

Competition and Technical Change in Aghion & Howitt and Marx: a Common View

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The aim of this paper is to give a further contribution to the literature investigating the existence of analogies between the Classical Theory and the New Growth Theory¹. This paper deals with competition and technical progress as presented in the work of Marx and in Aghion and Howitt's (1992) model, and some of its extensions proposed by the two authors in 1998. The comparison does not rest on the existence of analogies in the methods of analysis which reflect two different visions of the world, but on the identification of some fundamental assumptions which characterise Aghion and Howitt's model and which are to be found at the basis of Marx's idea of competition and technical progress.

Marx's analysis aims to determining the distribution of the surplus produced in the economy among different social classes in conflict together. Such distribution allows, through the accumulation process, the production of new surplus. Struggle characterises Marx's world, not only the struggle among social classes, but also the struggle among different capitals which seek to differentiate themselves in order to expand. This brings continuous changes in the structure of the economy in an environment which is uncertain. The competition process, as a fight among capitals, and technical progress, as a fundamental tool of this process, are the roots of Marx's vision of the world.

Aghion and Howitt propose a neoclassical general equilibrium analysis, in a world characterised by the absence of social classes. This world has the following parameters: initial endowments of the economy, initial individual endowments, individual preferences, technology and the probabilistic production function of new technology. The requisites of existence and stability of an equilibrium are sought thanks to the hypothesis of maximising agents who react to the same set of prices, that they consider as given. The agents act in a context of either perfect or probabilistic knowledge of the environment. Also in this model, as in Marx's analysis, growth is boosted by the competition among innovating firms which strive in order to reap a monopoly rent. Investigation of the basic assumptions made by Aghion and Howitt, in order to model technological change-driven growth, will show that these assumptions are really close to the elements characterising Marx's view of competition and technical change.

* I thank Neri Salvadori and Antonio D'Agata for very helpful comments. The usual caveats apply.

¹ See, for example Kurz and Salvadori (1994) and (1995), and Salvadori (1998).

In what follows I propose to read Aghion and Howitt's models under this perspective: underlining their characterising assumptions which are close to the foundation of Marx's view.

The plan of the work is the following: the first section proposes a careful investigation of Marx's analysis of competition; the second section studies the importance of technical progress as a powerful tool of the competitive process in Marx's analysis; the third section deals with Aghion and Howitt's model of 1992, and with some of its extensions proposed by the two authors in 1998. It also enucleates the fundamental issues at the basis of Aghion and Howitt's idea of competition and technical progress, and which also play a crucial role in Marx's analysis; the fourth section proposes some conclusions.

1.Competition in Marx's Analysis

1.1. Competition: a Twofold Idea

According to Schumpeter² one of Marx's major merits stems from his effort to give an interpretation of history based on economics by investigating the economic basis from which ideas, politics, religion and arts surge and decline. It is in this perspective that one has to interpret Marx's analysis of the competitive process.

In the *Grundrisse*, Marx refuses the idea of competition "*as the mutual repulsion and attraction of free individuals, and hence as the absolute mode of existence of free individual in the sphere of consumption and exchange*"³, and suggests a twofold idea of competition. Competition as a negative force which destroys the historic barriers impeding the free movement of capital, which he identifies, within a nation, with "*compulsory guild membership, governmental regulations and internal tariffs*", and, within the international sphere, with "*blockades, prohibitions and protections*";⁴ and competition as the process which allows the reproduction of the capitalistic mode of production.

The analysis of competition as a negative force, destroying any barrier impeding the free development of capital in its search to reap an ever increasing surplus value, can be mainly traced back to Volume I, Part IV, of *Capital*.[♦] Here Marx deals with the production of relative surplus

² Schumpeter, J. (1951).

³ Marx, K. (1973), p.649.

⁴ See, Marx, K. (1973), p.649 and also (1989), Vol. I, Ch. 24, pp. 812-816 and Vol. III, Ch. 20, pp. 393-394.

[♦]Quotations of Marx's *Capital* (Volume I) are taken from: Marx, K. (1989), "*Il Capitale, Libro I*" Ristampa anastatica della V edizione (ottobre 1964): dicembre 1989, a cura di Cantimori D., Editori Riuniti, Roma. The English translation is taken from the ONLINE VERSION (<http://cepa.newschool.edu/het/profiles/marx.htm>): The English edition of 1887, as edited by Frederick Engels -- including changes made by Engels himself in the 4th (1890) German edition. These changes are indicated as they are found. Transcribed for the Internet by K.K. Campbell, Hinrich Kuhls, Allan Thurrott, Bill McDorman, Bert Schultz, Martha Gimenez.

Quotations of Marx's *Capital* (Volume III) are taken from: Marx, K. (1989), "*Il Capitale, Libro III*" Ristampa anastatica della V edizione (ottobre 1964): dicembre 1989, a cura di Cantimori D., Editori Riuniti, Roma. The English translation

value; principally in Chapter 12-13 where he describes the transition from manufacture to modern industry. The analysis of competition as a process changing the structure of the economy by means of the continuous movement of capitals attracted towards the most profitable sector, is developed in Volume III, Chapter 10. In this chapter Marx deals with one of the laws of the capitalistic mode of production, the equalisation of the general rate of profit.

1.1.1. Competition as a Negative Force

The historical significance of competition is strictly connected with Marx's theory of value. In chapter 9, Part III, Volume I, of *Capital*, Marx tackles the issue of the direct relation between the surplus value mass and the dimension of the anticipated variable capital, given the surplus value rate and the value of labour.⁵ Because of this relation, he states that medieval guilds, by imposing a very strict limit on the number of journeymen the single master can hire, try to hinder the development of the artisan master into a capitalist. In fact, a necessary condition for capitalistic production is the employment, by means of the same capital, of a sufficiently high number of workmen in order to reap a surplus value mass big enough to allow the artisan to support himself without working, hence, to become a capitalist. The number of workers employed is the variable capital from which the capitalist extracts the surplus value. Hindering the concentration of labour means limiting the concentration of capital. In Chapter 10, Volume I, of *Capital*, which opens Part IV devoted to the production of the relative surplus value, Marx defines the difference between absolute and relative surplus value. The former is the surplus produced by prolonging the working day, the latter stems from the shortening of the labour time required to get the necessaries to reproduce labour.⁶ The increase of absolute surplus value is impeded by the objective limit imposed by the 24 hour day; relative surplus value can be increased by raising the productivity of labour power. Marx identifies the development of the capitalistic mode of production with the development of ways to increase the relative surplus value, hence labour productivity. The chapters of Part IV,⁷ are all devoted to the origins and development of the capitalistic mode of production.

The capitalistic mode of production stems from cooperation, based on the principle of the simultaneous employment of many workers. This allows an economy in the use of constant capital

is taken from the ONLINE VERSION (<http://cepa.newschool.edu/het/profiles/marx.htm>): First published in German. This English translation was first published in 1959 by the Institute of Marxism-Leninism, USSR. All misprints and errors from the 1894 German were corrected and all quotations from English or American sources checked directly against original sources. Also, extensive use was made of the 1909 English translation published by Charles H. Kerr & Co., Chicago. Transcribed for the Internet in 1996 by Hinrich Kuhls and Ken Campbell.

⁵ Which Marx, respectively, identifies with the exploitation rate and the part of the working day necessary to reproduce labour.

⁶ Marx identifies surplus value with surplus labour which is equal to the difference between the length of the working day and the part of this working day which is necessary to reproduce labour. See Marx, K. (1989), Ch.7, Part. III, Vol. I, p.251.

⁷ Which are: Chapter 10 (Cooperation and Division of Labour), Chapter 11 (Manufacture) and Chapter 12 (Machines and Great Industry).

and creates synergies among workers, the totality of whom can be seen as a "combined worker". The productivity of the combined worker is higher than the simple sum of the individual productivities. Marx distinguishes between simple cooperation, in which the capital hires several workers, each performing the same or similar tasks, and a more refined type of cooperation based on the division of labour. Manufacture is based on the division of labour, by means of which different jobs become dependent on each other, so that each job can be considered as a part of the same productive process. Moreover, within the same job, each different operation is divided into several tasks, performed by different individuals. The result of the division of labour is an increase in the productivity of labour, which is treated as a simple commodity. This explains why Marx envisages, as a limit imposed to the free development of the capitalistic mode of production, the medieval laws impeding the master from employing journeymen in tasks not related to his handicraft. According to Marx, guilds are based on the negation of manufacturing work; this is because the guild system negates the division of labour. If some form of specialisation is required, this leads to the scission of guilds into sub-guilds or to the creation of new guilds. This maintains the link between worker and means of production and avoids labour alienation. The guild system hinders capital development because it does not treat labour as any other commodity, the market price of which can be regulated by the forces of supply and demand. This prevents the movement of capital according to its internal laws. Marx starts Part VII, Volume I, of *Capital*, devoted to the process of capital accumulation, by stating the first two laws according to which capital moves. *"The conversion of a sum of money into means of production and labour-power, is the first step taken by the quantum of value that is going to function as capital. This conversion takes place in the market, within the sphere of circulation."*⁸.

