New Combinations :Taking Schumpeter's concept serious

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Abstract

Schumpeter's idea that innovations can be described as ***new combinations*** often is understood as a mere metaphor and slight generalization of what he considers as the characterizing feature of entrepreneurship. The main argument of this paper is that more and deeper issues are involved in the concept of new combinations than is commonly understood. Moreover, a proper understanding of these issues would not only enhance our knowledge about observed innovation processes in economic life, it might reveal several properties common to creative processes in general.

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Introduction

It has to be observed that the notion of new combinations immediately implies that there already exist elements which are combined anew. To determine what these elements are and how their properties enable and restrict possible combination clearly is not a trivial task. In chapter 1 of the paper a systematic approach to this analytic challenge is described. For any area of innovation it should provide a set of combinable, though not necessarily smallest elements. Though linkages between elements are surely restricted, in many cases the number of elements still is so large that any fully enumerated search through al combinatorial possibilities is finite but untreatable. This evidently is the point where another famous concept of Schumpeter enters the scene: his ‘animal spirits’ of the entrepreneur provide a stylish short-cut to circumvent - not to solve - this problem.

Chapter 2 of the paper presents another, more recent formal treatment of the re-combination problem, namely genetic algorithms. Indeed, this extremely successful algorithmic device that was built akin to observed biological selection processes is nothing less than a surprising implementation of the concept of ‘new combinations’. The basic elements just have to be translated into bit strings, i.e. symbols that represent them. The secret of the success of genetic algorithms, and at the same time its weakest point is the assumption of a given and well-defined fitness function – in some sense the opposite extreme to Schumpeter’s metaphysical ‘animal spirits’. But as already was the case with the latter an exogenously given fitness function seems to circumvent the re-combination problem rather than to solve it. The almost costless evaluation of this function lets the original problem degenerate into a simple, algorithmic search problem. A search problem that, of course, genetic algorithms are exceptionally well suited to solve. Still a lot can be learned from genetic algorithms with respect to re-combination. Not the least is knowledge about the necessity and quantitative amount of random elements in re-combination. The chapter thus provides a brief introduction into a basic toolbox of evolutionary modeling, defines basic concepts like selection, variety and growth, presents the skeleton of genetic algorithms and in the end incorporates central questions elaborated in chapter 1 into this framework.

Finally chapter 3 of the paper inspects several research areas that have produced empirical material on creative and innovative human activities. Since the preceding chapters identified the missing evaluation possibilities for trial combinations as crucial, it is only straightforward to take a closer look at existing empirical solutions to learn something about their general features.

1 – Some semantics for set theory, or 'who combines what'.

The expression 'new combination' makes only sense if it is contrasted with the background of elements currently bound in old combinations. The concept of combination itself immediately implies a kind of set theoretic view of process elements being members of a larger overall process. The idea that in the course of time elements from different old overall processes might be copied and combined to form new overall processes adds dynamics to the usually static set theoretic framework. Such a theory of development aims at two goals: It should be able to explain how old combinations came about in the past in the first place, and it should suggest some hypothesis how and where contemporary new combinations will emerge.

Note as a side issue that Schumpeter's distinctive view that his theory of development is a contraposition to his own early work in the Walras-Jevons-Menger tradition, his 'Das Wesen und der Hauptinhalt der Nationalökonome' [Schumpeter, 1908 (1970)], is fully justified. Of course, later formalization of Walrasian systems showed that set theory formidably lends itself to the description of possible exchange acts of owners (sets) of commodities (elements) with endogenous relative prices and exogenously given preferences of owners. But till today the major thrust of this body of theory, despite its formal sophistication concentrates on comparative static of such systems; entry and exit of commodity owners is mostly left to demography and business demography. Yet Schumpeter was the first to emphasize that it is exactly the dynamic part of the story that not only explains history, i.e. most of the essential economic developments since the industrial revolution, it is also the necessary background to understand the empirical content of the static part at all, i.e. the latter is logically dominated by the dynamics of development. Indeed it is current research in evolutionary economics that is on its way to attract more and more mainstream economists for precisely these reasons.

The concept of 'new combinations' thus opens up a dynamic view not only on the dimensions of the technology space and the preference space of existing economic agents, it also allows for a reshuffling of the dimensions of the agents' space itself. The latter idea is the source of most of the evolutionary approaches to institutional economics.

In a very direct form[1] this line of argument can be found in 'Business Cycles' [Schumpeter, 1939 (1969)]. First ***economic evolution*** is defined:

'… we immediately realize that innovation is the outstanding fact in the economic history of capitalist society or in what is purely economic in that history, and also that it is largely responsible for most of what we would at first sight attribute to other factors. … The changes in the economic process brought about by innovation, together with all their effects, and the

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[1] The reason for the use of the formulations found in Schumpeter's later work rather than the ones found in his earlier text [Schumpeter, 1911 (1964), p.99] is the more systematic treatment of the former.

response to them by the economic system, we shall designate by the term Economic Evolution.' [Schumpeter, 1939 (1969), p.61]

In short, ***it is innovation that drives the dynamics of the interdependent economic evolution***. Then the concept of innovation in capitalist firms is defined in two different, but complementary ways:

'Therefore, we will simply define innovation as the ***setting up of a new production function***. This covers the case of a new commodity, as well as those of a new form of organization such as a merger, of the opening up of new markets, and so on. … we may express the same thing by saying that innovation combines factors in a new way, or that it consists in carrying out ***New Combinations***.' [Schumpeter, 1939 (1969), p.62] (Emphasis added by the authors)

So here the magical term appears. And Schumpeter immediately adds a third characterization of innovation that adds a further dimension – the monetary system - but cannot localize where innovation actually appeared:

'We can define innovation also with reference to money cost. … Whenever a given quantity of output costs less to produce than the same or a smaller quantity did cost or would have cost before, we may be sure, if prices of factors have not fallen, that there has been innovation somewhere.' [Schumpeter, 1939 (1969), p.63]

For capitalist firms such a monetary indicator can be used to discover innovation, though its initiator might not be a member of the observed industry. In other words, it is the ***well-developed monetary system*** that spreads the fruits of local innovations over the whole broad path of economic evolution.

