Economies as a self organized living system**

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Abstract

Open, dissipative and inanimate physical systems like oceans and atmosphere exhibit some dynamical emergent phenomena related to the set of patterns found in all complex systems. Ocean streams and periodic climate phenomenon, like "El Nino", would be examples of such patterns. Social structures and economies as a living complex systems present also a similar behavior leading to an assemblage of identities of large generality which reinforces the general systems theory point of view. However, unlike inanimate systems, all living systems, by definition, must have a mechanism connected with its adaptive properties which guarantee its existence.

This paper describes and models the structural changes of economies seen as a living system. It is based on the non linear "predator-prey" differential equations with variable coefficients, connecting the productive capital stock (K) and its resultant gross domestic product (GDP) or Y. Classical diminishing returns, as well as, productive increasing returns, multiequilibria points, multiperiodicity, irregularities in business cycles and the classical question "why people makes investments", can be understood within this model approach. The early obsolescence of capital stock phenomenon emerges naturally from this approach as a need to economic growth in agreement with the Schumpeter´s Creative-Destruction view. The model can be useful to analyze investment policies from an aggregated perspective. As example, a simple application of the method is presented for Brazilian economic serial data.

Key words: Biomathematics; Self-organization; Non-linear equations; Economics

1. Introduction

One of the classical approaches to appraise the economic system is to consider it as a self organized object resultant of a complex interaction process between subsystems composed by things and human being. The self organization phenomenon can be observed either in inanimate or in living systems and according to Luisi (2006), the main

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assumption held by most scientists about origin of life on earth is that life originated from inanimate matter through a spontaneous and gradual increase of molecular complexity, which the general term for such processes is self-organization. In the biochemistry language some of these processes are under thermodynamic control, i.e., occurring with a negative free energy change; and that there are also self-organization processes that are not spontaneous, being under kinetic control.

Literature on self-organization is huge, as this notion is used in practically all fields of science, from classic organic chemistry to polymer chemistry (Lindsey, 1991; Lawrence et al., 1995; Pope and Muller, 1991; Zeng and Zimmermann, 1997). Practically all biology is characterized by self-assembly and self-organization. Still following Luisi (2006), it is possible to classify the self-organization phenomena:

1. Self-organization systems under thermodynamic control (spontaneous processes with a negative free energy change), such as supramolecular complexes, crystallization, surfactant aggregation, nano-structures, protein assembly.
2. Self-organization systems under kinetic control (biological systems with genomic, enzymatic and/or evolutionary control), such as protein biosynthesis, virus assembly, formation of beehive and anthill, swarm intelligence.
3. Out-of-equilibrium systems (non-linear, dynamic processes), such as the Zabotinski-Belusov reaction, and other oscillating reactions; bifurcation, and order out of chaos; convection phenomena; tornadoes, vortexes
4. Social systems: (human enterprises that form out of self-imposed rules), such as economies, business companies, political parties, families, tribes, armies, churches.

The question of whether the human social organization systems are genetically determined – socio-biology, like in the case of social insects – or induced by social and educational constrains is a quite polemic point and will not be discussed here.

2. Living systems

According to Miller (1973), general systems behavior theory is concerned with seven levels of living systems – cell, organ, organism, group, organization, society and supranational system, all of them showing a set of common characteristics which defines the *living* behavior:

a) They are open systems.
b) They use inputs of foods, fuels or equivalent to restore their own energy and repair breakdowns in their own organized structure.
c) They have more than a certain minimum degree of complexity.
d) They contain genetic material composed of DNA and other characteristic organic compounds.
e) They have a decider, the essential critical subsystem which controls the entire system, causing its subsystems and components to interact.
f) Their subsystems are integrated together to form actively self-adjusting, developing, reproducing unitary systems, with purposes and goals.
g) They can exist only in a certain environment. Any change in their environment outside a relatively narrow range, produces stresses to which they cannot adjust. Under such stresses they cannot survive.

So, living systems are self-organized adjusting system, in which they change constantly their own structure and characteristics in response to their environment for survival reasons, running away from the catastrophic conditions, which leads finally, to the Darwinian natural selection process.

Various definitions of life, including the famous *autopoiesis minimal life* definition [Maturana and Varela (1980)] can be found in Luisi (1998). This approach considers three basic life's characteristics: *self-maintenance, self-reproduction* and *evolvability* (mutation property), which are observed in all living system from a single cell to a complex social system. The following citation from Luisi (2006) emphasizes this three important characteristics found and deep concerned with economic systems:

"*The interaction between organisms and their environment is part of the more general scenario of ecology. It has been in fact stated that living organisms make and continuously change the environment in which they live, and vice versa, so that every act of consumption is also an act of production; also, that we must forget the idea that there is a constant and fixed world – as we are constantly changing it and cannot live without* *changing it. (Lewontin, 1991). From that, the difficulty of finding a healthy equilibrium that preserves as much as possible the identity of the living*."

