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The "Schumpeterian" and the "Keynesian" Stiglitz: Learning, Coordination Hurdles and Growth Trajectories

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The "Schumpeterian" and the "Keynesian" Stiglitz: Learning, Coordination Hurdles and Growth Trajectories*

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Abstract

This work, which shall contribute to the Fest "A Just Society: Honouring Joseph Stiglitz", discusses a major unifying theme in Joe Stiglitz monumental work, namely, the analysis of economies characterised by persistent learning and coordination hurdles. In his analysis Joe is in many respects a "closet evolutionist" who in fact highlighted and explored many evolutionary properties of contemporary economies in a Schumpeterian spirit. And he went further introducing genuinely Keynesian properties e.g. coordination failures and the possibility of path-dependent multiplicity of growth trajectories which are far and beyond Schumpeterian concerns. In this short essay, we shall illustrate this point with reference to some of Stiglitz works, out of many, linking them with significantly overlapping contributions from the evolutionary camp. We group them by two major themes, namely, the consequences of learning and dynamic increasing returns, and "Keynesian" coordination failures with the ensuing possibility of multiple growth paths, fluctuations, small and big crises.

Keywords

Stiglitz, Learning, Coordination Hurdles, Growth Trajectories, Knowledge, Information.

JEL codes

D5, D83, E12, O.

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1 Introduction

The analysis of economies characterised by persistent learning and coordination hurdles has been and is a major unifying theme in Joe Stiglitz monumental work. Such a world is plausibly the Mecca of evolutionary theorizing, bounded rationality, out-of-equilibrium dynamics. Joe, however, until recently has chosen to use rather conventional instruments and indeed went a long way with them in exploring crucial properties of economic realities as one observes them. In the 50^{th} anniversary party which led to this Fest, one of us (G. D.) offered the analogy with Paganini, the famous composer and violinist, who was able to play a whole concert on a single violin chord. But Paganini used at least one chord of the appropriate instrument, the violin, while Joe's task has been even harder: he has been mostly using equilibrium assumptions on the state of the system and maximization assumptions on the side of behaviours, still reaching profoundly insightful conclusions. In that, Joe has been extremely subversive in "the use of the unflinching application of the combined postulates of maximizing behaviour, stable preference, and market equilibrium" (Becker, 1978, p. 6) which are indeed the core pillars of the mainstream paradigm. And he has done that basically by studying the properties of highly stylised systems which however are *information-rich*, wherein information itself is asymmetrically and incompletely distributed, but can be and is persistently augmented over time.

In all that Joe is in many respects a "closet evolutionist" who in fact highlighted and explored many evolutionary properties of contemporary economies in a Schumpeterian spirit. And he went further introducing genuinely Keynesian properties e.g. coordination failures and the possibility of path-dependent multiplicity of growth trajectories which are far and beyond Schumpeterian concerns.

In this short essay, we shall illustrate this point with reference to some of Stiglitz works, out of many, linking them with significantly overlapping contributions from the evolutionary camp. We group them by two major themes, namely, the consequences of learning and dynamic increasing returns, and "Keynesian" coordination failures with the ensuing possibility of multiple growth paths, fluctuations, small and big crises.

2 The "Schumpeterian" Stiglitz

Learning and in particular technological learning is at the core of the interpretation of why for the first time in human history per-capita income started to grow exponentially since the Industrial Revolution, first in England and later in other parts of the globe. And learning is indeed at the core of the analyses of Classic thinkers, including Adam Smith and Malthus.

However, as Chris Freeman (1982) noted, since the Classics, little progress has been made for almost two centuries in our understanding – both empirically and

theoretically – of the ways new technological knowledge has been generated and of its economic impact. Karl Marx and Joseph Schumpeter stand out as major exceptions, but they were sort of mavericks in the economic discipline. The importance of technological change only reappeared almost by default, in Bob Solow's analysis of growth dynamics in the 50s.

Since then, major advances have been made toward the understanding of what happens "inside the black-box" of technology – using the felicitous expression of Nate Rosenberg. The huge advances in the interpretation of the evidence are reviewed in Dosi and Nelson (2010). Here we restrict ourselves to the theory side, pioneered by the explorations of the properties of technological knowledge, and its augmentation by Nelson (1959), Arrow (1962a), Arrow (1962b) and indeed Atkinson and Stiglitz (1969).

Let us focus on two fundamental properties of technological learning, namely (i) its *cumulativeness*, and (ii) its *locality* in some knowledge space, at least. Both are quite straightforward.

Individuals and organizations augment their knowledge by building, refining, modifying what they already know. Trivially, one learns the Calculus II course more easily if she has already mastered Calculus I program. And most likely there are *dynamic increasing returns* in the process. Advances in knowledge tend to be multiplicative. Indeed, such property of technological learning is overwhelming documented in the literature on the empirics of technological innovation. This applies to whole technologies and indeed to individual firms.

