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Towards Post-Keynesian Ecological Macroeconomics

by

Giuseppe Fontana (University of Leeds, UK and University of Sannio, Italy) and

Malcolm Sawyer (University of Leeds, UK)*

ABSTRACT:

The paper starts with a brief criticism of macroeconomic analyses of different schools of thought for their focus on economic growth and maximisation of output. This applies to the traditional Keynesian approach, which has focused on the achievement of sufficient aggregate demand to underpin full employment and full capacity utilisation, down-playing aggregate supply constraints. This also applies to the neoclassical approach, including the current New Consensus Macroeconomics approach, which asserts the dominant role of aggregate supply in the long run, and where growth is set by the so-called 'natural rate of growth', with no concerns over environmental and ecological issues. The paper then proposes a different approach to macroeconomic analysis. It explicitly acknowledges that economic growth is a double-edged sword. Growth can help to alleviate persistent levels of high unemployment, but it can also lead to potentially catastrophic environmental problems. Building on the Monetary Circuit theory and the Demand-led growth theory, the paper offers an analysis of the interconnections and interdependence of the economic, biophysical and social worlds and by doing it hopes to provide the building blocks for the establishment of post-Keynesian ecological macroeconomics.

Key words: Ecological Economics, Sustainability, Post-Keynesian, Monetary Circuit, Kaleckian, Demand-led Growth

Journal of Economic Literature codes: Q57, E12, E51

* Correspondence address: Prof. Giuseppe Fontana, Economics, LUBS, University of Leeds, Leeds, LS2 9JT, UK (E-mail: gf@lubs.leeds.ac.uk. Tel.: +44 (0)113 343 4503; Fax: +44 (0)113 343 4465).

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> The post-Keynesians have almost totally ignored environmental problems, as well as resource and energy constraints, in the tradition of maintaining capital accumulation and full employment. … Ecological economics is particularly weak on macroeconomic issues and, if anything, has tended to use economic equilibrium theories and concepts of capital, which are inconsistent with some of its basic premises about systems functioning derived from ecology. A more heterodox macroeconomic approach, sharing basic methodological concerns, would therefore be a significant step forward (Spash and Ryan 2012, p. 8).

1. Introduction

Macroeconomic analysis comes in many schools of thought and approaches and has been undertaken with little or no concerns over environmental and ecological issues. Indeed, in many respects macroeconomics has implicitly proceeded as though there are no resource and energy constraints. Keynesian macroeconomics, as represented by the *IS-LM* model of the neoclassical synthesis, focused on the determinants of aggregate demand, which in turn determined the level of economic activity in the short-run, with little or no interest over the supply-side of the economy. In some contrast, the mainstream approach in macroeconomics, appearing under headings such as the 'New Consensus Macroeconomics' (NCM henceforth) and neoclassical and endogenous growth theory, viewed aggregate demand as at most a short-run issue, and that the supply-side dominated the level and growth of economic output. Of particular relevance here is neoclassical growth theory with its assumption on substitutability between the factors of production and the role of the price mechanism in securing the full utilisation of resources (Rezai *et al.*, 2013). This has generated the idea that growth of output would belong to a sustainable equilibrium 'natural rate of growth' path.

This paper adopts a different approach from both traditional Keynesian macroeconomics and the current NCM. It is grounded in a framework which draws on the work of Keynes (1930, 1936), Kalecki (1971) and their modern followers, and is generally presented under the broad heading of post-Keynesian macroeconomics (PKM henceforth).[1] This framework recognises that a modern economy is a monetary production economy, i.e. an economy where money is crucial for the production of goods and services and the distribution of income, and in that way it makes the economy prone to solvency problems and financial instability (Brancaccio and Fontana 2012). This framework also acknowledges the role of fundamental uncertainty, rules out the possession of full information and optimisation under rational expectations, recognizes path dependence and the interdependence of aggregate demand and aggregate supply in determining the long-run level of output and employment (Arestis and Sawyer, 2009; Sawyer 2010).

PKM is not immune to the criticism of having largely ignored concerns with environmental and ecological issues. From its origin PKM has been concerned with the lack of automatic forces in a market economy, in both the short and long run, ensuring that the level of output corresponds to the full employment of labour. Full employment and economic growth as a means to achieve it have always been at the forefront of post-Keynesian contributions. As a result resource and energy constraints never played a prominent role in PKM. Yet, there have been noteworthy post-Keynesian contributions that have directly or indirectly touched on environmental and ecological issues.[2] These contributions can act as signposts for the creation of a PKM approach to ecological economics. More importantly, the past few years have seen the flourishing of a rich body of contributions relating PKM to ecological issues.[3] Most of these contributions recognise that economic growth is a double-edged sword. Growth can help to alleviate persistent levels of high unemployment, but it can also lead to potentially catastrophic environmental problems. The theoretical framework proposed in this paper explicitly acknowledges these potentially conflicting effects of economic growth. It offers an analysis of the interconnections and interdependence of the economic, biophysical and social worlds and by doing it hopes to provide some building blocks for the establishment of post-Keynesian ecological macroeconomics.

The paper is organized as follows. Section 2 briefly discusses the supply-side factors of the economy, mainly physical (or manufactured) capital, labour resources and 'natural capital', and the ways in which these three factors interact through a production function in order to determine the output of the economy, on the assumption that there is non-substitutability among these factors. Section 3 proposes an analysis of the monetary and financial system based on the monetary circuit, where money is created by the banking system through the lending activity to firms. Section 4 considers the demand side of the economy. Aggregate demand is driven by investment, which also provides additions to the capital stock, and hence to the future potential supply of the economy. Investment and the monetary circuit are closely linked to each other in that the financing of investment comes from loans, and banks decide how much and which forms of investment occur. Section 5 examines the ways in which the use of physical capital and labour, and the depletion of 'natural capital' could interact, and considers the possibility of the emergence of a sustainable rate of growth of output in the long run. Finally, Section 6 concludes.

2. **Resource use**

One of the main tenets of PKM is that the growth of an economy is driven by the growth of demand for goods and services, which in turn is set in motion by changes in the level of investment (in fixed capital formation). The central issue is then whether the growth of aggregate demand is sufficient to match the growth of the labour supply, and hence whether or not there is a tendency to underemployment of labour. Of course, a lack of capital equipment or supply bottlenecks can also prevent the full employment of labour (and indeed would be seen as major constraints). The analysis presented in this paper maintains this simple theoretical framework, but it enriches it with an analysis of environmental and ecological issues. The growth of the economy is perceived as driven by the growth of aggregate demand, and can be constrained by the growth of the labour supply in an economy approaching full employment. However, in addition to this, the growth process has to be constrained by the depletion of 'natural capital'. The working assumption in this paper is that the growth of aggregate demand tends to be greater than the sustainable growth of depletion of 'natural capital'.

