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Table of Contents

Session A2

Session B2

Session A3

Session B3

The Operative Logic of the Firm:

The Combinatory Systems Theory View

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Abstract

In this paper I propose two models to understand (not merely describe) the operating logic of the *firm* - that is the *business for profit organization* - both at the micro level, considering the firm as a unit, and at the macro level, considering collectivities of firms of the same kind:

1) when viewed as individual units firms can, at the micro level, be interpreted as operating systems for efficient transformation that carry out five parallel transformations,

a. *productive transformation* of factors into production; this is a transformation of utility, governed by productivity and by quality;

b. an *economic transformation* of costs and revenues into operating income; this is a transformation of value, governed by prices and therefore by the market;

c. a *financial transformation* of risks, which transforms capital into returns and guarantees the maintenance of its financial integrity;

d. an *entrepreneurial transformation* of information into strategies, which leads to a continual readjustment of the firm's strategic position;

e.a *managerial* (organizational) *transformation* of strategies into actions of management control.

2) when viewed as elements of the economic system firms can, at the macro level, form a *combinatory system of improvement and progress* in which each firm acts to maximize its efficiency measures, and this inevitably leads to *progress* in productivity, quality, costs and technology for the system as a whole.

Keywords: *Operative Systems, Combinatory Systems, Entrepreneurship, General and Strategic Management, Organizational Behaviour, Increasing returns in firm's processes*

1. The tools: Operating Systems and Combinatory Systems

We define a system of *transformation* as one that carries out a process of *transformation* of some kind (qualitative or quantitative) involving input variables x(t) that become output variables y(t) by means of the state s(t), according to an appropriate set of *transformation functions*:

Each *transformation system* that carries out these processes is characterized by several measures of *performance;* I mention: *efficiency* = e(t) = y(t')/x(t); *unit input requirements* = f(t) = x(t)/y(t'); *result* = R(t) = y(t') – x(t), and *return on input* = roi(t) = R(t)/x(t) = e(t) –1.

For systems set up to achieve a given output objective, y*(t*), other performance measures are: *effectiveness* = p(t) = y(t)/y*(t*), *variance* (error) = ε(t) = y(t) – y*(t*), and *delay*, r = (t - t*).

By Combinatory System I mean an *unorganised* system made up of a plurality of similar agents; the macro behaviour of the system, as a unit, derives from the *combination* (sum, mean, max, min, ecc.) of the analogous (uni-dimensional) behaviours of its similar agents, according to a feedback relation between micro and macro behaviours which guarantees the maintenance over time of the system's macro behaviour and directs the micro behaviour of each agent, producing some form of self-organization (accumulation, diffusion, pursuit and order).

If opportune sets of *necessitating* and *recombining* factors are present when the system starts up "by chance", it then maintains its self-organized behaviour "by necessity", as if an Invisible Hand or a Supreme Authority regulated its time path and produced the observable effects and patterns[1].

The most relevant class of combinatory systems are the *systems of improvement and progress*: their effect is to produce progress (according to commonly accepted value judgments) in the overall state of a collectivity in which the individuals pursue their search for individual improvement; that is, an increase in some parameter judged to be useful or favourable (Mella, 2001).

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[1] The Theory of Combinatory Systems searches for the conditions that produce the macro behaviours and proposes models to interpret the collective phenomenon See, for the complete theory and for references: www.ea2000.it/cst

