Market concentration and technological innovation in a dynamic model of growth and distribution *

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1. Introduction

A distinctive feature of the post-Keynesian approach to growth and distribution following the traditions of Keynes and Kalecki is the fundamental role played by the latter in the dynamics of the former. When technological change is brought into the picture, labour-saving innovations will affect distribution by lowering unit labour costs and thus the share of labour in income. Actually, technological change that raises labour productivity exerts a quite fundamental influence on capital accumulation and growth, either directly by eventually requiring the installation of new machines or indirectly by affecting distribution. Indeed, this influence becomes even greater and more complex when technological innovation is made endogenous rather than assumed to drop as manna from heaven. When technological change has been endogeneised in the post-Keynesian literature, though, it is usually seen as somehow following from the accumulation of capital.

This paper contributes to the post-Keynesian literature by elaborating a dynamic model of growth and distribution in which en-

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dogenous technological innovation also plays a pivotal role, though through a different route. The underlying presumption is that there are increasing returns to greater cross-fertilisation between the neo-Schumpeterian approach to technical change and the post-Keynesian approach to growth and distribution, there being interesting unexploited possibilities worthy of working out. One possibility is to have technological innovation determined by market structure, and the alternative pursued here is to have it in a non-linear way, with labour-saving innovations being quadratic in market concentration. This simplified 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. Market concentration dynamics is also affected by technological change, since in a situation of neo-Schumpeterian competition the relationship between them is double-sided, and the model of this paper incorporates this other dimension as well.

Given this non-linearity in the innovation function, firms' desired investment will also be non-linear in market concentration, which implies that the direction and the intensity of the effect of changes in concentration on capacity utilisation, growth and distribution will depend on the prevalent concentration. However, the dynamics of these variables, including the latter one, is as well affected by demand factors in a post-Keynesian manner, with both capacity and growth rising with the wage share, and concentration falling with the growth rate. Hence, this paper also contributes to the neo-Schumpeterian literature by incorporating effective demand and distributional elements into concentration dynamics. In the end, the stability properties of the system will depend on the direction and relative strength of the innovation effects with respect to the demand ones, and on the relative bargaining power of workers and capitalists.

This paper is organised 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 analyses its behaviour in the short run, while Section 5 does the same for the long run. Section 6 examines one possible long-run multiple equilibria dynamics leading to the emergence of cyclical behaviour, while the last one summarises the main conclusions derived along the way.

2. Conceptual interlude

The post-Keynesian approach to growth and distribution is mostly known for the models developed by Nicholas Kaldor, Joan Robinson and Luigi Pasinetti in the 1950s and 1960s. Here, however, we distinguish between those earlier models and the newer ones developed independently by authors more closely associated with the Kalecki-Steindl tradition like Robert Rowthorn and Amitava Dutt in the 1980s. Despite their shared non-neoclassical pedigree, there are two main differences between these approaches. First, while the older models are basically set in a Keynesian competitive world, the newer ones of Kalecki-Steindl inspiration deal with an oligopolistic setting in which cost-plus prices prevail. Second, the older models implicitly assume that in the long run either full capacity is reached or capacity utilisation is fixed at a given normal level, while in the newer approach capacity utilisation is endogenous, not being assumed to be equal to a normal value in any run. Consequently, while in the older view there is an inverse relation between the real wage and the rates of profit and capital accumulation, such relation is usually positive in the newer one.

A presupposition underlying this paper is that there are increasing returns to greater cross-fertilisation between the neo-Schumpeterian approach to technical change and the newer post-Keynesian approach to growth and distribution. In the former, several aspects of technical change and industrial structure dynamics have been examined, such as product and process variety through innovation, imperfect competition and changes in market structure via creative destruction, increasing returns and cyclical growth (Lima 1996). In the latter, formal models do not rely upon the tools of market clearing at full utilisation of capital and labour via competitive prices and intertemporal optimisation under unbounded rationality, with effective demand playing a central role instead. However, several possibilities that are opened up by a greater cross-fertilisation between these approaches have not been subject to elaboration in both sides of the fence.