Together, learning is *local*. Trivially, if you learn about mathematics you do not learn about football playing: on the contrary, learning about the former might make you neglect the latter. Even nearer to our technological concerns, learning about the production and/or use of an electromechanical lathe might well be uncorrelated (or even anti-correlated if attention is selective) with learning on say, CAD/CAM machinery.

Both points are strongly made by Atkinson and Stiglitz (1969), which could be taken indeed as "general theorem on the impossibility of convex production costs", and as a consequence, as demonstration on the generic existence of multiple equilibria, or, more broadly, of no equilibrium at all (see below).

Consider Figure 1 from Atkinson and Stiglitz (1969). Suppose that in some Paradise Lost, humans were originally endowed with the proper techniques as assumed in any micro manual, as depicted by the activities B-A-C. Suppose also that, given the incumbent relative prices, say, the tangent to point A, Adam and Eve choose technique A. It happened, however, that for known reasons, they got kicked out of Paradise, and, as a consequences, they were also made less than omniscient in their technical knowledge. They had to learn locally thereafter, so for example, given the initial equilibrium technique A at the time of their deportation, they had to learn just in its neighbourhood, and got, say to A'.

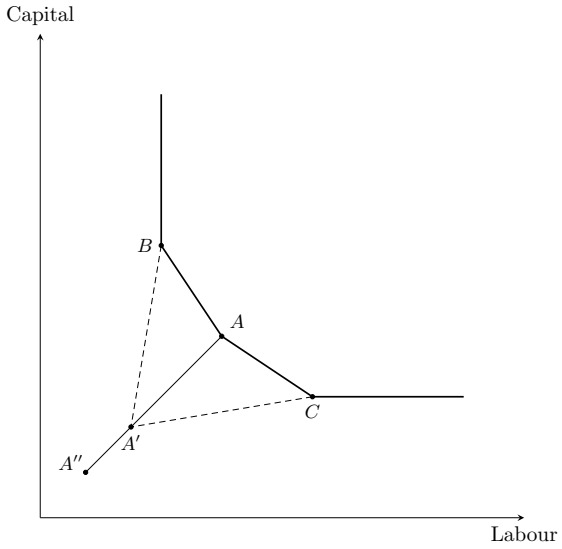

Figure 1: From ancestral convex cost functions to non convexities and technological trajectories. Source: modification upon Atkinson and Stiglitz (1969), fig. 3.

As emphasized by Atkinson and Stiglitz (1969), note that learning does not move the whole isoquant but just introduces a new technique superior to the old one *irrespectively of relative prices*. Suppose that the process went on and Adam and Eve searched in the neighbourhood of A', finding A". The moral of the story is indeed that learning turned out to occur along *technological trajectories* both in the space of input coefficients and of output characteristics (Dosi, 1982).

A *first* major consequence is *path-dependence*, and thus the importance of history in selecting particular technologies or variations thereof. The adoption of the keyboard QWERTY is possibly the most famous example (David, 1985) but the property is shared by all cases where dynamic increasing returns are present (see Arthur et al., 1983 and Dosi et al., 1994 for formalizations based on Generalized Polya Urns).

In an nutshell, consider the case of two competing technologies A and B. Let x and $(1-x)$ be their "initial" shares among adopters and the adoption process be sequential. Let $f(x)$ be the probability of adoption of the $n-th$ adopter. If the choice function is positively dependent on the share of past adopters, as in Figure 2, due say, to network externalities or technological-specific learning by doing, then, under dynamic increasing returns, one may well attain a lock-in into technologies which are Pareto-dominated (see David, 1985, Arthur, 1989, Dosi et al., 1994, Dosi and Kaniovski, 1994; and this is also an implication of Stiglitz and Greenwald, 2014).

Second, and relatedly, learning-by-doing is a general property of individual firms,

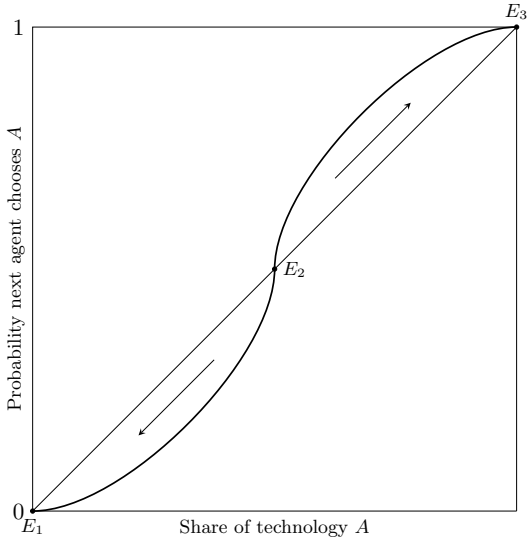

Figure 2: Competing technologies. Source: Arthur et al. (1983).

whole industries and economies (see Stiglitz and Greenwald, 2014 for an impressive analysis across all three levels, and also Cimoli et al., 2009).