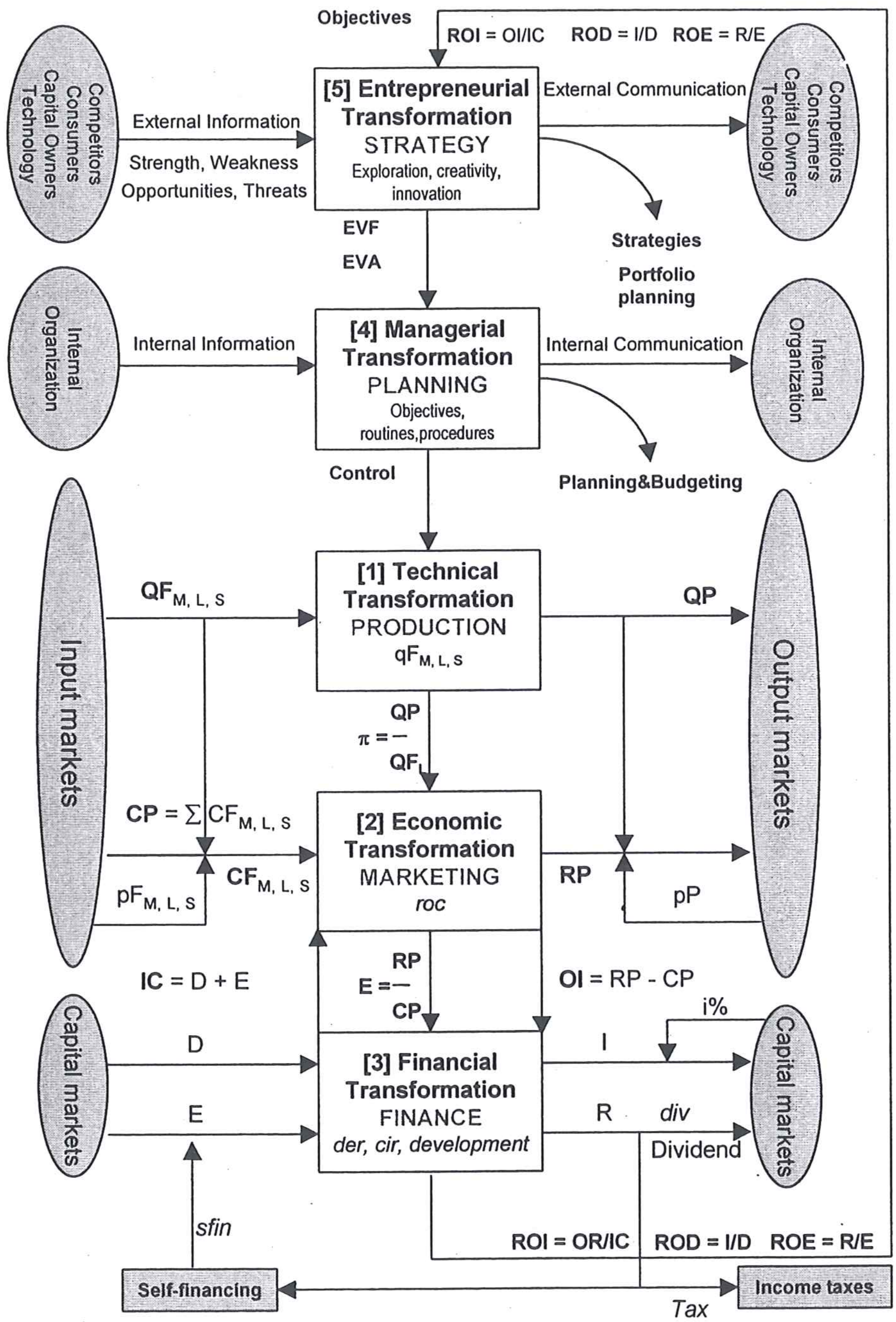

Fig. 1 – The firm as an operating system for efficient transformation

2. Production oriented organizations. The fundamental variables

Definition 1 – A *production-oriented organization* is a particular system of transformation that produces a system with four types of connected transformations, as shown in figure 1.

2.1 Technical or productive transformation or PRODUCTION.

This is a typical transformation of the *utility* of input factors into a greater *utility* of output production.

We indicate[2] by $qF_{M, L, S}$ the elements of the vector $qF(T) = [qM, qL, qS]$[3] , which expresses the average requirement coefficients for factors in T, given a selected production function, such that:

$$QF_{M, L, S} = QP_{\theta}\, qF_{M, L, S} \quad \text{..............................(1).}$$

represent the elements of the vector of Factor Quantities [QM, QL, QS] in period $T_n = (t_{n-1}, t_n)$ to produce the quantity QP at a given level of quality θ. Material and services (M) and Labor (L) represent the operative factors; Machines and other structural factors (S) – that is, production capacity factors.

2.2 Economic or market transformation, or MARKETING.

This is a transformation of *values*. The factors with a given value are transformed into production with a greater *value*.

The *economic transformation* depends on the price function and on the average prices consistent with the market volumes. We indicate by $pF_{M, L, S}$ the average prices, in T, for the factor inputs, and by pP a vector of average prices in T for the production output. Recalling equation (1) for the cost of supplies, or the value of the factors at time T, we obtain: $QF_{M, L, S}\, pF_{M, L, S} = [QP_{\theta}\,(qM\ pP),\ QP_{\theta}\,(qL\ pL),\ [(QP_{\theta}\ qS)/KP]\ pS] = [QP_{\theta}\ cM,\ QP_{\theta}\ cL,\ NS\ pS]$, where NS =

[2] From now on we will use the notation $F_{M, L, S}$ to indicate F = M, L, S.

[3] In general, we will use capital letters (Q, T, P, etc.) to symbolize overall volumes or periods, and lower case letters (q, t, c, etc.) to indicate unitary or instant quantities. Capital letters are also used to designate the names of the varriables (M, L, S).

[(QP_θ qI)/*KP*] represents the number of structure factors to acquire at time T, and CS = NS pS is the cost of the structure factors needed to produce $QP_\theta(T)$.

The full production cost for period T, using the chosen technology and supply policies, with QP_θ being the independent variable T, is: (2).$CP(T) = \Sigma_{M, L, S}\, CF_{M, L, S} = QP_\theta\,(cM + cL) + CS$.The average unit cost of production is (3) $cP(T) = CP(T)/QP_\theta(T)$.In general the costs for material and labor can be considered operating costs, proportional costs, or variable costs; the structure costs are fixed or semi-fixed.

We quantify the value of production, or revenue, as: (4) $RP(T) = QP_\theta(T)\ pP(T)$.The difference between revenue and the cost of production is the *operational income*[4]: (5). $OI(T) = RP(T) - CP(T) = [RP(T) - QP_\theta\,(cM + cL)] - CS = GM(T) - CS$,

having denoted with GM(T) the gross margin.

2.3 Financial transformation or FINANCE.

Is a typical transformation of risk: invested capital is transformed into returns.

We indicate by $E(t_0)$ the Equity capital and by $D(t_0)$ the portfolio of financings that represents the Debt that constitute the *investment capital*; thus we write: (6) $IC(t_0) = D(t_0) + E(t_0)$.In general we can state that in independent capitalistic production organizations $E(t_0)>0$.

If $E(t_0)=0$ we have a *non-independent* production organization, or a *labor production organization*[5].

The rotation of the invested capital: *rot* = CP/IC(t) and the Debit/Equity Ratio, or *financial leverage*, *der* = $D(t_0)/E(t_0)$ define the financial structure of the production organization.