The resources used in and used up in the production process are categorised under three headings, each with their own characteristics.

(i) Physical (or manufactured) capital: this is capital (e.g. machines, buildings) created through investment. A significant element here is that investment links the aggregate demand side and the aggregate supply side of the economy: the amount of investment undertaken is the major driver of demand, but investment also contributes to the future supply capacity of the economy. Furthermore, investment is the route through which new ideas, production processes and products are introduced in the economy, in the sense that new production processes, for example, have to be embedded in different forms of capital equipment.

The capital stock, K, is viewed as linked to capacity output (in the sense of physical limit), Y_c, by the following production relationship: $Y_c = K/v$ where v is the capital-capacity output ratio, which is treated as technically determined rather than influenced by relative prices. Actual achieved output, Y, is then $Y = u.K/v$, where u is a measure of capacity utilisation, Y/Y_c.

(ii) Labour: the augmented labour resource (labour resource for short, henceforth), N, that is the capacity to work of people is the multiple of labour productivity and person hours. Labour productivity q rises through several factors, including technical progress, skill formation and training activities, all of which can be influenced by aggregate demand and capital formation. Person hours L is determined by the average hours worked (per year) h, and the number of people employed E, that is $L=h.E$. Actual output Y is taken to be proportional to N, that is $Y = a.N = a.q.h.E$, where a is treated as constant over time. It then follows that the employment rate, e, is given by the following relationship: $e = E/F = Y/a.q.h.F$, where F is the labour force[4].

(iii) 'Natural' (or ecological or environmental) capital: this is a complex category of capital which is used, not without controversy[5], in ecological economics to indicate the role of nature in providing goods and services. Natural capital is a development of the notion of 'land', one of the factors of production in classical economics. It has both renewable (timber, river flow for hydropower) and non-renewable (e.g. oil, coal, natural gas) dimensions. Ekins *et al.* (2003) argue that natural capital performs four different environmental roles, namely (a) the provision of resources for production, (b) the absorption of wastes from productive processes, (c) basic life-support functions, and (d) amenity services. The first two roles are directly relevant for the production of goods and services.

The depletion of natural capital (DNC) is taken to depend on both the level and cumulative level of actual output Y, and research and development ($R\&D$), that is $DNC = f(Y, CumY, R\&D)$, where $f_Y>0$, $f_{CumY}>0$, $f_{R\&D}<0$. This means that DNC can change and be changed over time through several routes, including technical change, variations in the energy intensity of production, and the composition of output and consumption.[6]

A key feature of this paper is that there is no direct substitutability between the resources used in the production function. This stands in clear contrast to the use of production functions such as the Cobb-Douglas function in neoclassical economics, where there is the possibility of continuous substitution, and where the use of one input can be reduced at will and the level of output maintained with a sufficient increase in the use of other inputs. Furthermore, when continuous substitution between the resources used is assumed, it is generally taken that firms will make their choice among alternative use of available resources on the basis of profit calculations and relative prices. By contrast, in this paper there is no direct influence of relative prices on resource use, though the relationship between resource use and output can change over time, notably through technical change.

Drawing on what Kaldor (1955) referred to as one of the 'stylised facts' of modern economies, the relationship between capital stock, K, and capacity output, Y_c, is treated as a technical constant. Similarly, it is assumed that the use of the labour resource, N, is in a constant relationship with actual output, Y. However, since the analysis below treats technical progress as a labour-enhancing process, that along with skills and training means that, via increases in labour productivity q, the use of actual labour declines relative to output. This implies that skills, training and technical progress lead to a declining ratio between hours of work and output. Finally, the relationship between the growth of depletion of 'natural capital', g_{DNC}, and growth of output, g_y, is treated as subject to modifications through technical change, which can be enhanced through well-directed research and development and innovations.

These theoretical assumptions, including the non-substitutability assumption, are consistent with the views expressed by many ecological economists that physical (or manufactured) capital is a complement rather than a substitute to natural capital. "Economic production is a work process that uses energy to transform materials into goods and services; … producing a manufactured-capital substitute requires input of natural capital and … the multi-functional nature of ecosystems in sustaining socioeconomic development makes it difficult to substitute their life-support with manufactured-capital" (Ekins, Folke, De Groot, 2003, p. 160). This is another way to recognise the role of key PKM concepts like fundamental uncertainty, path dependency and irreversibility when analysing ecological issues (see also Daly 1991, 1996). This also means that the notion of sustainable growth rate in this paper is more akin to what is generally termed 'strong sustainability' rather than 'weak sustainability' in ecological economics (Ekins, Folke, De Groot, 2003), that is the possibilities of substitution between physical capital, labour and natural capital are very limited.

3. The monetary circuit

PKM is often associated with Keynes' *The General Theory of Employment, Interest and Money* (1936), and three of the main tenets that have been derived from that book, namely the principle of aggregate demand, the pervasiveness of involuntary unemployment, and the principle of policy effectiveness. However, it is not possible to fully comprehend those three tenets without a proper understanding of the nature, roles and origin of money in a modern economy. Among the post-Keynesian scholars that have devoted their work to monetary issues, the analysis of the Monetary Circuit theorists is prominent (Graziani 1989, 2003; see also Godley 2004).[7] In addition to Keynes (1930), early statements of the Monetary Circuit can be found in Wicksell (1898, Ch. 9, Section B), Schumpeter (1934, [orig. 1912], Ch. 2), and Kalecki (1990, p. 489).

The simplest model of a monetary circuit considers a closed economy with no state sector. It can be described by a five-stage sequential process among the following macro agents: producers (firms), banks, the central bank, and wage earners (households). Importantly, the Monetary Circuit is embedded within social relationships, and in turn the whole society is embedded within the natural environment. The links between the monetary circuit, and the economy more generally, society and the natural environment are represented in Figure 1a below. 'Social embeddedness' and 'natural embeddedness' highlight issues of uncertainty, power, norms and institutions that play a prominent role in the monetary circuit and PKM, more generally. Figure 1b below illustrates this simplest model of the Monetary Circuit.