Third, micro heterogeneity is a ubiquitous consequence of firm-specific idiosyncratic learning, on every dimension one is aware of – ranging from productivities to propensity to innovate, profitability, growth rates, etc. (for some review of the literature see Dosi and Nelson, 2010 and Syverson, 2011).

Joe is well aware of that, as repeatedly remarked also in the cited tour-de-force on learning economies (Stiglitz and Greenwald, 2014). Yet, it is still one of the less formalised intuitions in Joe's work, and in our view, this entirely goes to Joe's merit, fully aware as he is, that any reasonable formalization of heterogeneity implies an explicit acknowledgement of some sort of disequilibrium dynamics. Short of that, Joe has always masterly used max-cum-equilibrium assumption as a sort of *a fortiori tool*: "I show you properties which hold *even* under such far-fetched assumptions, which would apply, *much more so*, under more realistic set-ups". Or, putting the other way round, we are not aware of any Stiglitz contribution attempting to rationalize micro heterogeneity as an equilibrium phenomenon: in that he has stayed far away from the "Counter-Reformation tide" which has recently tried to marry innovation and micro heterogeneity with some industry level (or General) Equilibria (examples among many are Melitz, 2003 and Acemoglu, 2015). More generally a good deal of the recent literature in industrial economics, finally aware of micro heterogeneity has restlessly attempted to build Ptolemaic epicycles to reconcile it with the Becker imperative cited above. Joe never had anything to do with it.

Fourth, Joe Stiglitz, together with one of the giants of the contemporary eco-

nomic discipline, Ken Arrow, have forcefully pointed out one of the most devastating implication (for the standard theory, of course!) of information/knowledge and learning taken seriously: as already mentioned, non-convexities are everywhere, and with that, multiplicity of equilibria/growth paths or even no equilibrium at all.

As discussed in Stiglitz (2000), while Economics of Invention and Innovation is meant to analyse the process of creation and appropriation on *new knowledge*, the Economics of Information is meant to study the influence of *asymmetries in information* when new products, processes, behaviours emerge. Both theories recognise a limited scope for prices as means to convey information and for price competition to shape economic dynamics.

The known properties of information (its non-rival use, non-perishability, scale-freeness in its application etc.), when taken seriously, imply that the usual General Equilibrium results are not guaranteed any longer. In fact as discussed in Radner and Stiglitz (1984), whenever there are nonconvexities in the production function, discontinuities arise and information is naturally associated with nonconvexities because of the fixed cost of acquiring it. Then, the benefits of information increase with the scale of its production. But given nonconvexities, the existence of equilibrium is not guaranteed (see Rothschild and Stiglitz, 1976 and its manual-level acknowledgement in Mas-Colell et al., 1995). In fact, under nonconvex technologies, the supply curve is not equivalent to the marginal cost function and the intersection with the demand curve is not ensured. Arrow (1996) clearly states how the introduction of information in the production possibility set induces increasing returns:

> [c]ompetitive equilibrium is viable only if production possibilities are convex sets, that is do not display increasing return [...] with information constant returns are impossible. [...] The same information [can be] used regardless of the scale of production. Hence there is an extreme form of increasing returns. [Arrow, 1996 p. 647-648]

In fact, the existence of conventional General Equilibria is undermined in presence of innovation even neglecting increasing returns properties of innovation itself: see Winter (1971).

Indeed, in presence of information the very *existence of equilibrium* is undermined. Together, what is undermined is the miraculous equilibrating property of markets: as shown by the seminal contribution of Grossman and Stiglitz (1980) as knowledge diffuses among traders, traders themselves lose the incentive of bearing the cost of acquiring new information yielding the paradoxical result of *no trade under informationally efficient markets*. But, that implies that even when a notional equilibrium exists, nothing ensures that both the *first and the second welfare theorems* are satisfied. Competitive markets are not constrained Pareto efficient: some individuals could, in principle, be made better off without making anyone worse off. The economy cannot be efficient decentralised (II Welfare Theorem) whenever

welfare effects are present and the standard separation of equity and efficiency does not hold – the Coase Conjecture on the irrelevance of the distribution of property rights (see also Shapiro and Stiglitz, 1984 for a labour market application of the latter results).

Unfortunately, the Arrow/Stiglitz message is still largely neglected in most of the current theoretical practice, and worse, especially among young scholars, whose urge to publish well and quickly blinds them from exploring more daring routes which nonetheless are more respectful of both incumbent theorems and incumbent evidence.