If $D(t_0)$ is invested for period T at the rate i(T), then we obtain an interest amount equal to: $I(T) = D(t_0)\ i(T)$. Assuming that the income tax, Tax(T), is proportional to the *tax* rates, then the net income is given by the following difference: (7) $R(T) = OI(T) - I(T) - Tax(T) = [OI(T) - D(t_0)$

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[4] We can define a succession of margins:
Added Value: AV(T) = RP(T) – CM(T), Contribution Margin: CM = AV(T) – CL(T) = RP(T) – CM(T) – CL(T), so that: OI(T) = CM(T) – CS(T)

[5] If we assume that the sum total of IC(t) depends on the investment in structural factors, then we can write, in order to simplify: $IC(t_0) = k\ CS$, where $k \geq 1$ indicates the influence of inventory on capital investement.

i(T)] (1-*tax*)

2.4 Managerial transformation or PLANNING AND CONTROLLING

This directs the transformations down the road, transforming internal and external information into decisions rules (Prahalad/Bettis,1986; Lax/Sebenius, 1986) regarding the production function, the system of prices, and the financing system.

The output is represented by a system of *planning* and *budgeting* that aims at *efficiency*, and by a system of *controls* regarding the efficiency to achieve in future transformations.

3. Business organizations. Measures of performance

Definition 2 - A *business organization* is a particular *production-oriented organization* that develops business, solding products in markets, at a price $pP \geq cP$, and are whose managerial transformation operates to obtain an $OI \geq 0$.

In independent business organizations, each transformation is characterized by simple performance measures.

3.1 Performance of the PRODUCTION transformation.

The principal performance measures are the ratio of *productive efficiency*, or *average phisical productivity*:

(8)$\pi F_{M, L, S} = QP_\theta / QF_{M, L, S}$, and their inverse, which represent the $qF_{M, L, S}$ shown in (1).Particular importance is attributed to the average productivity of labor determined as: *[9]* $\pi L = QP_\theta/QL$ or, in a more complete expression: $\pi L = [(QP_\theta/QS)\ (QS/QLo)\ (QLo/QL)]$ in which (QP_θ/QS) measures the efficiency of capacity factors (QS), (QS/QLo) measures equipment per unit of labour; (QLo/QL) measures the rate of operative labour input (QLo) with respect to the total paid labour (QL).

3.2 Performance of the MARKETING transformation.

There are three basic indicators

a) the *economic efficiency* (total productivity): (10)$e(T) = RP(T)/CP(T)$,

b) the *economic operating income*: (11)$OI(T) = RP(T) - CP(T)$,

c) the average *return on cost*: (12)$roc = OI/CP$.

3.3 Performance of the FINANCE transformation.

It is shown by the following three indicators:

a)the return on equity: (13) $roe = R/E$,

b)the return on debt:(14) $rod = I/D$,

c)the return on invested capital:(15) $roi = OI/IC = (R+I)/(I+D) = roc \quad rot$[6].

3.4 Performance of the MANGERIAL transformation.

The typical measures of performance are *efficiency* and *variance*, which are common in *planning* and *reporting*. In particular, we must check the variance in *roe* and, working back, all the fundamental variables that define *roe*.

4. The fundamental relations (continued)

The technical, productive, economic and financial transformations are connected by several fundamental relations (Lev,1974; Lev/Sunder,1979; Bernstein, 1989):

a)the *economic relation* between OI and values as a function of production volume:

(16)$OI = (pP - cM - cL)\, QP_\theta - CS = mc\, QP_\theta - CF$

with the following capacity constraint[7]: $QF_{M,L,S} = QP_\theta\, qF_{M,L,S} \leq QF^{MAX}$;

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[6] The return on capital invested (ROI) is also called firm's accountant's rate of profit (ARP), accountant's rate of profit (ARR) and book yield. It is possible to establish a relation between the ROI and the internal rate of return (IRR) of the firm's capital investments (Luckett,1984; Gordon, 1974; Fisher/ McGowan, 1983).

b)the *financial relation* between the indicators of financial effiency (Modigliani/Miller):
(17)*roe* = *roi* + *spread der*, where *spread* = *roi* – *rod*, and *der* is defined by (11);

c)the general financial relation among the values shown in figure 1:

$$(18) \qquad roe = \frac{IC}{E}\ \frac{CP}{IC}\ \frac{RP}{CP}\ \frac{OI}{RP}\ \frac{R}{OI}$$

where *ier* = IC/E = 1+*der* represents the *investment/equity ratio* as a multiplier of the equity, which determines the invested capital; *rot* = CP/IC; e = RP/CP as in *[10]*; *ros* = OI/RP represents the *return on sales*; *nor* = R/OI represents the *net/operating ratio*.

d) balance sheet relation:

$E = KL + IC - D$

$R = RP - CF_{M,L,S} - DI - Tax = div + sfin$

where KL indicates liquidity, and *div* and *sfin* indicate, dividends and self-financing (Mella, 1992).

5. Profit and non-profit organizations.

Definition 3 – A business organization is a *for-profit organization* if the managerial transformation seeks to pursue the maximum productive and economic performance: pP←max→cP; if its objective is to obtain pP→min←cP, then we have a *non-profit* or *not-for-profit* business organization. A *supply organization* is a production oriented organization whose production is distributed to some class of users with a tariff tP ≤ pP.

