MARKET CONCENTRATION AND ENDOGENOUS TECHNOLOGICAL INNOVATION IN A NON-LINEAR DYNAMIC MODEL OF GROWTH AND DISTRIBUTION*

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1 Introduction

This essay elaborates a non-linear model of growth and distribution in which endogenous technological innovation plays a pivotal role. The rate of technological innovation is determined by market structure in a non-linear way, it being quadratic in concentration. This simplified technological innovation function is intended to capture a plausible neo-schumpeterian non-linearity in the influence of market structure on firms' propensity to innovate: innovation is lower for both low and high levels of concentration, it being higher for intermediate ones. Concentration is also endogenous, though, since in a situation of schumpeterian competition the relationship between market structure and technological change cuts both ways. Given this non-linearity, firms' desired investment will also be non-linear in concentration, which implies that the direction and the intensity of the effect of changes in concentration on capacity utilization, growth and distribution will depend on the prevalent concentration. However, the dynamics of these variables is also affected by demand factors in the newer post keynesian manner, with both capacity and growth rising with the wage share. The stability properties of the system then depend on the prevalent concentration and on the relative strength of the innovation effects with respect to the demand ones.

This essay is organized as follows. Section 2 presents a brief conceptual interlude on the double-sided relation between market structure and technological change. Section 3 describes the building blocks of the model. Section 4 analyzes its behavior in the short run, while Section 5 does the same for the long run. Finally, Section 6 examines one possible long-run multiple equilibria dynamics leading to the emergence of cyclical behavior.

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2 *Conceptual interlude*

A major presumption underlying this essay is that there are increasing returns, so to speak, to greater cross-fertilization between the neo-schumpeterian approach to technological change and the newer post keynesian approach to growth and distribution.[1] In the former, several features of technological change and industrial dynamics have been carefully examined, such as product and process variety through innovation, changes in market structure via creative destruction and cyclical growth (Lima 1996). In the latter, models do not rely upon market clearing at full utilization of capital or labor via competitive prices and optimization under unbounded rationality, with oligopolistic pricing and effective demand playing a pivotal role instead. As Stoneman (1992) cogently puts it, to include technological change in macro models based on perfect competition is not acceptable. Since technological change creates imperfectly competitive market structures and the incentives for technological change largely rely upon imperfect market structures, macro models incorporating technological change should be oligopolistic in nature.

When technological change has been treated as endogenous in the post keynesian literature – either the older or the newer one – it has been invariably linked to capital accumulation using either Kaldor's technical progress function (Kaldor 1957) or Arrow's learning by doing (Arrow 1962). A main claim in the neo-schumpeterian approach to competition, in turn, is that technological change is closely connected to changes in market structure. Technological competition through innovation is more important than price competition, since it is the most decisive weapon for firms seeking to adjust and to gain lasting competitive advantages. Moreover, the relation between market structure and technological change runs both ways: not only market structure affects the pace of technological change, but also the latter, by its very nature, affects the configuration of the market structure (Nelson and Winter 1982). Indeed, the relation between diffusion and market structure is a two-way relationship as well: market structure affects diffusion patterns, and diffusion patterns affect market structure (Stoneman 1992). Admittedly, there is a multitude of factors involved in this two-way relationship. Regarding the connection running from market structure to innovation, though, it seems natural to work out the implications of a Schumpeter-based hypothesis that concentrated markets may sometimes be conducive to higher rates of innovation.[2] A natural question to address regards to what extent, if any, and under what conditions, if any, this innovation effect may reverse the negative correlation between growth and distribution obtained in the newer post keynesian models.

One will find two distinct themes in Schumpeter himself. First, there is the view most clearly presented in Schumpeter (1912) that firms require the expectation of some

[1] The post keynesian approach is mostly known for the models developed by N. Kaldor, J. Robinson and L. Pasinetti in the 1950s and 1960s. In this essay, though, we distinguish between those earlier models and the newer ones developed independently by Robert Rowthorn (1981) and Amitava Dutt (1984, 1987) in the 1980s. While the older models implicitly assume that in the long run either full capacity is reached or capacity utilization is fixed at a normal level, in the newer ones capacity utilization is not assumed to be equal to a normal value in any run. As a result, while in the older view there is a long-run inverse relation between the real wage and the rates of profit and growth, such relation is usually positive in the newer one.