For instance, the newer post-Keynesian approach can benefit from several elements of the neo-Schumpeterian literature on the links between market structure and technical change. As Stoneman (1991) cogently puts it, technical change will usually generate imperfectly competitive market structures and the incentives for innovation largely rely upon imperfect market structures, so that models incorporating technical change should be oligopolistic in nature; and this is the case in the newer post-Keynesian models. Cross-fertilisation is a two-way avenue, though, meaning that the micro-oriented neo-Schumpeterian approach to technological change and industrial dynamics will benefit from the incorporation of some elements of the macro-oriented post-Keynesian approach to growth and distribution, especially distributional and effective demand ones under endogenous capacity utilisation.[1]

When technological change has been treated as an endogenous phenomenon in the post-Keynesian literature, be it the older or the newer one, it is usually linked to accumulation of capital using either Kaldor's technical progress function (e.g. 1957, 1961, 1966) or Arrow's (1962) learning-by-doing function (e.g. Rowthorn 1981; Dutt 1990, 1994; Taylor 1991; You 1994a, 1994b; Watanabe 1997).[2] In the

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[1] In turn, some neoclassical endogenous growth models have already explicitly pursued the incorporation of some Schumpeterian ideas, with some early contributions including Segerstrom, Anant and Dinopoulos (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992). More recently, Smulders and van de Klundert (1995) incorporated some neo-Schumpeterian elaborations on firms' accumulation of knowledge and derived a relation between concentration and growth. Concentration determines the propensity to innovate by affecting the amount of sales per firm (scale effect), by influencing general knowledge spillovers (public knowledge effect and learning-by-watching effect) and by changing competition and mark-up rates (monopolisation effects). A rise in concentration has a positive impact on the growth rate up to some level, beyond which further increases in concentration may be deleterious to growth due to monopolisation effects. Peretto (1999), in turn, studied the joint determination of concentration and growth using a model in which firms undertake in-house R&D to generate cost-reducing innovations. A larger number of firms creates fragmentation of the market and dispersion of R&D resources, which prevents the exploitation of scale economies internal to the firm and slows down the rate of growth. R&D spending is a fixed cost, though, thus implying that there is a negative feedback of the growth rate on the number of firms.

[2] For Kaldor, technical progress is both the cause and the result of economic growth, so that anything that increases the rate of growth also leads to a faster rate of technical change. Kaldor formulated this idea in a variety of ways, ranging from the technical progress function of his early work (1957 and 1961), where the rate of growth of labour productivity is positively related to the rate of growth of capital per worker, to the Verdoorn's Law of his later writing (1966), where the rate of growth of labour productivity is positively related to the rate of growth of the economy. Arrow's (1962) learning-by-doing approach, in turn, takes productivity as increasing with experience in production, with this experience being measured by cumulative investment – which, in the absence of depreciation, is given by the capital stock.

neo-Schumpeterian view, though, technological competition through innovation is seen to be more important than price competition, for it is the most decisive weapon for firms seeking to gain and/or maintain lasting competitive advantages. Although it is not denied that technological change is somehow endogenous to the process of capital accumulation and to the labour market dynamics, it is claimed that changes in market structure are a major force shaping the rate and the direction of technological change.

Besides, this relationship is a two-way one: market structure affects and is affected by technological change (Nelson and Winter 1982). Admittedly, there is a multitude of factors involved in this two-way relationship, and to mention just a few of them: degree of inter-firm competition and propensity to innovate; effect of the degree of diffusion of new technological knowledge on the urge to invest in R&D; innovative competition over products and methods of production; and influence of the threat of new competitors on the propensity to innovate. Regarding the connection running from market structure to innovation, though, it seems natural to work out the growth and distributional implications of a Schumpeter-based hypothesis that a more concentrated market may eventually be conducive to higher innovation rates. A natural question to address regards to what extent – and under what conditions – this innovation effect may eventually reverse the positive relation between growth and distribution obtained in the newer post-Keynesian models developed by Rowthorn (1981) and Dutt (1984 and 1987).[3]

In Schumpeter's discussion of the effects of market power on technical innovation, there are two distinct themes. First, there is the view most clearly presented in Schumpeter (1912) that recognises that firms require the expectation of some transient market power to have the incentive to invest in R&D. Indeed, it is a relatively uncontroversial claim that the innovator must see some means (patent, barriers to entry, etc.) for actually realising extraordinary profits from her in-

[3] Admittedly, a careful reading of the literature will find no consensual view about whether this hypothesis can actually be traced back to Schumpeter himself. Although Schumpeter paid a great deal of attention to the effects of market structure on innovation, it is not clear whether his views could be captured by a single hypothesis of this kind. But since it is not the purpose of this paper to engage in exegetical disputes, we 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.