In business for profit organizations, managerial transformation objective is max *e*(t), (see (10)) or, in equivalent terms, max OI(T), as defined in (11). Substituting (8)into (10) we immediately obtain:

$$(19) \qquad e = \frac{QP_\theta}{QF_{M,L,S}}\ \frac{pP}{pF_{M,L,S}} = \pi F_{M,L,S}\frac{pP}{pF_{M,L,S}}$$

[7] In general the non-negativity condition QP ≥ 0 is valid.

Thus, a necessary and sufficient condition to achieve the max *e*(t), is that the managerial transformation:

1) maximizes the *productive efficiency* (or technical, or combination, or internal efficiency), expressed by $\pi F_{M, L, S}$ – or inversely by $qF_{M, L, S}$ – and by the *quality* of the production, θP;
2) maximize the *business efficiency* (or market, or negotiating, or external efficiency), expressed by the *price differentials* that represent the efficiency of the *market* (last factor in (19)).

The profit organizations that mainly pursue productive efficiency can be defined as *production efficient.* Those that mainly pursue business efficiency can be defined as *marketing efficient.*

(19) can be rewritten simply as: (20) $e = (pP / cP)\ \theta P$ which shows that the essence of economic efficiency is represented by prices, costs and quality.

(11) can be rewritten as follows: (21) $OI(T) = RP - CP = QP_\theta\ (pP - cP)$

and, in this form, expresses even better than (20) that a necessary and sufficient condition for the maximum operating results is that the managerial transformation:

1) maximizes the sales volume QP_θ at the chosen level of quality θ;
2) maximizes the average selling prices;
3) minimizes the average unit cost of production.

6. The system of risks

The *business profit organizations* bear three types of correlated risks:

a) technical, or *production, risk* entails not being able to *attain* production goals;

b) economic, or *market, risk* is the risk of not being able to *sell* the production obtained; there are two kinds of risk in this case:

1) demand risk which derives from *consumer* freedom

2) competitive risk which derives from the *freedom to take economic initiatives.*

c) financial risks, connected to the impossibility of maintaining IC and E *financially integral.*

Lemma – A capital $K(t_0)$ that yields an income R(T), with a *roi* = R(T)/ $K(t_0)$, is kept *financially integral* at the end of period T = [t_0, t_1] if *roi* ≥ *roi**, where *roi** is the *opportunity cost* of $K(t_0)$ defined as the best *roi** of all the alternative available investments.

Proof – The financial value K^F of a capital K that yields an income R(T) can, for simplicity's sake, be set equal to the present value of R(T) at rate *i*: $K^F = R/i$.

By definition, K is *financially integral* at the end of T if $K^F \geq K$. If $i = roi = R/K$, then $K^F = K$. If i <(>) *roi,* then K^F >(<) K. Setting i = *roi** we obtain the following conclusion: in order to maintain a capital K financially integral the *roi* that is obtained must be greater than the opportunity cost.

7. Capitalistic Firms. The entrepreneurial transformation

Definition 4 – An autonomous *business-for-profit organization* that develops a *business portfolio* and activates a *financing portfolio,* accepting the system of risks (Ruefli and al., 1999), and that is constituted in order to maintain $E(t_0)$ financially integral, and that thus pursues the max *roe,* is defined as a *capitalistic firm.*

Proposition 1 - From the preceding definition we can assume that a necessary condition for a *capitalistic firm* to be created and continue to exist for period T is that $E^F \geq E(t_0)$. , where E^F = R(T)/*roe** and *roe** is the minimum acceptable return for *equity holders* to maintain their capital invested in the firm.

Proposition 2 - If $E^F \geq E(t_0)$. , and if R*(T) is the net income that assures *roe**, then the difference *sfin*=R(T) – R*(T) can be invested for the growth of the firm.

Thus, the capitalistic firm:

sets the objective of *roe** in order that $E^F \geq E(t_0)$, but tries to achieve max *roe*≥ *roe** by also exploiting its financial leverage, thereby controlling the *spread* and the *der*;

manages the *business portfolio* in order to produce a sufficient OI(T) that guarantees a min*roi**;

manages its *financing portfolio* at a financial cost I(T) such that max *rod* ≤ min*roi**.

To represent the capitalistic firm, the model in figure 1 also shows a *fifth* transformation:

7.1 *Entrepreneurial transformation* or STRATEGY.

This manages the system mainly on the basis of external information and representations of the environment (Macintosh/Maclean 1999); it produces an *innovative,* and therefore *creative,* way of thinking (Christensen, 1997; Deephouse, 1999) by trying to change the *strategic position* of the firm in the environment (Nonaka/Takeuchi, 1995; Mintzberg and al., 1998), in order to achieve the max *roe* necessary for maintaining the invested capital financially integral. By taking advantage of *[17]*, the entrepreneurial transformation transforms the external information into a strategy for creating the optimal mix of the *business* and *financing portfolios* (Jensen, 2000; Bednarzik, 2000) according to the following rules (Sea/Harbir,1999):

1) choose those investments having a *roi* greater than the min*roi** for the entire firm; if there is more than one, choose that having the maximum *roi;*
2) else, choose the investments that in any event have a positive *roi*, as long as it is at least equal to the *rod* of the correlated financing and sufficient to guarantee min*roe*;
3) choose the financings with min*rod*;
4) if *rod*<*roi*, increase D and reduce E, or move on to rule 1);
5) substitute, when possible, investment I with J if *roi*(J) > *roi*(I); in this way the average *roi* for the entire firm will increase;
6) substitute, when possible, the financing F with G if *rod*(G) < *rod*(F); in this way the average *rod* of the entire firm will decrease.