In discussing in the sequel the modus operandi of innovation another important idea pops up:

'…, we shall in general argue as if ***every innovation*** … were ***embodied in a New Firm*** founded for this purpose. … Most new firms are founded with an idea and for a definite purpose. The life goes out of them when that idea or purpose has been fulfilled or has become obsolete or even if, without having become obsolete, it has ceased to be new. That is the fundamental reason why firms do not exist forever. Many of them are, of course, failures from the start. ***Like human beings, firms are constantly being born*** that cannot live. Others may meet what is akin, in the case of men, to death from accident or illness. Still others die a "natural" death, as men die of old age. And the "natural" cause, in the case of firms, is precisely their inability to keep up the pace in innovating which they themselves had been instrumental in setting in the time of their vigor. No firm which is merely run on established lines, however conscientious the management of its routine business may be, remains in capitalist society a source of profit, and the day comes for each when it ceases to pay interest and even depreciation.' [Schumpeter, 1939 (1969), p.69] (Emphasis added by the authors)

In this paragraph Schumpeter not only identifies firms with their modus vivendi, i.e. innovation, he even generalizes the characteristics of these entities by the use of biological metaphor! The evolution of the firm structure starts to look "natural" in a way easily to be amenable to generalized evolutionary modeling.
Since innovation - new combinations - are the central elixir of life of these entities one last distinguishing characteristic has to be introduced: innovations and inventions are different things. In Schumpeter's words:

'… the making of the ***invention and the carrying out of the corresponding innovation are two entirely different things***. … Personal aptitudes – primarily intellectual in the case of the inventor, primarily volitional in the case of the businessman who turns the invention into an innovation – and the methods by which the one and the other work, belong to different spheres.' [Schumpeter, 1939 (1969), p.60] (Emphasis added by the authors)

This clear-cut picture of the process of economic evolution, of its carriers and their central function - in Schumpeter's own view, and despite his sidestep to a biological metaphor - refers to a well-defined historical episode, namely 19th century capitalism till World War I. The interwar period made Schumpeter already believe that this type of capitalism had finished its historical life-cycle (compare [Schumpeter, 1939 (1969), p.71]).

The simple formula - historical task (innovation) needs a "natural" carrier (firm) that internally is organized by a leader (entrepreneur) – could be observed not to work any more in the 20th century. Something new was about to happen, Schumpeter sensed (compare [Schumpeter, 1942 (1980); 1947 (1987) p.193]). But still the central metaphor was valid: From which broken elements will new combinations be formed?

It is therefore tempting to purify Schumpeter's vision of industrial capitalism, the one just sketched in the previous paragraphs, by transforming it into a more formal description. The aim, of course, is not to produce an adequate model for contemporary economic dynamics; the setting from which this vision was derived has vanished in the already distant past. The objective of this exercise (that will be presented in the next chapter) rather is to get some experience in the use of the toolset itself. To see where its strengths and where its shortcomings are. Only then transplantation, indeed a transcription of the framework can be envisaged – the object investigated always influences the language in which this investigation is carried out. A formalization of Schumpeter's vision of economic evolution therefore only is an effort to determine the starting point for the transcription.

2 – A toolbox for evolutionary arguments

The most important argument in Darwin's path breaking work on the origin of species is that the existing variety of species is the result of a long-run selection process. This nowadays seemingly simple idea summarized Darwin's observations during his exploratory journey to the Galapagos Islands [Darwin, 1836 (1997)]. The ingredients of this argument are two-fold: a set of individual members with different characteristics and an environment that in the course of time deletes members with unfavorable characteristics. Additionally the time structure that Darwin encountered on the Galapagos Islands proved to be an exceptionally clear-cut profile: Each island had been completely isolated for a long time, assuring long-run constant but for every island different environmental conditions. The adjustment of the species' members to their island's environment thus had a long time to run, with almost no influence on this environment taking place. Visiting different islands therefore enabled Darwin to study, i.e. to contrast, the respective adjustment processes.

To express this scenario more formally, assume that there are n different types of a species entering a new, unchanging environment. Assume further that selection in this environment consists of letting only one type survive to the next time period. If the carrying capacity of the island equals the number of entities, n, entering the island in period 1 – one entity per type, then figure 1 depicts the invasion process.

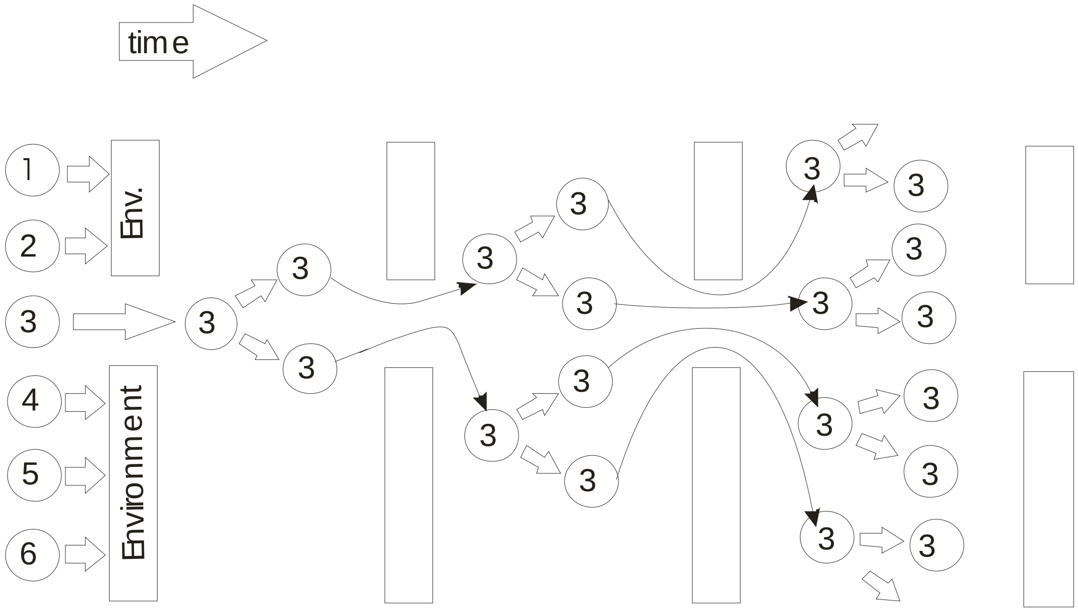

Figure 1: Selection in a stable environment

The environment restricts the growth process of certain types (number 1,2,4,5 and 6) that runs from the left to the right in figure 1. Since a strict binary survival gate for types is assumed only type 3 survives the first test. Then a growth process for the survivor sets in, in the example a doubling per period. Since the environment is stable the survival gate remains where it was, all selection appears in period 1, from then onwards the innate growth process of type 3 dominates population dynamics. The last phase finally starts when the capacity of the environment, the island, is reached and part of the offspring of the surviving type dies. In the example this appears in period 3, when two individuals out of an offspring of 8 exceed the capacity constraint of 6 and the two have to die. From then onwards phase 3 is characterized by a divergence between the potential growth rate of 100% and the actual growth rate of 0%; half of the individuals of each new born generation die[2].