vestment in the innovation. Second, and more controversially, there is the view most clearly argued in Schumpeter (1942) that the possession of *ex ante* market power also favoured innovation. One reason is that an oligopolistic structure makes rival behaviour more stable and predictable, thereby reducing the uncertainty associated with excessive rivalry that tends to undermine the incentive to innovate. Another reason is that with imperfect capital markets the profits derived from the possession of *ex ante* market power provides firms with more internal financial resources to invest in innovative activities. In fact, this second reason is related to the first one: owing to the presence of moral hazard associated with developing a new process whose feasibility is uncertain, the innovating firm must bear a substantial share of the development costs (Kamien and Schwartz 1982). As a third reason, 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. The underlying presumption seems to be that innovation is both a means for realising monopoly profits and a method of maintaining them afterwards. Since monopoly profits can only be realised through innovation if imitation by rivals can be limited or prevented altogether, the power to exclude rivals is the key to the achievement and retention of them.[4]

The other side of the picture is that weak competition may reduce the spur to innovation, in that the firm already in possession of monopoly power feels less threatened by rivals and therefore less compelled to innovate; absent either opportunities to increase market share significantly or a threat of being driven out of business as a laggard, the incentives and pressures to search for innovations are dulled. For instance, a firm with monopoly power is in an advantageous position to be a 'fast second' in the development of an innovation. Because of its resources and established reputation and channels of dis-

[4] For Nelson and Winter (1982), one way to rationalise the hypothesis that market concentration is conducive to innovation is by saying that the absence of competitors, and the ability to block imitation by competitors, are factors that in their own right influence appropriability conditions. A related but distinguishable argument is the following: absence of competition or restrained oligopolistic competition, by leading to high rates of return in the industry generally, can serve to shelter firms that do innovative R&D in circumstances where, if competition where more aggressive, firms that aim for a 'fast second' would drive the innovators out of business.

tribution, a firm with monopoly power can afford to wait until someone else innovates and imitate it quickly if it appears to be successful. Moreover, in a firm realising extraordinary profits managerial whim may decide whether resources are devoted to keeping technological leadership or to other forms of managerial consumption.

On the other hand, concentration also matters for the extent to which cost reductions generated by technological innovations are translated into lower prices. According to Sylos Labini (1969), such price reductions will follow only in case those innovations are accessible to all categories of firms. If this is not the case, those cost reductions may end up leading to an increase in the mark-up, and this is a possibility which rises with advancing concentration, since concentration accentuates the technical discontinuities which protect larger profits.

Turning to the empirical literature, one will find few conclusive evidence on the relationship between market structure and technological innovation. Empirical studies indicate that even if some generalisations can be made, they have to be interpreted with utmost care. The reason is that these results are strongly dependent on specifics of the empirical study like the type of industry or sector, time period, kind of innovation and, most importantly, local features such as technological opportunities and appropriability conditions.[5] All in all, empirical studies tend to boil down to general statements such as that there is a market structure intermediate between monopoly and fierce competition which is actually most conducive to innovation. Thus, 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. It is this specification that will be used in the following sections to formalise this side of the double-sided relationship between market structure and innovation (cf. eq. 4 below).

On the other hand, those who claim that a concentrated market is more conducive to innovation should be ready to admit that the reverse pattern could also be true: a firm that innovates successfully may grow and capture a larger share of the market, thus causing con-

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[5] Surveys that ably summarise findings concerning Schumpeter-based hypotheses and related propositions include: Freeman (1982), Kamien and Schwartz (1982), Baldwin and Scott (1987), Cohen and Levin (1989) and Cohen (1995).

centration to rise. In turn, an innovation that is relatively easy to imitate may well result in many new firms and the emergence of a more competitive industry, even though the number of firms may decline as the market becomes saturated. Therefore, the inherent formal difficulties associated with an adequate modelling of the non-linear causation running from market structure to technological innovation are compounded by the empirical evidence showing that market structure cannot be taken as an independent variable; the incessant process of creative destruction, by means of changing the relative balance between firms, engenders the endogeneity of market concentration (Dosi, Malerba and Orsenigo 1994).

Technological change affects market structure in two primary ways. First, through influencing the optimal scale of production in an industry. In case the minimum efficient plant size increases (decreases) as a result of technological change, then there will be a tendency for the industry to become more (less) concentrated. In many industries, the volume required for a firm to use all the specialised resources and promote continuous substitution in production methods means that only a few firms can exist. Second, through the erection of barriers to entry: the first firm to introduce a successful innovation may gain a significant advantage over its rivals, an advantage that may derive, for instance, from the realisation of extraordinary profits that are available for additional R&D expenditures and the development of an expertise that cannot be easily duplicated.