Please insert Figure 1a and Figure 1b

Stage one: On the basis of the expected level of demand for goods and services, producers negotiate the nominal wage and the level of employment (i.e. the wage bill) with wage earners in the labour market. If producers are considered as a whole, then the cost of all other factors of production including capital and land can be neglected, because it counts as an internal transfer between producers. The wage bill is the only cost faced by producers. The wage bill also represents the credit requirements that producers need to negotiate with banks. Once the negotiations about the quantity and price of credit are concluded, banks grant the requested loans to creditworthy producers. This is the so-called initial finance (M). At this stage, it is noteworthy to note that banks play a crucial role in the monetary circuit. They finance the production process and select creditworthy business plans. The price of credit, namely the short-run nominal interest rate on loans (r), is set as a mark-up (σ) on the short-run nominal interest rate (i) determined by the central bank:

(1) $r = (1 + \sigma)\, i$

Stage two: Producers use the initial finance to purchase labour services from wage earners. In this way, the initial finance (M) created by banks at the request of producers is transferred from producers to wage earners. Thus, at the end of all transactions on the labour market, producers are indebted to banks for the same amount that wage earners are credited to it. The initial finance (M) now represents the income (W) of wage earners.

Stage three: Goods and services are produced and put on sale in the commodity market. Wage earners use their income (W) to buy goods and services in the commodity market (C_w) or to save it (S_w).

Stage four: Wage earners allocate their saving between deposits with banks (D_w) and securities in the financial markets (B_w). If, for the sake of simplicity, it is assumed that wage earners spend all their income either in the commodity market or the financial markets, that is $D_w = 0$, then producers get back the whole finance (M) created at their request by banks. This is the so-called final finance (M`).

Stage five: Producers use final finance (M`) to repay the whole principal of their debt to banks. The monetary circuit is closed without losses: all initial finance introduced into the economy is returned to banks. Producers are solvent and a new monetary circuit (stages one-five) can start again. Thus, the final finance ($M$`) measures the total returns to producers from selling goods and services in the commodity markets and securities in the financial markets. In diagrammatic terms, the simple model of a monetary circuit with no state sector or foreign sector can be represented by the following money flows:

(2) $M \rightarrow W \rightarrow (C_w + S_w) \rightarrow M$`

Despite its simplicity there are two crucial propositions that can be derived from this model of a modern economy. Importantly these propositions are still valid in more complex and realistic models (e.g. see for a monetary circuit analysis of the two-way relationship between banks and financial markets Veronese Passarella and Sawyer, 2013). First, the monetary circuit allows a proper understanding of the nature and functions of money. In a modern economy money has the nature of a debit-credit relationship. It fulfils the need for a standard of value in which contractual obligations for the organisation of production and exchange activities are made. The roles of money as a final means of payment and as a store of wealth are then derived from this function on the hypothesis that economic agents interact in an environment subject to fundamental uncertainty. Second, the monetary circuit model shows that money is a by-product of the workings of a production economy. The stock of money arises as a result of the creation of new bank liabilities (deposits) within the income generation process. In other words, the quantity of money in an economy is determined by the demand for loans, and the latter is causally dependent upon the economic variables that affect the level of output. Because the process of money creation lies within the economic system rather than in the independent discretionary actions of the central bank, this view has also been labelled the endogenous money theory. This is in contrast with the mainstream monetary theory that considers money as manna from heaven or (as in Milton Friedman's story) "helicopter drops" by central bankers.[8] From these two propositions, it follows that monetary circuit theorists reject the quantity theory of money and the principle of neutrality of money and monetary policy of the neoclassical school (Fontana, 2007, Table 1).

In summary, the monetary circuit explains how banks create money in the process of loan creation, and how money is destroyed through loan repayment. The creation of loans rests with decisions by banks in response to loan requests from firms. The monetary circuit thus highlights crucial demand and supply aspects of the money supply process. On the supply side, the monetary circuit draws attention to the fact that, by deciding whether or not to extend loans, banks determine which investments[9] take place. On the demand side, the monetary circuit brings to light the fact that firms need to borrow money in order to realise their expenditure plans.

4. A demand-side analysis

Traditional neoclassical and Keynesian macroeconomics as well as the currently dominant NCM assume that outside of the short run the level and growth of output is exclusively determined by changes in supply-side factors, namely capital, labour and technology. Demand-side factors like changes in investment or government expenditure do not have any real effects in the long run. In contrast, the theoretical framework here is based on the axiom of interdependence between aggregate demand and aggregate supply in both the short run and the long run. According to this axiom, aggregate demand play a crucial role in determining the degree of utilization of existing productive resources as well as the expansion of these resources over time. This means that the long-run time path of real output and employment, and not only their short-run fluctuations, is affected by the path of demand of goods and services. In addition to the interdependence between aggregate demand and aggregate supply, it is also generally assumed that unemployment of labour and underutilisation of productive capacity are the norm rather than the exception in a modern capitalist economy.

The axiom of interdependence between aggregate supply and aggregate demand together with non-binding supply constraints are at the core of the post-Keynesian growth theory, namely demand-led growth theory (Setterfield 2010). This section builds on the demand-led growth theory with the purpose to show how credit-driven investment has the dual effect of affecting the demand for goods and services, while also changing the capital stock available in the economy. There are two features of investment (in fixed capital formation) that stand out. First, investment expenditures are the driver of aggregate demand, and the level of saving in the economy comes into line with the investment expenditures through changes in the level of economic activity (as represented here by the adjustment of capacity utilisation, u). Second, investment adds to the capital stock and thereby to the future potential supply of goods and services. The evolution of the economy is therefore path dependent, i.e. what happens in one time period influences the future path of the economy. There is not a pre-determined equilibrium growth path (as in neoclassical growth theory) towards which the economy moves.

Following Kalecki (1971, 1990) and the Kaleckian tradition[10], the desired level of investment is dependent on the following three factors: 1) the rate of capacity utilisation u, relative to some 'desired' rate of capacity utilisation u^*,[11] with $u^* = Y^*/Y_c$: as u increases expected sales move towards the maximum productive capacity, which in turn stimulates investment plans; 2) the profit share, $m = P/Y$, which reflects profit opportunities influencing investment decisions; and 3) a variable, μ, which encompasses a range of factors influencing investment, including the state of 'animal spirits', and the impact of technological opportunities. Equation (4a) below represents the desired investment function I^d relative to the capital stock.

$$(4a)\ \frac{I^d}{K} = [\alpha(u - u*) + \beta m + \mu]$$

However, not all desired investment is necessarily realised, as production plans need to be financed in order to come to fruition (e.g. Moore, 1988). The proportion of investment projects that are deemed creditworthy and hence financed by banks is indicated by γ, while s_p represents the proportion of profits that are retained by firms to fund investment. Retained profits are given by the following equation:

$$s_p P = s_p \frac{P}{Y}\frac{Y}{Y^*}\frac{Y^*}{K}K = s_p m \frac{u}{v} K$$

Equation (4b) below represents the effective investment function I^e. It has been normalised by the capital stock, *K*, in order to highlight the link between effective investment and the growth rate of capital stock, i.e. changes in investment lead to changes in the path of the capital stock and the economy.

$$(4b)\ \frac{I^e}{K} = \gamma\left[\alpha(u - u*) + \beta m + \mu - s_p \frac{mu}{v}\right] + s_p \frac{mu}{v}$$

There are three points about the effective investment function worth mentioning. First, the influence of credit conditions on investment through changes in the variable γ is consistent with the Monetary Circuit analysis in the previous section. Access to credit and the interest rate on loans *r* (Equation 1) are two crucial factors to make investment plans effective. This means that the structure of investment depends on the loan decisions of banks as well as on the public policy regulating access to credit. As a result, some investment plans may not come into effect. Secondly, the profit share *m* has a positive effect on effective investment: as *m* increases more internal funds are available to finance investment. Third, there is an important difference between financing investment through banks loans and through profits. The former is potentially without limits, since banks can create credit *ex nihilo*. By contrast, at any given time retained profits are a given amount, and hence they represent a limited source of financing.