The argument so far has been made on the full equivalence between technological knowledge and sheer information. However, also an exploration of the differences between the two is crucial and bears far reaching implications (much more in Dosi and Nelson, 2010). In the perspective of "knowledge equal information" one is inclined to focus on the links between patterns of *distribution of information* and the ensuing *incentive* problems. Conversely, in the perspective of Economics of Knowledge and Innovation the focus tend to be on the role of individual and especially organizational *capabilities*: organizations are not seen primarily as collection of contracts for which one should design the right scheme of incentives, in order to align e.g. manager and worker interests, but they are the results of practices, norms, behaviour, unwritten conducts meant at "doing something", and learning has to do with improvements thereof.

The two perspectives are far from being mutually exclusive, but to date, little dialogue has been going on. Indeed, putting it emphatically, one badly needs Stiglitz and Greenwald (2014) meeting Nelson and Winter (1982), and vice versa.

3 The "Keynesian" Stiglitz

Joe Stiglitz is deeply and genuinely Keynesian. However, *formally* Stiglitz is largely a *supply side* theorist. How come?

Well, in our view, it is the virtuouso of Joe's "a fortiori epistemology" mentioned earlier. With information taken seriously, even if with only two functionally or informationally different agents, "quasi-equilibria" or, as Joe puts it, set-ups with an "equilibrium amount of disequilibrium" (Stiglitz, 2000) generally arise, characterised by e.g. efficiency wages and involuntary unemployment; the impossibility of efficient markets; credit rationing; systematic underinvestment in learning, etc. All properties whose identification led to a more than deserved Prize.

Take two of the best known results. On the labour market side, unemployment can be the result of the design of contracts whereby high efficiency wages are paid in order to make shirking not optimal for workers. However, if one accepts a standard production function as Shapiro and Stiglitz (1984) do – for rhetorical purposes we believe – when high wages are paid, labour demand turns out to be weak,

and vice versa. Under relatively low employment rates, whenever shirking workers are caught, they expect to be unemployed for long spells. As a result, they will not shirk, reaching a behaviour compatible with the objectives of the firm. But, non shirking wages are not consistent with full employment, hence a (*persistent*) equilibrium amount of involuntary *unemployment* will arise. Indeed, it is Marx put into asymmetric information shoes.

Similarly, in Stiglitz and Weiss (1992), whenever both asymmetric information and adverse selection are present, credit rationing equilibria are likely to arise. The chosen/offered contracts are the *equilibrium one* because they satisfy a Nash condition: nobody increases her utility or profit by deviating from the chosen equilibrium contract. But, of course, under the equilibrium contracts, market clearing does not occur: in this case a persistent amount of credit rationing will be observed, so that excess demand for credit will be the norm, not the exception.

Notice that these and many other Stiglitzian results are *not* obtained as "frictions" vis-à-vis the standard GE model. It is not, for example, that involuntary unemployment stems from some lack of "flexibility" on some markets. That is, nominal (or less often) real rigidities, typically on the labour market, but sometimes also in the product market are by no means the cause of the "bad" equilibria. In this Joe is anything but a good-hearted ante-literam "New Keynesian" DSGE guy.

On the contrary, the foregoing properties come from *structural* features of contemporary economic systems, while more "flexibilization", that is attempts to render the world more akin to GE may well make things in the aggregate *worse*.

Together, capitalist systems are characterised by massive and huge *coordination failures* also in the demand side. Coordination failures are a clear-cut example of the absence of any isomorphism between the micro adjustments and the macro outcomes. A simple and vivid illustration, which in the literature has been almost ostracised, is Cooper and John (1988):

> Strategic complementaries are associated with the presence of "Keynesian features" such as multiple equilibria and a multiplier process [...]. When this occurs a *coordination failure* is present: mutual gain from an all-around change in strategies may not be realised because no individual player has an incentive to deviate from an initial equilibrium. [Cooper and John, 1988 pp. 442-443]

Consider an economy with many agents, wherein $e_{i,j}$ are the j strategies of the i agent (say, in terms of demand levels). Call $\bar{e}$ the action of the other agents, and $V_{i,j}(e_i, \bar{e})$ the pay-off function of agent i when strategy j is chosen. If $V_{i,j}(e_i, \bar{e}) > 0$ there are strategic complementaries and with that, also Pareto rankable equilibria. Under this set-up, demand shocks tend to be amplified: that is, they have *multiplier effects*. Such complementaries are a fundamental ingredient of a genuine Keynesian

world which allow, indeed *imply*, demand-driven or at least demand-propagated small and big crises (Stiglitz, 2016).

And in fact, such coordination hurdles are even stronger in presence of a financial sector which is not just a "veil" upon real dynamics: here Minskyian intuitions (the so called *financial fragility hypothesis*) significantly overlap with Stiglitzian ones: while for the former high interest rates signal euphoria in financial markets, as prelude of the emergence of Ponzi scheme traders, for the latter, high interest rates in capital markets induce both a *sorting effect*, reducing the proportion of low risk borrowers, and an *incentive effects*, inducing borrowers in using riskier technique (see Stiglitz and Weiss, 1992), then triggering the emergence of crashes.