[2] Truly enough, a reading of the literature will find no consensual view about whether this hypothesis can be traced back to Schumpeter himself. Even though Schumpeter paid a lot of attention to the effects of market structure on technological innovation, it is not totally clear whether his views could be captured by a single hypothesis of this kind. However, since it is not the purpose of this essay to engage in exegetical disputes, we will apply the label Schumpeter-based to several conceptually consistent and empirically plausible propositions regarding the relationship between market structure and innovation found in the neo-schumpeterian literature.

transient market power to have the incentive to innovate. Second, there is the view most clearly suggested in Schumpeter (1942) that the possession of ex-ante market power also favored innovation. A first reason is that an oligopolistic structure makes rival behavior more stable and predictable, thereby reducing the uncertainty associated with excessive rivalry that tends to undermine the incentive to innovate. Second, it is suggested that the profits derived from the possession of ex-ante market power provide firms with the internal financial resources necessary to invest in innovative activity. This second reason is actually related to the first one, in that owing to the presence of moral hazard associated with developing a new process or product whose feasibility is uncertain, the innovating firm must bear a substantial share of the development costs. Third, Schumpeter appeared to argue that ex-ante market power would tend to confer ex-post market power, in that a successful innovation will grant at least some temporary market power. Indeed, the underlying presumption seems to be that innovation is both a means for realizing monopoly profits and a method of maintaining them afterwards. The other side of the picture, though, is that weak competition may reduce the spur to innovation, in that a firm already in possession of monopoly power feels less threatened by rivals and thus less compeled to innovate. Absent opportunities to increase market share significantly, and absent a threat of being driven out of business as a laggard, the incentives and pressures to search for innovations are dulled.

The empirical literature delivers only few conclusive evidence on the relationship between market structure and technological innovation, with several surveys on the subject having examined inumerous studies just to conclude that the results derived so far are to some degree inconclusive.[3] Indeed, several of them tend to boil down to general statements such as that there is a structure intermediate between monopoly and competition which is actually most conducive to innovation. Even though a persistent finding about the effect of concentration on R&D intensity is that it depends upon industry-level variables such technological opportunities, appropriability conditions, degree of product differentiation and the industry's stage in the technology life cycle, there is some evidence of a non-linear, inverted-U relationship between R&D intensity and concentration. Hence, it seems conceptually reasonable and empirically plausible to specify an innovation function stating that the rate of innovation is lower for both low and high levels of concentration, it being higher for intermediate ones.

The inherent difficulties associated with an adequate modeling of the non-linear causation running from concentration to innovation are compounded by the evidence showing that market structure cannot be taken as an independent variable: it is the incessant process of creative destruction itself, by means of changing the relative balance between firms, which creates the endogeneity in concentration (Winter 1984 ; Dosi, Orsenigo 1988 ; Dosi, Malerba, Orsenigo 1994). Basically, technological change affects market structure in two ways. First, through influencing the optimal scale of production. If the minimum efficient plant size increases (decreases) as a result of technological change, there will be a tendency for concentration to rise (fall). Second, through the erection of barriers to entry: the first to introduce a successful innovation may gain a significant advantage over its rivals, which may derive, for instance, from the realization of extraordinary profits that are available for additional R&D expenditures and the development of an expertise that cannot be easily duplicated. These two channels are related, in that some of barriers to entry have to do with the large capital expenditures required to build plants. Now, barriers to entry are the less formidable, the higher the growth rate. A higher growth rate facilitates new entry by reducing the share of market needed to attain the most efficient scale of production. Besides, they are less formidable

[3] Surveys which ably summarize findings concerning Schumpeter-based hypotheses and related propositions include: Scherer 1980 ; Freeman 1982 ; Kamien and Schwartz 1982 ; Baldwin and Scott 1987 ; Cohen and Levin 1989 ; Cohen 1995.

with faster growth since new entrants are encouraged to enter industries through the attraction of higher profits. Support for a view that rapid technological innovation leads to concentration can be found in the stochastic models of firm growth used in the simulation models of Nelson and Winter (1982). On the other hand, Blair (1972) reviewed the impact of technological change upon economies of scale and concluded that from the late 18th century through the first third of the 20th century it increased concentration. Since then, though, newer technologies tended to reduce both plant size and capital requirements for optimal efficiency. Geroski (1994), in turn, provides evidence showing that the major innovations introduced in most industries in the UK during the 1970s actually lowered concentration.

As seen above, market structure also influences diffusion, which means that the speed with which transient quasi-rents are eroded away by potential imitators is itself affected by concentration. Even though there is no consensus around a general model of diffusion, most studies agree that the rate of diffusion is positively related to the cost advantage of the innovation, while the recent survey of empirical works by Karshenas and Stoneman (1995) shows that there is evidence of a positive relation between growth and diffusion as well. This finding corroborates a point already made by Steindl in the introduction to the 1976 reprint of Maturity and Stagnation: innovation diffusion depends on income and its rate of growth. Relatedly, a conclusion drawn in Silverberg, Dosi and Orsenigo (1988) and Silverberg (1990) is that diffusion is the faster, the higher the prospects for learning – through intra- and inter-industry externalities, processes of costly search such as R&D, and learning by doing and learning by using. Since the prospects for learning in this broad sense are the higher, the higher the growth rate, diffusion is the faster, the higher growth rate. Moreover, Lissoni and Metcalfe (1994) reviews empirical evidence showing that the adoption profitability is a chief factor in the speed of diffusion, with diffusion being more rapid when a broadily defined rate of return from adopting it is greater. Now, this rate of return may be proxied by the rate of profit, and since in the model of this essay the rates of profit and growth move in the same direction, it is plausible to assume that the higher the growth rate, the faster the rate of diffusion and thus the shorter the transient extraordinary profits generated by an innovation.[4]