Equation (5) provides the saving function. Saving *S* are related to the distribution of income between wages (*W*) and profits (*P*). The parameters s_w and s_p represent the marginal propensity to save out of wages and profits, respectively, and for simplicity it is assumed that saving out of profits is the retained earnings, i.e. there is no further saving out of dividends.

$$(5)\ S = s_w W + s_p P$$

The saving function can also be normalised by the capital stock, *K* to give:

$$(6)\ \frac{S}{K} = \frac{s_w W + s_p P}{K} = \frac{s_w W + s_p P}{Y}\frac{Y}{Y_c}\frac{Y^c}{K} = \left(s_w \frac{W}{Y} + s_p \frac{P}{Y}\right) u \frac{1}{v} = \left[s_w(1-m) + s_p m\right]\frac{u}{v} = \frac{su}{v}$$

where *(1-m)* = *W/Y* indicates the wage share, and $s = s_w(1-m) + s_p m$, represents the average propensity to save out of income.

The short-run equilibrium condition between desired saving and desired investment is brought about through the adjustment of capacity utilisation *u*. The one-period growth rate of the capital stock, $g_K(t)$ is equal to *I/K*, and the time subscript (*t*) is introduced to indicate that the variable changes overtime. Applying the equilibrium condition between saving and investment $\frac{S}{K} = \frac{su}{v} = \gamma\left[\alpha(u - u^*) + \beta m + \mu - s_p \frac{mu}{v}\right] + s_p \frac{mu}{v} = \frac{I^e}{K}$, it yields equation (7) and equation (8) for capacity utilisation and then growth, respectively:

$$(7)\ u(t) = \frac{\gamma[\beta m(t) + \mu(t) - \alpha u^*(t)]}{\frac{\gamma s_P m(t)}{v} + s_W \frac{(1 - m(t))}{v} - \gamma\alpha}$$

$$(8)\ g_k(t) = \frac{s\gamma[\beta m(t) + \mu(t) - \alpha u^*(t)]}{\gamma s_P m(t) + s_W(1 - m(t)) - \gamma\alpha v}$$

Equation (7) is a demand-oriented interpretation of the determination of capacity utilisation in the short run. An aggregate demand stimulus as measured by a higher level of the variable μ would lead *ceteris paribus* to higher capacity utilisation. Equation (8) shows that an aggregate demand stimulus would also lead to a higher growth rate, provided that the 'Keynesian' stability condition holds, that is the denominator of the equation is positive. The effects of a change in the profit margin *m* on capacity utilisation *u(t)* and growth $g_k(t)$ can be positive or negative depending on whether the regime is wage-led or profit-led. These equations also account for the so-called 'paradox of thrift': an increase in the propensity to save *s* leads to a reduction in capacity utilisation *u* (Equation 7), and to lower saving *S/K* (Equation 6).

The growth of output and employment follows directly from the definition of output, $Y = u.K/v$, and of labour $N = Y/a = u.K/a.v$, respectively:

$$(9)\ g_y(t) = g_u(t) + g_k(t)$$

$$(10)\ g_N(t) = g_u(t) + g_k(t)$$

The term g_u moves over the business cycle, averaging out at zero. Therefore, in the following the growth of output is taken as to be driven by the growth of capital.

From the definition of $N=q.h.E=q.h.e.F$, it follows that:

$$(11)\ g_N(t) = g_q(t) + g_h(t) + g_e(t) + g_F(t)$$

Equation (11) suggests several factors that impact on the growth of the supply of labour $g_N(t)$, namely the growth of labour productivity *q*, average hours worked *h*, the employment rate *e*, and population (as reflected in size of the labour force, *F*). The growth of labour is then conditioned by, inter alia, social norms and conventions regarding hours of work, age of entry into and exit from the labour force, and demographic factors. The growth of aggregate demand can influence productivity growth through increasing returns, learning by doing, and enhanced investment as reflected in, for example, the Kaldor-Verdoorn Law[12]. The depletion rate of natural capital follows from the relationship $DNC = f(Y, CumY, R\&D)$:

$$(12)\ g_{DNC} = \frac{Y}{f} f_Y g_Y + \frac{f_{CumY}}{f} Y + \frac{f_{R\&D}}{f} \frac{dR\&D}{dt}$$

where $(Y/f)(f_Y)$ is taken to be an increasing function of g_Y. Equation (12) portrays the depletion rate of natural capital as influenced by three terms. The first term $\frac{Y}{f} f_Y g_Y$ relates the depletion rate of natural capital to the growth of output. This relationship could be represented *ceteris paribus* (that is holding the second and third terms of equation (12) constant) as an upward sloping curve, and at an increasing rate. This means that beyond some point the rate of growth of output has more and more damaging ecological effects. The second term $\frac{f_{CumY}}{f} Y$ allows that the level of output has some impact on the depletion rate of natural capital. Finally, the third term $\frac{f_{R\&D}}{f} \frac{dR\&D}{dt}$ captures among other things the effects of technical change, and it can be discussed (e.g. Freeman, 1982) in terms of 'technology-push' (often related to the ideas of Schumpeter) and 'demand-pull' (often related to the work of Schmookler). In the latter case, aggregate demand and output could have positive effects on the depletion rate of natural capital by e.g. fostering the use of low-carbon production techniques. In other words, these technical change effects could potentially lead to a higher rate of growth being consistent with a constant depletion rate of natural capital.

The scale of the capital stock in period T would be given by:

$$(13)\ K(T) = K(0) \prod_{1}^{T} (1 + g_k(t))$$

Equation (13) clearly indicates the level of the capital stock is path dependent and demand-led (since investment is demand-driven). The scale of the capital stock at any point *T* depends on the values of $g_K(t)$ in the preceding time periods. Similar equations and conclusions can be derived for e.g. output, the labour resource, employment, though they are not shown here as they are not central to the analysis.