3. The economic system seen as a self adaptive living system

Self-adjusting, or adaptive systems [Melby P. et alii (2000); Melby P. et alii (2005)] is a particular case of self-organized systems [Turcotte D. and Rundle J. (2002); Bak P. et alii (1987); Bak P. et alii (1988); D.L.T.; J.B.R. and Frauenfelder H. (2001)]. Both the systems have in common the differential equations parameters variation, rather than constant. This variation reflects the adaptive properties of the system and follows the organization internal "rules", which depend of each particular system considered [Luisi, (2006)]. The reason of the limited number of structural association's occurrences is due to the finite allowed states defined by those rules. The formal description of *autopoiesis* for analytic models of life and social systems can be found in Nomura (2002).

Economies are open, dissipative, living and self adjusting systems, constituted by interacting organizations, institutions, market structure, market imperfections, trade, government policy, legal framework and individuals in permanent innovative/changing process. It can be assumed that the main purpose of such system is their survival through evolving dynamic "paths". If such system can be represented mathematically via a set of differential equations, then its *adjusting* dynamical behavior can be reproduced by parameter variation of the respective equations describing them. The time variation of these parameters means the changing, adjusting and renewal of the economic output process: the *production structure*, *knowledge and technology*, continuously changing over time in the GDP breeding process, as expected for all *living* economic system.

Following basic economic textbooks, *capital* K is one of three factors of goods and services production, the others being *land* and *labor*. Goods and services produced in a given country can me measured through the GDP – gross domestic product. Land or natural resources refers, for example, to soil and minerals. Labor is the human effort used in production. Capital being a stock K of physical items that are used in the production process, such as machinery, including agriculture devices, tools and buildings. Classical economics associates the following payments for the factors of production: rent to land, wage to labor and interest to capital. The act of increase capital stock K is through investment on renew or spending on a specific type of goods, i.e., capital goods. Depreciation, physically speaking, is the process in which capital is eroded when goods and services are bred.

So, economic theory expresses the GDP of a country by adding all the production's factors payment. It is a monetary way to put in a common basis, all these factors variables, in order to handle mathematically with them. So, the identity relations between macroeconomic variables like: GDP (gross domestic product) = C (private plus government consume) +I (investment) + total trading (export-import) are obeyed.

Neoclassical growth theory as conceived by Solow [Solow (1956), Aghion (1998)], includes *physical capital stock*, *homogeneous labour and knowledge* (effectiveness of labour) as production factors. The theory assumes the existence of competitive markets, that offer new goods, new process and the search for new markets to sustain the output process against *diminishing returns* and that all factors would be rewarded according to the marginal costs of production. In subsequent "*augmented"* Solow models appear the inclusion of other explicative *factors* such as *knowledge production* (technology) and *human capital* [Aghion (1998), Lucas (1988), Mankiw (1992), Guellec (1996)] in the production function. All of these "augmented" models were developed within the same mathematical framework, that is, the *output* (Y) is represented by an homogeneous production function F(K, L, H, …) of the *independent* production factor variables (capital stock, labour, human capital, etc). In the accounting process considered in the above approach, none production factor payment (capital interest, land rent and labour wage) is neglected. Economic system, as a complex evolving system, presents long term recognizable patterns, for example, the Juglar oscillations, known for a most one century, and presents also persistent economic growth behavior. A considerable amount of papers were done and there is a substantial literature on this subject. See Aghion (1998), for example, for an extensive list of economic cycle and growth references, the most of them reported to the mainstream economic theory.

In this paper the macroeconomic variables – K and GDP will continue to be measured in monetary basis. However, the total GDP production will be considered depending exclusively on the physical items K. By doing this, some simplification in the breeding output process will be possible. Explaining, consider, for example, a single steel nail factory in a normal situation: its annual output depends essentially on its production capacity, that is, on investment to replace the eroded equipment used in the nail breed process or to renew the productive structure. Although others productions factors are utilized in this output process – labor, energy, raw materials, water and others, it is unnecessary to explicit them to express the total nail output, unless one or more of these factors became supply lacking, at long interval. Transitory worker strike would be an abnormal situation and can be neglected, in benefit of the basic mechanism understanding. As known the capital stock K doesn't have a *constant capacity,* in the sense that different countries and regions have different "structure" and distinct capacities to generate economic output. Countries with prevailing agricultural economy have lower capacity to breed economic output as do highly technological or plus developed societies, even when the monetary stock K value are almost equivalents. See, for instance Hall (1999).

3. The Model

In the previous papers Kamimura and Guerra, (2001), proposed a model to describe endogenous fluctuations in macroeconomic variables, observed in all economies. In that paper the authors suggest an elementary description to produce goods and services, based on the well known set of non-linear coupled differential equations, named Lotka-Volterra [see, for instance, Boyce et al. (1997)], connecting Y (GDP) and its production capacity K or physical capital stock. This paper neglects, for reasons pointed before, others production factors considered by economic mainstream theory, for instance *Land* and *Labor*, since like raw materials, energy, and others don't represent a restriction to production in normal situation. Then, the economic production can be obtained from the following set of coupled non linear differential equations:

