editorial in The Lancet (2018) written well before the COVID-19 pandemic.

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