This setting is almost as simple as the definition Herbert Simon writing almost a hundred years after Darwin gave:

‘The simplest scheme of evolution is one that depends on two processes; a generator and a test. The task of the generator is to produce variety, new forms that have not existed previously, whereas the task of the test is to cull out the newly generated forms so that only those that are well fitted to the environment will survive.’ [Simon, 1969 (1985), p.52]
Simon’s ‘generator of new forms’ takes place only as invasion of 6 new types in period 1, but on the other hand it is augmented by an innate growth process of types that does not produce new forms. The test consists also of a more narrow component, namely always the same rigid selection of the one surviving type; plus a constraint on the total number of individuals (independent of their types) that this environment is able to support.

Despite its almost trivial setting this archetype of evolution allows for some interesting observations and questions:

1. Consider the idea that the variety of types invading the environment might be variable. If the window of survival (type 3 in the example) is unknown to invaders, then the probability of invaders consisting only of one type to survive period 1 is very low. To be precise, with a window of size 1 and n possible types it would be $\frac{1}{n}$, whereas m invading types, $m \leq n$, would have a chance of $\frac{m}{n}$ that one of them passes to period 2. If survival in period 1 counts as a necessary condition for success of a species, then

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[2] Note that three distinct, sequential processes are involved in this example: an invasion of new territory, once arrived a selection process that sets in and modifies co-evolution of innate growth characteristics, and finally a capacity constrained that again modifies dynamics to conform to some upper limits of evolution.

variety of types certainly contributes to it: There is a positive relationship between the variety of invaders and the survival probability of the species they belong to[3].

2. As soon as a type has survived, the whole force of selection has vanished and only the innate growth rate limits the population explosion of the selected type. The speed of the conquest of the environment, how long it will take to reach full capacity, only depends on the growth characteristics of this single type. This second component of success of a species thus hinges on the features of the single types[4].
3. At least after an adjustment period till phase 3, the ***stability of the environment***, its feature of performing the same selection rule independent of time, ***is reflected in a stable reproduction and death process of just one monolithic type*** – or of no types at all. The initial stimulus of the invading species thus at best is transformed into a time profile of structural stability that looks very much like the one the environment showed before the invasion. Just one more type of a species has been added[5].
4. Finally one could ask the question where the species with variety came from. If all environments were always stable and therefore only produced monotype species then there never would have been a chance for a group with high variety to develop. As a matter of logic this leaves open only two ways out: Either the world we describe always consisted of this set of monotype environments and the assumed invasions never occurred, or the stability of environments concerns only a long time as compared to the adjustment process of phase 1 and 2. Of course, the scientific answer[6] is the second answer. But this implies that in between relatively long periods of environmental stability, there must always be periods of turmoil. And reappearing successive stages of stability and turmoil mean that there will be some kind of long-run periodicity. In other words the importance of time specifications, where stability always has to be understood as a short-run approximation within a long-run oscillation emerges as a logical consequence[7].

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[3] Note that the survival probability of a single individual does not change if it is part of an invading group with higher variety, it remains unchanged. This observation opens a view on one of the most prominent debates in evolutionary biology: ***knowledge about survival of the species is embedded in the group structure*** and need not be necessarily experienced or known by individuals (compare John Maynard-Smith's hawk-dove model, the textbook example for evolutionary game theory [Smith J. M., 1982]).

[4] A fractal approach to this problem is interesting: Interpret each single individual as a (micro-) 'species' of the individual features it exhibits. Its environment then evidently consists mainly of the original species within which it lives. For any small enough time slice a predominant co-evolutionary structure of species could then be determined. Interpretation of all living systems in that way enriches the understanding of the concept 'nature'.

[5] Speculation certainly would suggest that in the long-run periodically changing environments will force their invaders into oscillations.

[6] It is remarkable that this logical crossroad encapsulates the profound contradiction between an emphasis on evolution and the position of externally given species held by the church in Darwin's time. Darwin was very aware of this fundamental conflict and was rather afraid of provoking the church.

[7] As in the space domain a fractal approach to the time domain is looming in the background.

Turn now to some simple extensions of this archetype[8], which build on these remarks. Starting with the last one an obvious extension is to let the survival window move in the course of time. As a consequence any selected monotype species would be killed immediately. Turning the argument around this extreme vulnerability of monotype species makes it rather implausible that they have been selected in the first place. The really difficult question is: ***how does variation in a species emerge?*** The simplest, and in many respects most unsatisfactory answer came from the field of gene biology: There is random mutation on the gene level. A stochastic property, the radioactive fields surrounding genes is thought to be the ultimate cause of variation. Why this is an insufficient explanation of the observed evolution of living systems is evident even for researchers with a strong inclination to sociobiology: If a mutation of a single gene where favorable to a human individual the average chance that this mutation will occur in this individual would be about one to one billion! And then with some bad luck this advancement could even be destroyed by sexual reproduction[9]. In short, this type of improvement is much too slow to explain what has been observed as evolution on earth. Again turning the argument around, this small influence of mutation of random mutation can be interpreted as evolutionary favorable result: species with such small random disturbances on the gene level were actually selected.

A second type of more sophisticated variation could emerge if one starts with the assumption of ***periodically changing environments***. The immediate examples of such environments are the physical environments on earth changing with the season and with day and night. Imagine now that members of a species become different types due to their different adaptation speeds to the oscillations of the physical oscillations. Then it can easily be modeled that a certain variety of types will be selected by an evolutionary dynamics, e.g. the set of members whose adaptation frequency times a natural number gives exactly the frequency of the environment[10]. With respect to the third remark made above, this really provides a nice extension: Periodicity in the environment produces a structure of innate frequencies in the members of the species that mirrors this periodicity.