8. Measures of performance of the entrepreneurial transformation

The *performance* of the entrepreneurial transformation can thus be evaluated on the basis of a constructed indicator for the adequacy of the obtained *roe**, and in particular by referring to the Economic Value of the Firm (EVF) and the Economic Value Added (EVA).

The (22)EVF = R(T)/*roe*°,

is the value of the firm considered as an asset for the shareholders, and in its simplest form corresponds to the financial value of the capital that derives from the capitalization of the earnings R(T) at a rate equal to the opportunity cost to the shareholders (*roe°*).

From the previous lemma we see that if *roe°* < (= >) *roe** < *roe*, and RN represents the average standard earnings, then EVF > (= <) E.

Thus EVF is a *dynamic performance indicator* since it takes account of the variations over time in the *opportunity cost* of the capital for the shareholders (*roe°*) and of the strategy's capability to produce a *roe** sufficient to exceed this.

The (23)EVA = IC (*roi- coi),*

can be viewed as the value added by the firm to original IC(t0): that is, the extra return after having paid the interest on debt and granted a proper *roe°* to shareholders[8]. With reference to the entire period T, this represents the equivalent of the company's goodwill, synthetically determined.

The cost of invested capital or capital cost rate: ccr = coi – or also the weighted average capital cost (wacc) – represents the cost of investment and is determined by the following expression:

$$(24) \quad coi = \frac{rod\,D + roe°\,E}{IC} = rod\frac{D}{IC} + roe°\frac{E}{IC} = wacc = ccr.$$

So, while *roi* is the *return on investment* as defined by (15), the *wacc* represents the part of this return that is needed to pay the interest on the Debt, at an average cost equal to *rod*, as well as to guarantee the shareholders a proper return equal to their opportunity cost, *roe°*.

Conclusion: for any firm the fundamental variable is the *roi*, because all fundamental measures of performance of the economic, financial and entrepreneurial transformations depend on it.

Proposition 3 - An economic condition for the existence of the *capitalistic firm*, as defined in definition 4, is that it succeeds in producing a *roi* such that *roi* > *coi*, which, as we can also see from (24), implies that *roe* > *roe°* (Porter/McGahan,1997; 1999).

If this second condition is met, then also EVF>E, thereby achieving the financial integrity of

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[8] An equivalent definition is: EVA = OPBT – Tax – (IC *coc*) = NOPAT – (IC *coc*) where OPBT is the operating profit before tax and NOPAT is the net operating profit after tax.
A complete tutorial on EVA is at: http://www.pitt.edu/~roztocki/evasmall/index.htm (Steward, 1999).

the capital invested by the shareholders, as can be seen in (22):

A high *roe* guarantees the production of value; since it depends on the *roi* as well as on the *der*, these become the *maximum management objectives* on which the other operating objectives depend: the *volume* of production and sales, *costs, quality,* and unit *prices*.

The real problem today for economically "healthy" firms is to guarantee investors a financial return (interest or dividends) at least equal to the opportunity costs of their best alterntive investments, by maintaining an acceptable degree of risk (actuarial integrity) preserving, in any case, the purchasing power of their capital (monetary integrity) (Boulton, 2000).

When the wealth is relatively scarce, and the capital is needed in order to start up and maintain the production processes, the efficiency in the management transformation is sufficient to assure the teleonomy of the production oriented organization. When the capital is abundant, it is the profitable businesses which are necessary in order to maintain the financial integrity of the capital invested and an efficient entrepreneurial transformation also becomes necessary for the teleonomy of the firm.

This makes evident the relevance of human capital and intangible assets in capitalist production (Griliches, 1996) and on the need for:

creativity, by which products and processes are continually innovated, favoring applied scientific research and technological innovation,

intelligence in understanding internal and external processes, in order to rationalize the technical processes of production,

organizational learning and the formation of *learning organizations* to meet the competitive challenges through new work rules (Schmitz Jr, 2001),

management control (from the Decision Support System to Just-In-Time production) (Wilcox and al.).

9. The Hypothesis of increasing productivity and quality

If we shift our analysis from the individual firm to the *collectivity* of firms, we can demonstrate that:

Proposition 4 - The combinatory system of the capitalistic firm is a system of improvement and progress where the following correlated trends occur, on the condition there is *freedom of economic initiative* and *consumer freedom*:

A. a gradual reduction in pP,

B. a necessary reduction of the cP (David/Wright, 1999b),

C. an unavoidable increase in labour productivity πL (Nordhaus, 1997),

D. an unceasing increase in the quantity and quality of production (Galbraith 1952; Maddison, 1982; contra: Sen/Farzin, 2000),

E. an increase in the wealth of the system (Arnold/Dennis, 1999; Coyle, 1997; Quah, 2000),

F. a reduction in the labor requirement (David/Wright, 1999a; Blank/Shapiro, 2001).

Proof – Let us first consider points A. to D. As we can see from *figure 2*, and recalling equations (19)and (20) - in order to produce adequate levels of OI(T) for the purpose of achieving levels of *roi* and *roe* that will produce values and maintain the integrity of the invested capital, firms, as systems of *managerial and entrepreneurial transformation,* have to follow one of the these paths (Stiroh, 2001b):

a) increase their "contractual strength" and try to position themselves far from the competition (internal firm's growth and mergers and acquisitions strategies) in order to have the possibility to control prices and, in particular, raise selling prices (Chandler, 1990);

b) increase productivity: in other words, search for productive efficiency through old and new factors of productivity – ability, plant, equipment and machinery (Syverson, 2002) and organization – and especially through new information technologies (Stiroh, 2001a) for production and control processes (computers) (Brynjolfsson, 1994; Brynjolfsson/Hitt, 2000) and artificial fertility (biotechnologies) (Grossman/Elhanan, 1991);

c) increase quality, in order to support prices and *selling volumes* by means of differentiation.