3 The structure of the model

We model an economy which is closed and has no government. A single good which can be used for investment and consumption is produced. Two factors of production, capital and labor, are combined via a fixed-coefficient technology

$$X = \min\ [Ku_k, L / a] \tag{1}$$

where X is the output, K is the capital stock, L is the employment level, u_k is the technologically-full capacity utilization, and a is the labor-output ratio. Production is carried out by oligopolistic firms, and prices are given at a point in time, having resulted from previous dynamics. Firms will produce according to demand, it is being

[4] A final methodological word. As seen in this brief discussion, the causal links and feedback effects at play are quite complex. The modeling challenge is thus to devise a simple formal framework that allows the sorting out of some plausible and relevant mechanisms and the working out of some of their implications. This framework should be as transparent as possible so that the results can be satisfactorily interpreted and eventually reconsidered in a more inclusive setup. It was this presumption that guided the specification of the model to be worked out in the following sections.

assumed that demand is not enough for them to produce at full capacity at the ongoing price.[5] Employment is determined by production

$$L = aX \tag{2}$$

Firms' investment plans can be described by a desired investment function like

$$g^d = \alpha_0 + \alpha_1 u + \alpha_2 r + \alpha_3 h \tag{3}$$

where α_i are positive parameters of the desired investment function, g^d, expressed as a ratio of the capital stock, $u = X / K$ is the actual capacity utilization, r is the profit rate, and h is the rate of labor-saving technological innovation. Since we assumed that capacity output is proportional to the capital stock, we can identify capacity utilization with the output-capital ratio. We follow Rowthorn (1981) and Dutt (1984, 1987), who in turn follow Steindl (1952), in assuming that investment depends positively on capacity utilization due to accelerator-type effects. Like Rowthorn and Dutt, who follow Kalecki (1971) and Robinson (1956, 1962), we make investment to depend on the profit rate. The rationale is that the current profit rate is an index of expected future earnings, on the one hand, and it provides internal funding for accumulation and make it easier to raise external finance, on the other hand. Desired investment is also made to depend positively on the innovation rate, the latter leading to more investment, at any given capacity utilization and profit rate, than would otherwise be the case (Rowthorn 1981). While Dutt (1994) invokes Kalecki's (1971) idea that the higher the rate of technological change, the more desirable is to install new machines, there are other plausible reasons. One of them is the Marxian claim that cost-reducing technological change places continuous pressures on any individual firm to invest. It is as well consistent with Schumpeter's (1912, 1942) view that the process of innovation itself opens up new investment opportunities for firms, and with the neo-schumpeterian (e.g. Nelson and Winter 1982, Winter 1984) notion that investment is influenced by the dynamics of technical change.[6]

At a point in time, the technological parameters u_k and a are given, having resulted from previous technological and accumulation dynamics. Over time, labor-augmenting, Harrod-neutral technological change taking place results in the labor-output ratio falling at rate h. In terms of the taxonomy proposed by Freeman (1982), distinguishing between incremental innovation, radical innovation, new technology systems and changes of techno-economic paradigm, we are dealing with the former: innovations which occur more or less continuosly, although at differing rates in different industries, and are concerned only with improvements in the existing array of products and processes of production.

The fixed-coefficient technology assumed here is amply supported by a reputable literature. As several eminent contributors to the economics of technical change have documented – from David (1975) and Rosenberg (1976) to Nelson and Winter (1982) and Dosi (1984) – technological change has strong cumulative effects – 'learning' in its

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[5] For Steindl (1952), firms hold excess capacity to be ready for a sudden rise in demand. First, the ocurrence of fluctuations in demand means that the producer wants to be in a boom first, and not to leave the sales to new competitors who will then press on her market when the boom is over. Second, it is not possible to expand capacity step by step as the market grows due to the indivisibility and durability of the plant and equipment. Finally, entry deterrence is always a concern: if prices are sufficiently high, entry of new competitors becomes feasible even where capital requirements are large; hence, the holding of excess capacity allows oligopolistic firms to confront new entrants by rapidly raising supply, which will push prices down.

[6] Steindl (1981) admits that Maturity and Stagnation was carried out on the naive assumption that technological change does not affect investment. In the introduction to the 1976 reprint of the book he made the same mea culpa and recognized that innovations which are sufficiently advanced, and which can be exploited without too much delay and risk, are a powerful inducement to investment.

various forms. Hence, technological change is typically characterized by 'localized' shifts in some production function, to use David's (1975) term, or by progress along particular 'natural trajectories', to use Nelson and Winter's (1982) concept. This implies that a more rigid, if not (at least in the short run) fixed set of production coefficients will prevail. Recently, consistent analyses such as Freeman and Soete (1987) and Verspagen (1990) have shown that localized technological change strongly diminishes the short-run possibilities for factor substitution, there being several characteristics of innovation which work to make it strongly localized: inter-relatedness and complementarities of many technological and organizational innovations, heterogeneity of many production inputs and specificity of particular skills and types of production equipment, and firm-specific nature of much technical innovation and technological accumulation.