The ***big leap forward*** in the evolution of living system clearly comes with the possibility of ***anticipation***. And still no satisfactory theory explaining this evolutionary jump has been produced. It is known by many names and it roughly coincides with the emergence of

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[8] Stanley Metcalfe and his followers have developed and explored a different algorithmic archetype model that immediately uses business firms as entities. Though such a methodology is certainly more attractive for economists interested in specific questions in the area of competition policy and the like, it also bears the danger that easily imported concepts and ideas hide important, more essential problems (compare for example [Metcalfe J.S., 1998, pp. 40-103]). On the other hand, despite the differences in specification, Metcalfe clearly shares the broad perspective underlying our approach in this paper (compare [Metcalfe J.S., 2002]).

[9] For details on this argument see [Smith J. M., 1988, p.167].

[10] An elegant little model of this kind is provided by Paul Krugman [Krugman, 1996, pp.22-29]. He also gives the important hint that this feature is formally equivalent to a property of Fourier analysis.

conscious memory and self-awareness. Time and space, Kant’s fundamental dimensions, open up in the brains of animals, and later in those of humans.

In the context of the presented simple model, enriched by a periodically changing survival window, a correctly anticipating species evidently would let the chosen type follow this window. This outcome would have to assume at least two things: First, some central control of types that allows an immediate and complete switch from one type to the next type must exist. Second, the currently unfavorable types must somehow be preserved to reappear when they are needed again. These conditions clearly reshape the scope of interpretation of the model: Some kind of additional consciousness has to be injected on the level of the larger entity constituted by the individuals. There must be language to support anticipation and memory, and there must be transfer of the fruits of growth to those individuals that currently are not needed, but are anticipated to be important in the future.

An important consequence of these more sophisticated circumstances is that the elementary concept of ***diversity***, introduced above as a property of the invading set of individuals, now splits up into ***two different measures***:

(i) On the one hand there still remains the old measure that should give an idea about the variation of types in a set. This measure should reflect two ideas, namely that (a) variety increases if the share of types found in the set in the total number of possible types increases; and (b) that variety also increases if existing types are more uniformly distributed. A possible formulation of such a measure is what we call ***instantaneous diversity*** div:

$$div_t = \frac{x_t}{z_t} \cdot u(V_t) \qquad (1.1)$$

In this expression x is the number of types found in the species at time t, z is the number of all possible types of the species at time t, and u is a function that maps the distribution of actually found types, vector V, into the interval $[0,1]$, with uniform distribution corresponding to 1, which implies maximum instantaneous diversity as long as $x_t = z_t$.

One possibility of a function u is to use the share of the actual variance of vector V in the maximum variance that the observed number of individuals using x types can produce. Let vector V consist of elements v_t^i counting the individuals of type i. Then total population in time t is

$$n_t = \sum_i v_t^i$$

Note that maximum variance $\sigma_{\max}^2$ for population size n always is

$$\sigma_{\max,t}^2 = \sigma^2[1,1,1,...,1,(n_t - (x_t - 1))] \,.$$

Function u then simply is defined as

$$u_t = \frac{\sigma^2(v_t^1,..,v_t^x)}{\sigma^2_{\max,t}} \qquad (1.2)$$

Evidently instantaneous diversity defined that way will be normalized between 0 (no diversity) and 1 (maximum diversity).

(ii) On the other hand there has to be a dynamic measure of the drive towards diversity that captures how much of additional diversity is produced per time period. Let us call this measure the ***diversity drive*** of period t, variable dd_t.

One possibility for this measure consists of simply counting of how many individuals of the most populous type are transferred to the least populous type per time period[11]. There certainly exist more sophisticated possibilities for this measure, but for the purpose at hand this one is sufficient.

Note that at this level of analysis it is not necessary to specify why a certain drive to diversity exists. It can be conscious redistributive incomes policy in the macroeconomic sense, it can be diversity policy of firms, or it just can be explained by the general assumption that the species with the most rewarding dd behavior had been evolutionary selected in the distant past.

Nevertheless some rather interesting results can already be derived at this general level. In a ***simulation study***, using 6 types out of 6 possible types (i.e. concentrating on redistributive issues) and 60 individuals initially equally distributed, success of this species was measured by the average time that this species survived in a periodically changing environment. The window of survival of the environment was assumed to have size 2 (in each period 2 types were allowed to survive) and the speed of change of this window was experimented with. It was varied from change in every period to change every 20th period only. To see the influence of innate growth rates, these rates (uniform for all types) were changed from 10% to 20% to 30%. Figure 2 shows a typical development of the population types over time with the window changing every 10 periods, am innate growth rate of 20% and diversity drive of 3. The population clearly survived the test of 100 periods.

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[11] If just one individual has to be assigned to (or taken away from) a set of types with equal population then the type is chosen with uniform probability.