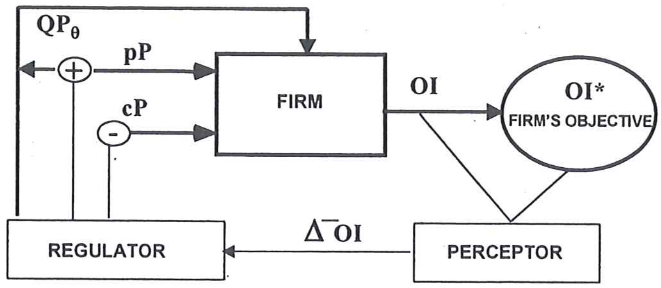

Fig. 2 – Model for the regulation of average costs and prices

The first path, the increase in selling prices or the reduction in purchasing prices, is difficult to pursue because the increase in prices increases the *market risks*: the freedom of the consumer, anti-trust laws aimed at guaranteeing the liberty to take initiatives, economic incentives for restructuring, associations of workers and consumers, and so on, are roadblocks along the way over the long run.

On the contrary, the *reduction in* pP (or an increase which is less than that of the competitors) appears indispensable for meeting the *market risks*.

But if the firm reduces pP then, in order to maintain the level of OI, it is also necessary to reduce cP to the same extent as the reduction in p(B).

There is a continuous *feedback* among OI, price, cost and risks that leads to the reduction (non-increase) of the pP and a continuous increase in *productivity* in order to achieve the reduction in the c(B).

If, in the combinatory system of the firms, a firm "by chance" introduces a new technique to increase productivity, then "by necessity" that technique will spread throughout the system of the firms and eliminate the productivity advantage, forcing the firm to search for new techniques.

In order to counter the reductions in OI firms, rather than try to reduce the cP, often try to increase pP by searching for monopoly positions in order to eliminate the competition and stop consumers from having purchasing alternatives. But once again the freedom of initiative, antitrust laws, incentives for the creation of new firms, and other measures to protect the consumer, *block* firms from increasing pP through anti-competitive actions.

In order to counter the reductions in OR firms can try to bolster pP – without seeking a monopoly position – by raising the quality of their products.

This increase in quality has two consequences:

a) a greater *appreciation* of the product, with the possibility of an increase in the pP given QP;

b) a *differentiation* with respect to other producers, with a *near-monopoly* position (monopolistic competition).

If, in the combinatory system of the firms, a firm "by chance" introduces a new method to increase quality, then "by necessity" that method will spread throughout the system of the firms; but this will lead to the *macro effect* characterized by the gradual increase in average quality which, by reducing the OI, will trigger the *micro-macro feedback.*

Corollary – Regarding the previous point E. (par. 9) we will prove that the increase in productivity will spread the *wealth* and reduce the *labor time* in the system.

Proof – Let [QL(T) πL(T) = QP(T)] and [QL(T+1) πL(T+1) = QP(T+1)] be the quantities of labor, product, and the average productivities in periods (T) e (T+1).

We assume that πL(T+1)>πL(T); then if QL(T) = QL(T+1) it must follow that QP(T+1)>QP(T); wealth increases. If instead QP(T+1)= QP(T), it must follow that QL(T)>QL(T+1); labor is reduced. (QDE).

10. The combinatory system of Increasing productivity

Proposition 5 - I propose the following Hypothesis of increasing quality and productivity:

The search for the highest levels roe* necessary to produce value and meet the expectations of the firms' stakeholders gives rise to a combinatory system of improvement and progress whose macro effect is increasing levels of productivity and quality.

Productivity and quality represent the parameters of the *individual improvement* and *collective progress* of the combinatory system[9].

The heuristic models reveal the *modus operandi* the system of greater productivity can take on the following forms:

MICRO OR NECESSITATING RULE - If your unit profit falls and you want to remain in the economic system as a producer - and if you cannot alter the selling price - you must reduce the average unit cost of production and increase productivity to the same level - or higher - as the average level of the other producers you are competing with, by searching for some productivity factor;

MACRO RULE OR RECOMBINING RULE - The introduction of a productivity factor (*fertility, skill, equipment, organization, motivation,* and *satisfaction*) improves the average level of productivity in the system, thereby eliminating the advantages for the producer; the firm tries to equal - or preferably exceed - the average level of productivity in the system;