Indeed, these two channels are related, in that some of these barriers to entry have to do with the large capital expenditures required to build plants. Entry in small scale would presumably be unsuccessful, the reason being that small firms are usually less efficient than large ones in concentrated industries. Besides, scale and efficiency in production may become more important as technologies mature, so that the opportunities for small firms become fewer. Now, barriers to entry are the less formidable, the higher the growth rate. A higher growth rate, for instance, facilitates new entry by reducing the share of market needed to attain the most efficient scale of production. Further, barriers to entry appear less formidable with faster growth because new entrants are encouraged to enter industries through the attraction of higher profits.

For Kalecki (1940-41), one of the most important effects of technical change is that it increases the degree of oligopoly because it promotes market concentration, and support for the proposition that a rapid rate of innovation leads to concentration can be found in the stochastic models of firm growth used in the simulation studies of Nelson and Winter (1982). However, arguments have also been made that technological innovation does not necessarily imply a more concentrated market structure. According to Sylos Labini (1969), while the process of concentration in concentrated oligopoly is essentially due to the pursuit of higher technical efficiency, the situation is normally different in markets where differentiated oligopoly prevails. The more differentiated the products are, the more difficult it is to introduce mass-production methods which are the main source of both continual cost reductions and the process of concentration.

Mansfield (1983), in turn, argues that the presence of long-lived capital and costly adjustment by firms and consumers implies, at least in the short run, that innovation can make a market either more or less concentrated. Blair (1972) reviewed the impact of technical change upon economies of scale and concluded that from the late 18th century through the first third of the 20th century technical change increased concentration, as advances in steam power, materials and methods of fabrication and transportation permitted and encouraged scale expansion. Since then, though, newer technologies tended to have the opposite effect, reducing plant size and capital requirements for optimal efficiency. While Mansfield (1984) presents mixed empirical evidence on the Blair hypothesis, Geroski (1994) provides evidence showing that the major innovations introduced in a wide range of industries in the UK during the 1970s actually lowered levels of concentration. In the model that follows, the rate of change in concentration is made to depend negatively on the innovation rate (cf. eq. 23 below).

Market concentration is also influenced by technological diffusion, since it determines the speed with which transient quasi-rents generated by successful innovations are eroded away by potential imitators. 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. In turn, the survey by Karshenas and Stoneman (1995) reports that most of the empirical studies on inter-firm diffusion has found a positive relation between firm size and speed of adoption in relation to a wide range of technologies in different industries. Even though the evidence on the influence of market structure is more ambiguous, this survey shows that there is evidence of a positive relationship between growth and diffusion – a finding which corroborates a point made by Steindl in the introduction to the 1976 reprint of his *Maturity and Stagnation*, where it is argued that the diffusion of consumer and investment goods depends on income and its rate of growth.

Relatedly, a conclusion derived in Silverberg, Dosi and Orsenigo (1988) is that diffusion is the faster, the higher the prospects for learning in a broad sense, with the latter being the higher, the higher the growth rate. Besides, Lissoni and Metcalfe (1994) reviews empirical evidence showing that the adoption profitability is a chief determinant of the speed of diffusion, with diffusion being more rapid when a broadly defined rate of return from adopting it is greater. Since in the model of this paper 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 the shorter the transient extraordinary profits generated by an innovation. Hence, the specification that will be used in what follows makes the rate of change in concentration to depend negatively on the growth rate (cf. eq. 23 below).

A final methodological word. As seen in this brief discussion of some conceptual issues related to the connection between market structure and technological change, the causal links and feedback effects at play are quite numerous and complex. The modelling 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. Besides, this formal framework should be as transparent as possible so that the results of the model can be satisfactorily interpreted and eventually reconsidered in a more inclusive set-up. It was this presumption that guided the specification of the model to be described and analysed in the following sections.

3. The structure of the model

We model an economy that is closed and has no government. A single good that can be used for investment and consumption is produced. Two factors of production, capital and labour, 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, u_K is the technologically-full capacity utilisation, and a is the labour-output ratio. Oligopolistic firms carry out production, and prices are given at a point in time, having resulted from previous dynamics. Firms will produce according to demand, it is being assumed that demand is not enough for them to produce at full capacity at the ongoing price.[6] 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 utilisation, r is the profit rate, and h is the rate of labour-saving technological innovation. Since we assumed that capacity output is proportional to the capital stock, we can identify capacity utilisation 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 utilisation 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

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[6] For Steindl (1952), firms hold excess capacity to be ready for a sudden rise in demand. First, the occurrence 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. Indeed, one central theme in Sylos Labini (1969) is that price determination is influenced by the possibility that new firms enter the market and not simply by competition between established firms, with the fixing of the limit price ultimately depending on the existence of barriers to entry due to the scale of operation.

one hand, and provides internal funding for accumulation plans and make it easier to raise external finance, on the other hand. Indeed, this specification is also in line with Sylos Labini's (1969) suggestion that the expected rate of profit and the expected degree of capacity utilisation principally determine investment.[7]

Desired investment is also made to depend positively on the innovation rate, the latter leading to more investment, at any given capacity utilisation 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 also consistent with Schumpeter's (1912, 1942) and Sylos Labini's (1969) 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.