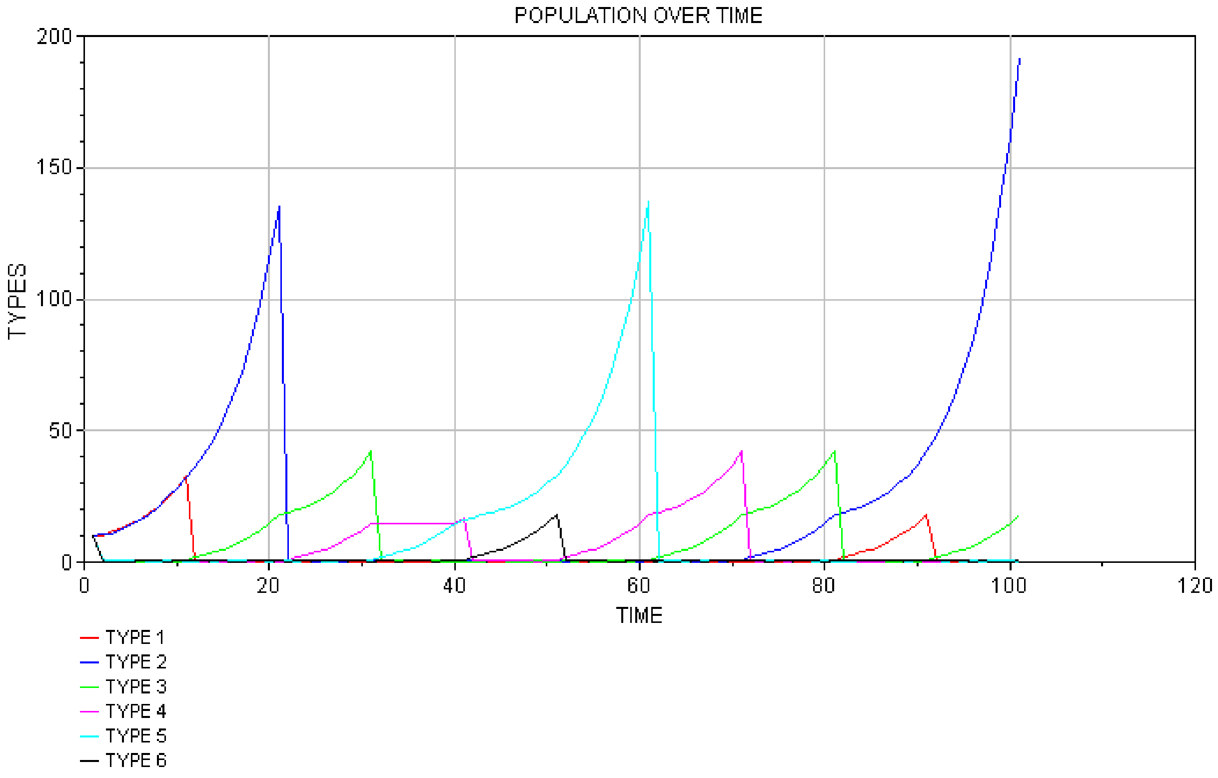

Figure 2: Survival in a periodically changing environment

Note that due to the low number of types the randomness in the drive to diversity plays an important role. Due to that a large number of runs was performed and averaged for each parameter set. Without going into many details studied, a few results are important:

As figure 3 shows survival increases dramatically in slowly changing environments combined with low drive to diversity (‘V-push’). Only if the environment changes every period, then the maximum diversity drive of 6 is optimal. This reassures the idea suggested by the archetype model that diversity (drive) should mirror the movement of the environment – slow change, slow drive. Innate growth in the graph shown was 10%, every increase clearly lead to longer survival. But even with 30% growth the survival in the fastest changing environment and drive to diversity of 6 was still 8 periods, only more stable environments did catch up easier.

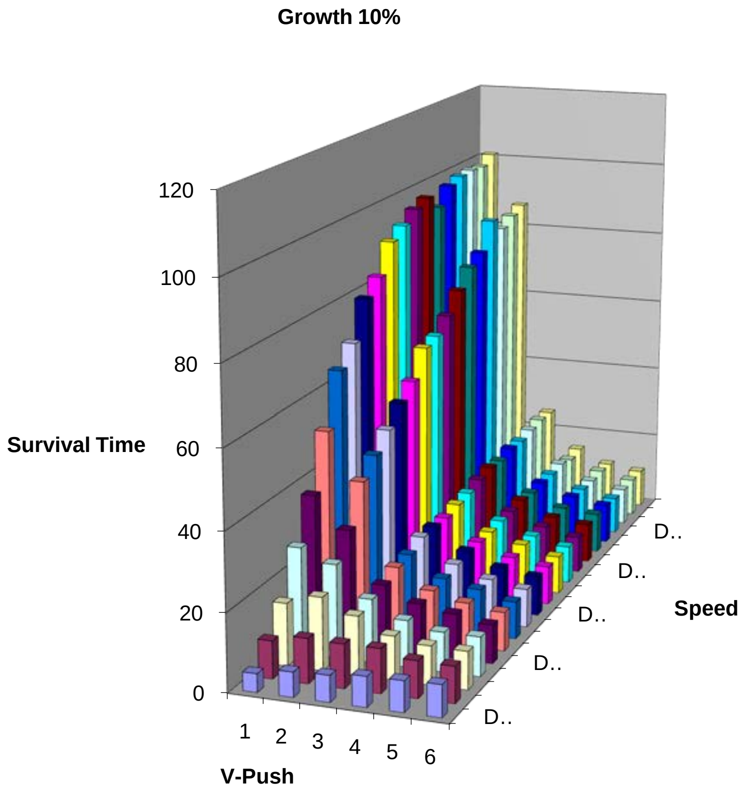

Figure 3: Survival time as a function of speed of environmental change and drive to diversity

Looking now at instantaneous diversity figure 4 reveals that there is a threshold of diversity drive (here between 3 and 4) where the evident negative relation between low diversity and long period of change can be overcome by a strong push towards diversity.

Experiments with different innate growth rates show that this threshold moves up if growth gets stronger; for 30% growth it is between 5 and 6.

The most interesting result of these experiments emerges if one looks at the optimal (in the sense of survival maximizing) instantaneous diversity. Plotting these optimal instantaneous diversity values against speed of environmental change, then an obviously negative relationship pops up (figure 5). For believers in the strength of evolutionary selection this indicates that faster changing environments will select more diverse populations.

But note also how optimal instantaneous diversity was derived: For each speed the highest survival time was used to look up optimal drive to diversity (this relationship is shown in figure 6), and then the corresponding diversity was computed.