Technological innovation is endogenously determined in a non-linear manner

$$h = \rho c - \phi c^2 \tag{4}$$

where c is an index of market concentration, with $0 \leq c \leq 1$, and ρ and ϕ are positive parameters. We assume that $\rho = \phi$, so as to ensure that this concave-down parabola has two real roots, $h(0) = h(1) = 0$. Hence, h is positive throughout its (economically) relevant domain. The level of c which will yield the highest rate of innovation is given by $c^* = \rho / 2\phi$, meaning that higher market concentration will speed up (slow down) the rate of innovation for levels of c to the left (right) of c^*. This simplified innovation function is intended to capture the Schumpeter-based non-linearity in the influence of concentration on firms' innovative propensity discussed in the preceding section.[7]

The economy is populated by two classes, capitalists and workers. Following the tradition of Marx, Kalecki (1971), Kaldor (1956), Robinson (1956, 1962), and Pasinetti (1962), we assume that they have a different saving behavior. Workers supply labor and earn only wage income, which is all spent in consumption, while capitalists receive profit income, which is the entire surplus income over wages, and save a fraction s of it. The division of income is given by

$$X = (W / P)L + rK \tag{5}$$

where W is the money wage, P is the price level, and r is the profit rate, which is the flow of money profits divided by the value of capital stock at output price. From (2) and (5), the labor share can be expressed as

$$\sigma = Va \tag{6}$$

where $V = (W / P)$ stands for the real wage. The profit rate can then be expressed as

$$r = (1 - \sigma)u = \pi u \tag{7}$$

where $\pi = (1 - \sigma)$ is the profit share. The price level is given at a point in time, rising over time whenever firms' desired markup exceeds the actual markup. Formally,

$$\hat{P} = \tau[\sigma - \sigma_f] \tag{8}$$

where $\hat{P}$ is the rate of change in price, $(dP / dt)(1 / P)$, and $0 < \tau \leq 1$ is the speed of adjustment. Inflation is determined within a framework of conflicting claims, it resulting whenever the claims of workers and capitalists exceed the available income. Prices are determined à la Kalecki (1971), as a markup over prime costs

[7] An alternative specification of endogenous technological innovation can be found in Lima (1997b), where its elaborated a dynamic post keynesian model of capital accumulation in which labor-saving innovations depend non-linearly on distribution itself.

$$P = (1 + z)Wa \tag{9}$$

where z is the markup. Given labor productivity, $(1 / a)$, the markup is inversely related to the wage share, and the gap between the desired and the actual markup can be measured by the gap between the actual and the desired wage share. Desired markup depends on the state of the goods market: higher capacity utilization, which reflects more buoyant demand conditions, will lead firms to desire a higher markup:

$$\sigma_f = \varphi - \theta u \tag{10}$$

where φ and θ are positive parameters.[8] The money wage is given at a point in time, its rate of change over time being in line with the gap between workers' desired wage share, σ_w, and the actual wage share:

$$\hat{W} = \mu[\sigma_w - \sigma] \tag{11}$$

where $\hat{W}$ is the rate of change in money wage, $(dW / dt)(1 / W)$, and $0 < \mu \leq 1$ is the speed of adjustment. We follow Keynes (1936) in assuming that wage bargain takes place over nominal wages rather than real wages.[9] Workers' desired wage share is assumed to depend on their bargaining power, which is the higher, the tighter the labor market. A higher rate of change in labor employment will increase workers' bargaining power, and thus stimulate them to desire a higher wage share

$$\sigma_w = \chi + \lambda \hat{E} \tag{12}$$

χ and λ are positive parameters and $\hat{E}$ is the rate of change in employment given by

$$\hat{E} = \hat{X} - h \tag{13}$$

where $\hat{X}$ is the rate of change in output. Given the demand-driven nature of the model, the equality between investment and saving will be generated by changes in capacity utilization. Assuming that capital does not depreciate, g, the growth rate of capital stock, which is the growth rate for this one-good economy, is given by

$$g = sr \tag{14}$$

4 *The behavior of the model in the short run*

The short run is defined as a time span in which the capital stock, the labor-output ratio, the price level, the money wage, and concentration can be taken as given. Excess capacity prevails and firms will produce according to demand, thus realizing

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[8] Procyclical markups can be supported on several grounds. Following Harcourt and Kenyon (1973) and Eichner (1976), we can argue that during expansions firms may want to invest more by generating higher internal savings and hence desire a higher markup. Rowthorn (1977) claims that higher capacity utilization allows firms to raise prices with less fear of being undercut by their competitors, who would gain little by undercutting due to capacity constraints. Gordon, Weisskopf and Bowles (1984) argues that marked-up prices are inversely related to the perceived elasticity of demand, which is a negative function of industry concentration and of the fraction of the firm's potential competitors who are perceived to be quantity-constrained and thus not engaged in or responsive to price competition. In the downturn, markup will fall because the general fall in capacity utilization gives rise to a smaller share of the firm's potential competitors being perceived to be operating under capacity constraints, and hence to an increase in the perceived elasticity of demand facing the firm.