At a point in time, the technological parameters u_K and a are given, having resulted from previous technological and accumulation dynamics. Over time, labour-augmenting, Harrod-neutral technological change taking place results in the labour-output ratio falling at rate h. The fixed-coefficient technology assumed here is amply supported by a reputable literature. As 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 various forms. Hence, technological change is typically characterised by 'localised' shifts in some production function, to use David's (1975)

[7] Bhaduri and Marglin (1990) argue for a formulation of investment as a function of the profit share, rather than the profit rate, on the ground that this separates the two influences at work whereas the rate of profit reflects the dual influences of profit share and capacity utilisation. In other words, one should not assume that an increase in capacity utilisation would necessarily stimulate investment when the profit rate is held constant, for this implies that the profit share has fallen. Indeed, it will be seen below that the specification used here implies that a rise (fall) in the wage (profit) share raises capacity utilisation and the rates of profit and growth – which might not be the case, as correctly recalled by one of the referees. As stated earlier, though, the purpose of this paper is to introduce some Schumpeterian elements into an otherwise standard newer post-Keynesian model.

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.[8]

The rate of technological innovation is determined non-linearly in a way given by

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

where c is an index of market concentration, while ρ and ϕ are positive parameters. We assume that, $\rho = \phi$, 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 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 nonlinearity in the influence of concentration on firms' innovative propensity discussed in the preceding section.[9]

Two classes, capitalists and workers populate the economy. Following the tradition of Marx, Kalecki (1971), Kaldor (1956), Robinson (1956, 1962), and Pasinetti (1962), we assume that they have a different saving behaviour. Workers supply labour and earn only wage income, which is all spent in consumption. Capitalists receive profit in-

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[8] Freeman and Soete (1987) and Verspagen (1990) have shown that localised technological change strongly diminishes the short-run possibilities for factor substitution, there being several characteristics of innovation which work to make it strongly localised: inter-relatedness and complementarities of many technological and organisational 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. Probably the most quoted formalisation of localised technological change is still the one by Stiglitz and Atkinson (1969). The underlying idea is that for any industrial grouping the range of efficient techniques is often very small, sometimes reaching one technological system which rules at any point in time. Hence, localised technological change strongly diminishes the short-run possibilities for substitution, with constant improvements of one single production technique usually leading to a Leontief- shaped function.

[9] An alternative specification of endogenous technological innovation can be found in Lima (1997), where it is elaborated a dynamic post-Keynesian model of capital accumulation and distribution in which labour-saving innovations depend nonlinearly on distribution itself. The idea is that the level of distribution determines both the incentives to innovate and the availability of funding to carry it out.

come, which is the entire surplus income over wages, and save all of it, so that $s = 1$. 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 labour share is given by

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

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. The markup over prime costs, *à la* Kalecki (1971), is given by

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

where z is the markup. Given labour 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 by firms. Desired markup depends on the state of the goods market: higher capacity utilisation, which reflects more buoyant demand conditions, will lead firms to desire a higher markup. Besides, it is only natural that in a model in the Kalecki-Steindl tradition a greater concentration leads firms to desire a higher markup,

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

where φ and θ are positive parameters.[10] The money wage is given at a point in time, its rate of change being in line with the gap between workers' desired share, σ_w, and the actual one:

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

where $\hat{W}$ is the rate of change in money wage, (dW/dt) $(1/W)$, and $o < \mu \leq l$ is the speed of adjustment. Workers' desired share is assumed to depend on their bargaining power, which is the higher, the tighter the labour market. The degree of tightness of the labour market is measured by the rate of change in employment. Formally,

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

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

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

where $\hat{X}$ is the rate of change in output.[11] Given the demand-driven nature of the model, the equality between investment and saving will

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[10] Harcourt and Kenyon (1976) 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 utilisation allows firms to raise prices with less fear of being undercut by competitors, who would gain little by undercutting due to capacity constraints. Gordon, Weisskopf and Bowles (1984) argue 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 utilisation 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.