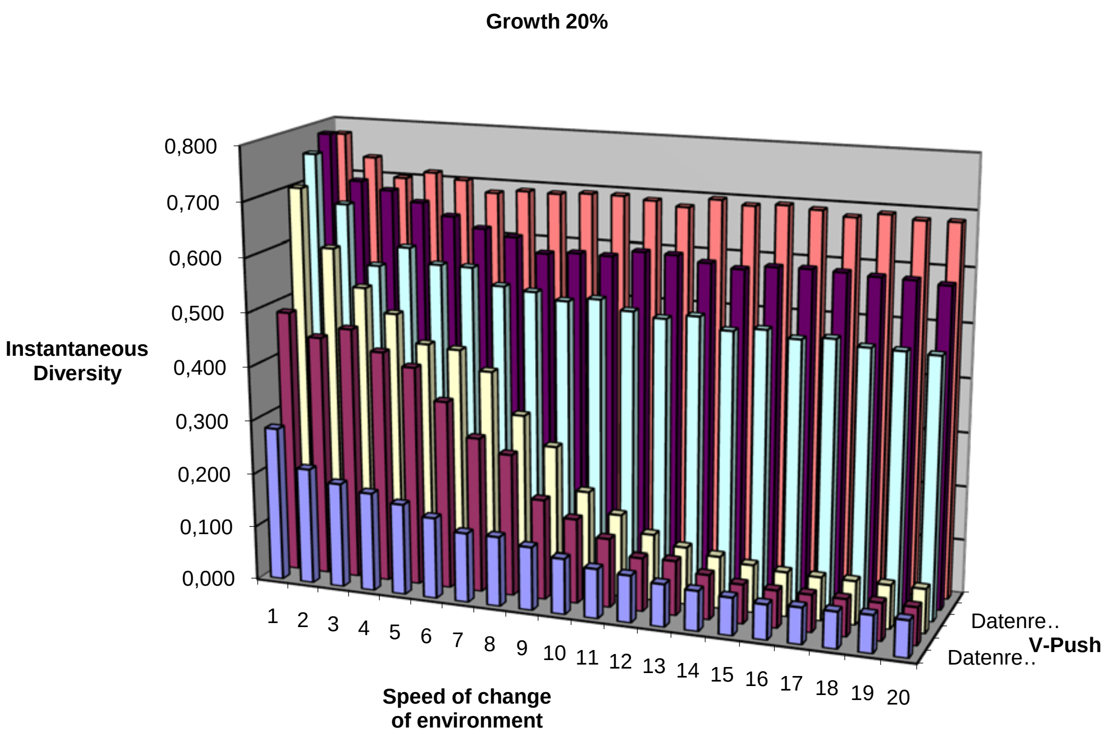

Figure 4: Instantaneous Diversity – the Variety Push Threshold

As figure 5 shows, the crude suggestion implicit in the first archetype model is reappearing in

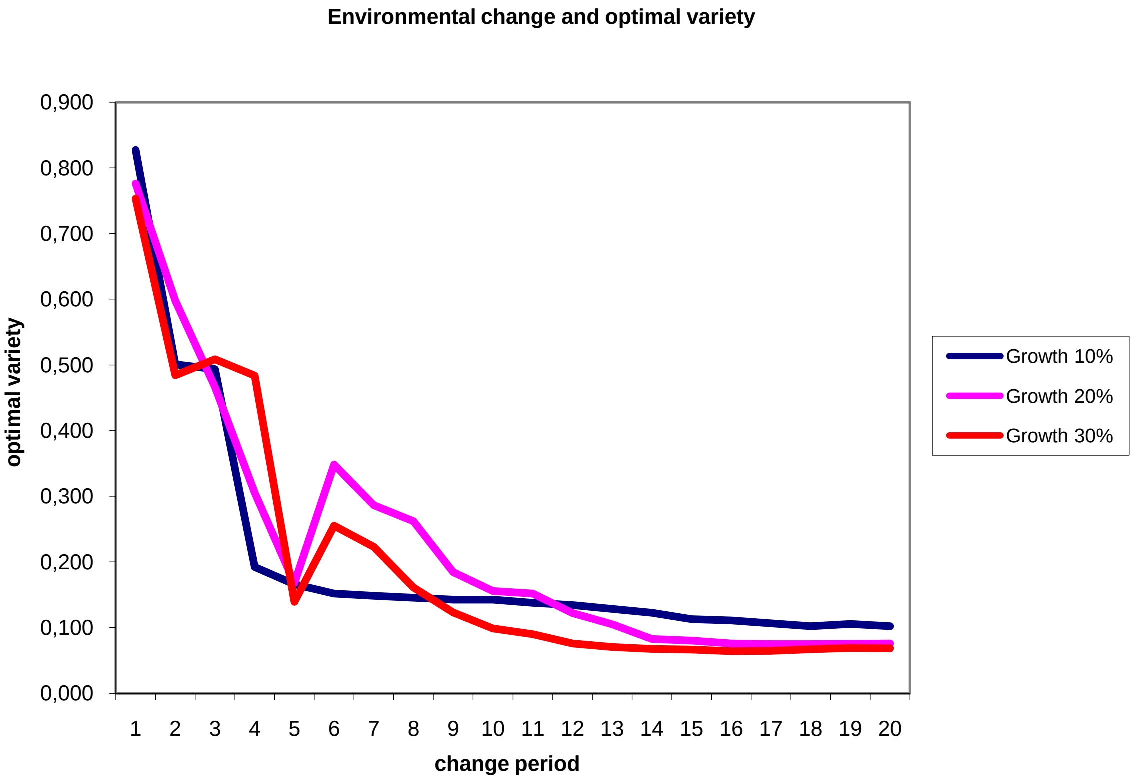

Figure 5: Optimal variety determined by environmental change

this considerably more sophisticated dynamic setting: A certain drive to diversity is optimal for fast changing environments, and it leads to a negative relationship between a static measure of diversity and the periodicity of environmental change[12].