Marx, in Chapter 21 of the above mentioned section, deals with simple reproduction and explains that the first movement of capital requires the application of the commodity-exchange law to labour. This is the prerequisite of surplus creation which is accomplished in production.⁹

At the end of Chapter 12, Volume I, of *Capital*, Marx states that when manufacture reaches its full development and can be identified with the capitalistic method of production, the capitalistic mode of production itself demands further methods to increase labour productivity. The capital realises that the mode of production based on manufacture does not allow the complete appropriation of labour, which becomes possible only with the introduction of machinery. As will

⁸ Marx, K. (1989), Vol. I, Introduction to Part VII, p.619. The passages continues as follows *"The second step, the process of production, is complete so soon as the means of production have been converted into commodities whose value exceeds that of their component parts, and, therefore, contains the capital originally advanced, plus a surplus-value"*.

⁹ Marx tackles this issue in a very detailed way in Chapter 8, Part III, Volume I, of *Capital*, in which he deals with the variation of the limits to the working day length, in order to reap an ever increasing absolute surplus value.

be developed later, the use of machinery entails a further increase in the scale of production. As the scale of production rises, the necessity for international market expansion becomes greater, as it is necessary to find new markets for the ever-increasing bulk of commodities. From this stems the need for competition to break down every obstacle to international trade.

The consequences of competition as a negative force are therefore freedom of circulation for capital and labour, considered as a good; and freedom of circulation of all goods, thanks to the abolition of internal tariffs, custom barriers, prohibitions and protections.

1.1.2. Competition as a Process¹⁰

Marx's idea of competition as a process which reproduces the conditions of the capitalistic mode of production is principally developed in Chapter 10, Part II, Volume III, of *Capital*. Marx distinguishes between competition within and among industries. Within each industry, competition expresses itself as price competition, aimed at increasing each firm's market share. In this context Marx tackles the problem of determining a unique market value and, consequently, a unique market price.¹¹ Once market value is determined, in order to make market price coincide with it the amount of goods supplied to the market must be identical to the amount of goods representing the social need, which is the amount of goods for which society can pay the market value. Behind the social need there are not the consumer's tastes but a specific income distribution between labour and capital, hence, a specific composition of the demand for goods. This demand is merely made up of labour productive consumption and of the means of production which are necessary to activate such an amount of labour.¹² If the need is bigger than the amount of goods brought to the market, such goods will be sold at a price which is higher than their market value, vice versa, if the need is smaller. It is only when supply matches demand that market price equals market value. In this way Marx considers a price competition among goods owners, given the demand. As stressed by Levine (1980), this type of competition is not firm specific. The firm acts as a goods owner whose objective, within a market, is to sell all the good at the highest possible price.¹³

¹⁰ On the interpretation, in Marx's analysis, of competition as a process see: Elliott, J.E.(1980), Duménil, G. e Lévi, D. (1987, 1999.a., 1999.b), Harris D.J. (1988), D'Agata, A. (1998), Horverak, Ø (1988), Semmler, W. (1984.A e 1984.b), Sylos Labini, P. (1977).

¹¹ The market value is the weighted average of the values of the good produced under different conditions, the weights are given by the share on the total supply of each good produced with a different technique. Marx, K. (1989), Vol. III, Ch.10, p.221.

¹² In capital accumulation Marx considers the institutional role of the capitalist as crucial, this is why, in Ch.. 2, Vol. II of *Capital*, he makes the hypothesis that all the surplus value is accumulated, hence transformed into means of production and additional labour.

¹³ Duménil and Lévi (1999.b) argue that this mechanism works if the demand schedules are decreasing. I think that it is possible to apply to Marx the analysis proposed by Garegnani (1983). In the classical analysis Garegnani excludes the existence of demand schedules. According to Garegnani, however, it is only necessary to suppose supply reactivity. I think, instead, that in Marx there is textual evidence of demand reactivity with respect to price variations. See Marx (1989), Vol. III, Ch.10, p.232.

When Marx says that the market value (and not the market price) will vary according to the relation between supply and demand, he considers a longer time-horizon. A variation in the market value implies variations in the activated productive processes and entails a capital migration from one sector to another, which takes time.¹⁴ Competition no longer expresses itself at the production level. This drives Marx to consider competition among industries which, according to him, requires a sufficient development of the capitalistic mode of production.

Marx extends his reasoning about the determination of market values to the determination of production prices¹⁵ which become the centres of gravitation of market prices. Marx extends his reasoning from a market value structure to a production price one. Production prices (like market values) are the expression of a long period position of the economy, in which persistent forces act and guarantee the reproduction and expansion of the capital at a given rate of profit, and the expansion of labour at the current wage rate, given the state of the technology. If, in a productive sector, market price is higher than production price, in this sector there will be extra profits. Each capitalist moves his capital into the sector which pays him the highest profit rate. This continuous movement of capital entails the tendency towards a uniformity in profit rates, hence, a distribution of the surplus among the industries.

Duménil and Lévi (1987) observe that the competitive equilibrium, to which Marx often refers, is characterised by a set of production prices and relative outputs which guarantee the matching between supply and demand, i.e. the equality between market and production prices, and the uniformity of the profit rates, therefore the immobility of labour and capital¹⁶. In reality, however, the system gravitates around the equilibrium but never reaches it within the period considered.¹⁷ ¹⁸ There are some factors which automatically perturb the adjustment process towards equilibrium (external shocks, speculation, restricted mobility of capital, technical progress). These factors cause variations in the market value of goods and, consequently, change the centres of gravitation. As far as these changes in the gravitation centres are concerned, Semmler (1984.a, 1984.b) argues that, because in Marx the oscillation of market prices around production prices and of industry profit around average profit are considered the normal state of the economy, there is not

¹⁴ On the different time-horizons in Marx's dynamic analysis of vol. III of *Capital*, see Duménil, G. and Lévi, D. (1999.b)

¹⁵ I am not going to deal with the transformation problem, on this issue see Garegnani (1981), pp.26-48, and Steedman (1977), Ch. 3 and 4.

¹⁶ See Marx K. (1989), Vol. III, Ch.50, p. 979, and also Ch.10, p.233.

¹⁷ Duménil and Lévi (1987) argue that although Marx states that excess of supply entails a price reduction and vice versa, he says little about the actual process. According to them Marx does not specify who changes the prices and what information is used. Marx proposes a mechanism based on the firm, but he does not fully specify it.

¹⁸ On the concept of competition as a tendency toward a predicted result, already present in Smith, see Mc Nulty (1967), p. 398 and (1968), p.643.

only a tendency towards profit rates equalisation but also towards the existence of profit rate differentials.¹⁹

1.2. The Competition Process and Rivalry among Capitalists

In Marx, competition is identified with the process which allows the reproduction of the capitalistic mode of production, which is characterised by capital accumulation. The accumulation process is distinguished in two phases, concentration and centralisation. Interpretation of the capitalist behaviour within the accumulation process depends on which phase of such a process is considered, concentration or centralisation.

In Part VII, Volume I, of *Capital*, Marx describes the process of accumulation of capital. By means of capital accumulation the capitalist transforms surplus value into capital, this allows not only simple reproduction but also expanded reproduction of the system

In Chapters 21-22, Part VII, Marx describes simple and expanded reproduction respectively. He deals with simple reproduction to demonstrate that *"Apart then from all accumulation, the mere continuity of the process of production, in other words simple reproduction, sooner or later, and of necessity, converts every capital into accumulated capital, or capitalised surplus-value. Even if that capital was originally acquired by the personal labour of its employer, it sooner or later becomes value appropriated without an equivalent, the unpaid labour of others materialised either in money or in some other object."*²⁰

Marx presents the extended reproduction process to show how surplus value is transformed into capital, hence he describes the real accumulation process: *"Employing surplus-value as capital, reconverting it into capital, is called accumulation of capital"*.²¹ Marx considers the role of the capitalist in the accumulation process: it is, in fact, the capitalist who decides to transform surplus value into capital. If his role is to accumulate, what pushes him to do so? Marx affirms that the capitalist, being *personified capital*, fulfils his capital accumulation function not driven by the use value, but by the exchange value multiplication. However in doing so the capitalist obeys an immanent necessity of the capitalistic mode of production: *to produce for production's sake*. According to Marx *"Only as personified capital is the capitalist respectable. As such, he shares with the miser the passion for wealth as wealth. But that which in the miser is a mere idiosyncrasy, is, in the capitalist, the effect of the social mechanism, of which he is but one of the wheels."* Marx continues this paragraph as follows: *"Moreover, the development of capitalist production makes it constantly necessary to keep increasing the amount of the capital laid out in a given industrial*

¹⁹ On the theoretical problems arising from taking into account the gravitational process and the changes in the centres of gravitation see Harris (1988).