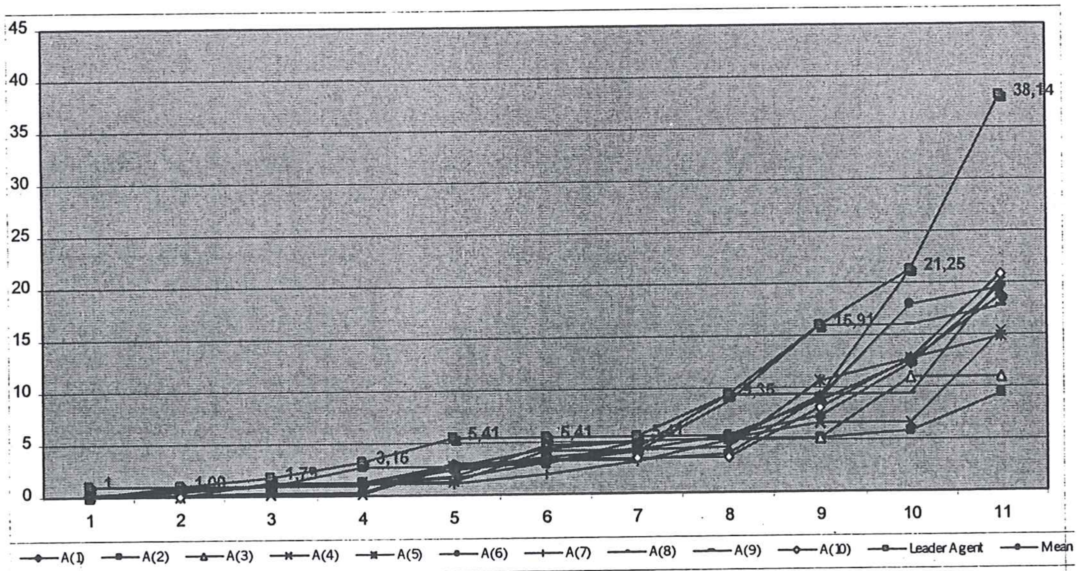

Fig. 3 – Simulation of a maximal system of improvement and progress producing greater productivity (one-dimensional lattice of 10 firms; the red line show the productivity of the leader firm; the coloured lines show the pursuers)

MICRO-MACRO FEEDBACK (CHANCE AND NECESSITY) - The increase in the average level of

[9] There are many techniques to determine productivity rates as measures of progress of the entire economy and of specific sectors. A general an flexible software is OnFront2® (Fare/Grosskopf, 2000); see also (Nordhaus, 2001)

productivity in the system is the result of past micro behaviours of the firms, but this also conditions the search by the firms for new factors of productivity. If "by chance" a producer introduces a new technology - for example, robots or fiber optics in production - then the combinatory system guarantees that "by necessity" the robots and fiber optics will expand to the entire sector unless other alternatives are found that could, if more efficient in terms of productivity, replace the previous ones.

From the heuristic model we can derive this general model that shows the mechanism for producing a continuous rise in productivity in any combinatory system of firms[10]:

[A]

$$\mu(n, t_0) \leftarrow \text{“CHANCE”} \qquad 1 \leq n \leq N \qquad [A.1]$$

$$\pi(S^M, t) = \text{Max}_n\, \mu(n, t) = \mu(n^M, t), \qquad \forall t \in T, \qquad [A.2]$$

$$\mu(n, t+dt) = \{ \mu(n, t) + p(n, t)\, i(n, t)\, [\mu(n, t) + \pi(S, t)] \} + \{ r(n, t)\, [k\, \mu(n, t) + h\, \pi(S, t)] \} \qquad 1 \leq n \leq N \qquad [A.3]$$

In model [A] whose dynamical behaviour can be simulted by a *combinatorial lattice*:

N is the number of firms constituting the lattice simulating an observed combinatory system;

$\mu(n, t_0)$ indicates the measure of productivity that the single firm (agent) must improve in order to survive (micro behaviour);

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10 At time $t<t_0$ we can suppose $\mu(n, t) = 0$ for each $1 \leq n \leq N$ of the combinatorial lattice. At time t_0 we can instead assume that, "by chance", $\mu(n, t_0) > 0$ for some n. We identify the "*lead*" *agent* in terms of improvement - that is, the agent $A(n^M, t)$ that show the higest measure of productivity - and we use it as the indicator of progress. At this point the combinatory system begins to operate as a system of pursuit, since – as shown by the first addendum of equation *[A.3]* - the other firms "pursue" the leader and try to eliminate the gap between their productivity and that of the "best"; we then can observe a rise, "by necessity", in both the individual productivity (level of *improvement*) and that of the system (collective *progress*). The system, however, gives rise to a *second type of progress*, which takes place even when the maximum productivity determined by equation *[A.2]* does not undergo an increase from t to t+1; this progress consists of *a rise in the average level of the measures of productivity* for the firms in the system. In fact, it is easy to see – observing the second addendum of equation *[A.3]* – that the attempts to reach and overtake the *leader* can push the firms to raise their individual measure of productivity; even if the maximum level of productivity does not change from t to t+1, the system may increase the level of some firms. Naturally "chance" can influence the dynamics of the levels of improvement, and consequently that of progress, since it can reduce or accentuate the attempt of individuals - as well as the leader - to raise their level of individual improvement.

$\pi(S^M, t)$ represents the measure of productivity of the lead agent, e. g. of the firm that at any time t (assumed to be discrete) shows the maximum level of productivity of the system (macro effect);

p(n, t) represents the probability for a firm to reach the leader;

i(n, t) represents the coefficient of reduction of the inferiority in productivity that each firm try to eliminate (individual improvement);

$\{ r(n, t) [k\ \mu(n, t) + h\ \pi(S, t)] \}$ represents the influence of exogenous factors on the micro behaviour of the firm in improving its gap in productivity with respect to the lead firm.

The system of increasing quality operates like the system of greater quality.

11. Productivity and employment

Regarding the previous point F. (par. 9) ,as a result of the unceasing increase in productivity the following phenomena can be observed (Giorno and al. 1995):

the increase in the age when man begins his working life (Iacovou/Berthoud, 2001),

lowering of the age when the working life ends (retirement),

a reduction in the average annual amount of working days (long holidays);

a fall in the average daily hours of work (very short work week);

increase in non-employment (unemployment, delayed employment, and dismissals because of an excess of workers).

Will productivity become infinite and production be carried out without human labour?