Equation (14) is an alternative way to represent the equilibrium condition between desired saving and desired investment. It draws attention to the direct link between the rate of profit, $\pi = P/K$, and the rate of accumulation of capital, i.e. the level of investment normalized by the capital stock, I/K.

$$(14)\quad \frac{I}{K} = \frac{S}{K} = \frac{s_w\,(Y-P) + s_p P}{K} = s_w \frac{Y}{K} + \left(s_p - s_w\right)\frac{P}{K}$$

Equation (14) shows the link between the rate of profit, P/K, and the rate of growth of the capital stock, I/K. In the case that the marginal propensity to save out of wages is nil, i.e. $s_w=0$ (the 'classical saving' function), then the rate of growth of the capital stock and the rate of profit are proportional. This simple result raises the crucial question of the sustainability of a profit-driven capitalist economy with a low growth rate. A lower growth rate could be achieved through lower investment, but it would entail a lower rate of profit.[13]

5. Supply-side constrained demand-led growth

Three growth rates of resources can be identified from the framework above, namely the growth of the capital stock (based on credit-led investment), the growth of labour (based on based on person hours and labour-augmenting technical changes), and the depletion rate of natural capital. These three growth rates of resources give rise to three theoretical growth rates of output:

(i) The growth of capital stock g_K arises from the interactions of intended investment and intended saving. This is a demand-led growth rate (which is similar to the 'warranted rate of growth' in a Harrodian setting) and is derived from equation (8) above (and equation (17), Appendix 1, in the case of an open economy). Since the capital-capacity output ratio is deemed to be constant, (capacity) output grows in line with the capital stock. This is represented by point A in Figure 2 below. The 45° degree line indicates that in correspondence of this point the growth of output is g_1.

(ii) The growth of the labour resource g_N is derived from equation (10) above. It depends on the growth of output and is represented in Figure 2 as an upward sloping curve, and at a decreasing rate (i.e. the first derivative is positive, while the second derivative is negative). Since the labour-capacity output ratio is deemed to be constant, a constant rate of employment would correspond to point B. The 45° degree line indicates that in correspondence of this point the growth of the labour resource g^*_N is equal to the growth of output g_2.

(iii) The depletion rate of natural capital g_{DNC} is derived from equation (12) above. Holding all other terms of the equation constant, the relationship between the depletion rate of natural capital and the growth of output is represented in Figure 2 by an upward sloping curve, and at an increasing rate. The curve will shift over time as a result of changes in the other terms of equation (12), that is rising income would move the curve upwards, while changes in *R&D* would shift it downwards. The growth rate of output consistent with the sustainable depletion rate of natural capital g^{*}_{DNC} is represented by point C. This is g_3 (a rate which may be zero or negative). The growth of output g_3 will be referred to below as the natural capital constrained rate of growth of output.

Please insert Figure 2

Figure 2 above provides a representation of the demand-led g_K, supply-led g^{*}_{N}, and nature-led g^{*}_{DNC}, together with the growth rates of output associated with them, namely g_1, g_2, and g_3. Since there are different forces and actors behind g_K, g_N, and g_{DNC}, it would only be by coincidence that $g_1 = g_2 = g_3$. In general these growth rates of output will be different. This immediately raises two questions. First, what are the consequences of the lack of equality of these growth rates of output? For instance, since the growth of output derived from the growth of the labour resource differs from the growth of output derived from the growth of capital, rising or falling unemployment will necessarily results. Is this feasible, and for how long? More to the point for the purpose of this paper, if the growth of output derived from the sustainable use of natural capital is lower than the growth of output derived from the growth of capital and labour, severe environmental problems will follow. Again, is this acceptable, and for how long? Second, and closely related to the first question, in a modern economy are there forces at play which would tend to bring these growth rates of output into line with each other? And, what is the nature of those forces? Can they be reasonably described as self-adjusting market forces, policy decisions, or changing conventions and social norms?

The growth rates of output g_1, g_2, and g_3 are theoretical growth rates of output, and at most one of those rates will be actually achieved. If the economy is in a demand-led regime, that is the growth rate of physical capital, via credit-led investment, is the main factor determining the actual growth of output in the economy, then the achieved rate would be g_1. If, in the first instance, it is also assumed that $g_1 > g_2 > g_3$[14], then it is possible to derive the depletion rate of natural capital and the growth of labour corresponding to the demand-led growth rate of output g_1.

The depletion rate of natural capital corresponding to g_1 is indicated by point D in Figure 2, namely $g'_{DNC,}$ a rate which exceeds the sustainable rate g^*_{DNC}. In a similar way, when the actual growth rate of output is g_1, the growth of labour will be g'_N, which is above g^*_N. This means that corresponding to growth rate g_1, the required growth of labour will be above the growth of the domestic labour force. If there is neither a pool of unemployed labour resources nor a positive net inflow of foreign labour resources, then the actual growth rate of output g_1 is also problematic from a labour perspective. In other words, the depletion rate of natural capital and the growth of labour corresponding to the achieved growth rate of output g_1 would be both unsustainable in the long run.

In Figure 2 it is assumed that $g_1 > g_2 > g_3$. Of course, different implications will be derived for various combinations of size of g_1, g_2, g_3. But, as long as the natural capital constrained rate of growth of output g_3 is lower than g_1 and g_2, than the previous conclusion about the long-run un-sustainability of the achieved growth rate of output will be confirmed. In other words, g^*_{DNC} sets an upper constraint on the long-run (to be achieved) growth rate of output. The economy can only grow in an ecologically sustainable manner at any rate below or equal to g^*_{DNC}. This conclusion then leads to the second set of questions posed above. Do there exist in a modern economy self-adjusting market forces that will bring the growth rates of output arising from the use of physical capital, natural capital and labour into line with each other?

Building on the analysis of the previous sections, and in particular on the assumption that physical capital, labour and natural capital cannot be readily substituted for each other, it follows that, contrary to the neoclassical theory, there would not be no automatic market forces which would bring g_1, g_2, and g_3 into alignment with each other. The scarcity (abundance) of a resource will not lead to a self-adjusting change in its relative price such that individuals will be encouraged to decrease (increase) its use in favour of the use of other resources. As a result, the economy will experience severe imbalances in the use of its own resources.