$$dK/dt = a\,K - b\,K\,Y \qquad (1a)$$

$$dY/dt = -d\,Y + e\,K\,Y \qquad (1b)$$

With parameters (a, b, d, e) > 0

Equation (1a) reveals the *forced – dissipative* feature of this system: the first term on the right express the added investment to maintain the production capacity K, in entire accordance with the alive system behavior (section 2, b) and f) properties) and with capitalist *rationality*, that is, the greater the capital stock K is, bigger its variation will be. The second term of equation (1a) expresses the physical dissipation or depreciation of K, caused by output breed process. The parameter ***a*** in Equation (1a) refers to the *investment* growth rate, or the proportion of K added yearly to K. The fact is that, if no investment is made (a = 0), the economic capacity will "die" (K→ 0). Consequently, no output will be generated, leading to the economy disappearance. At this point, may be worth while a parenthesis concerning the classical question: *why people do investments?* As a matter of fact, this question can be addressed to all living systems, since it refers exactly to the item b), section 2, which guarantee the self reproduction. Philosophically, at deeper level, this kind of question can lead to the notion of *finality* in self organization. Following Luisi (2006):

"The pictures of the swarm intelligence, an axoneme or an anthill arises an old question-the question of finality. One may in fact argue that these complex biological systems appear to have a rather specific finality - the question of the relationship between self-organization and finality arises."

As can be seen in the figure 1a, the parameter **a**, in the historical Brazilian data oscillates around 1.1, in the period 1970-2000, revealing a purpose, at least, to maintain the *status quo* of the economic environment condition.

The parameter ***b*** refers to the K consuming (*depreciation*) process: the smaller *b* is, the greater (dK/dt) growth rate will be and consequently, more output (Y) per time will be produced, through Equation (1b). This parameter variation concerns with the "saving K technologies" of the output production process.

Equation (1b) shows "*how dependent on K*" and "*how predatory*" the output (dY/dt) generation rate can be, acting on the stock K, through ***d*** and ***e*** parameters. Equation (1b) describes the time variation of the GDP production (dY/dt) growing with the product of K times Y (e.KY). The term (-d.Y) reflects the fact that in the absence of productive capacity K, the production (Y) goes exponentially to zero. It can be seen by direct integration of equation (1b): if K=0, the integral of equation (1b) gives Y = Yo.exp(-d.t), which decays with intensity **d**. This means that distinct **d** parameters are related with distinct output production K capacities, or in other words, *there are production processes with distinct degrees of dependence on stock K.* It is the main point of this paper and will be shown through further numerical analysis that the **d** parameter decaying means deep economic output structure changing and is the stronger economic growth "factor". *Production paths changing mean obviously substitution of the scrapped "old" structure by a "new" one more efficient to breed news products and services*. It can be seen and interpreted as the "Creative-Destruction" innovation Schumpeter´s process: "*Schumpeter called innovation phenomena in the form of new consumer goods, new production methods, new transportation methods, the creation of new markets and new forms of industrial organization, which is the fundamental impulse that sets and keeps the capitalist engine in motion. Creative Destruction is the process that from time to time revolutionizes the economic structure from within. An innovation comes along that changes the economic system and in the process destroys the old ways of doing things…Iordanis Petsas of the University of Scranton confirms that the long-run growth rate of the economy depends positively on the magnitude of quality innovation (Petsas, 598)"* (Ebert, (2004). Michal Kalecki also supports the idea that there is a strong link between the high rate of technological innovations and the early stock K obsolescence (Kalecki, 1987).

Finally, the parameter ***e*** is related to the *strength* of "how predatory" or "K stressing" the generation of output Y process can be: the larger this coefficient is the greater output rate (dY/dt) will be. However, this implies also that the stock K will suffer more erosion through Equation (1a).

The parameters *a, b, d* and *e* defines the "equilibrium" point of the system [Kº, Yº] = [d/e, a/b], around which, time fluctuations in K and Y take place, with *periodicity* given by

$$T = 2\pi/(a.d)^{1/2} \qquad (1.c)$$

As well known in the non-linear differential equations literature, [Kº, Yº] is the "equilibrium point" or the "centre" of the closed orbits of the *Lotka-Volterra* equations and remains "static" for constant parameters *a, b, d* and *e*. In this case, however, the parameters variation, the oscillation period T, varies inversely with **a** and **d** parameters:

increasing investment rates **a** will shorten the oscillation, while more efficient capital K output structure (diminishing **d**), will elongate it. *The straight consequence of this is the multiperiodicity and irregularity observed in the economic fluctuations output for each and every country*. The parameters variation **a, b, d** and **e**, gives also, as a consequence, the time shifting of the above equilibrium point [Kº, Yº].

Still explaining equations (1a) and (1b), it is reasonable to assume that both the variation, economic output (dY/dt) and production capacity (dK/dt) are proportional to the product K times Y. If the K erosion to get output is proportional to (K.Y), the correspondent output Y will also be proportional to (K.Y), with another proportionality parameter ($b \neq e$). In other words, it is assumed that if a given production device is not utilized to breed goods its physical dissipation (*note that it's not obsolescence*!) will be also null.

At first sight, this set of non-linear differential equations appears to be an *ad hoc* proposition. However, this set of equations was proposed in the same epistemological basis which dynamical equations of "natural systems" are placed on, that is, by connecting the time dependence between related differential quantities.