The static concept of strategic complementarity (or more humbly, complementaries among many agents of whatever kind) can be rephrased in a dynamic perspective, as suggested by Cooper and Haltiwanger (1993). Dynamically, even the very simple Keynesian worlds of the foregoing kind are characterised by: positive comovements across agents; temporal agglomeration (agents have an incentive to synchronise discrete decisions); magnification and propagation of aggregate demand shocks.

Indeed, in our view, evolutionary Agent-Based Models are the Mecca where the conjecture of the "demand-side Keynesian Stiglitz" can be fully vindicated. In fact, the ABM route has been increasingly explored by Joe himself (see Caiani et al., 2015, Landini et al., 2015, Dosi et al., 2016a).

In this perspective, let us flag some of the results from Dosi et al. (2010) to Dosi et al. (2016b) which can be robustly shown as emergent properties out of the interaction of heterogeneous agents. Quite remarkably, *all* the properties inherently linked with macroeconomic externalities listed in Cooper and Haltiwanger (1993) emerge in such "Schumpeter meeting Keynes" (K+S) family of models, and many more as shown in Table 1.

Another profoundly Keynesian proposition, offered by Joe, concerns the perverse effect of "making the word more alike the theory":

> "The problem that Keynes recognized was that wages can be *too flexible*. Indeed, when wages fall, people's income falls and their ability to demand goods falls as well. Lack of aggregate demand was the problem with the Great Depression, just as lack of aggregate demand is the problem today. Imposing more wage flexibility can result in exacerbating the underlying problem of lack of aggregate demand". [Stiglitz, 2013 p. 10]

Again, such a proposition can be naturally vindicated on the grounds of our K+S modelling platform with an explicit interaction between microfounded labour market dynamics and aggregate demand. So, in Dosi et al. (2016c) we show that more flexibility in terms of variations of monetary wages and labour mobility is prone to induce systematic coordination failures, higher macro volatility, higher

Firm level SF	Aggregate level SF
Skewed firm size distribution	Endogenous self-sustained growth with persistent fluctuations
Fat-tailed firm growth rate distribution	Fat-tailed GDP growth rate distribution
Productivity heterogeneity across firms	Relative volatility of GDP, consumption and investment
Persistent productivity differentials among firms	Cross-correlation of macro variables
Lumpy investment rates at firm-level	Pro-cyclical aggregate R&D investment
Firm bankruptcies are counter-cyclical	Cross-correlations of credit-related variables
Firm bad-debt distribution fits a power-law	Cross-correlation between firm debt and loan losses
	Banking crises duration is right skewed
	Fiscal costs of banking crises to GDP distribution is fat-tailed
	Persistent unemployment
	Wage curve
	Beveridge curve
	Okun curve
	Separation and hiring rates volatility
	Matching function
	Productivity, unemployment and vacancy rates volatility
	Unemployment and inequality correlation

Table 1: Stylised facts matched by the K+S family of models

unemployment, higher frequency of crises. In fact, it is precisely the downward flexibility of wages and employment and the related higher degrees of inequality – as profitable as it might be for individual firms – that lead recurrently, *as system-level emergent properties*, to small and big aggregate demand failures. Conversely, the model shows that seemingly more rigid labour markets and labour relations are conducive to *coordination successes* with higher and smoother growth.

Finally, a major genuine Keynesian – and, even more so Kaldorian – theme in Joe's work has been the importance of income distribution in terms of growth patterns. While on somewhat more arcane debates like the famous one on "capital theory" he has been relatively agnostic or mildly for the American side of the controversy, on the short- and long-term relevance of distributive dynamics he is certainly on the side of Cambridge, England, and beyond, with a sensitivity to the added deep social damages of inequality almost unique among economists: see Stiglitz (2012), Stiglitz (2015) and Gallegati et al. (2016).

4 Stiglitz and the standard Paradigm

As known, for more then three decades after WWII there were more or less three tenets of an uneasy intellectual compromise which dominated the economic disci-

pline, based on the division of labour between (i) microfounded general equilibrium models, (ii) short run macroeconomics, and (iii) growth theories.

4.1 The Micro

The coordination research program, as known – with its early roots more in Leon Walras than in Adam Smith – culminated into the Arrow-Debreu-Meckenzie General Equilibrium Model, indeed an elegant and institutionally very parsimonious demonstration of the possibility of equilibrium coordination amongst decentralized agents.

In fact, subsequent, basically negative, results have shown, *even in absence of innovation*, the general impossibility of moving from existence theorems to the implicit dynamics captured by proofs of global or local stability – loosely speaking, the ability of the system, when scrambled, to get back to its equilibrium state. Quite the contrary, even empirically far-fetched processes such as tatonnements (with the omniscient Walrasian auctioneer proclaiming equilibrium transaction when he sees them) in general do not converge.