The long-run un-sustainability of this situation leaves open the question of which sustainable growth rate of output, if any, could finally prevail in the economy. There are several factors that affect the determination of the sustainable growth rate of output in the long run. First and foremost, the growth of output g_1, which corresponds to the growth of the capital stock g_K, as of any other realised output, needs to be financed by banks. The credit conditions imposed by banks are thus a major channel to consider for achieving a sustainable growth rate of output. Furthermore, for a given capacity utilisation ratio, the growth of g_1 depends positively on the capital-capacity output ratio, the profit share, the state of animal spirits, the impact of technological opportunities, and negatively on the desired rate of capacity utilisation.[15] Second, the growth of the labour resource g_N is influenced positively by changes in the average hours worked, the number of people employed, population growth and labour productivity, where the latter in turn depends on technical progress, skill formation and training activities. Finally, the depletion rate of natural capital g^*_{DNC}, which will give rise to the natural capital constrained rate of growth of output g_3, is influenced by the same factors, including credit conditions, influencing the growth of output g_1.

There are also several feedback mechanisms between each theoretical growth rate of output g_1, g_2, and g_3.[16] For example, the growth of output g_1 impacts on (human) migratory behaviour, entry or exit into the work force, and hence on the growth of the labour resource g_N. Similarly, through dynamic economies of scale and learning by doing, the growth of output g_1 also influences labour productivity, which in turn affects g_N. More generally, forces that lead to an adjustment of investment, e.g. changes in credit conditions imposed by banks will affect both the growth of the capital stock and the growth of the labour resource, and consequently the growth of output g_1 and g_2, respectively. Interestingly, this also applies to the growth of output g_3. Forces that lead to an adjustment of investment will affect the depletion rate of natural capital g_{DNC}, and the related constrained rate of growth of output g_3. For instance, the imposition of more stringent environmental obligations may negatively affect the profit expectations of firms, which in turn by dampening animal spirits will lead *ceteris paribus* to lower investment.

The impact of credit conditions on the growth of output g_1, g_2, and g_3 is also important. Firms need to borrow money in order to make effective their investment plans. Therefore, public authorities may seek to influence the growth of output g_1, g_2, and g_3, and hence the determination of the sustainable growth rate of output in the long run, through manipulation of the total amount and the composition of credit-led investment that take place in a modern economy. For instance, monetary authorities could change the short-run nominal interest rate (i) with the purpose of affecting the short-run nominal interest rate on loans (r). Monetary authorities may also impose different asset-based reserve requirements for each class of loan made by banks in order to discriminate lending by types of borrowers and/or projects.[17] Forms of credit guidance to banks to favour environmentally friendly investments represent another possible approach.

Conventions and social norms also play a key role in aligning the growth of the capital stock, the labour resource, and the depletion rate natural capital for the purpose of affecting the determination of the sustainable growth rate of output in the long run. For instance, when the labour force is seen in terms of average hours worked, participation rate, population and labour productivity there is a broad range of policies, including changing working hours, age of entry into and exit from labour force, that public authorities may seek to use in order to affect the actual growth rate of output in the economy.

In summary, two features stand out for the development of post-Keynesian ecological macroeconomic analysis. First, there is paucity of self-adjusting market forces that serve to reconcile the three growth rates of resources when the corresponding levels of output growth are different. Government policies are likely to be a more effective force to influence the factors determining the sustainable growth rate in the long run. Changing social norms are also needed to play a major role. For instance, ideas or views about the sustainable growth of the economy in the future are going to influence, among other things, the lending behaviour of banks as well as the borrowing needs of firms. As a result, the actual level of investment in the economy will be affected. Government policies and changing social norms are also likely to trigger supporting feedback mechanisms, ranging from length of the working week through to ensuring that investment and research and development are directed towards sustainability. Second, the growth of physical capital, labour and natural capital are all path-dependent. Each sequence of changes and adjustments to the growth rate of capital, labour and natural capital imbues the economy with memories that affect current and future growth rates of output. Therefore, path-dependency, uncertainty and financial instability all call for a cautious approach when trying to predict the emergence of a sustainable rate of growth of output.

6. **Concluding comments**

This paper has argued that in a monetary production economy the rate of growth of output is demand-led and depends to a large extent on the rate of investment. A lower rate of growth arising from recognition of the interconnections and interdependence of the economic, biophysical and social worlds would have severe macroeconomic consequences, including a lower rate of profit, lower capacity utilisation and lower level of labour resource utilisation. The paper has also shown that the achievement of lower growth would require control over the volume and composition of investment. Given the close links between credit creation and investment, this has clear implications for the lending activities of banks as well as on the public policy regulating access to credit. Finally, the paper has argued that government policies and changing social norms are likely to be more successful than market forces in bringing the growth of output toward a sustainable path.

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[1] There is some ambiguity concerning the spelling and meaning of "Post Keynesian" economics. This manuscript adopts a broad definition of Post Keynesian economics, and more to the point of Post Keynesian Macroeconomics, that encompasses among other things Kaleckian growth theory and the Monetary Circuit theory. Therefore, following the recommendation made by one of the referees, throughout the manuscript the spelling "post-Keynesian" replaces the more traditional "Post Keynesian" spelling. See, for an analysis of the different features of PKM, Fontana (2010, Ch. 2), King (2012), and Harcourt and Kriesler (2013).

[2] See, for instance, Davidson (1963, 1979a, 1979b), Bird (1982), Gowdy (1991), Vercelli (1998), Metroeconomica (2001), and Roncaglia (2003).

[3] See, for instance, International Journal of Environment, Workplace and Employment (2005), Holt, Pressman, Spash (2009), Kronenberg (2010), Chen and Galbraith (2011, 2012), entries by Courvisanos, Perry, and Winnett in King (2012), Cambridge Journal of Economics (2012), and Foley (2013).

[4] For simplicity, the labour force F is treated as a proportion of the population, i.e. variations in the age of entry into and exit from labour force are ignored.

[5] See, for a detailed discussion of different views of 'natural capital' in ecological economics and their implications for distinct conceptions of 'sustainable development', Burkett (2003).

[6] See, for the relevance of post-Keynesian consumer choice theory to ecological economics, Lavoie (2009).

[7] See, for an analysis of the nature and origin of post-Keynesian Economics and the Monetary Circuit strand of it, Fontana (2010, Ch 2 and Ch. 5, respectively). See also, for recent Monetary Circuit contributions, Fontana and Realfonzo (2005) and entries by Gnos and Realfonzo in Arestis and Sawyer (2006).

[8] See, for an early but still relevant discussion of the endogenous money theory as opposed to the exogenous money theory, Moore (1988). Several entries in Arestis and Sawyer (2006) provide a guide to different perspectives on endogenous money (e.g. by Dow and by Lavoie) and the empirical support for the endogenous money approach (e.g. Howells).

[9] Monetary circuit theorists prefer to talk of financing production plans (of both consumption and capital goods) rather than financing investment, where the latter term is used to indicate the purchase of capital goods. For the purpose of this paper, financing production and financing investment are considered synonymous. The purchase of capital goods is better refereed as the funding of investment.