²⁰ Marx K. (1989), Vol. I, Ch. 21, p. 625.

undertaking, and competition makes the immanent laws of capitalist production to be felt by each individual capitalist, as external coercive laws. It compels him to keep constantly extending his capital, in order to preserve it, but extend it he cannot, except by means of progressive accumulation".²² With the development of the capitalistic mode of production, the capitalist fights for his own survival and feels the impulse to increase his profit as *an external coercive law*, independent from his will. He obeys an immanent law of the capitalistic system.²³

We can envisage the capitalist's behaviour driven either by the mere desire to increase his profit²⁴, and therefore his control over labour, or by the need to survive. Elliot (1980) sees in Marx's capitalist a forerunner of the Schumpeterian entrepreneur and argues that the successful Marxian capitalist is neither a mere utility maximiser nor a mere profit maximiser. He wants to *"found a private kingdom"*, has the *"will to conquer"* and a *"joy to create"*²⁵. As will be shown, it is possible to share Elliott's position if the capitalist's action is framed within the concentration process and not within the centralisation process.

It is in Chapter 23, in the above mentioned part, that Marx distinguishes within the accumulation process between capital concentration and capital accumulation. In the concentration process (which Marx identifies with accumulation itself), thanks to the continuous transformation of the surplus value in capital, every single accumulated capital becomes the tool for a further accumulation. Each single capital is divided into several independent capitals. As the capital in the hands of each individual rises, the total capital grows. Marx associates with the concentration process a possible increase in the number of capitalists, depending on the increase in the system wealth. Moreover, *"the part of social capital domiciled in each particular sphere of production is divided among many capitalists who face one another as independent commodity producers competing with each other."*²⁶ Capital concentration is therefore characterised by the increased mass of capital in the hands of each single capitalist and by the *"repulsion of many individual capitals one from another"*.²⁷

If capital concentration acts as a centrifuge force leading to the scission of a single capital into many capitals, capital centralisation acts as a centripetal force by attracting the several fractions of the existing social capital into a single enormous capital. *" This last does not mean that simple*

²¹ Ibid., Vol. I, Ch. 22, p.635.

²² Ibid., Vol. I, Ch.22, p.648.

²³ See also Ibid., Vol. I, Ch.8, p.305-306. On this issue see Levine, D. (1980) who states that in Marx *"Competition simply forces each firm, so far as it is to survive, to accept the fate of the system as a whole, conforming as best as it can to that predetermined destiny"*, p.10.

²⁴ Though he is entrapped in the capitalistic mechanism of the production for the sake of production.

²⁵ See Elliott, J.E. (1980). The words in italics are those used by Schumpeter in his *Theory of the Economic Development*.

²⁶ Marx, (1989), Vol. I, Ch.23, p.684.

²⁷ Vol. I, Ch.23, p.685.

concentration of the means of production and of the command over labour, which is identical with accumulation. It is concentration of capitals already formed, destruction of their individual independence, expropriation of capitalist by capitalist, transformation of many small into few large capitals."²⁸ As centralisation presupposes a different partition of the same social capital, it is not bounded by capital growth. The bulk of capital owned by a single capitalist increases because some other capitalist loses possession of his capital.

Marx considers the centralisation process as the outcome of competition which fights by selling goods at a lower price. This is possible if labour productivity is increased. Labour productivity is strictly connected to the scale of production and to technological progress which, as we will see, partially depends on that scale of production. This is why the bigger capitals ravage and absorb the smaller ones. The consequence of the competition struggle, characterised by high capital mobility, is an unceasing change in the productive structure.

In Marx, as in classical authors, competition is identified with the "act of competing", it is competition which acts through the market, and it is not, as in the neoclassical analysis, a market form or a market attribute. The number of actors in the market does not determine the presence or absence of competition but the way in which it manifests itself.²⁹ This ever-changing dynamic process, which envisages competition and monopoly as the main actors, is identified by Marx with the capitalistic production process.³⁰

2. Technical Progress and Competition

According to Marx, competition is a process in which each capital struggles either to create an empire or to survive, and technical progress is a very powerful instrument in this struggle. Thanks to the introduction of new machines, production costs are lowered and, though momentarily, extra profits are gained.

In Chapter 13, Volume I, Part III, of *Capital*, within his enquiry about the production of relative surplus value, Marx deals with the development of machinery and the consequent formation of modern industry. According to Marx, the introduction of new technology is caused by the capitalists' incessant search for increasing labour productivity.

The introduction of a new technology within a productive sector has two consequences: it lowers the price of the goods used in the reproduction of labour, hence lowering the price of labour; and it raises labour productivity. Thanks to the adoption of a new technique, the production of a good requires less labour than the bulk of the same good produced under the average social

²⁸ Ibid..

²⁹ See Stigler (1957).

³⁰ See Marx's letter to Pavel Vasilevic Annenkov, in Marx, K. (1998), p.132.

conditions of production. This allows the capitalist/innovator to enjoy, though momentarily, a monopoly position and to earn extra profits till the new technique becomes widespread. Although the introduction of a new technique grants the innovating firm only a momentary appropriation of extra profits, it plays a crucial role in the competitive process as it contributes to the continuous change of the productive structure. The determination of the production price in each industry and the law of the tendency towards the uniformity of profit rates lead to continuous investments in the innovating sector and to ever-increasing requests for more efficient techniques in all the other sectors.^{31 32}

2.1. Technical Progress Eliminates the Barriers which Impinge on the Free Development of Capital

Marx's conception of technical progress makes the evolutionists consider him as one of their forerunners.³³ Clark and Juma (1987) write that although Marx refuses, for ideological reasons, the implicit Darwinian gradualism applied to the socio-economic evolution, he adopts a Darwinian concept of technological progress.³⁴ According to Marx, it is the mode of production, characterising the different historical periods, that makes innovations necessary. Technology and environment influence each other, and technology evolves from the rudimental designs for more refined manufacture systems.³⁵

Marx, in Chapter 12, Volume I, of *Capital*, draws attention to the fact that the necessity to better and differentiate the production instruments stems from division of labour; moreover in a footnote to the same chapter, he quotes the Darwinian law of variations revealing the source generating the link between division of labour and technical progress.³⁶ Ricoy (1998) refers to Marx's treatment of the manufacturing period and of interdependence, during this period, of technical progress and division of labour. Division of labour depends on technical progress because every labour organisation variation stems from a labour instrument variation. Division of labour in

³¹ In the following pages I will tackle the issue of the diffusion of technical progress in different sectors.

³² Marx argues that the use of new and more efficient techniques paradoxically starts the law of the tendency of the profit rate to fall. For a review on the debate of the plausibility of Marx's position see Foley (1998), quoted in Duménil and Lévi (1999.b). On the empirical test of such a law see Duménil and Lévi, *ibid.*

³³ On Marx as a fore runner of the evolutionists see Duménil and Lévi (1999.a), see also Semmler, W. (1984).

³⁴ Giuseppe Montalenti argues that both Marx and Engels welcome Darwinism with moderate enthusiasm as they fight Malthus' thesis identifying in the disproportion between population growth and subsistence goods the cause of poverty, which is then permanent and ineluctable. See the introduction to Darwin's *The origins of Species*, Darwin (1996), p.32-33.

³⁵ On this issue see Clark, N. and Juma, C. (1987) who quote the following passage of *Capital* which describes the evolution of the mechanical loom: " *In Birmingham alone 500 varieties of hammers are produced, and not only is each adapted to one particular process, but several varieties often serve exclusively for the different operations in one and the same process. The manufacturing period simplifies, improves, and multiplies the implements of labour, by adapting them to the exclusively special functions of each detail labourer.*" Marx, 1989, Vol. I, Ch. 12, p. 384.

³⁶ See Clark and Juma (1987).

one productive sector causes a further division of labour in others. Ricoy stresses that, in Marx's analysis, manufacture supplies the basis for modern industry in which technical progress must be considered an evolutionary process of accumulation and amelioration of several human, organisational and material factors. Technical progress evolves thanks to the interaction between science and the learning process acquired from production experiences.

It is worth stressing, however, that Marx distinguishes between perfecting and inventing new instruments, which stem from the division of labour, and the introduction of new machinery which does not depend on the division of labour in general. Marx argues that caste division is division of labour, as well as the guild system, and that the division of labour characterising manufacture is different from that characterising modern industry. Every division of labour system employs different instruments, *"There could be nothing more laughable than to assume that machinery is engendered by the division of labour per se"*³⁷. According to Marx, invention and machinery employment stem from the necessity to reap an ever-increasing surplus value.

In Chapter 13, Volume I, of *Capital*, Marx states that the modern industry epoch introduces machinery in order to overcome the limits created by the labour force to the capitalistic mode of production. In order to stress how capitalists introduce and perfect machinery to reduce the use of labour, Marx quotes the evidence of Nasmyth, the inventor of the steam-hammer, before the Trades' Union Commission: *"The characteristic feature of our modern mechanical improvements, is the introduction of self-acting tool machinery. What every mechanical workman has now to do, and what every boy can do, is not to work himself but to superintend the beautiful labour of the machine. The whole class of workmen that depend exclusively on their skill, is now done away with. Formerly, I employed four boys to every mechanic. Thanks to these new mechanical combinations, I have reduced the number of grown-up men from 1,500 to 750. The result was a considerable increase in my profits."*³⁸ It is worth noting that an increase in labour productivity is not the sole effect of new machinery, the introduction of which can change the quality of the labour used in production. Technical progress reduces labour to simple labour, this is strictly connected to the necessity to subvert the artisan and manufacture base from which modern industry stems. *"Just as the individual machine retains a dwarfish character, so long as it is worked by the power of man alone, and just as no system of machinery could be properly developed before the steam-engine took the place of the earlier motive powers, animals, wind, and even water; so, too, Modern Industry was crippled in its complete development, so long as its characteristic instrument of production, the machine, owed its existence to personal strength and personal skill, and depended*

³⁷ Marx (1998), p. 129. Translation is mine. This passage belongs to Marx's letter to Pavel Vasilevic Annenkov, in which Marx, commenting on Proudhon's *Philosophy of Poverty*, briefly summarises his position on the division of labour, manufacture and modern industry, stated in Chapter 12-13, Volume I, of *Capital*.