[9] One of the reasons why Keynes (1936) rejected the classical second postulate is that it flows from the mistaken idea that wage bargain determines the real wage. For Keynes, the postulate incorrectly presumes that labor can decide the real wage for which it works, even though not the quantity of employment forthcoming at this wage, when it is other forces which determine the real wage. Keynes' economics of employment is analyzed in detail in Lima (1992).

their investment plans. This implies that capacity utilization will adjust to remove any excess demand or supply, so that in short-run equilibrium, $g = g^d$. Using (3), (4), (7) and (14), we can solve for the short-run equilibrium value of u, given c, σ and the other parameters of the model, to obtain

$$u^* = \frac{\alpha_0 + \alpha_3(\rho c - \phi c^2)}{[(s - \alpha_2)(1 - \sigma) - \alpha_1]} \tag{15}$$

Meaningful values for the wage and profit shares are required, and a positive profit share is automatically ensured by $z > 0$. A positive wage share is ensured by $z < +\infty$, which we assume. As regards short-run stability, we employ a keynesian short-run adjustment mechanism stating that output will change in proportion to the excess demand in the goods market. Hence, u^* will be stable provided the denominator of (15) is positive, which is ensured by the standard condition for macro stability that aggregate saving is more responsive than investment to changes in output (capacity utilization), which we assume to be satisfied. Since h is positive within its relevant domain, this will also ensure a positive value for the numerator of u^* and thus for u^* itself. As for the impact of changes in the wage share on capacity utilization, we have

$$u_\sigma^* = \frac{(s - \alpha_2)u^*}{[(s - \alpha_2)(1 - \sigma) - \alpha_1]} \tag{16}$$

a subscript denoting the variable with respect to which the differentiation is being taken, a notation followed throughout. Hence, u_σ^* is positive and wage-led capacity utilization obtains. Like in the models by Rowthorn (1981) and Dutt (1984, 1987), an increase in the wage share – by redistributing income from capitalists who do save to workers who do not – raises consumption demand, increases investment spending through the capacity utilization effect on investment and hence raises the level of activity. Another issue regards the impact of changes in concentration on capacity utilization. The innovation effect embodied in the investment function implies that given u and r, higher concentration will raise (lower) the innovation rate and thereby investment for concentration levels below (above) $c^* = \rho / 2\phi$. We assume that changes in concentration will not lead to immediate changes in the markup, implying that distribution is insensitive to changes in concentration in the more immediate short run. As detailed in the next section, over time distribution is crucially affected by changes in concentration, though. Formally,

$$u_c^* = \frac{\alpha_3(\rho - 2\phi c)}{[(s - \alpha_2)(1 - \sigma) - \alpha_1]} \tag{17}$$

Hence, a rise in concentration will raise (lower) capacity utilization in the short run for levels of concentration below (above) $c^* = \rho / 2\phi$. Given our assumptions that workers do not save and capitalists save a fraction s of their income, the rates of profit and growth move in the same direction. Substitution of (15) into (7) and then the resulting equilibrium for the profit rate into (14), we obtain

$$g^* = \frac{s(1 - \sigma)[\alpha_0 + \alpha_3(\rho c - \phi c^2)]}{[(s - \alpha_2)(1 - \sigma) - \alpha_1]} \tag{18}$$

Having seen that a rise in the wage share will raise capacity utilization, it is natural to wonder whether the same positive relationship will prevail between distribution and growth. Using (7) and (14), we have

$$g_\sigma^* = sr_\sigma^* = s[u_\sigma^*(1 - \sigma) - u^*] \tag{19}$$

Whether a wage-led growth will obtain depends on whether $u_\sigma^*(1 - \sigma) > u^*$, which upon substitution from (15) and (16) can be simplified to $\alpha_1 > 0$, so that a higher wage share will actually raise the rates of profit and growth. As regards the impact of higher concentration on the rates of profit and growth, the non-linear nature of the innovation function implies that both the direction and intensity of that impact depends on concentration. Using (18), the impact of changes in concentration on the growth rate in the short run can be formally expressed in the following way

$$g_c^* = \frac{s\alpha_3(1-\sigma)(\rho - 2\phi c)}{[(s-\alpha_2)(1-\sigma)-\alpha_1]} \tag{20}$$

A rise in concentration will therefore raise (lower) the growth rate in the short run for levels of concentration below (above) $c^* = \rho / 2\phi$.

The relevant subset of the c-domain can thus be divided into two regions. In the first, comprised by low and intermediate-low concentration levels ($c < c^*$), innovation, capacity utilization and growth are positively related to concentration, and we refer to it as LMC region in what follows. In the second, comprised by intermediate-high and high levels of concentration ($c > c^*$), innovation, capacity utilization and growth are negatively related to concentration, and we refer to it as HMC region. Capacity utilization and growth are wage-led throughout this subset.