The dynamical non linear characteristic between these two macroeconomic variables was treated in [Kamimura and alii (2004)]. It is worth to remember that usual numerical economic calculations consider a direct and linear relation between K and GDP.

Constant or time fixed parameters in systems described by non linear differential equations (1a) and (1b) have several implications: high sensitivity to initial conditions, allowing no *feed-back adjustments* through forward time, coming from the interactions between *new technologies* and *productive structure elements*, gives as consequence the maintenance of the *structural form* of the productive system. These interactions acts upon and change the output process in the socio-economic system. Besides this, fixed parameters means no more than one equilibrium point, defined by initial conditions and violates the basic *living* systems "rules" and properties. By ***a, b, d*** and ***e*** parameters time variation process, "new equilibrium" points are created and such variation affects the *intensity* of "how" K is "consumed", "saved", "destroyed" or "changed" to breed Y, reflecting the *self adjusting* character of the economies, avoiding undesirable and "catastrophic" conditions. In so doing, all the other factors that influence growth such education and technology are hidden inside the changing parameter values.

Note: similar approach – the *predator-prey* framework - was done before by Goodwyn[2] (Goodwin, 1967) to describe oscillatory behavior in another variable context and fixed equations parameters. This last condition drives his model to fail in order to describe "living" economic dynamical process, since in this case his model faces the non-linearity "curse" or strong initial conditions dependence.

3. Numerical approach

The basic approach to solve numerically equations (1a) and (1b) is the *Heun* discretizing method, which gives for K(t) and Y(t):

$$K(n+1) = K(n) + h\{f(K,Y) + f[K + hf(K,Y),\ Y + hg(K,Y)]\}/2 \qquad (2a)$$

$$Y(n+1) = Y(n) + h\{g(K,Y) + g[K + hf(K,Y),\ Y + hg(K,Y)]\}/2 \qquad (2b)$$

Where $f(K,Y) = aK – bKY$ *and* $g(k,Y) = -dY + eKY$. The values of K and Y are advanced simultaneously; that is all the values on the right correspond to the values at the present step and the values on the left correspond to the new values. The range of *h* is [0,1] and the limit of h → 0 gives the exact solution of the differential equations.

Using again the "nail factory" metaphor K represents the equipment available to produce nail. According to the proposed model, there are at first glance, four direct and independent *ways* or *paths* available to increase production, starting from a given state. These paths are:

1.) Increasing the stock K or the nail factory equipments through investment or coefficient ***a*** (*investment* growth rate) increasing.

2.) Decreasing waste, through *new techniques* (*technology* and *knowledge*), to deal with the production process, consequently saving stock K; this is attained by diminishing the coefficient ***b***. This means (Y/K) increases or *increasing return* economic phenomena. However, as it is well known, this procedure is technologically limited, reaching early productivity saturation.

[2] Goodwyn considers the following variables: worker´s share of the product (predator) and employment ratio (prey).

3.) Changing "business" to other activities less intensive or dependent on physical capital stock, for instance, searching for "*increasing returns technologies*" (GTPs, referred ahead) or *moving to services sector*. GTPs technologies – General Purposes Technology are technologies that allow increasing output and productivity in the long term. This is possible through coefficient ***d*** decreasing, which means *changes in the production frame* through equipments substitution and shifting to service sector production. As shown in the Brazilian case, it is the most efficient way to assure a consistent economic growth. Decreasing b parameter represents the Schumpeter´s Creative-Destruction process that leads to a strong and mostly early stock K obsolescence.

4.) Intensifying the "predatory" rate (dY/dt) equivalent to *stress* the production process, through augmentation the coefficient ***e***. It represents the *diminishing return* classical case. This gives rise to increasing Y over the short term, but at forward times, it gives as a consequence the quickly vanishing of the capacity production K and *oscillatory stagnation* as shown later by numerical results.

These four alternatives mean individually variation of one parameter (up or down), maintaining the others fixed. Real situations, however, implies simultaneous variations of the four parameters (*a, b, d* and *e*). If each one of the parameters can assume three states (up, constant, down), the *number of possible dynamic scenarios* will be $(3)^4 = 81$, showing the whole set of adaptive situations richness. However, by reasons pointed in the introduction, there are internal self organization "rules" that put limitation on that number.

The following figures (1) to (4) picture the Y and K time behavior described before. It is obtained by applying Equations (2a) and (2b) for a hypothetic economic system. The starting values for the parameters *a°, b°, d°* and *e°* is obtained from:

a) The equilibrium point (Kº, Yº) defined by initial economic conditions; initial depreciation b°Y°K° = (8%)K°.

b) The initial (t=0) investment (a°.Kº). This procedure gives for the parameters the following values: *a° = 0.0798, b° = 0.0165, d° = 4.24 and e° = 0.3035*. The equilibrium point, in a hypothetical constant currency, being *[Kº, Yº] = [13.97, 4.84]*.

All the simulations were obtained through "ceteris paribus" condition by continuous individual variations of the parameters *a, b, d and e*, via equations (2a) and (2b):

Figure (1): ***a*** increasing means increasing investment rate giving as a consequence the increasing of the economic output Y. The fluctuation period decreases that is, the oscillations frequency grows due to *a* increasing (equation 1c).