*on the muscular development, the keenness of sight, and the cunning of hand, with which the detail workmen in manufactures, and the manual labourers in handicrafts, wielded their dwarfish implements*³⁹. Technical progress allows the substitution of the force of human traction with automatic machines and eliminates the limit posed to production by the semi-artistic nature of the human labour force.⁴⁰

The reduction of labour force employment and the demotion of labour to simple labour are the levers that stimulate the single capitalist to innovate, because they produce direct effects on his profit. Moreover, technical progress has important effects on the entire system: it increases the labour reserve army and, reducing labour to simple labour, makes the worker indifferent about the nature of his work, hence facilitating inter-sectorial labour mobility which is the crucial premise to capital mobility.

While it is possible to say, following the evolutionists,⁴¹ that Marx's competition process is comparable to the Darwinian natural selection process,⁴² this statement requires a further specification. One of the major problems tackled (and not solved) by Darwin is the understanding of the origins of diversity. Darwin believes that diversity is ruled by uncountable laws, most of which are unknown. If the variations originating in nature make the individual more capable of fighting the survival struggle, they are selected and transmitted to future generations. In Marx, on the contrary, it is the capitalist/innovator who aims to create that kind of diversity which allows his firm to win the selection struggle operated by the competition process. In current terms, one must consider the capitalist/innovator as somebody who invests in research on firm genetic bioengineering. Using Marx's words: “ *Technology discloses man's mode of dealing with Nature, the process of production by which he sustains his life, and thereby also lays bare the mode of formation of his social relations, and of the mental conceptions that flow from them.* ”⁴³.

³⁸ See Marx, K. (1989), Vol. I, Ch. 13, p.480

³⁹ See Marx, K. (1989), Vol. I, Ch. 13, p.425.

⁴⁰ Marx, commenting on the "puddling" process (an iron fusion technique) born with the boost of modern industry, stresses that, thanks to the invention of such a process, there is an increase in capital dimensions and raw materials which enter production, together with a given amount of labour force. The development of such a process brings an internal contradiction: menial labour, which is limited by the single worker's abilities, jeopardises the full development of the metallurgical industry. Ibid. Vol. I, Ch. 23, p.681, footnote to the French translation.

⁴¹ Interpreting the need for innovation, i.e. obedience to a coercive law of the capitalistic mode of production, as a component of the Darwinian struggle for survival, in an evolutionary context, is not the sole possible point of view. Veblen (1998) states that the economy is not an evolutionary science because it is still too linked to the classical idea of general laws, of "normal" value, of "regulatory" principles, outside which everything is considered as a disturbing factor. This is not the interpretation given by Duménil, G. and Lévi, D. (1999.b) of the gravitational process of prices around the production price in Marx's analysis.

⁴² On the analogy between natural selection and competition, see Leoncini and Sabbatini (1992) who stress that, when comparisons between evolutionism in biology and economics are suggested, it is necessary to remember a crucial difference: in economics individual actions are the outcome of voluntary choices.

⁴³ Marx, K. (1989), Vol. I, Ch.13, p.414, footnote 89.

2.2. Social Memory, Collective Labour and Scale of Production

In Marx, both the economy dimension and the firm dimension are crucial aspects. In fact, with the growth of the economic system grows social memory which results from the systemic accumulation of knowledge. An increase in a single firm's dimension boosts experience accumulation and allows the firm to exploit ideas which are a common patrimony and to enrich the common patrimony of ideas itself.⁴⁴ A new idea originates thanks to the pre-existing ideas heritage and allows the production of radical inventions. Each radical invention gives birth to a sequence of incremental inventions which are the outcome of scientific and technical development together with the learning process of collective labour. Marx, in fact, clearly distinguishes between radical and incremental invention.⁴⁵

In Chapter 5, Part I, Volume III, of *Capital*, devoted to the economy in the use of constant capital, Marx states that ideas are *universal labour*, and "*universal labour is all scientific labour, all discovery and all invention*"⁴⁶, ensuing from use, by the living, of the labour of the dead, while collective labour is the result of *cooperation among living people*. *Universal labour* and collective labour converge and both contribute to the productive process. In the same chapter, Marx expressly refers to the analysis of manufacture and modern industry developed in Chapters 12-13 of Volume I, and links the employment of collective labour to scale economies. Big plant-size allows not only a constant capital saving due to increasing returns to scale but also the accumulation of practical experience through the work of the combined collective worker. In modern industry, in fact, the production process does not leave any room for individual initiative. The isolated worker is absorbed by the socialised worker which is the resultant of different kinds of labour, of all the figures in the productive process, each of which is functional with regard to the others. The suppression of the isolated worker is a systematic process because "*Machinery, with a few exceptions to be mentioned later, operates only by means of associated labour, or labour in common.*"⁴⁷

The importance of Marx's collective worker in the capitalistic production system is stressed by Bonzio (1992) who quotes the following passage from Chapter 13, Volume I, of *Capital*: "*Here, the process as a whole is examined objectively, in itself, that is to say, without regard to the question of its execution by human hands, it is analysed into its constituent phases; and the*

⁴⁴ On this issue see Duménil and Lévi (1999.a), who argue that although the relationship between Marx and the evolutionists is strong, because of the treatment of adaptation to disequilibrium and uncertainty, Marx gives importance to the social dimension in the reproduction and creation of science and culture, while for the evolutionists the firm is the knowledge depositary.

⁴⁵ Marx criticises Smith for not having distinguished between invention and tool differentiation, see Marx, K. (1989), Vol. I, Ch. 12, p.391, footnote n.44.

⁴⁶ *ibid.*, Vol. III, Ch. 5, p.138.

⁴⁷ *Ibid.*, Vol. I, Ch.13, pp.428-429.

*problem, how to execute each detail process, and bind them all into a whole, is solved by the aid of machines, chemistry, &c. But, of course, in this case also, theory must be perfected by accumulated experience on a large scale.*⁴⁸ This passage is important because it stresses the relevance of the large scale of production in the accumulation of collective experiences, acquired by several generations of modern industry workers. It also underlines the two levers of technical progress: knowledge, from which radical inventions stem, and productive experience, i.e. learning by doing, which produces incremental inventions, and at the same time increases knowledge at the systemic level. In another passage of the same chapter Marx argues that although ideas are a common patrimony, a minimum plant-size, and therefore a high initial investment, are necessary to exploit them. *“Once discovered, the law of the deviation of the magnetic needle in the field of an electric current, or the law of the magnetisation of iron, around which an electric current circulates, cost never a penny. But the exploitation of these laws for the purposes of telegraphy, &c., necessitates a costly and extensive apparatus”.*⁴⁹

2.3. Endogenous Technical Progress: Supply and Demand of Inventions and Innovation Activity Uncertainty

In the above paragraph it has been stressed that Marx envisages an endogenous mechanism of incremental inventions which results from the collective worker experience, hence from the division of labour. Under this perspective, technical progress can be seen as a "side effect" of the accumulation process, characterised in its different phases by different types of division of labour. However, in Marx's analysis, it is possible to identify subjects who purposefully act in order to change the productive technique set.⁵⁰ Marx attributes to the capitalist, in his search for an ever-increasing surplus value, the role of the innovator. This does not merely entail the capitalist's choice of the best technique from a technical set which exogenously changes without his control, but his possibility to interfere with the variation of the technical set. The capitalist has a crucial role in the genesis of the innovative process. While it is true that a necessary condition for the technical progress is the accumulation of scientific knowledge at the systemic level, it is also true that it is the capitalist who expresses the demand for inventions.⁵¹ Capitalists, in their continuous search to increase the surplus value to reap, demand better and better performances from machines, this leads

⁴⁸ Ibid., Vol. I, Ch. 13, p.422. See also, p.477.

⁴⁹ Ibid., Vol. I, Ch.13 p.429.

⁵⁰ On endogenous technical progress in Marx see Clark, N. and Juma, C. (1987), Duménil, G. and Lévi, D (1999.a), Ricoy, C. (1998) and Rosenberg, N. (1974).

⁵¹ According to Rosenberg, N. (1991) the capitalistic mode of production gives great stimulus to the introduction of technological change, he stresses the importance of trade and industry as practical bases and incentive to the development of pure science. Rosenberg believes that the role of demand is one of the major components of technical progress production.

to the continuous introduction of new and more efficient ones. The demand for inventions is a deliberate action. But who supplies the system with new machines? Marx clearly conceives an organised system of patents which inventors deliberately produce in order to sell them to capitalists.⁵² Yet Marx believes that it is extremely easy for the capitalist, who owns the economic means, to gain possession of a new but already tested production technique. This implies that Marx does not conceive a perfectly functioning patent system. Moreover, the innovating capitalist faces an environment characterised by uncertainty about the outcome of the new technique application.