5 The behavior of the model in the long run

In the long run we assume that the short-run equilibrium values of the variables are always attained, the economy moving over time due to changes in the capital stock, the labor-output ratio, the price level, the money wage, and concentration. We follow the behavior of the system via the dynamics of the short-run state variables σ and c. Given (6), and using an overhat to denote a time-rate of change, the state transition function for the wage share is given by

$$\hat{\sigma} = \hat{W} - \hat{P} + \hat{a} \tag{21}$$

or

$$\hat{\sigma} = \mu[\chi + \lambda(g - \rho c + \phi c^2) - \sigma)] - \tau(\sigma - \varphi + \theta u) - (\rho c - \phi c^2) \tag{22}$$

where u and g are given by (15) and (18), respectively. As seen above, it is plausible to assume that changes in concentration are negatively related to the growth rate and to the innovation rate. The transition function for concentration is

$$\hat{c} = \beta - \gamma h - \psi g \tag{23}$$

where β, γ and ψ are positive parameters. Upon substitution, we obtain

$$\hat{c} = \beta - \gamma(\rho c - \phi c^2) - \psi g \tag{24}$$

where g is given by (18). Eqs. (22) and (24), after using (15) and (18), constitute an autonomous two-dimensional non-linear system of differential equations in which the rates of change of σ and c depend on the levels of σ and c, and on parameters of the system. The matrix M of partial derivatives for this dynamic system is

$$M_{11} = \partial\hat{\sigma} / \partial\sigma = \mu(\lambda g_\sigma^* - 1) - \tau(1 + \theta u_\sigma^*) \tag{25}$$

$$M_{12} = \partial\hat{\sigma} / \partial c = \mu\lambda[g_c^* - (\rho - 2\phi c)] - \tau\theta u_c^* - (\rho - 2\phi c) \tag{26}$$

$$M_{21} = \partial\hat{c} / \partial\sigma = -\psi g_\sigma^* < 0 \tag{27}$$

$$M_{22} = \partial\hat{c} / \partial c = -\gamma(\rho - 2\phi c) - \psi g_c^* \tag{28}$$

Only one of these partial derivatives can be unambiguously signed. Eq. (27) shows that an increase in the wage share, by raising the growth rate, will lower the rate of change in concentration. Eq. (25) shows that the impact of a change in the wage share on its own rate of change operates through changes on capacity utilization and growth. A higher wage share, by raising capacity utilization, will raise the markup desired by firms and put a downward pressure on the rate of change in the wage share by raising the rate of change in prices. However, this same rise in capacity utilization will raise the growth rate and, for a given rate of technological change, will as well raise the rate of change in employment. As a result, the wage share desired by workers will rise and, by raising the rate of change in nominal wages, will put an upward pressure on the rate of change in the wage share. Eq. (26) shows that the impact of a change in concentration on the rate of change in distribution operates through several channels. First, a change in concentration will affect the rate of change in employment by changing the rate of growth and the rate of innovation, which will thereby affect the rate of change in nominal wages. Second, a change in concentration, by changing capacity utilization, will affect firms' desired markup and thereby the rate of chance in prices. Third, a change in concentration, by changing the rate of innovation, will have an effect of its own on the rate of change in the wage share. Finally, eq. (28) shows that a change in concentration will affect its own rate of change by changing both the rate of growth and the rate of innovation.

We now have all the elements for a qualitative phase-diagrammatic analysis of the (local) stability properties of this dynamic system. The way we proceed is by analyzing the stability of an equilibrium located in each one of the two regions into which we divided the relevant subset of the c -domain. Given the non-linearity of the corresponding isoclines, several multiple equilibria configurations are possible, and we take up this issue in the next section.

5.1 LMC region ($c < c^*$)

The rates of innovation, capacity utilization and growth are positively related to concentration. A rise in concentration will put a double downward pressure on its own rate of change, through itself and by raising the growth rate, which makes for an unambiguously negative sign for M_{22}. The sign of M_{12} is likely to be negative. A rise in concentration will put a strong downward pressure on the rate of change of the wage share by raising capacity utilization and the rate of innovation. Higher capacity utilization will raise the rate of change in prices by raising firms' desired markup, while higher innovation will lower the rate of change in the wage share both directly and by lowering the rate of change in nominal wages. This latter effect works through a fall in the rate of change in labor demand leading to a weakening of workers' relative bargaining power. However, higher concentration, by raising the rate of growth, will bring up the rate of change in labor demand, and in case this positive effect is strong enough to more than compensate for the negative ones, M_{12} will be positive. Now, inspection of (4), (17) and (20) shows that since $0 \leq s(1-\sigma) \leq 1$, it follows that $u_c^* > g_c^*$, whereas $h_c^* > u_c^*$ in the event $(s-\alpha_2)(1-\sigma)-\alpha_1 > \alpha_3$. Hence, even though a positive sign for M_{12} cannot be ruled out, a negative one is more likely.