[11] Alternatively, in other post-Keynesian models of this type the degree of tightness of the labour market is usually measured by the rate of employment (e.g. Skott 1989; Dutt 1992, 1994; You 1994a). Now, to use e, the employment rate, L/N, we would have to link it functionally to the state of the goods market as $e = uk$, with k standing for the ratio of capital stock to labour supply in productivity units, $k = K/(N/a)$, and N being the supply of labour. This formal link between u and e would be required because the fixed-coefficient kind of technology implies that an increase in output in the short run will be necessarily accompanied by an increase in employment. Therefore, k would be another state variable, in addition to σ and c, and the long-run dynamic analysis below would become three-dimensional – even in case the growth rate of labour supply were assumed to be exogenously given. In order to save on dimensionality, therefore, the degree of tightness of the labour market is measured here by the rate of change in employment.

be generated by changes in capacity utilisation. 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 behaviour of the model in the short run

The short run is defined as a time span in which the capital stock, the labour-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 realising their investment plans. This implies that capacity utilisation 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,

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

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 utilisation), 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 utilisation, 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 utilisation 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 utilisation effect on investment and hence raises the level of activity. Another issue regards the impact of different degrees of concentration on capacity utilisation. The innovation effect embodied in the investment function implies that given u and r, a higher concentration means a higher (lower) innovation rate and thereby investment for concentration levels below (above) $c^* = \rho/2\phi$. Formally,

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

Hence, a higher concentration implies a higher (lower) capacity utilisation 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. Substituting (15) into (7) and then the resulting profit rate into (14),

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

Having seen that a rise in the wage share raises capacity utilisation, it is natural to check if the same positive relation prevails between distribution and growth. Using (7) and (14),

$$g^*_\sigma = sr^*_\sigma = s[u^*_\sigma (1 - \sigma) - u^*] \tag{19}$$

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 different degrees of 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. Formally,

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

A higher concentration thus implies a higher (lower) 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 utilisation and growth are positively related to concentration, and we refer to it as LMC region. In the second, comprised by intermediate-high and high levels of concentration ($c > c^*$), innovation, capacity utilisation and growth are negatively related to concentration, and we refer to it as HMC region. In turn, capacity utilisation and growth rise with the wage share throughout.

5. The behaviour 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, with the economy moving over time due to changes in the capital stock, the labour-output ratio, the price level, the money wage, and the concentration level. We follow the behaviour 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, upon substitution,

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

where u and g are given by (15) and (18), respectively. As seen in Section 2, it is plausible to assume that changes in concentration are negatively related to the rates of growth and innovation. Formally,

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

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). Equations 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

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

$$M_{12} = \partial\hat{\sigma}/\partial c = \mu\lambda[g^*_c - (\rho - 2\phi c)] - \tau(\theta u^*_c + \eta)\,(\rho - 2\phi c) \tag{26}$$

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

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

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 utilisation and growth. A higher wage share, by raising capacity utilisation, 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, a higher wage share will also raise the growth rate and, by raising the rate of change in employment, may raise the rate of change in nominal wages. Eq. 26 shows that the impact of a change in concentration on the rate of change in distribution operates through several channels. First, it will affect the rate of change in employment by changing the rates of growth and innovation, which will affect the rate of change in nominal wages. Second, a change in concentration, in its own and by changing capacity utilisation, will affect firms' desired markup and thereby the rate of change in prices. Third, a change in concentration, by changing the innovation rate, 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 the rates of growth and 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 analysing the stability of an equilibrium located in each one of the two regions into which we divided the relevant subset of the c-domain.

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

The rates of innovation, capacity utilisation 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 more 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 utilisation and the rate of innovation. Higher capacity utilisation will raise the rate of change in prices by raising firms' desired markup even more – recall that a rise in concentration will have a direct positive impact on the latter. A higher innovation rate, in turn, will lower the rate of change in the wage share directly and will put a downward pressure on the rate of change in nominal wages. This latter effect works through a downward pressure on the rate of change in employment leading to a weakening of workers' relative bargaining power. However, higher concentration, by raising the growth rate, will put an upward pressure on the rate of change in employment, and in case this positive effect is strong enough to more than compensate for the negative ones, M_{12} will be positive.

The sign of M_{11} depends on the relative bargaining power of capitalists and workers. Since (19) shows that $u^*_\sigma > g^*_\sigma$, it may take a strong relative bargaining power by workers to ensure a positive sign for this partial derivative. For instance, a rise in the wage share, leading to a rise in capacity utilisation and growth, will only lead to a rise in its own rate of change in case the ensuing rise in workers' desired wage share is strong enough to cause a rise in the rate of change in nominal wages which is greater than the rise in the rate of change in prices caused by the concomitant rise in firms' desired markup.