Figure (2): ***b*** decreasing. Through *technology and knowledge* the factory saves his capital stock, allowing *increasing returns (Y/K)* growth, but as said before, there is a technological limitation for this procedure.

Figure (3): ***d*** decreasing means that the output production process changes K, allowing increasing Y and (Y/K). As explained before, this could represent a path growth fueled by *technology, knowledge and production structure changes* (Creative-Destruction). This is the most representative *increasing return* case pointed by this model, whose *General Purpose Technologies* (GPT) action, referred later, may have a preponderant role. The oscillation period becomes larger.

Figure (4): ***e*** increasing means stress the "predator" production process, whose initial effect is the Y increasing. However, it is nothing but the initial period of a stagnant process, returning to decaying behavior after a half cycle, yielding place to classical *diminishing return* case. The capital stock K vanishes.

Figure 1: increasing a

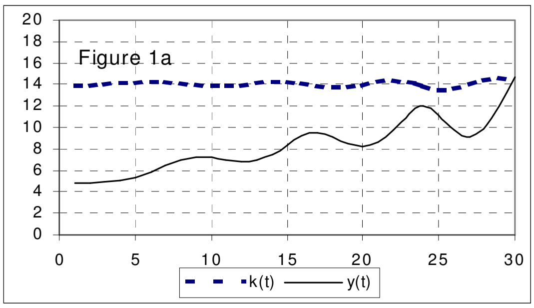


Figure 2: decreasing b

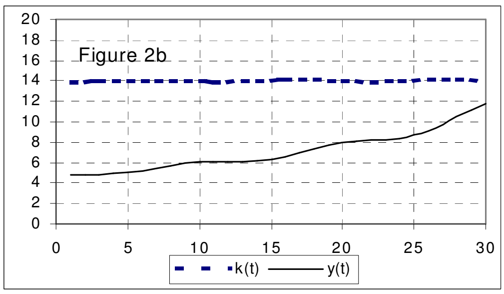


Figure 3: decreasing d

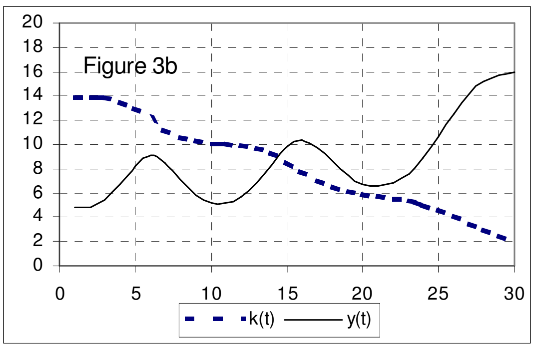
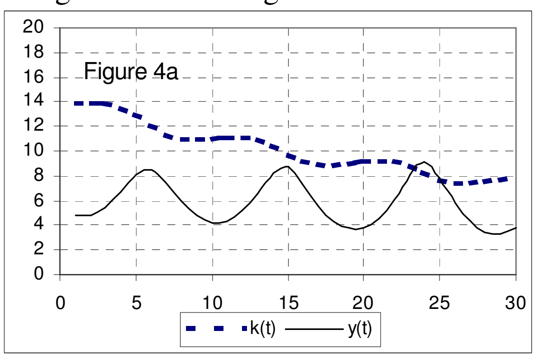


Figure 4: increasing e



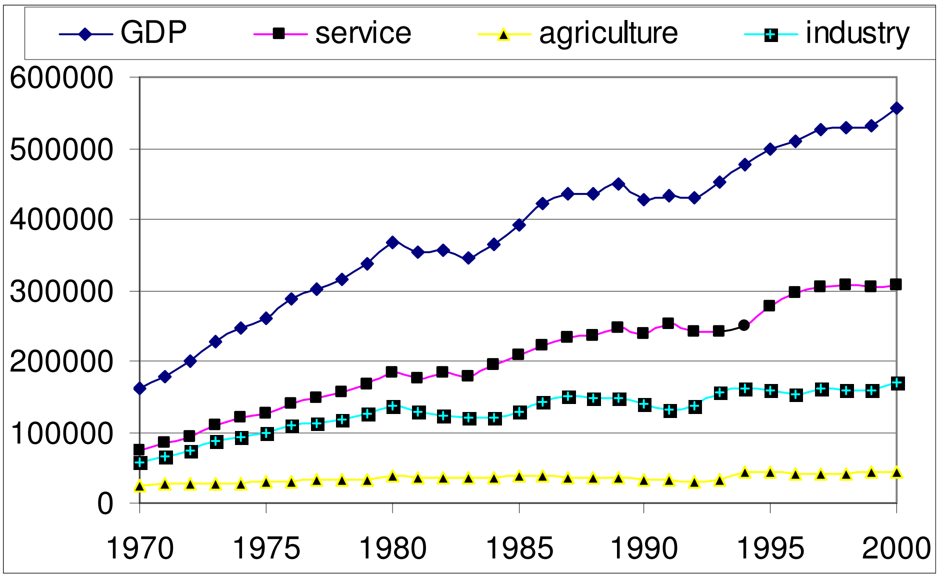
All numerical procedures concerning changing parameters calculations in the non-linear differential equations are worked with the *Heun method* [Sprott, (1995)].