Even more powerfully, some of the founding fathers of GE themselves have shown that existence does not bear any implication in terms of the shape of excess demand functions (this is what the Sonnenschein-Mantel-Debreu theorem implies). Putting it shortly, in general forget even local stability.

Conversely, any careful look at the toll requirements which sheer existence entails – in terms of information and rationality – highlights the extent to which GE is a beautiful but extremely fragile creature, certainly unable to withhold the weight of any account of the dynamics of the economy as a whole and even less so to offer any serious microfoundation to transforming economies undergoing various forms of innovation.

In fact – even forgetting search and innovation – it is quite ill-founded to claim that standard GE models can be an account, no matter how utterly stylized, paraphrasing Adam Smith, of why the butcher offers meat day after day more or less at the same price, mainly motivated by self-interest. If the conditions – in terms of rationality, characteristics of the exchanges, etc. – required in reality were even vaguely as stringent as those required in GE models, probably no one would ever offer meat or whatever else.

In any case, that was the Micro for the standard paradigm.

4.2 The Macro

Then there were basically two Macros. One was (equilibrium) growth theory which largely lived until the end of the '70s a life of its own. While it is the case that models à la Solow invoked maximizing behaviours in order to establish equilibrium input intensities, no claim was made that such allocations were the work of any represen-

tative agent, in turn taken to be the synthetic version of some underlying General Equilibrium. By the same token, the distinction between positive (i.e. descriptive) models, on the one hand, and normative ones before Lucas and companions, was clear to the practitioners. Finally, in the good and in the bad, technological change was kept separate from the mechanisms of resource allocation: the famous Solow residual was, as well known, the statistical counterpart of the drift in growth models with an exogenous technological change.

Together, in some land between purported GE microfoundations and equilibrium growth theories, lived for at least three decades a macroeconomics sufficiently Keynesian in spirit and quite neoclassical in terms of tools. It was the early neo-Keynesianism – pioneered by Hicks, and shortly thereafter by Modigliani, Patinkin and a few other American Keynesians – which Joan Robinson contemptuously defined as "bastard Keynesians". It is the combination of short-term macro (fixed prices) IS-LM curves – meant to capture the aggregate relations between money supply and money demand, interest rates, savings and investments – with the Phillips curve on the labour market, which yields the AS-AD aggregate equilibrium.

The quick Keynesian synthesis presented by Hicks had been offered as a seemingly sensible and parsimonious account of Keynes's General Theory – cutting out all the detours and qualifications. In fact, it was its most rudimentary general equilibrium translation with an implicit representative agent and various sort of frictions added up. However, it took almost half a century for the American Macro Mainstream to further sterilize, reformulate, refine the neo-Keynesian apparatus and baptise it as the Dynamic Stochastic General Equilibrium (DSGE) model.

4.3 *Take no prisoners*: the Lucas Revolution

What happened next?

First, New Classic Economics (even if the reference to the Classics cannot be more far away from the truth) fully abolished the distinction between the normative and positive (i.e. descriptive) domains – between models à la Ramsey vs models à la Harrod, Domar, Solow, etc. (notwithstanding the differences amongst the latter ones).

In fact, the striking paradox for theorists who are in good part market fanatics is that one starts with a model which is essentially of a benign, forward-looking, central planner, and only at the end, one claims that the solution of whatever inter-temporal optimization problem is in fact supported by a decentralized market equilibrium.

The reasoning could be much easier for this approach if one could legitimately summarize a genuine general equilibrium (that is with many agents, heterogeneous at least in their endowments and preferences) into some representative agent. But the fact is that one cannot (Kirman, 1992). By doing that nonetheless, one simply

assumes away as solved by construction the coordination problem. Notwithstanding the name, there is very little of General Equilibrium in the DSGE models, and earlier antecedents. All that irrespectively of the trust in the ability of GE to capture the essentials of the coordination hurdles, mentioned above, in market economies, which is very low indeed.

The representative agent holds all the micro and macro on its shoulder, folding together the expectation-augmented Phillips curve (for the labour market), the Euler equation (for the inter-temporal allocation between consumption and saving, and leisure and working-time), and finally the Taylor rule (for monetary policy), in order to build DSGE models.

Second, but relatedly, the last three decades have seen the disappearance of the distinction between long-term and short-term – with the latter as the locus where all frictions, liquidity traps, Phillips curves, some (temporary) real effects of fiscal and particularly monetary policies, could all hazardously survive. Why would a representative agent be able to solve sophisticated inter-temporal optimization problems from here to infinity display frictions and distortions in the short-run? We all know the outrageously silly propositions, sold as major discoveries, associated with rational expectation revolution, concerning the ineffectiveness of fiscal and monetary policies and the general properties of markets to yield Pareto first-best allocations. In this respect, of course, it is easier for that to happen if the market is squeezed into a representative agent: in that case, coordination and allocation failures would involve serious episodes of "schizophrenia" by that agent itself.