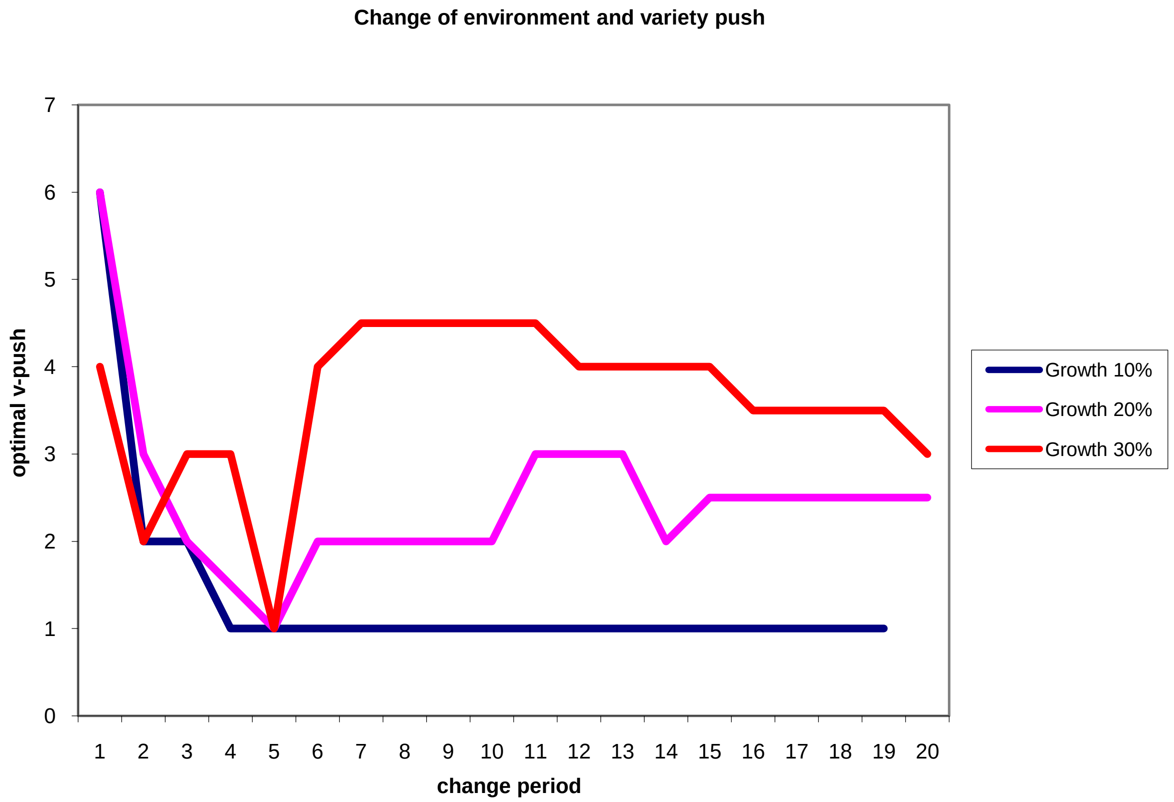

Figure 6: Optimal Drive to Diversity

But figure 6 is also interesting in its own right: Notice that only in slowly changing environments the optimal drive to diversity increases with innate growth rates. The higher innate growth in slowly changing environments, the higher also the choice of optimal diversity push, i.e. redistribution!

Extensions of this simulation model really open a Pandora's Box and go far beyond the scope of this paper[13]. What has not been covered so far at all is the emergence of new types, which was the prime reason to include in the measure of instantaneous diversity both, an actual and potential number of types. Indeed, with this idea one enters the area of ***genetic algorithms***.

In a genetic algorithm the behavior of a type is represented as a bit string, and one could think of the innate growth rate of this type as its fitness function. The crucial assumption then is that

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[12] This result, of course, lies also at the heart of the choice of optimal portfolios in portfolio theory (see e.g. [Mishkin F.S. and Eakins S.G., 1998, pp. 73-86]).

[13] It is also interesting to incorporate and re-interpret standard concepts like the famous replicator dynamics. But again we have to refer to a more extensive treatment to be published soon.

parts of the bit strings of successful types can be clued together – ***and the new fitness of this newly born type is immediately available***. In the standard applications fitness functions are taken to be constant over time and exogenously given.

Taking a closer look at this assumption reveals even deeper problems: At first glance the bit strings are just names for algorithms, and names are much more compressed than the algorithm itself. Clearly each explicit algorithm can also be translated into a language of long bit strings – but ***it does not yield into a form amenable to crossing with other algorithms if it does not have any semantics***. It needs a reference to objects outside its own language![14]
Plugging in pre-designed fitness functions obviously circumvents the problem that true innovation has. The search of genetic algorithms thus is only search for a solution that logically already is implicitly given in the fitness function - long before the search starts. Contrary to that, true innovation is not working on re-combination of (successful) names. It rather works on digesting, often imitating, pieces from sometimes quite distant areas of perception: successful innovators in other domains, inventions, non-economic social behaviors. And it fills it with a semantic re-interpretation that leads to economic action[15]. The agent - directly and indirectly - produces its own fitness function.

To stress the comparison with genetic algorithms again: Consider the case that the bit strings are program names. The programs themselves are sequences of statements. Recombining partial statement sequences of different programs might sometimes – in a few cases – be possible. In most cases it certainly is nonsense. But even if a new combination would work, it still would be only an extremely small subset that would do something better than existing programs. To trust in random mutation in such a programming environment, not to speak of business environments, would be pointless. Indeed it needs an entity that anticipates the possible outcomes and pre-selects elements for combination ***before*** fitness is known or can be tested - in the economics of the last two centuries this entity has a name: the entrepreneur. And its predictive capacity has been labeled with a very indicative term by Schumpeter: vision. Vision in some sense is the antipode of the rational expectations approach. It is bound to be an attribute of a single entity rather than an assumption of some common knowledge. It is bound to fail most of the times just to support the variety needed to cope with changing environments, while the RE approach builds on static and exogenously given environments. ‘Vision’ is bound to compress the enormous amount of perceived signals into a dense image that sometimes is difficult to justify (compare the notion of ‘dreaming’ that Freud, Schumpeter’s contemporary, so vividly introduced), while the RE approach assumes away all

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[14] ‘Evolution gives meaning to language.’, as Ariel Rubinstein has aptly dubbed this idea in the title of an essay on this topic [Rubinstein A., 2000, pp. 25-36].

[15] The metaphor of the routines used by firms [Nelson and Winter, 1982] hints in the correct, the semantic, direction – but never was filled with economic life.

signals that are not instantaneously translated into price signals, and simply ignores information processing capacity constraints of entities.

Evolutionary, algorithmic approaches are on the verge to mimic this type of behavior, at least in some small, well documented areas of economic life. The most illuminating results of biologists which are of interest for economics in the future probably will come from areas that most evolutionary economists have not even touched upon yet:

Note also that talking about new combinations is not talking about an analogue to the interaction between living systems and their selecting environment; it is talking about an analogue to sexual selection. The point is that making new combinations is intentional, i.e. maintenance of the own features enters an active search process – an abstract concept of an 'intentional nature' somehow embedded in the environment is certainly less plausible than the analogue to sexual selection in the fauna. Many biologists view the re-combination via sexual selection as a means to lock-out the many small parasites that are the primal cause of death of large living systems. Sex, according to many biologists, has little to do with reproduction – so innovation (sic Schumpeter) might have little to do with capital growth. But to overcome such wild speculation a lot of theoretical work will have to be done.