In case M_{11} and M_{12} are negative, *Tr(M)* is 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 workers' desired wage share effect dominates in M_{11} is smaller than (the absolute value of) M_{22}. In case workers' desired wage share effect 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. Finally, in case workers' desired wage share effect 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 utilisation 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 ambiguous. A rise in concentration will exert an upward pressure on the rate of change of the wage share by lowering capacity utilisation and the rate of innovation. Lower capacity utilisation will put a downward pressure on the rate of change in prices by lowering firms' desired markup, whereas a lower innovation will raise the rate of change in the wage share directly and will put an upward pressure on the rate of change in nominal wages. This latter effect works through an upward pressure on the rate of change in employment 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 employment, and in case this effect is strong enough to more than offset the latter one, the resulting effect on the rate of change in nominal wages will be negative. Besides, higher concentration will put a direct upward pressure on the rate of change in prices by raising firms' desired markup, and in case the combination of these two latter effects is strong enough, 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 may take a strong relative bargaining power on the part of workers to ensure a positive sign for this partial derivative. 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.

As for the pair given by $M_{11} > 0$ and $M_{12} < 0$, *Det(M)* will be likewise ambiguous. 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 one. In case workers' bargaining power is strong enough to make for a positive sign for M_{11}, and M_{12} is also positive, this will make for an unstable solution. Finally, in case workers' bargaining power is not strong enough to make for a positive sign for M_{11}, and M_{12} is also negative, the equilibrium solution will be saddle-point unstable.

Given all these possibilities, therefore, the HMC region appears to be more instability-prone than the LMC one. Indeed, it is only in the latter that stability will surely obtain for some combination of signs for M_{11} and M_{12}, as seen above. In case an equilibrium is located in the borderline between the two regions, in turn, an inspection of equations 25-28 shows that it will be saddle-point unstable, since *Det(M)* is negative.[12]

6. Multiple equilibria analysis

The Schumpeter-based non-linear innovation function makes for the possibility of multiple equilibria within the relevant subset of the $(\sigma - c)$-space. Given that innovation, capacity utilisation and growth are all quadratic in concentration, the equations describing the corresponding isoclines will as well be quadratic in concentration. Whether

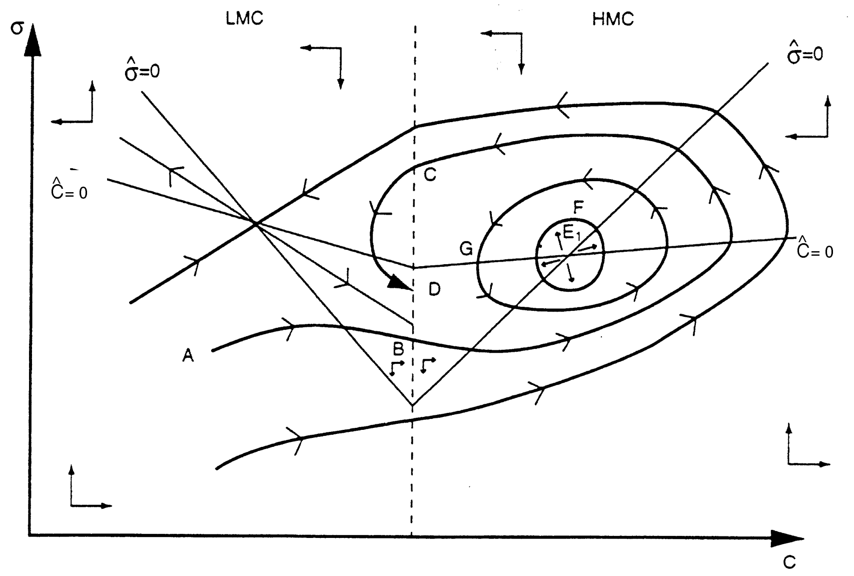
[12] The preceding analysis was conducted under the assumption that firms' desired markup is directly related to capacity utilisation, as formalised in eq. 10. In case we had assumed a countercyclical desired markup instead, eq. 25 shows that chances for a positive M_{11} would be improved. Regarding the sign of M_{12}, eq. 26 shows that chances for a positive (negative) one in the LMC (HMC) region would be higher than in the original situation with procyclical desired markup.

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 a parametric configuration leading to the emergence of multiple equilibria, with one equilibrium obtaining in each one of the regions discussed above.

One possible configuration contains a saddle-point unstable solution in the LMC region and a solution in the HMC region that can be either stable or unstable. Let us hypothesise that the parameters are such that the following obtains. First, a negative sign for M_{11} along the c-domain, meaning that the price change effect dominates the nominal wage change one. Second, a negative sign for M_{12} in the LMC region, meaning that workers' bargaining power is not strong enough. Third, a positive sign for M_{12} in the HMC region. Finally, eq. 28 shows the sign of M_{22} will be unambiguously negative (positive) in the LMC (HMC) region. This configuration is pictured in Figure 1.