It is easy to appreciate the "light-years" distance between Stiglitz perspective and the standard paradigm, especially in its more extreme version. Even if Joe generally assumes maximazing agents, the system-level properties he identifies are more the outcome of structural features of the *distribution of information among types of agents/technique of production*, rather than the outcome of rational agents optimizing over an inter-temporal horizon.

5 Alternative Paradigms: Keynes meeting Schumpeter

What about the alternatives? Well, Joe's work has been a bastion throughout, suggesting an *alternative economic theory* which never interpreted any difference between observed dynamics of any economy and the prediction of the "economic model" as frictions, rigidities, etc. but rather as properties of the inner working of information-rich, innovating, capitalist systems.

On a parallel track, evolutionary, Schumpeterian-inspired models went a long way in interpreting processes of endogenous innovation-driven growth. The literature spurring from the seminal Nelson and Winter (1982) has been impressively blossoming.

All this notwithstanding, these two alternative streams rarely interacted with each other. Worse than that: as a significant contributor of one of the latter stream, one of us (G.D.) easily admits that evolutionary theorists have tended to be far too "Schumpeterian", in their neglect of any Keynesian coordination hurdle in both the short- and the long-run.

Certainly, here there is no betrayal of Schumpeter: his book review of Keynes' *General Theory* (Schumpeter, 1936) sounds, more often than not, as a note by a grudging, solid but not-too-insightful, Chicago-style Ph.D student. So, after suggesting that Keynes' *General Theory* "expresses forcefully the attitude of a decaying civilization" and "invites sociological interpretation in the Marxian sense" (p. 792), he shows no understanding at all of involuntary unemployment, whose notion is considered by Schumpeter equivalent to "artificial definitions which [...] produce paradoxical-looking tautologies" and, relatedly, of the relation between demand for labour and aggregate demand:

> The definition of involuntary unemployment, page 15, may serve as an example. Taken literally (which of course would be unfair to do) it would mean that there is no practically conceivable case in which workmen are not partially unemployed by definition. For if prices of wage good rise a little, other things being equal, it is clear that both the demand for, and the supply of, labor will increase under competitive conditions, the latter at least as long as the flexibility of the marginal utility of income to the workmen is what present statistics lead us to believe. [*sic*] [Schumpeter, 1936, footnote 1, p. 792]

Indeed, well in tune with the later "neo-Schumpeterian" perspective, he hand-waves us "the most powerful propeller of investment, the financing of changes in that production functions" ridiculing demand-based multiplier and investment accelerators, as " having no grater practical importance than a proof that motor cars cannot run in the absence of fuel" (p. 793).

Two outstanding exceptions, focusing on the crucial interactions between coordination-demand generation, on the one hand, and innovative dynamics, on the other, are Christopher Freeman on the one side of the Atlantic, and Joe Stiglitz on the other, despite different but quite complementary interpretative lenses.

Here, let us flag the pioneering emphasis of the contribution by Joe to the World Conference of the International Schumpeter Society in Japan (Stiglitz, 1994). His point counters any rough Schumpeterianism as it can: *there are positive feedbacks between levels of aggregate activities and innovative search.* To reinforce the point, Chris Freeman would have added that there are also powerful interactions between aggregate demand and *diffusion* of innovations. Indeed both Stiglitz and C. Freeman

agree that alone neither Schumpeter nor Keynes are enough (see Freeman and Soete, 1994).[1]

Whenever one abandons the unfortunate idea that the macro economic system is held up to some mysteriously stable, unique equilibrium path, it could well be that *negative demand shocks exert persistent effects*, because less aggregate demand entails less innovative search, which in turn entails less innovation stemming from technological shocks:

> [During recessionary phases], typically firms also reduce their expenditures in R&D and productivity-enhancing expenditures. The reduction in output reduces opportunities to "learn by doing". Thus, the attempt to pare all unnecessary expenditures may have a concomitant effect on long-run productivity growth. In this view, the loss from a recession may be more than just the large, but temporary, costs of idle and wasted resources: the growth path of the economy may be permanently lowered. [Stiglitz, 1994, p. 122]

Despite the 2008 crisis, many economists continue to believe in some version of the model underlying example A in Figure 3: the economy is bound to spring back, with no permanent loss to its long-run equilibrium rate of growth. The econometric side of this belief is the Frisch-like idea of the economy as a "pendulum", responding to exogenous shocks.[2] In this perspective, it seems almost a miraculous that in the empirical literature one recently finds impulse response function implying multipliers significantly grater than one: as such, we suggest, a witness of the depth of the current crisis (see, Blanchard and Leigh, 2013).