[10] See, for introduction to Kaleckian growth theory, Dutt (2012). See also, for early contributions to the development of the Kaleckian approach to economic growth, Rowthorn (1981), Dutt (1984), and Bhadhuri and Marglin (1990).

[11] The 'desired' rate of capacity utilization appears in a number of Kaleckian formulations (e.g. Setterfield, 2010). Drawing on Harrodian models, some scholars (e.g. Skott, 2010) have argued that these Kaleckian formulations fail to recognise that capacity utilisation cannot be less than desired in the long-run. In this manuscript, desired capacity utilization plays little role, and for the sake of simplicity the traditional Kaleckian interpretation of the 'desired' rate of capacity utilization is used (see, also, Hein *et al.*, 2011).

[12] According to Verdoorn (1949) and Kaldor (1966) the growth of labour productivity is a positive function of growth of output, especially for the manufacturing sector.

[13] In the case of an open economy with state sector, a lower rate of growth of the capital stock could go with a high rate of profit, but it will require corresponding adjustments either in the government budget *d*, or, at the national level, in net exports *x* (see Appendix 1 for further details).

[14] The relative size of g_1 and g_2 will determine whether employment rates are rising or falling.

[15] In an open economy with a state sector, the growth of output g_1 also depends positively on the budget deficit, and the trade deficit (Appendix 1).

[16] See, for a detailed analysis of the feedback mechanisms between the growth of the capital stock, the growth of the labour resource, and the growth of output associated with them, Sawyer (2012).

[17] See, for similar suggestions, Rozenberg *et al.* (2013), and Campiglio (2014).

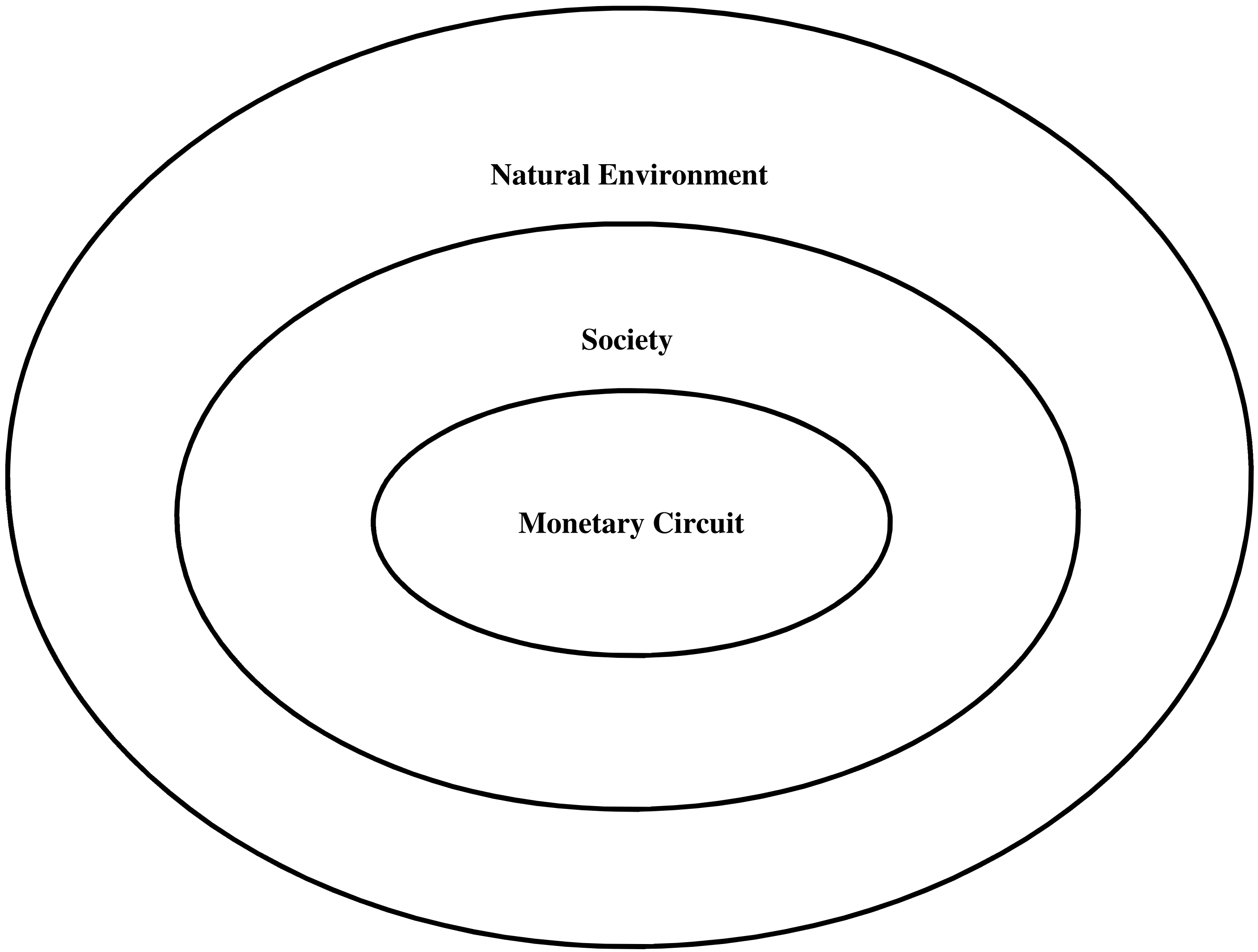

Figure 1a: The Stratification of the Monetary Circuit in Society and the Natural Environment