In principle the answer cannot be negative if we refer to a single firm which acts teleonomically or to a specific sector which acts as a combinatory system[11].

Scientific research and technological progress, made possible and necessary by the need for the growth in productivity, have reached levels that allow us to foresee the possibility of an extreme increase in productivity, which will result in the absence of a need for the majority of human labour; much production will tend toward the ideal of "zero cost".

Proposition 6 - If $\pi L(T)$ increases over time, as a tendential phenomenon following the *Hypothesis* of increasing productivity, and if the increase in wealth is a factor indicating progress,

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[11] Productivity growth of the entire economic system depends not only on firms' efficiency in production and on abundance of capital (Maital) but also on the growth of population. So, we can speak of productivity growth referring to productive labour. Nevertheless productivity inevitably grows also for the entire economy although with different rates of increase in different countries and in different cycle phases (Baumol and al., 1989; Darby, 1984).

we cannot stop the reduction in the quantity of work needed for production.

Proof - To simplify, we bring back equation *[9]* and express QL as the dependent variable:

(25) $$QL(T) = \frac{QP_\theta(T)}{\pi L(T)}$$

We immediately see that we can choose between two alternatives to ensure that $QL_\theta(T)$ does not diminish over time: (i) slow down the increase in $\pi L(T)$; this hypothesis is not realistic in the combinatory system of the firm; (ii) try to increase $QP_\theta(T)$.

In order to analyze the latter alternative, we must remember that products can be divided into two large groups, according to the velocity of consumption:

a – *immediate consumption goods* (Icg): food, standard clothing, services, etc.;

b – *durable consumption goods* (Dcg): housing, furniture, cars, high-quality clothing, etc..

We introduce the *simplifying hypothesis* that in period T= year 1 only two classes of goods are produced, one Icg and one Dcg.

We can calculate the quantity to produce in period T for each class of good:

a) Icg – If we assume that in period T = year 1 the per-capita average unit consumption is equal to κ(Icg), then in T the quanity of Icg to produce is:

$$IcQ(T) = \int^T \kappa(Icg)\, dt = \kappa(Icg) \int^T dt = \kappa(Icg)\, T$$

Example: if everyone eats one sandwich per day, then in T = year 1 we will have Qsandwiches(year1) = 365 sandwiches.

b) Dcg – If we assume that in T = year 1 average unit consumption is equal to θ(Dcg) and that each good has an average life equal to d, then r = T/d indicates the *average turnover* of each unit of a good, so that the quantity to produce will be:

$$DcQ(T) = \theta(Dcg)\, r = \theta(Dcg)\, (T/d)$$

Examples: if everyone uses one pair of shoes per month, then d = 1/12 and r = 12, and in one year there will be Qshoes(year1) = 12 pairs. If people buy a new car once every 5 years, then d = 5 and r = 1/5, and in one year there will be Qcars(year1) = 1/5

If there are M consumers in the system and average consumption is uniform, then overall production in period T will be:

(26) $Q(T) = M\,[IcQ(T) + DcQ(T)] = M\,[\kappa(Icg)\,T + \theta(Dcg)\,r]$

If $\pi(T)$ is unique for the entire system (a non-necessary but useful hypothesis), then from (25) and (26) we get:

$$(27)\quad L(T) = \frac{M\,[\kappa(Icg)\,T + \theta(Dcg)\,r]}{\pi(T)}$$

From this it is easy to deduce that we must look at the following alternatives in order to stop the reduction in L(T) despite an increase in $\pi(T)$:

a. *increase* $\kappa(Icg)$. Example: more oranges in orange sodas, more sugar in sweets, etc.,

b. *increase* $\theta(Dcg)$. Example: two cell phones per person, 2 cars per family, 3 pairs of shoes each month,

c. *increase* the turnover: r. Example: new personal computer every two years; throw away shoes after they are worn out, etc.,

d. *increase* M. Example: a computer for everyone, a cell phone for children, a car at 14 years of age, open new markets, reaching new consumers, and so on;

e. *invent* new goods aimed at satisfying people's aspirations.

The first four alternatives are already in use, though in various ways and degrees (Schumpeter, 1942; McKnight and al., 2001).

The last is more problematic, in that aspirations arise when goods are scarce or low in quality. If there is an abundance of goods, and all high in quality, then the motivating effect is lost. Example: Patek & Philippe and Ferrari are conspicuous only if possessed by a small number of persons.

Thus goods aimed at consumers' aspirations are also produced in limited quantities and are high in quality, and thus come under the *Hypothesis of increasing productivity* (Bresnaham/Gordon, 1997).

If $\pi(T)$ in the system is continually increasing, will there be work for everyone?

If we assume that there are N workers in the system, we can write: L(T) = N hl, where hl are the labour hours per capita which are necessary to have L(t)

Making substitutions in equation (27) we obtain:

$$N\,hl = \frac{M[\kappa(Icg)\,T + \theta(Dcg)\,r]}{\pi\,(T)}$$

We can clearly see that if π (T) increases and the numerator remains unvaried then:

with *hl* fixed, labour would be freed up, because N would decrease; unemployment would become a structural factor;

given N, the unit labour requirement, hl, should fall; the reduction over time in labour is progressive.

This represents one of the problems today.

The world of the *networks* is developing. The computer revolution has only just begun and its development is unpredictable (Levitt, 1993). The economic system is increasingly more integrated: firms and manufacturing companies form a single, interconnected *network*.

The only firm will be the entire network, which is also governed by the law of increasing productivity and quality.

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