5. Example: the Brazilian "*ex-post*" analysis – 1970/2000 period

In this section, Equations (2a) and (2b) are applied as a simple and naive numerical illustration of the approach adopted and doesn't claim for any kind of model proof.

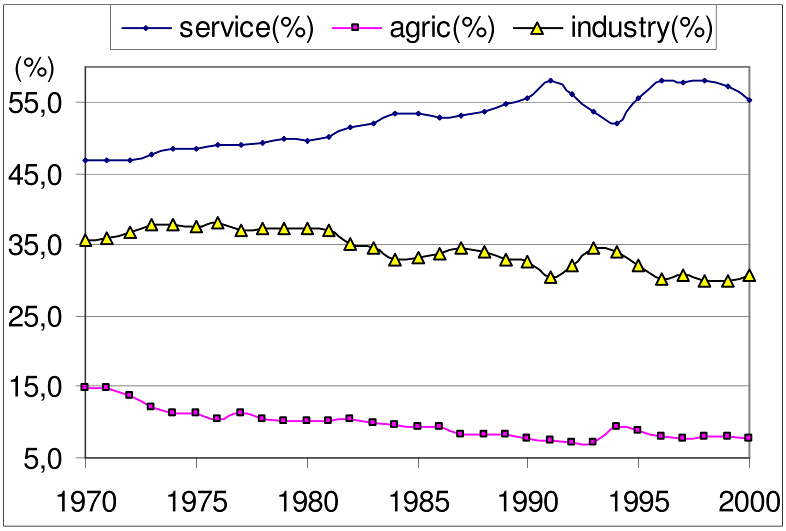
For that matter, the B*razilian* GDP behavior was reproduced over the period of 1970 – 2000, in which the country experienced a deep productive structural change, mainly concerning industrial and service sector changes. These facts can be observed in the following figures: (5), (6) and (7), which respectively give:

Figure (5): Composition of the Brazilian GDP in 10^6 (2004) constant US$, in the 1970/2000 period:



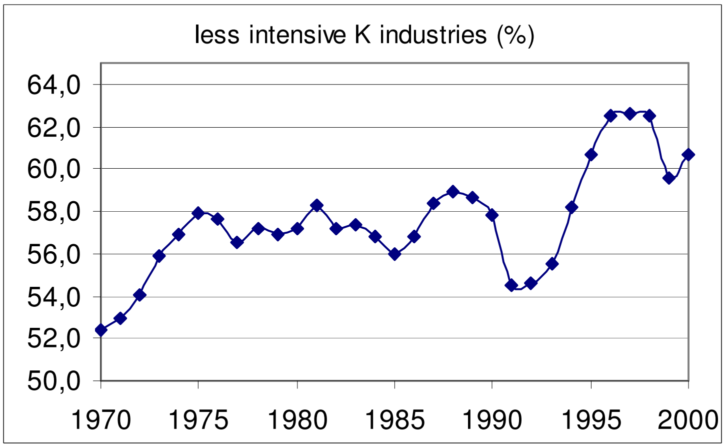
Source: BEN(2005)

Figure (6): Percent participation of services, agriculture and industry in the GDP production (1970/2000 period):



Source: BEN(2005)

Figure (7): Percent participation of less intensive K industries in total GDP industry (1970/2000 period):



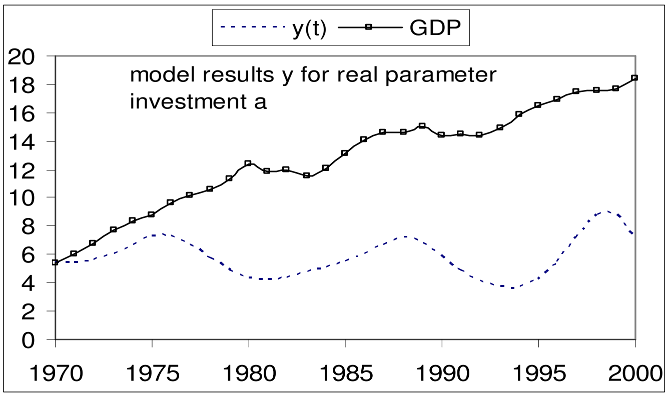
Source: BEN(2005).
Less intensive K industries are others transformation industries. Intensive K industries here: Mining (exclusive petroleum extraction), Metallurgic, Chemical (exclusive petroleum refining, alcohol distilling), Paper and Pulp, Textiles (exclusive clothes, shoes and cotton artifacts), Food and Beverages.