However, a small but significant minority of the profession has been forced by the evidence to buy case B in Figure 3: recession-induced output losses are permanent, and even if the system goes back to the pre-crisis *rates* of growth, that implies an exponentially growing *absolute level gap*. Moreover, as discussed in Stiglitz (1994), imperfect capital markets and credit rationing may exacerbate the effect of recessions, hampering the recovery.

But, more than that, recurrent negative demand shocks implied by austerity policies or labour market flexibilization, might well yield *lower long-term rates of growth* (see Figure 4): this is what we show in Dosi et al. (2016b) and in Dosi et al. (2016c). In the latter scenario, presented in Figure 4, the growth trajectories diverge, implying a decaying long run rate of output growth.

[1] See the latter contribution for a more general argument on the relationship between technological innovation, aggregate demand and employment.

[2] For an enticing reconstruction of the discussion between Frisch and Schumpeter on the "pendulum" metaphor, see Louca (2001).

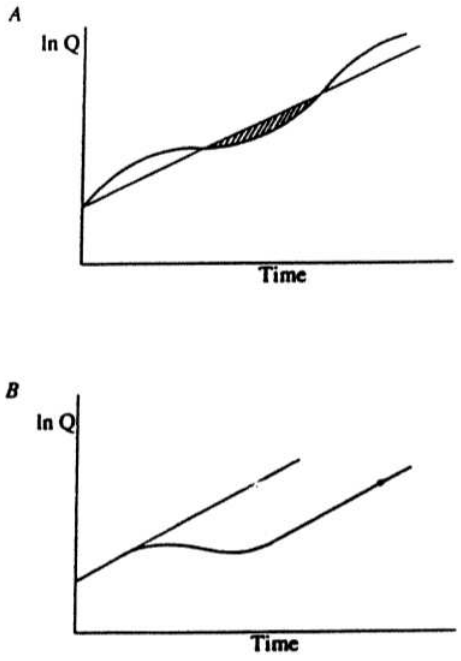

Figure 3: Positive feedbacks between levels of aggregate activities and innovative search: short-run (A) and long-run (B) effects of recessions. Source Stiglitz (1994), p. 123.

6 Conclusions: building bridges

This short essay has been mainly focused on the links between the research program of the Economics of Information, to which Stiglitz has offered seminal contributions and the one of Economics of Knowledge and Innovation (more broadly, Evolutionary Economics). We tried to highlight the bridges and overlappings between the two, including the very emphasis on knowledge-information and the implications for "learning economies". In environments populated by multiple learning and interacting agents, coordination hurdles are likely to emerge together with feedback mechanisms linking crises driven by shortages in aggregate demand, and changing intensity of innovative search: hence the possibility of persistent losses in the levels and/or rates of growth of output, giving rise to multiplicity of growth trajectories. The analysis of these properties of the economy represents a powerful file rouge between the Economics of Information and Evolutionary Economics.

Stiglitz (2000) proposes two priority areas of investigation common both to the Economics of Information and the Economics of Knowledge, namely:

> But perhaps the most important advances will be in two areas [...] on

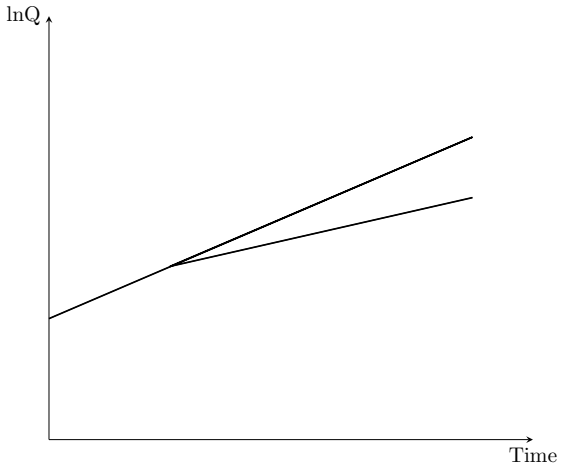

Figure 4: Divergent growth trajectories: permanent losses in output growth rates. A stylised version from Dosi et al. (2016b) and Dosi et al. (2016c).

> *dynamics* and on [...] *organizations*, on how and how well organizations and societies absorb new information, learn, adapt their behaviour, and even their structures; and how different economic and organizational designs affect the ability to create, transmit, absorb, and use knowledge and information. [Stiglitz, 2000, p. 1471]

In our view, between the two domains of Economics of Information and Knowledge there are also largely unexplored complementaries in the modelling approach. Bridges between "reduced forms", low-dimensional models, often amenable to analytical solutions, on the one hand, and fully fledged Agent-Based evolutionary models with explicit links between micro *interactions* and macro *emergent properties*, on the other, are markedly necessary. They hold the promise to allow a deeper understanding of worlds where "Keynes meets Schumpeter" and well beyond.

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