The sign of M_{11} depends on the relative bargaining power of capitalists and workers. Since (19) shows that $u_\sigma^* > g_\sigma^*$, it takes a strong relative bargaining power on the part of workers to ensure a positive sign for this partial derivative. Hence, there seems to be an affinity between the signs of M_{11} and M_{12}, in that even though different signs for them cannot be ruled out, they sharing the same one seems more likely than otherwise. In case M_{11} and M_{12} are negative, $Tr(M)$ is unambiguously negative. However, the sign of $Det(M)$ can be negative or positive, meaning that an equilibrium solution of this type will be saddle-point unstable or stable, respectively. In case M_{11}

and M_{12} are positive, the situation becomes even more ambiguous, since the sign of both $Det(M)$ and $Tr(M)$ are ambiguous. A necessary condition for stability is $Tr(M) < 0$, which requires that the extent to which the positive workers' desired wage share effect dominates in M_{11} is smaller than (the absolute value of) M_{22}. Although it is more likely that M_{11} and M_{12} have the same sign, they having opposite ones cannot be ruled out. In case workers' relative bargaining power is strong enough to make for a positive M_{11} but not strong enough to make for a positive M_{12}, the equilibrium solution will be saddle-point unstable. In case $g_c^* > h_c^*$ and workers' relative bargaining power is strong enough to make for a positive M_{12}, but not strong enough to make for a positive M_{11}, equilibrium will be stable.

5.2 *HMC region* ($c > c^*$)

The rates of innovation, capacity utilization and growth are negatively related to concentration. A rise in concentration will thus put a double upward pressure on its own rate of change, through itself and by lowering the growth rate, making for a positive sign for M_{22}. The sign of M_{12} is likely to be positive. A rise in concentration will exert an upward pressure on the rate of change of the wage share by lowering capacity utilization and the rate of innovation. Lower capacity utilization will lower the rate of change in prices by lowering firms' desired markup, whereas lower technological innovation will raise the rate of change in the wage share both directly and by raising the rate of change in nominal wages. This latter effect works through an increase in the rate of change in labor demand leading to a strengthening of workers' relative bargaining power. However, higher concentration, by lowering the rate of growth of the economy, will put a downward pressure on the rate of change in labor demand, and in case this effect is strong enough to more than compensate for the other ones, M_{12} will become negative.

As in the LMC region, the sign of M_{11} depends on the relative bargaining power of capitalists and workers, and since (19) shows that $u_\sigma^* > g_\sigma^*$, it takes a strong relative bargaining power on the part of workers to ensure a positive sign for this partial derivative. This shows that there seems to be another affinity between the signs of M_{11} and M_{12}, in that even though they may share the same sign, they having opposite ones seems more likely than otherwise. In case $M_{11} < 0$ and $M_{12} > 0$, the stability properties of an equilibrium solution of this type will be ambiguous, since both $Det(M)$ and $Tr(M)$ do not have definite signs. A necessary condition for stability is that $Tr(M) < 0$, which requires that the extent to which the price change effect dominates the nominal wage change effect in M_{11} is higher than the extent to which a change in concentration provokes a change in the same direction in its own rate of change. Combined with a positive sign for $Det(M)$, this will make for a stable solution.

As for the affine pair given by $M_{11} > 0$ and $M_{12} < 0$, which will result in case the bargaining power of workers is strong enough, $Det(M)$ will be ambiguous again. The sign of $Tr(M)$ will be positive, though, which rules out the possibility of a stable equilibrium. While a negative sign for $Det(M)$ will make for a saddle-point unstable equilibrium solution, a positive one will make for an unstable node. Even though it is more likely that M_{11} and M_{12} have opposite signs, they sharing the same sign cannot be ruled out. Suppose workers' bargaining power is strong enough to make for a positive sign for M_{11}, but it is not strong enough to generate a nominal wage change effect which makes for a negative M_{12}. Combined with [illegible] being negatively related to the wage share ($M_{21} < 0$) and positively related to concentration ($M_{22} > 0$), this will make for an unstable solution. Suppose now that workers' bargaining power is not strong enough to make for a positive sign for M_{11}, but it is strong enough to generate a nominal wage change effect which makes for a negative M_{12}. In this case, the equilibrium solution will be a saddle-point unstable one.

6 Multiple equilibria analysis

The Schumpeter-based non-linearity embodied in the innovation function makes for the possibility of multiple equilibria within the relevant subset of the $(\sigma - c)$-space. Given that technological innovation, capacity utilization and growth are all quadratic in concentration, the equations describing the corresponding isoclines will as well be quadratic in concentration. Whether any of these isoclines, or both, will be a concave up or concave down parabola depends on the actual constellation of parameters. Admittedly, the latter may be such that no equilibrium will obtain in the relevant subset of the $(\sigma - c)$-space. In any case, we proceed by developing a phase-diagrammatic analysis of the dynamics of some parametric configurations leading to the emergence of multiple equilibria, with one equilibrium obtaining in each one of the regions discussed above.