3 – Interdependent theory evolution, or 'empirical singularities spark theory'

As any brief survey of actual business life reveals, trial combinations are usually conditioned by expected goal achievement, which in turn differs not only in ***goal definition*** but also in the ***expectation formation process*** used. For economic settings often some kind of growth rate for a given time profile and with respect to a certain social entity (with a certain risk profile) is considered as goal variable. For example capitalist firms are thought to aim at an optimal time path of the growth rate of their capital, i.e. their profit rate[16]. With respect to the expectation process they use models of their socioeconomic and political environment, models which in turn include other model-building and goal-seeking entities like other firms, households, political units or some smaller units that constitute them. For households usually a similar framework – with utility growth playing the role of the goal variable –is proposed. Note that for innovation in firms, Schumpeter's main focus in discussing new combinations, the firm's expectation process includes an anticipation of the expectation processes of its customers[17] as well as of its input providers (labor, intermediate products, infrastructure, etc.). So even if the goal set can be narrowed down to one variable, the expectation process

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[16] For the purpose at hand we ignore problems articulated by the assumption of independent (Keynesian) investment functions.

[17] In ‚Business Cycles' Schumpeter for theoretical convenience assumes that the influence of the demand side can be neglected. Contrary to that in the 'age of high mass consumption' (Walt Rostock) after WW2 the influence of demand side preferences has surely grown considerably.

necessary for anticipation is overwhelming – making Schumpeter’s reference to the entrepreneur’s instincts understandable.

Compare again the fitness function used in genetic algorithms. Interpreted as hill-climbing algorithm, the closest analogue to expected growth evidently is the expected gradient. And if only a small set of past observations of this gradient are available, then strong assumptions about the functional form of the fitness function must substitute this lack of information; though this is seldom mentioned in standard formulations of genetic algorithms. It is therefore clearer, and easier to validate, if the actual behavior of entrepreneurs is mimicked directly.

But which entrepreneurs should be modeled? New combinations in the recent decades most often enter the stage of innovation immediately as new combinations of entrepreneurial units, as conglomerates of new mergers, plus political units, plus certain consumer regions. As units grow larger, competition changes its character. It more often takes place between different sectors of the economy and between political actors hosting the giant corporations. ***Innovations thus take on the form of new contracts between these strata*** – the innovative product often degenerates to a marketing blip that does not reflect the underlying large scale innovation at all. It is just a superficial symbol for the households. While most of these characteristics point into the direction of a rather smooth, contractually secured economic development, it nevertheless bears the risk of infrequent, but heavy and deep crisis.

The most fundamental reason for this is the very fast growing interdependence of all economic actors. As is well known from network analysis the big advantage of such strongly connected networks is that they can digest the permanently occurring small shocks at all nodes particularly well, they even can swallow medium size shocks pretty well as long as no resonance effects amplify them. But innovations of the above mentioned kind become more and more ***large permanent shocks*** moving the economies ever further away from market- and expectation-equilibrium. They increasingly cause a kind of ***economic vibration throughout the world economy that might petrify potential competitors rather than challenge their innovative forces***. The incredibly long period of low interest rates that has been experienced is just a reflection of this stagnating innovative power[18].

Looking back to chapter 2 there also the idea of larger and larger social entities has been implied. Diversity or more precisely the drive towards more diversity has been shown to play a decisive role in insuring units against changing circumstances. And, as can be learned from biology, ***large entities die from inner parasites rather than from heavy fights with their competitors***.

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[18] This is not to say that profits or revenues are stagnating. It only holds that they are not built on innovation but rather on large scale redistribution of income from households and states to firms. As Schumpeter rightly anticipated, such a state of affairs cannot last too long.

Innovation – the emergence of new combinations - in the just unfolding new century will have to ***change its character radically***. Indeed it already has started to do so. It might well be that any further development of product or process innovation in the future will be conditioned by a large-scale institutional innovation[19]. Solutions to questions of political economy might turn out to be the only drivers that enable the introduction of basic innovations. In several respects the carrying capacity of our environment is almost reached – this is not so much concerning energy resources but much more concerning the hidden stress on global social relations. Schumpeter, as Marx, was particularly clear with respect to the past up to the time he lived in; and both were – as they admitted - particularly silent with respect to the future.

What Schumpeterean economics has at its command therefore rather is a way of arguing, a way of generating theoretical insight by - innovation, producing new combinations!

Two properties of applications often encountered in successful new combinations – in both, practical and theoretical innovations - can be stated:

- Once a local optimum of old combinations is reached, i.e. experienced by stagnating goal achievement, it needs a somewhat wider jump away from this local point to find positive gradients leading to higher grounds. The role of ***experience of an innovating unit*** is particularly important with respect to the determination of what ‘somewhat wider’ means in a given context.
- The ***urge for new combinations*** is based on ***contradictions experienced***. Be it that they emerge within the entity, or be it that they are anticipated in environmental dynamics.

Taking the toolbox of evolutionary biology on board of evolutionary economic modeling is an example that meets both criteria.

Conclusion

Schumpeter’s time, the room for new combinations undertaken by small social entities (small firms, households or even individuals) ***has almost vanished***. Entrepreneurship in the classical sense of the function nowadays is almost exclusively a many-facetted and complicated process carried out by large transnational firms interacting with large political institutions. This trend has accelerated incredibly in the course of globalizing interdependencies in recent

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[19] It is interesting to see that even one of the most optimistic commentators of capitalisms innovation based success, William Baumol, senses major threats for this mode of production coming from macroeconomic relationships [Baumol W.J., 2002, pp. 262-282]. A far less sanguine account of capitalisms prospects due to institutional sclerosis can be found in [Cornwall J. and Cornwall W., 2001, pp. 261-269].

decades. New combinations in contemporary societies are a matter of far reaching interventions in the political economy.

But – contrary to Schumpeter’s melancholic baseline – we hold that this is not just the end of a story. It is ***simultaneously the beginning of a new story***. And we even suggest that this story is again a story of innovation, of new combinations. ***Large scale social innovations, innovations concerning the mechanisms of political economy will enable and condition all other types of innovations***. And science, in particular evolutionary political economy, hopefully will be able to give some guidance to this process. To do so, it needs new combinations itself.

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