Figure (5) shows the GDP growth and its main components. It's evident the increasing importance of the services sector in this period, showed also in the figure (6). This sector increase percent participation from 45% to 55% in the 1970/2000 period, showing the decreasing dependence on stock K to generate GDP. Even focusing the industry sector,

it's clear the same phenomenon can be observed through figure (7), which shows the increasing the participation of industries less intensive on K in the total industry sector.
Table 1 show the observed GDP in the 1980 constant currency (1000 Cruzados) and the *total investments* as a fraction of GDP, which occurred at that time. The Brazilian economy experienced a torrent of investments during the 1960s and 1970s, mainly applied towards *modernization, raw material and durable goods production* and *establishment of basic infrastructure*.
At the beginning of the seventies, the initial years of the following simulation, the economy as a result of the capital stock K was in good condition to produce *goods and services*. However, as showed by table 1, the investment capacity declined through the forward years, as a consequence of several factors such as oil "shocks" and other important internal and external economic issues that interacted with economic growth.
Over this thirty-year period, Brazil's production structure experienced a deep transformation, moving from a capital goods production and infra-structure establishment to a non durable goods and service production and consequently, to an early capital stock obsolescence.
The simulation starts with the following initial states, in order to reproduce initial values (10^9 constant 1980 currency - Cruzados): *Y(1970) = 5.42*, and *K(1970) = 21,68*, assuming that the initial capital productivity (Y°/K°) relation is *0,25*. The initial equilibrium point is done by $[K^o, Y^o] = [d°/e°, a°/b°]$. The initial value a° (= 0.05) comes from the 1970 investment (table 1). The initial K° *dissipation* given by b°Y°K° is assumed to be 5% of K°. Those conditions lead to other initial parameters: *b° = 0.009225, d° = 6.5* and finally, *e° = 0.299815*.
So, the ***first interesting result of the model*** comes from the initial oscillatory period calculation: $[T^o=2\pi/(a°.d°)^{1/2}] \approx 11$ years, in agreement with the *Business Cycles* Juglar fluctuations. This result explains why countries - *no matter its size* - have approximately the same oscillation period, since **a** and **d** parameters are also approximately equal for the mostly of economies.
Applying the observed investment rates (varying parameter a) from table 1 in Equations (2a) and (2b) generates the Figure 8:

Figure (8) shows the expected values for Y, at the "*ceteris paribus*" condition that is by parameter **a** variation (historical values) and maintaining the others initial value parameters (b°,d°,e°) constant. This figure also shows the *observed historic values* for Y, revealing the "inability" of investment rate, by itself, to explain Y real growth data. This is what would happen if the capacity production *structure* is maintained constant.

Figure 8: Model result for GDP with real "a" investment parameter variation. The "b", "d" and "e" parameters are fixed at initial conditions.



At this point the following question can be placed: which would be the set of others parameters in order to fit the real Brazilian GDP? One possibility is shown through figure (9), in which the **b** parameter decreases yearly at 1.7% rate and the **d** parameter fits quite well a *Gompertz curve* [d(t) = 1-exp(-1.216952-0.080975*t), with fitting statistical parameter R=0,9944], showing strong early obsolescence. Such hypothesis for **b** and **d** agrees with the historic economical facts, that is, deep destructive-creation modernization process, which took place in Brazil at 1970/2000 years.

The figure (10) shows the Capital stock (K), the historical (GDP) and model (Y) results for investment **a** parameter with historical values, *the **b** parameter decreasing* at rate 1.7% by year and **d** parameter decaying according a *Gompertz* curve. This case represents a deep modification in the productive structure. It means *changing the stock K* production capacity (Destructive-Creation) acting in the Brazilian economy (note the Capital stock K behavior, following also a Gompertz curve).

Figure (9): "b" and "d" parameter variation for the GDP best fit

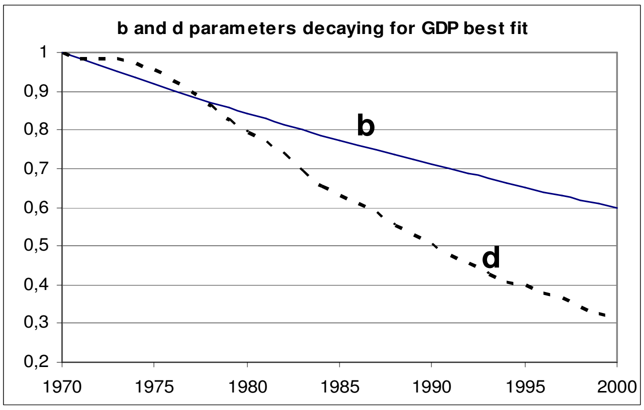
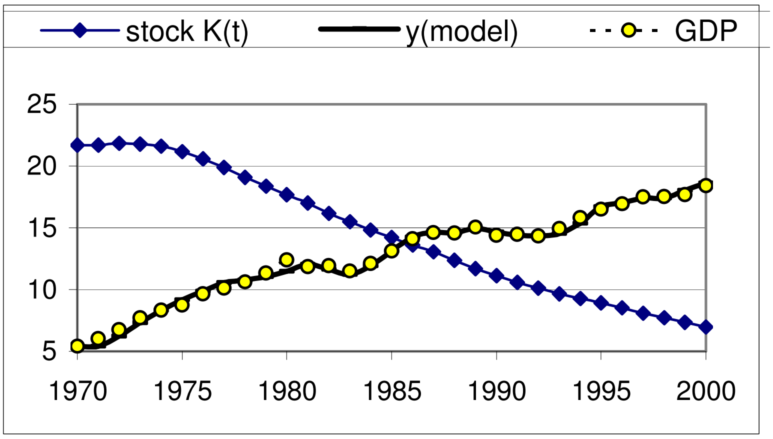


Figure (10): Model result for capital stock K and GDP



The figure (10) may induce erroneous enthusiastic interpretations and a bucket of cold water is necessary: it is worth to remember, the **b** and **d** curves were obtained *ex-post*, in order to fit the real GDP behavior. Again the *non-linearity curse* is present: for prospective aims slight modification in any year for **b** or **d** curve, will cause big differences ahead, in the GDP behavior. If the **d** data obtained through **d(t)** *Gompertz* curve were utilized in the model, the real GDP behavior would not be reproduced.