Marx's position can be traced back to both Chapter 13, Volume I, and Chapter 5, Volume III, of *Capital*. In Chapter 13, Marx describes the passage from manufacture to modern industry as follows: "*As inventions increased in number, and the demand for the newly discovered machines grew larger, the machine-making industry split up, more and more, into numerous independent branches, and division of labour in these manufactures was more and more developed. Here, then, we see in Manufacture the immediate technical foundation of Modern Industry*".⁵³ In Chapter 5, Marx describes the introduction of innovations which reduce production costs as resulting from capitalists' exigencies. For this purpose Marx quotes an 1852 factory inspector's report: "*The very economical results derived from the employment of high-pressure steam in working condensing steam-engines, together with the much higher power required by mill extensions from the same engines, has within the last three years led to the adoption of tubular boilers, yielding a much more economical result than those formerly employed in generating steam for mill engines.*" (*Reports of Insp. of Fact., October 1852, pp. 23-27*)⁵⁴.

In Chapter 13, Volume I, Marx not only stresses the importance of inventions which improve labour productivity in order to increase the bulk of appropriable surplus value, but also shows his awareness of the existence of a well organised patent system. "*The greatness of Watt's genius showed itself in the specification of the patent that he took out in April, 1784. In that specification his steam-engine is described, not as an invention for a specific purpose, but as an agent universally applicable in Mechanical Industry. In it he points out applications, many of which, as for instance, the steam-hammer, were not introduced till half a century later. Nevertheless he doubted the use of steam-engines in navigation. His successors, Boulton and Watt, sent to the exhibition of 1851 steam-engines of colossal size for ocean steamers*"⁵⁵. The existence of this system stems, according to Marx, from the fact that science is sold to capital. In the same chapter, in fact, he criticises Ure's ingenuousness and cynicism with the following words: "*For instance, after propounding the "doctrine" stated above, that capital, with the aid of science taken*

⁵² Marx, K. (1989), Vol. I, Ch.13, p.424, Vol. III, Ch.5, pp.133-134.

⁵³ Ibid. Vol. I, Ch.13, p.424.

⁵⁴ Ibid. Vol. III, Ch.5, pp.133-134.

into its pay, always reduces the refractory hand of labour to docility, he grows indignant because "it (physico-mechanical science) has been accused of lending itself to the rich capitalist as an instrument for harassing the poor."⁵⁶ Marx assertion that science is sold to capital,⁵⁷ may signify either that it is the capitalist who buys the invention or even that it is the capitalist who finances the inventive process. In both cases the demand for new technologies is expressed by the capitalistic class and this demand is matched by a well organised supply. If one thinks that Marx is influenced by the Darwinian theory, it is necessary to stress that, in his analysis, it is the capitalist who directly generates the variation which is necessary to create a competitive advantage. Technological variation is the outcome of voluntary actions, however uncertain.

The uncertainty of the outcome of technological progress can be traced back to Chapter 5, Volume I, of *Capital*. In a paragraph dealing with the increase in machine power associated with a reduction in the use of fuel, Marx attributes this technical improvement to the daring capitalist. Marx, in fact, quotes Nasmyth on the enormous increase in traction force due to the continuous transformations and improvements of steam engines, obtained thanks to some capitalist's boldness: "*Beyond this speed it was not considered prudent or desirable to work the engine; "... However, at length, either through fortunate ignorance of the 'rule', or by better reasons on the part of some bold innovator, a greater speed was tried, and as the result was highly favourable, others followed the example, by, as it is termed, 'letting the engine away'.*"⁵⁸ In the same chapter Marx speaks of the frequent failure of the first innovator, at the expense of whom the *monetary capitalist* prospers: "1) *The great difference in the cost of the first model of a new machine and that of its reproduction (regarding which, see Ure [The Philosophy of Manufactures, Second edition, London, 1855. - Ed.] and Babbage [On the Economy of Machinery and Manufactures, London, 1832, pp. 280-81. - Ed.]).*

2) *The far greater cost of operating an establishment based on a new invention as compared to later establishments arising ex suis ossibus. This is so very true that the trail-blazers generally go bankrupt, and only those who later buy the buildings, machinery, etc., at a cheaper price, make money out of it. It is, therefore, generally the most worthless and miserable sort of money-capitalists who draw the greatest profit out of all new developments of the universal labour of the human spirit and their social application through combined labour.*"⁵⁹ This passage also stresses

⁵⁵ Ibid. Vol. I, Ch.13, p.420.

⁵⁶ Ibid. Vol. I, Ch.13, p.481.

⁵⁷ Marx, in the above mentioned footnote to the French translation, commenting on the hindering of the full development of the metallurgical industry, caused by the obsolescence of "puddling", quotes *The Engineering*, June the 13th, 1874, and shows that engineers have the same intolerant attitude as capitalists towards limits to the free development of capital. Ibid. Vol. I, Ch. 23, p.681.

⁵⁸ Ibid., Vol. III, Ch. 5 p.131

⁵⁹ Ibid., Vol. I, Ch.5, p.139.

that, though there is a patent system, it is not perfect, and that there is a difference between the capitalist who innovates and the capitalist who merely imitates successful innovations.

2.4. Interdependence among Industries and Technical Progress Diffusion

According to Marx, a revolution in one industry's mode of production causes a revolution in that of other industries, because of the strong interdependence among productive sectors. Some sectors, although they produce isolated goods, can be seen as gears of the same complex productive mechanism.

In Chapter 13, Volume I, Marx also proposes the example of mechanical spinning that causes the necessary introduction of mechanical weaving, and the impact of both on the chemical-mechanical revolution in the clothes bleaching, colouring and printing processes.

Marx offers, as a further example, the adaptation of the communication system to the necessities of modern industry. The need for railways and transoceanic ships entails the construction of huge machines in order to build the first engines *“Modern Industry had therefore itself to take in hand the machine, its characteristic instrument of production, and to construct machines by machines. It was not till it did this, that it built up for itself a fitting technical foundation, and stood on its own feet.”*⁶⁰ Technological progress is always the result of the necessity to destroy whatever hinders the development of capital, it is the outcome of a problem solving⁶¹ activity within the accumulation process.

Marx is aware that the full application of the invention to the productive process is not always immediate. Some time has to elapse before the development of the productive process allows the entire exploitation of the original invention.⁶² According to Marx, in fact, industrial revolution flows from the working machine, which is a modified version of the tools used by manufacturing workmen. The impossibility of the single worker to activate several working machines simultaneously, makes it necessary to discard man as the prime mover of the working machine and to introduce the steam-engine: *“The steam-engine itself, such as it was at its invention, during the manufacturing period at the close of the 17th century, and such as it continued to be down to 1780, did not give rise to any industrial revolution. It was, on the contrary, the invention of machines that made a revolution in the form of steam-engines necessary. As soon as man, instead of working with an implement on the subject of his labour, becomes merely the motive power of an implement-machine, it is a mere accident that motive power takes the disguise of human muscle;*

⁶⁰ Ibid., Vol. I, Ch.13, p. 427. In the same page, Marx argues that the production of machines by means of machines is possible thanks to the invention of the slide-rest, which is, according to Marx, a very important tool as it is able to substitute human strength and to produce the single machine parts in a very precise and quick way.

⁶¹ On this issue see Rosenberg, N. (1974, 1991).

⁶² See Ibid.

and it may equally well take the form of wind, water or steam."⁶³ As Rosenberg (1974) stresses, only when the productive process is free from the dependence of human work, can science incorporate its findings in the productive process. This means that a change in the productive paradigm does not occur as soon as the new invention is generated but only when the production exigencies require and allow it. As the mode of production varies, an obsolescence process develops. For this reason, Rosenberg (1974) envisages in Marx's analysis a sort of product life-cycle of each new machine, the first prototype of which is almost always inefficient as its functioning has not been tested in production.

3. The Hypotheses at the Basis of Aghion and Howitt's Analysis and their Affinity with Marx's Ideas

Both Marx's ideas on competition are connected with the appropriation of a surplus value and its consequent transformation into capital to be accumulated. Competition as a negative force "sets the stage", in which competition as a process can act. Competition as a process is identified with the capitalistic mode of production, characterised by the struggle among capitals in their search to reap an ever-increasing surplus value. This brings continuous changes in the productive structure and differences in profitability, that though momentarily are always recreated by the capitalists' effort to invent and perfect more and more efficient production techniques. Technical progress, by increasing labour productivity, is a powerful instrument of competition. In the following pages it will be shown that many of Marx's ideas on technical progress and competition are present in Aghion and Howitt's models.