Amongst the possible configurations leading to multiple equilibria, one worthy of analysis contains a saddle-point unstable solution in the LMC region and a solution in the HMC region which can be either stable or unstable. In order to conduct this multiple equilibria analysis, let us hypothesize that the parameters which govern the relative strength of the efffects at play make for a negative M_{11} throughout the c-domain. Eq. (26) shows that it takes a strong bargaining power of workers to avoid a negative (positive) sign for M_{12} in the LMC (HMC) region. Let us hypothesize that the parameters governing the effects at play are such that workers' bargaining power is weak enough to reverse those signs. Finally, eq. (28) shows the sign of M_{21} will be negative (positive) in the LMC (HMC) region.

A situation like the one being hypothesized is pictured in Fig. 1, with a saddle-point unstable equilibrium solution obtaining in the LMC and either a stable or unstable one obtaining in the HMC region. While in the LMC region the $\hat{\sigma} = 0$ isocline being steeper than the $\hat{c} = 0$ one makes for a saddle-point solution, in the HMC it makes for either a stable or unstable solution. Let us call these equilibria E_1 and E_2, respectively. It can be seen that there is a subset of the phase plane which the economy will never leave in the event it is in it. We refer to this subset as zone of stability and to its complement as zone of instability. Starting from a point in the lower part of the LMC region and to the right of the upward separatrix through E_1, this zone of stability can be found by tracing back the path of the economy which leads into the upper part of the separatrix all the way through the LMC and HMC regions and then (eventually) back to the LMC region.

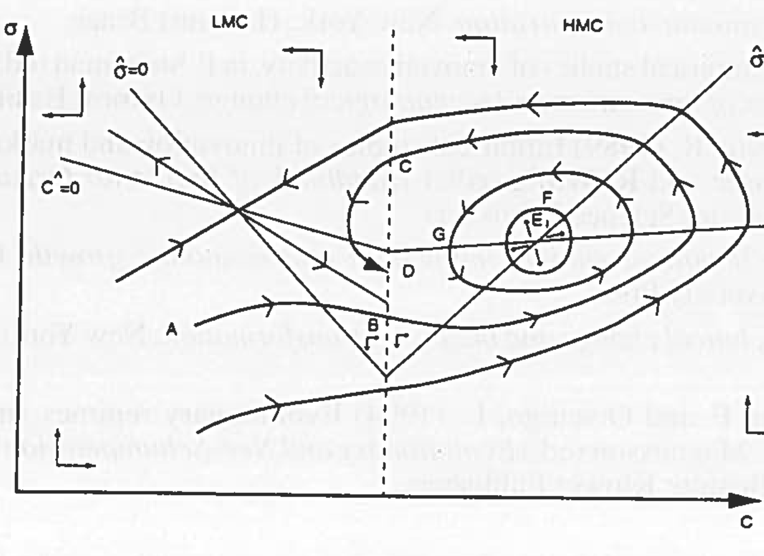

Figure 1

Once inside the zone of stability, the economy will move cyclically. Suppose we begin a trajectory at point A in Fig. 1. The direction of motion of the system indicates that it must flow rightward up until the lower part of the $\dot{\sigma} = 0$ isocline is reached, after which the system will flow rightward down. It will enter the HMC region – through, say, point B – and then keep the same direction of motion until the $\dot{\sigma} = 0$ isocline is reached once again, after which it will start flowing rightward up. Once the $\dot{c} = 0$ isocline is reached, the direction of motion of the system indicates that it will flow lefward up until the upper part of the $\dot{\sigma} = 0$ isocline is reached, after which it will then flow leftward down. After a while, the system will re-enter the LMC region through, say, point C, and will keep flowing leftward down until it reaches the $\dot{c} = 0$ isocline once again. It will then start flowing rightward down in its way to reach back the HMC region through, say, point D, at which another cyclical motion will begin. In case this inner part of the trajectory started at point A does not re-enter the LMC region once more, the system will remain in the HMC region thereafter.

In case E_2 is stable, there is a neighboorhood of it within which all the possible trajectories of the system will tend to it, which means that the hypothetical trajectory started at point A will eventually converge to E_2. In the event E_2 is unstable – the case shown in Fig. 1 – there is a neighborhood of it, say F, within which all trajectories of the system will move away from E_2. Since the system will end up reaching that neighborhood along the hypothesized trajectory initiated at point A, it will not reach E_2. Indeed, there may eventually be a closed, bounded area encircling the neighborhood F and from which no trajectory will exit. Since this area would contain no equilibrium points, the Poincar•-Bendixson theorem would ensure that it must contain at least one stable limit cycle (Arrowsmith and Place 1992). But whether or not some limit cycle will emerge, the system will move cyclically within the zone of stability, which shows its propensity to experience endogenous, self-sustaining fluctuations in concentration and wage share, with technological innovation, capacity utilization and growth fluctuating as well.

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