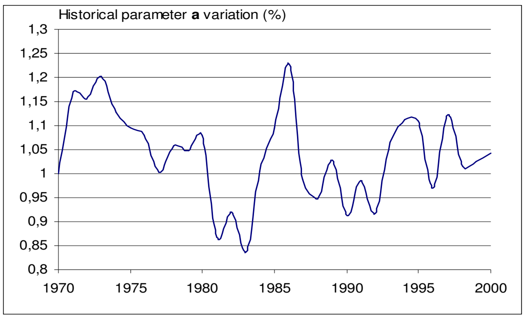
The natural dubiety which arises from the adherence and "goodness" of the model results concerns to the "uniqueness" or how "best" each solution can be, since there are many trajectories with distinct parameters variation, which could "fit" better the real behavior. Unfortunately, it is impossible to repeat the "economic experience" in order to check the model. Validation of the model requires investigation beyond the scope of this paper which shows, coincidently or not, a "good" path. This path means *decreasing d and b* parameter procedure – *less stock K dependence and modernization process.* This agrees, qualitatively, with the economic events which actually took place in Brazilian economy during this period: strong and mostly early capital stock K obsolescence and moving of output production from durable goods to consumption goods and service sector. No doubts remain that this process would not be possible without a deep structural change in the production activities supported by *technology, knowledge and production frame innovations*.

Table 1: Brazilian *Gross Domestic Product* (GDP) and *total Investment* (% GDP)

year	GDP	Inv.(%GDP)	year	GDP	Inv.(%GDP)
1970	5418500	0,2057	1986	14108655	0,1866
1971	6036771	0,2131	1987	14617818	0,178
1972	6758074	0,2222	1988	14577572	0,1696
1973	7700322	0,2358	1989	15058403	0,1662
1974	8335945	0,247	1990	14410892	0,1551
1975	8762865	0,2577	1991	14459587	0,1517
1976	9654222	0,2502	1992	14340555	0,1398
1977	10129966	0,2356	1993	14941122	0,1438
1978	10629123	0,2351	1994	15836561	0,1527
1979	11348343	0,2288	1995	16507465	0,1662
1980	12399842	0,2277	1996	16946563	0,16
1981	11853391	0,2088	1997	17500716	0,175
1982	11929103	0,1937	1998	17539217	0,173
1983	11515673	0,1684	1999	17677777	0,162
1984	12104401	0,1619	2000	18420244	0,17
1985	13114496	0,1632	**(1000 Cz$ constant) year 1980**		

Source: [IBGE], [IPEA]

Figure 1a: Historical parameter a plotted for Brazilian case (%):



6. Conclusion

The alternative analysis presented in this paper, based on *living* systems framework, offers one possible "alternative" to express the robust economic output behavior of a country. It is likely that others unpredictable and circumstantial factors will intervene and change slightly or not slightly the main behavior described before. The non linear relation between macroeconomic variables to produce goods and service appears to be a reasonable representation of complex system process involving "inputs", "stocks" and "outputs", which is the main characteristic of the evolving *living* systems. Another typical characteristic of this kind of system is the (economic) growth and can be explained through several alternatives paths, corresponding each one to ***a, b, d*** or ***e*** positives parameters variation. A fixed coefficient means "static" production structure. However, by considering these parameters changing and adjusting over time, as the real *living systems* suggests, catastrophic situations can be avoided. The interaction between oscillatory behavior and the long term economic growth can be seen through the Equation 1c. This equation gives rise to multiperiodicity and irregularity in business cycles. *Diminishing returns* as well as *increasing returns* can both be viewed within this approach. Application of the model to the Brazilian (1970-2000) data series have shown that the investment rate, by itself (fig. 8), is unable to explain the economic growth. One good fitting is obtained by diminishing *d and b parameter* that means a deep structural change in the economic output generation mechanism, through *knowledge, new technologies* (for instance GPTs – General Purpose Technologies or changing capacity production to *service sector*, that allow a long run economic growth and *increasing returns* behavior. In other words, the investment in one "fixed" productive capital K, by itself, is insufficient to guarantee the persistent growth. It is necessary to renew continuously such capital stock K, driving it to strong early scrapping and shift the production capacity to more efficient path to produce GDP (Schumpeter´s Creative-Destruction process). It is worth to remember that the capital stock K refers to "effective" production capacity and not to the total capital stock K.

This model can be useful for many purposes, other than a scholastic economic description, especially as an aide to analyze investment policies, from an aggregate perspective, in the short run, since this model suffers also from the *non-linearity curse*, as shown before. The reliability of this approach waits for the task of the systematic tests in other economies.

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