3.1. The 1992 Aghion and Howitt's Model

According to Solow (1994) *"the real value of endogenous growth theory will emerge from its attempt to model the endogenous component of technological progress as an integral part of the theory of economic growth"*⁶⁴. It is in this tradition that Aghion and Howitt (1992) propose a model in which economic growth is solely driven by technological progress, engendered by competition among research firms which generate innovations. What makes firms carry out research are the expected monopoly rents which can be gained when the new innovation is patented. The model takes into account both the risk related to the research activity and the creative destruction effect, which is ignited by every new invention that makes the previous one obsolete.⁶⁵ For this reason, this

⁶³ Marx, K. (1989), Vol. I, Ch.13, p.417.

⁶⁴ Solow, R. (1994), p.51.

⁶⁵ Grossman, G. M. and Helpman, E. (1991) develop a similar analysis. The main difference they introduce is that the diversity struggle does not take place at a global level, but at each industrial sector level, within each industry the firms struggle to obtain a patent.

model is referred to as a neo-Schumpeterian growth model⁶⁶ and, as we will see, it proposes an idea of competition which, for certain aspects, is close to that of Marx.⁶⁷

Aghion and Howitt study a three-sector economy: the final good sector uses as inputs unskilled labour and intermediate good; the research sector produces a random series of innovations by the use of skilled labour and specialised labour; the intermediate sector uses as inputs skilled labour and a design bought from the research sector. The amounts of the different types of labour are given. The model is characterised by perfect competition in all sectors but one, the intermediate output sector, which can be monopolised by the successful innovator.

The final good sector is characterised by the following constant return production function: $Y=AF(x)$ with $F'>0$, $F''<0$, where Y is the output flow, x is the flow of intermediate good input and A is the intermediate good productivity parameter.⁶⁸

The research sector produces a random series of new designs, each new design allows the production of a new intermediate good, the use of which increases the final sector productivity by the proportional factor $\gamma>1$. For this reason the firm that innovates obtains a patent that lasts forever, but will be used till a new better intermediate input is invented. The productivity rise due to each successful innovation lasts forever; this introduces an important intertemporal spillover effect in the model. At the macro level, dimension is important. As the economy grows with the growth in the number of inventions, **so does** the intermediate good productivity parameter. This scale effect is a feature common to many New Growth Models.⁶⁹

For each firm the invention of a new intermediate input is a random event governed by a Poisson distribution with an arrival rate $\lambda\phi(z, s)$, where z and s are, respectively, researcher-specific skilled labour and specialised labour, and ϕ is a production function characterised by constant returns to scale. From this it follows that each researcher's work does not influence the productivity of the other researchers.⁷⁰ At a macro level the invention of a new intermediate good is a random event governed by a Poisson distribution with an arrival rate $\lambda\phi(n, R)$, where n is the skilled labour and R the stock of specialised labour employed in research, this because ϕ is characterised by

⁶⁶ Romer, P. (1994) gives a different definition of neo-Schumpeterian models, by gathering under such a category all the New Growth Models that abandon the hypothesis of perfect competition and in which the discoveries are the outcome of a monopoly profit-seeking activity.

⁶⁷ As Aghion and Howitt explicitly refer to Schumpeter in their analysis, a comparison between Marx and Schumpeter, as a further development of this study, could be fruitful.

⁶⁸ Unskilled labour disappears from the analysis because it is all used in the final sector.

⁶⁹ Aghion and Howitt (1992), p.325 explicitly refer to Romer. In Romer's **1990** model, thanks to the externalities in the knowledge stock, investing human capital **at a constant rate** in the production of knowledge entails a constant growth rate of the knowledge stock. The increase in the number of intermediate durable goods raises the whole system productivity.

constant returns to scale and each invention, at the aggregate level, is an independent event. The length of time which elapses between two inventions is a random variable, governed by a Poisson distribution characterised by the arrival rate $\lambda\phi(n_t, R)$, where n_t is the amount of skilled labour used during the interval t .

The intermediate sector is monopolistic and produces the intermediate good using skilled labour together with a design. The incumbent firm in the intermediate sector does not perform any research activity, as it considers not only the value of the future patent on the new invention, but also the loss caused by the destruction of the present patent. This happens because all the researchers can use the incumbent technology, A_t , to develop their own research. This effect is called Arrow effect or Replacement Effect. The potential entrant, on the contrary, does not consider this loss among its costs.

This model is a general equilibrium model. The problem of finding the equilibrium is solved by the satisfaction of an arbitrage condition in the labour market, together with a labour market clearing equation; these two equations are considered by Aghion and Howitt the *backbone of the basic model*. To find the equilibrium means to determine in every period the allocation of skilled labour between intermediate and research activities, taking as given: the arrival rate $\lambda\phi(n_t, R)$, the skilled labour wage, and the expected income resulting from the use of the patent on the new invention. This choice must entail an increase of the same proportional factor in wages, profits and output, as a consequence of a new invention. It must also be compatible with the choices of all economic agents who consider prices, wages and interest rate as given.

It is worth looking at the two *backbone* equations which stem directly from the general equilibrium setting that Aghion and Howitt choose. The arbitrage condition, $w_t = \lambda V_{t+1}$, reflects the fact that labour can be freely employed either in the research sector or in the manufacturing sector, imposing that the hourly wage paid in the manufacturing, w_t , equal the expected value of an hour in research (which is the expected discounted payoff, V_{t+1} , multiplied by the flow probability of an innovation of value V_{t+1} , that is λ). This arbitrage condition stylises Marx's idea of the need for the free mobility of capital towards the most remunerative uses. It states what competition in Marx's world should create, by destroying barriers to the free movement of capital and labour. Skilled labour in Aghion and Howitt's analysis cannot be considered as labour in Marx's analysis, but as an asset which looks for the most remunerative use. The skilled labour market equation is $N = n_t + x_t$, where n_t and x_t are respectively the amount of skilled labour used in research and the amount of

⁷⁰ Aghion and Howitt (1992), p.339, footnote 11, sketch the possibility of removing this hypothesis by introducing an arrival rate which is a constant returns function of their own and others' research.

skilled labour used in manufacturing. It reflects the frictionless nature of this market and assumes market clearing. On this issue is worth referring to what Duménil and Lévi (1987) argue: according to them, there are different conceptions of the market mechanism. The common characteristic of all dynamic equilibrium models consists in equality between supply and demand, however, it is possible to conceive of different market mechanisms which respectively lead to: i) an ex-ante equilibrium in which demand immediately matches supply, as in the Walrasian model with production (this is what happens in the New Growth Models with perfectly competitive markets); ii) an ex-post equilibrium which is only reached asymptotically. The supply is determined together with the prices of the goods before the demand is known, and the information available is that of the previous period (this is what happens in Marx's and the classical economists' analyses). The New Growth Theory uses the ex-ante equilibrium concept because it adopts an intertemporal equilibrium model, in which the Walrasian auctioneer determines in advance the complete sequence of events. Equality between supply and demand is obtained in each period, given the prices.⁷¹ As Duménil and Lévi suggest, a characteristic of the competitive process in Marx is *adaptation* to disequilibrium. From this it follows that, in order to find similarities between the two authors' and Marx's analysis, we must focus our attention on the monopolistic intermediate sector. Growth, in Aghion and Howitt's model, stems from rivalry among innovating firms. Innovation is the tool which allows a firm in the intermediate sector to reap a monopoly rent at the expense of the previous incumbent firm which will be expelled from the market. The mechanism which generates growth in Aghion and Howitt's model is the same mechanism which propels the accumulation of capital, and allows the reproduction of the capitalistic mode of production in Marx's analysis. Aghion and Howitt's idea of creative destruction grasps a fundamental element of Marx's analysis, the importance of the invention as a competitive tool in the accumulation process. The capitalist, in Marx's analysis, looks for more efficient productive techniques in order to reap a higher surplus and accrue his capital, in a setting characterised by a continuous expulsion of capitals from the market.

In Aghion and Howitt's model, endogenous technical progress is the engine of growth because of the possibility of patenting the new invention. Profit is the only motive for investing in research. Patenting makes the research outcome excludable and allows the innovating firm to monopolise the intermediate sector. Also on this issue, the analogy with Marx's analysis is evident: Marx has in mind a sector which produces and patents inventions, in order to sell them to profit-driven capitalists.

⁷¹ If it is true that the adoption of a general equilibrium approach entails the impossibility to investigate the behaviour of the firms that struggle for differentiation in a disequilibrium context, it is also worth noting that Grossman and Helpman (1994), p.34, allow that at the microeconomic level firms continually fight and that the growth process is uneven and stochastic, but "*aggregation masks this micro-level turbulence*."

At the basis of the growth mechanism in Aghion and Howitt's analysis is the intertemporal spillover effect which makes the intermediate good productivity parameter grow by the same amount for every successful new invention.. This "scale effect" is close to Marx's idea of the importance of the accumulation of experiences at a macro level. It is worth stressing, however, that in Aghion and Howitt's model research activity is characterised by the lack of memory, because the arrival rate depends solely on present research and not on the stock of past research.⁷²

Aghion and Howitt model the research activity as a risky one, the outcome of which is governed by a random process. By doing so they acknowledge the existence of elements which cannot be completely controlled by economic factors. This aspect is close to Marx's idea that the outcome of the innovation activity is uncertain and that technological development paths have potentialities that are not immediately discovered and are regulated by unknown laws.