FIGURE 1

PHASE DIAGRAM FOR MULTIPLE EQUILIBRIA, STABILITY ZONE AND CYCLICAL BEHAVIOUR



There is a subset of the phase plane that 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.

Once inside the zone of stability, the economy will move cyclically. Suppose we begin a trajectory at point A. The direction of motion of the system indicates that it must flow rightward up until the lower part of the $\hat{\sigma} = 0$ 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 $\hat{\sigma} = 0$ isocline is reached once again, after which it will start flowing rightward up. Once the $\hat{c} = 0$ isocline is reached, the direction of motion shows that the system will flow leftward up until the upper part of the $\hat{\sigma} = 0$ 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 $\hat{c} = 0$ 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 neighbourhood 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 Figure 1 – there is a neighbourhood of it, F, within which all trajectories of the system will move away from E_2. Since the system will end up reaching that neighbourhood along the hypothesised trajectory initiated at point A, it will not reach E_2. Indeed, there may eventually be a closed, bounded area encircling the neighbourhood F and from which no trajectory will exit. Since this area would contain no equilibrium points, the Poincaré-Bendixson theorem would ensure that it must contain at least one stable limit cycle (Arrowsmith and Place 1992). Whether or not some limit cycle will emerge, the system will move cyclically within the zone of stability, showing its propensity to experience endogenous, self-sustaining fluctuations in concentration and wage share, with innovation, capacity utilisation and growth fluctuating as well.

Indeed, a similar zone of stability in a two-equilibria situation is also obtained in Dutt (1992, 1994), from which this paper has drawn a lot of inspiration. Dutt (1992), however, does not incorporate technological change, and relies on full capacity being reached for multiple equilibria – one below and other at full capacity – to obtain within the relevant domain of a (real wage-capital to labour ratio)-space. As it turns out, Dutt's (1992) system experiences self-sustaining fluctuations within a zone of stability encompassing levels of real wage at which the economy is operating both at and below full capacity. Dutt (1994), in turn, does incorporate (exogenous and endogenous) technological change, but again relies on full capacity being reached for multiple equilibria – one below and other at full capacity – to obtain within the relevant domain of a (wage share-capital stock to effective labour supply ratio)-space. As it turns out, Dutt's (1994) system experiences self-sustaining fluctuations within a zone of stability encompassing levels of wage share at which the economy is operating both at and below full capacity. Finally, technological change is endogenised in Dutt (1994) by being made to depend linearly on the accumulation rate, whereas here it is endogenised by being made to depend non-linearly on market concentration.[13]

7. Conclusion

This paper contributes to the post-Keynesian literature by elaborating a model of growth and distribution in which a neo-Schumpeterian

[13] Dutt (1994) considers two possibilities in terms of a linear relationship between the rate capital accumulation and the rate of labour-saving technological change: a variant of Arrow's (1962) learning-by-doing notion that productivity increases with experience in production, an assumption which is also consistent with the idea that increases in productivity can be attained only with the introduction of new machines; and a variant of Schumpeter's (1912) suggestion that when the profit rate falls, so that the accumulation rate falls as well, firms will be pressured to innovate to increase their profits.

endogenous technological change plays a central role. The innovation rate is determined by market structure in a non-linear way, with the rate of labour productivity growth being quadratic in market concentration. This specification 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 dynamics is also affected by technological change, though, given that in a situation of neo-Schumpeterian competition the relationship between them is double-sided, and the model incorporates this other dimension as well.

Given this non-linearity in the innovation function, desired investment is also non-linear in market concentration, implying that the direction and the intensity of the effect of changes in concentration on capacity utilisation, growth and distribution will depend on the prevalent concentration. The dynamics of these variables, including the latter one, is also affected by demand factors, though, with both capacity and growth rising with the wage share, and concentration falling with the growth rate. Therefore, this paper also contributes to the neo-Schumpeterian literature by incorporating effective demand and distributional elements into concentration dynamics.

As it turns out, the stability properties of the system depends on the direction and relative strength of the innovation effects with respect to the demand ones, as well as on the relative bargaining power of workers and capitalists. Basically, the system is seen to be more instability-prone at higher levels of concentration than at lower ones. By examining one possible long-run multiple equilibria dynamics, the paper closes with an analysis of the potential emergence of cyclical behaviour inside a zone of stability.

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