Aghion and Howitt (1998) discussing their 1992 model outline some of its shortcomings. They acknowledge the need to consider learning and experimentation as basic features of the growth process. As will be shown, the introduction of these features in their 1998 extension enriches their model with more ideas which are at the basis of Marx's competitive process.

3.2. Aghion and Howitt (1998): Some Extensions to the Basic Model

3.2.1. Learning by Doing and Basic Innovation

Aghion and Howitt (1998)⁷³ propose a further development to their 1992 model in which they try to represent the firm and its research effort. They acknowledge that in order to exploit research generated knowledge, a firm must apply its own theoretical knowledge in practice, solve unexpected problems and grasp new opportunities. For this reason they deal with the heterogeneity in the innovative structure by distinguishing between fundamental and secondary innovations, which are complementary to each other. They consider a model in which two extreme kinds of research co-exist, R&D and learning by doing.⁷⁴

With learning by doing, Aghion and Howitt model an element which is at the basis of Marx's conception of technical change. Ideas can be produced not only by an R&D activity, but also as the outcome of a learning activity within the production process.

Aghion and Howitt propose a first variant of the basic model, in which learning by doing is only accumulated at the macro level. There is an R&D sector which invents intermediate goods by

⁷² Aghion and Howitt (1998) present a simplified version of their 1992 model and propose a possible extension. They relax the hypothesis of a constant return function in the research sector and introduce the existence of externalities among different researchers

⁷³ See Aghion and Howitt (1998), Ch. 6.

⁷⁴ The implication of this model is the following: there exists a value of the growth rate beyond which the increase of research, at the expense of secondary innovations, jeopardises growth.

means of research labour and general knowledge. Growth in general knowledge depends on the level of each kind of research, R&D and learning by doing, and on the previous amount of general knowledge. Also in this model there is an exogenously given researcher's Poisson arrival rate of fundamental innovations. The higher the level of general knowledge in period t , the higher the potential quality of the intermediate good of vintage t . These hypotheses embody the importance of the accumulation of ideas and production experience at a macro level and are close to Marx's conception of social memory: ideas and production experience, once produced, become part of social memory and are at everybody's disposal. In the final sector, labour jointly produces output and secondary innovations. Secondary innovations are not internalised by each single firm, but improve the quality of the already existing intermediate goods at the systemic level. This hypothesis further stresses the importance of the accumulation of production experience at a macro level, which is crucial in Marx, and also sketches his idea of interdependence among productive sectors.

In this model, Aghion and Howitt also introduce the idea of a product life-cycle. The quality of each intermediate good is continuously increased by the accumulation of systemic learning by doing; however, as older intermediate goods incorporate less aggregate knowledge than new ones, with the introduction of new intermediate goods the contribution to production of old vintage goods decreases till they become obsolete. This outlines Marx's idea of a machinery life-cycle.

Aghion and Howitt also propose a further variant of the basic 1992 model in which learning by doing is completely internalised by the firm.⁷⁵ Only the firm that solves the problem within the productive process is able to improve its product quality. This model formalises Marx's idea of the learning process by means of the combined worker.

Both variants introduce an exogenous worker adaptability parameter, which is the rate at which a worker can move from producing an old to producing a new vintage intermediate good or to producing research. With internalised learning by doing, Aghion and Howitt find that the size of the adaptability parameter is positively related to the growth rate. This partially models Marx's idea that there is an important link between capital accumulation and capital/labour mobility, the realisation of which characterises the action of competition as a negative force .

3.2.2. Higher Competition, Technical Progress and Growth

Aghion and Howitt in 1992, making particular assumptions on the form of the final output production function, find an inverse relation between a higher degree of competition, defined as higher elasticity of the demand curve faced by the innovator monopolist, and the research equilibrium level. This is because it is the existence of monopoly quasi-rents in the intermediate sector that induces firms to innovate. Aghion and Howitt (1998) argue that this finding is in conflict

with a Darwinian approach, according to which market competition forces firms to innovate. This is why they suggest several extensions to their first model that investigate the Darwinian relation between technical progress and competition.⁷⁶

3.2.3.a. Gradual technical progress

Aghion and Howitt propose a model in which the intermediate industry is characterised by two duopolistic sectors. In the first, the *leveled sector*, there exist two duopolists with the same technology level, in the second, the *unleveled sector*, there is a leader and a follower. The costs of producing the intermediate good depend on the technology level. The leader does not innovate because it is assumed that the technological gap between leader and follower is constant and equal to one. Aghion and Howitt demonstrate that, in the *leveled sector*, the higher the competition⁷⁷, the higher the innovative effort. This captures the Darwinian aspect, as defined by the two authors. In the *unleveled sector*, the higher the competition, the lower the competitive effort of the follower; this confirms the basic model's results. This further development of Aghion and Howitt's analysis, by introducing a Darwinian hint to the model, takes into account a fundamental aspect of Marx's analysis of competition as a struggle for survival, which distinguishes the centralisation phase of the capital accumulation process. It also takes into account two factors which characterise Marx's competitive process: the possibility of imitation and the non-immediate diffusion of technical progress.⁷⁸

3.2.3.b Barrier to Entry in the Research Sector

Aghion and Howitt relax the assumption of constant returns to scale in the research sector that is still ruled by a Poisson arrival rate $\lambda\theta(z-\phi)$, where the function θ is increasing and concave, and z is total labour employed in the industry and ϕ is the entrance cost. Aghion and Howitt identify the competitiveness level with the entrance cost ϕ , and demonstrate that higher degree of competitiveness in the research sector stimulates growth because it stimulates innovation. This model focuses on one aspect of competition which is crucial in Marx's analysis of competition and technical progress: the presence of barriers to entry in the research sector.

4. Conclusion

⁷⁵ The implication of this extension is that when firms do not internalise the learning by doing it is impossible for the level of research to be too high.

⁷⁶ See Aghion and Howitt (1998), Ch. 7.

⁷⁷ Defined as the increase in the elasticity of substitution between the goods produced by the two firms.

⁷⁸ In a footnote to their 1992 work, Aghion and Howitt suggest that gradual diffusion could be introduced by assuming that the productivity parameter, after each innovation, follows a predetermined gradual path which approaches the limit A_t , and jump to A_{t+1} as soon as the next innovation is introduced, and from A_t follows a new predetermined path approaching the limit A_{t+1} .

The previous pages present the fundamental aspects of Marx's analysis of competition and technical change and suggest that the ideas at the basis of Aghion and Howitt's 1992 model, and some of its extension of 1998, can be traced back to Marx.

The above analysis shows that in Marx, competition as a process is identified as the capitalistic mode of production itself and is characterised by the struggle between capitals. In this struggle, technical progress is a very powerful weapon, it is the outcome of a deliberate research activity and allows the innovator/capitalist to increase his profit. These ideas are developed by Aghion and Howitt's 1992 analysis which deals with the idea of creative destruction and also grasps the Marxian idea that, in the capital concentration process, the capitalist acts in such a way as to build an empire. The idea that, in the capital centralisation process, the Marxian capitalist is obliged to innovate in order to survive, is formalised in Aghion and Howitt's 1998 Darwinian extension. In such an extension they also deal with the non-immediate diffusion of technology, also present in Marx's analysis. The uncertainty of the innovation activity, considered by Marx, is tackled by Aghion and Howitt by regulating the research activity through a stochastic law; the capitalist/innovator knows that success is not certain, and that he can be easily imitated. Marx's social memory can be considered modelled, in Aghion and Howitt (1992), by the intertemporal spillover effect which increases productivity at the systemic level.

Aghion and Howitt's 1998 extension, in which the two authors introduce the two forms of learning by doing, grasps an important aspect of Marx's analysis: the difference between radical innovation and incremental innovation. Learning by doing accumulated at a macro level also models the idea of Marx's social memory development, by means of accumulation of experiences at a macro level. Learning by doing, by increasing the productivity of already existing intermediate goods, also shapes the interdependence in technological advancement of different sectors of production, present in Marx's analysis. The learning by doing internal to each firm recalls the importance of the learning process by means of Marx's combined worker. The introduction of the relevance of the worker's adaptability models Marx's idea of the importance of capital/labour mobility, which is at the basis of the action of competition as a "negative force"; the introduction of a product life-cycle also considers a problem discussed by Marx.

The 1998 extension, in which Aghion and Howitt introduce barriers to entrance, models Marx's idea of a minimum plant-size required to implement inventions.

Still considering worthy of note that at the basis of Aghion and Howitt's analysis there are ideas characterising Marx's treatment of competition and technical change, something must be said about the parts of Marx's analysis that necessarily have not been developed by Aghion and Howitt. Although in their models competition drives firms to innovate in order to gain a monopoly power,

their analysis greatly simplifies the representation of the struggle for diversity that characterises Marx's work. In Aghion and Howitt's 1992 model, the invention of a new intermediate input is a random event governed by the same Poisson distribution. This models the firm's effort to innovate, hence to differentiate, but does not take into account that each firm, through research, becomes different from the other firms and will have a different research production function. The same can be said about the 1998 extension which, with the entrance barriers hypothesis, introduces identical firms facing the same entrance cost and the same functional form of the arrival rate. These hypotheses are related to Aghion and Howitt's reliance on a general economic equilibrium construction, typical of the New Growth Theory approach. The general equilibrium construction is based on the presence of maximising agents. As Nelson and Winter (1974) stress⁷⁹, maximisation does not match well with firms' technical differences, hence with differences in profitability, knowledge and luck. As Nelson and Winter argue, to use a general equilibrium approach means to assume that in equilibrium even the best firms do not modify their strategies.

The existence of a gap in the analysis of firm organisation is acknowledged by Aghion and Howitt who, in their book of 1998, state that *"The endogenous-growth models developed in the previous chapters can legitimately be criticized for their overly simplified representation of R&D activities. Indeed, except in Chapter 6 where we touched on the distinction between researchers and developers, we have otherwise taken R&D activities to be systematically performed by a single "aggregate" agent playing simultaneously the role of financier, creator, owner and user of the innovation"*⁸⁰. Aghion and Howitt realise that R&D is a much more complicated activity than the one described by the New Growth Theory, so they envisage, in the descriptive theory and in the theory of organisations, new lines of development in the study of the link between R&D and growth. They affirm that *"Although essentially descriptive and informal, the existing literature on the organization of R&D addresses a broad range of interesting and relevant questions"*.⁸¹

References

Aghion, P., Howitt, P.(1992), "A model of Growth through Creative Destruction", *Econometrica*, n.60, pp.323-351 .

Aghion, P., Howitt, P.(1998), *Endogenous Growth Theory*, The MIT Press, Cambridge, Massachusetts, London, England.

⁷⁹ Nelson and Winter (1974), p.889.

⁸⁰ Aghion and Howitt (1998), p. 449.

⁸¹ Ibid.

- Bonzio, M. (1992), "Riflessioni (e Critiche) su Marx e Schumpeter", *Studi Economici*, n.47, pp.129-170.
- Clark, N., Juma, C. (1988), "Evolutionary Theories in Economic Thought", in *Thechnical Change In Economic Theory*, ed. by Dosi, G., Freeman, C., Nelson, R., Silverberg G., Soete, L., Pinter Publisher Limited, UK.
- Darwin, C. (1996), "*L'Origine della Specie*", introduzione di G. Montalenti, Universale Bollati Boringhieri, Serie scientifica.
- D'Agata, A. (1998), "Competition", in *The Elgar Companion to Classical Economics*, ed. by Kurz, H.D. and Salvadori, N., Edward Elgar, Cheltenham, UK- Northampton, MA, USA.
- Duménil G., Lévi D. (1985), "The Classical and the Neoclassicals: a Rejoinder to Frank Hahn", *Cambridge Journal of Economics*, Vol.9, pp.327-345.
- Duménil G., Lévi D. (1987), "The Dynamics of Competition: a Restoration of the Classical Analysis", *Cambridge Journal of Economics*, Vol.11, pp.133-164.
- Duménil G., Lévi D. (1999.a), "Smith, Ricardo et Marx aux Racine de l'Évolutionisme.?", *Version: 16 Septembre 1999. Communication au Colloque "L'Évolutionisme : Fondement, perspective et réalisations", organisé par METIS, Université de Paris I Panthéon-Sorbonne, Les 19 ct 20 Septembre 1996 à Paris.*
- Duménil G., Lévi D. (1999.b), "The Three Dynamics of the Third Volume of Marx's Capital: *Version February 15, 1999. Paper prepared for the conference Karl Marx Third Volume of "Capital":1894-1994 organised by the department of Economics of the University of Bergamo, December 15-17, 1994.*
- Elliott, J. E. (1980), "Marx and Schumpeter on Capitalism's Creative Destruction" *Quarterly Journal of Economics*, vol. XCV, August, pp.45-68.
- Fama, E.F., Laffer, A.B. (1972) "The Number of Firms and Competition", *American Economic Review*, Vol.62, pp.670-674.
- Garegnani, P. (1981), *Marx e gli economisti classici, Valore e distribuzione nelle teorie del sovrappiù*, Giulio Einaudi editore, Torino.
- Garegnani, P. (1983), "The Classical Theory of Wages and the Role of Demand Schedules in the determination of Relative Prices", *American Economic Review*, May, pp.309-313.
- Grossman, G. M., Helpman, E. (1991) "*Innovation and Growth in the Global Economy*", The MIT Press, Cambridge - Massachusetts, London - England.
- Grossman, G. M., Helpman, E. (1994). "Endogenous Innovation in the Theory of Growth", *Journal of Economic Perspectives*, Vol.8, n.1, pp.23-44.
- Harris, J. (1988), "On the Classical Theory of Competition", *Cambridge Journal of Economics*, vol. 12, pp.139-167.

- Horverak, Ø. (1988), "Marx's View of Competition and Price Determination", *History of Political Economy*, 20, pp.275-297.
- Kurz, H. D., Salvadori, N. (1994), *"The 'New' Growth Theory: Old Wine in New Goatskins"*
- Kurz, H. D., Salvadori, N. (1995), *Theory of Production: A Long Period Analysis*, Cambridge University Press, Cambridge, New York, Melbourne.
- Levine, D.P. (1980), "Aspects of the Classical Theory of Markets", *Australian Economic Papers*, June, pp.1-15.
- Leoncini, R., Sabbatini, R. (1992), "La Teoria Evoluzionista del Progresso Tecnico: un'Introduzione", *Memorie di Ricerca IDSE*.
- Marx, K. (1992), "Excerpts from James Mill's Elements of Political Economy" in *Karl Marx Early Writings*, Penguin Classics, London.
- Marx, K. (1987), "Concorrenza", *Grundrisse*, ristampato in *Concorrenza Monopolio, Regolamentazione*, a cura di Cossutta, D, e Grillo, M., Il Mulino, Bologna.
- Marx, K. (1989), *"Il Capitale, Libro I"* Ristampa anastatica della V edizione (ottobre 1964): dicembre 1989, a cura di Cantimori D., Editori Riuniti, Roma.
- Marx, K. (1989), *"Il Capitale, Libro III"* Ristampa anastatica della V edizione (ottobre 1964): dicembre 1989, a cura di Cantimori D., Editori Riuniti, Roma.
- Marx, K. (1998), *"Misericordia della filosofia. Risposta alla "Filosofia della miseria" del signor Proudhon"*: VIII edizione: settembre 1998, introduzione di Badaloni, N., Editori Riuniti, Roma.
- Mc Nulty, P. J. (1967), "A Note on the History of Competition", *Journal of Political Economy*, vol.75, August, pp. 396-399.
- Mc Nulty, P. J. (1968), "Economic Meaning of Competition", *Quarterly Journal of Economics*, vol.82, November, pp.639-656.
- Nelson, R. R. and Winter, S. G. (1974), "Neoclassical vs. Evolutionary Theories of Economic Growth: Critique and Prospectus", *The Economic Journal*, vol. 84, pp. 886-905.
- Ricoy, C. (1998), "Cumulative Causation", in *The Elgar Companion to Classical Economics*, ed. by Kurz, H.D. and Salvadori, N., Edward Elgar, Cheltenham, UK- Northampton, MA, USA.
- Romer, P.M. (1994), "The Origins of Endogenous Growth", *Journal of Economic Perspectives*, Vol.8, n.1, pp.3-22.
- Rosenberg, N. (1974), "Karl Marx on the Economic Role of Science", *Journal of Political Economy*, luglio-agosto, pp.713-728..
- Rosenberg, N. (1991), "Marx Studioso di Tecnologia", in *Dentro la Scatola Nera*, ed. Rosenberg, Il Mulino, pp.57-78.

Salvadori, N. (1998), "A Linear Multisector Model of 'Endogenous ' Growth and the Problem of Capital", *Metroeconomica*, Vol.49, n.3, pp.319-335.

Schumpeter, J.A., (1951), "*Epoche di Storia delle Dottrine e dei Metodi: Dieci Grandi Economisti*".

Semmler, W. (1984.a), "On the Classical Theory of Competition, Value and Price of Production", *Australian Economic Papers*, June, pp. 130-150.

Semmler, W. (1984.b), "Marx and Schumpeter on Competition Transient Profit and Technical Change", *Economie Appliquée*, Vol.37, n.3-4, pp.419-455.

Solow, R. M. (1994), "Perspective on Growth Theory", *Journal of Economic Perspective*, Vol.8, N.1, pp.45-54.

Steedman, I. (1977), "*Marx after Sraffa*" Lowe & Brydone Printers Limited, Thetford, Norfolk.

Stigler, G.J. (1957), "Perfect Competition, Historically Contemplated", *Journal of Political Economy*, Vol.65, n.1, pp.1-17.

Sylos Labini, P. (1977), "Il Problema dello Sviluppo Economico in Marx e Schumpeter" in *Problemi dello Sviluppo Economico*", Universale Laterza, Roma-Bari.

Veblen T. (1998), "Why is Economics not an Evolutionary Science?", *Cambridge Journal of Economics*, Vol.22, pp.403-414.