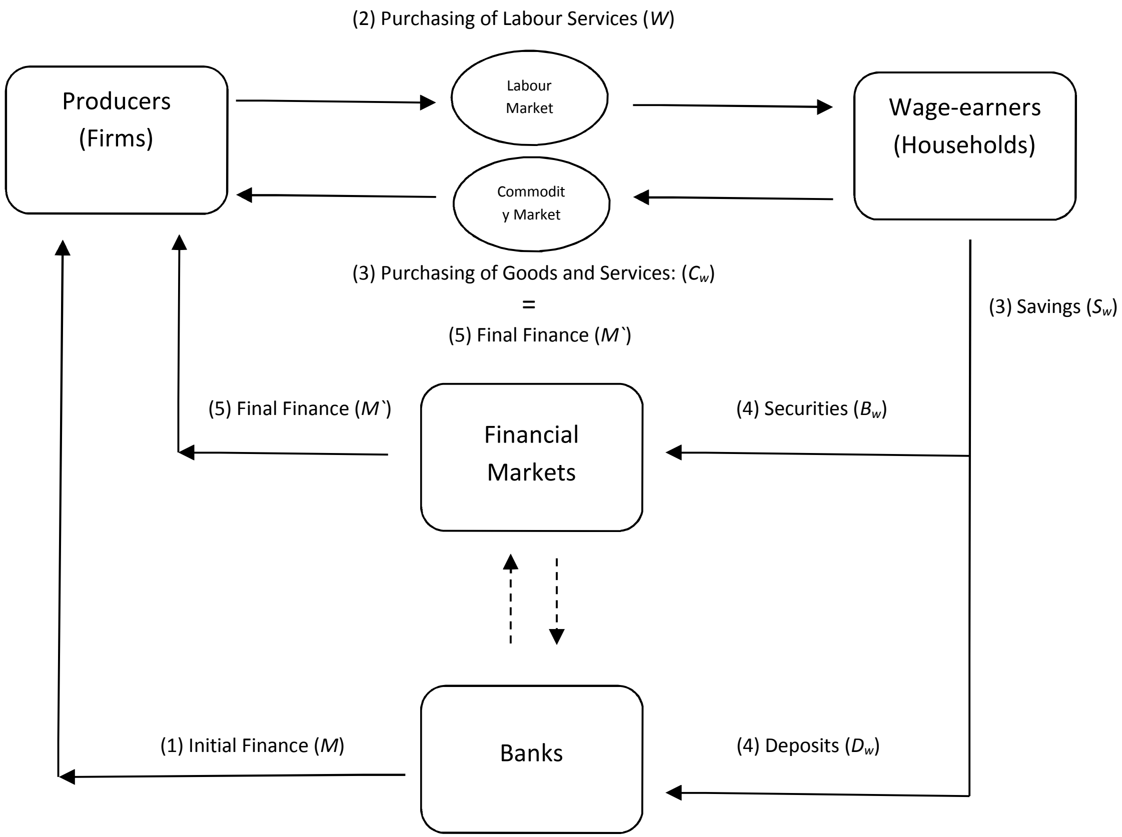

Figure 1b: The basic model of the monetary circuit for a closed economy with no state sector

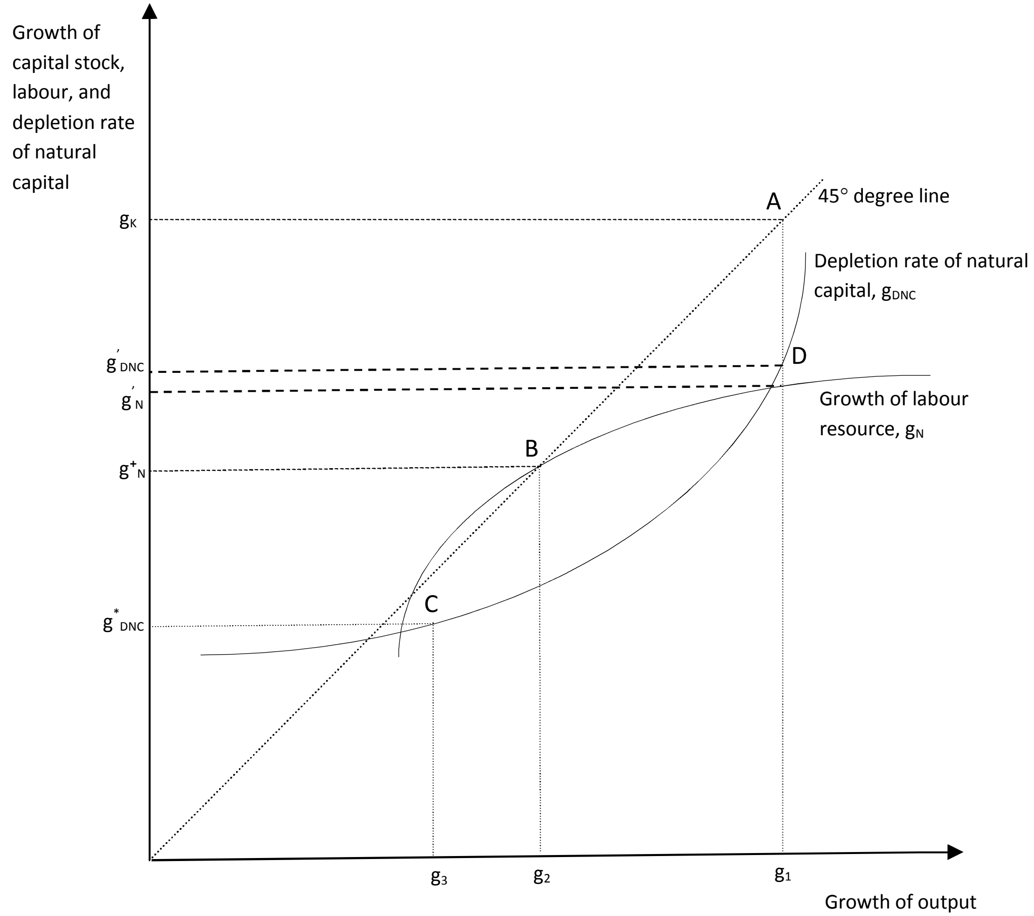

Figure 2: The growth of resources (and related output) and the sustainable growth of output

APPENDIX

A demand-side analysis in an open economy with a state sector

The analysis in section 4 has considered a closed economy with no state sector. At the global level net exports, *NX*, i.e. (exports minus imports), of course sum to zero. However, at the national level net exports are a component of the aggregate demand for goods and services. Therefore, for the completeness of the analysis, the short-run equilibrium condition between savings and investment is amended with a variable, *x*, representing net exports relative to the capital stock, *NX/K*. The aggregate demand for goods and services is also affected by fiscal policy and government budget positions. A budget deficit (*(G-T)<0*; where *G* is government expenditures and *T* is government taxes) is equal to the difference between domestic private savings and investment plus capital account inflow (equal to current account outflow). Again, for the completeness of the analysis, the short-run equilibrium condition between savings and investment is amended with a variable, *d*, representing the budget deficit relative to the capital stock, *(G-T)/K*.

$$(15)\quad \frac{S}{K}=\frac{su}{v}=\frac{I^e}{K}+\frac{NX}{K}+\frac{G-T}{K}=\gamma\left[\alpha(u-u^*)+\beta m+\mu-s_p\frac{mu}{v}\right]+s_p\frac{mu}{v}+x+d$$

Like in the case of a closed economy, the short-run equilibrium condition between savings, investment, net exports relative to the capital stock, *NX/K*, and the budget deficit relative to the capital stock, *(G-T)/K* is brought about through the adjustment of capacity utilisation, *u*. Equation (16) represents the equilibrium condition for an open economy with a government sector:

$$(16)\; u(t)=\frac{\gamma[\beta m(t)+\mu(t)-\alpha u^*(t)]+\; x(t)+d(t)}{\frac{\gamma s_P m(t)}{v}+s_W\frac{(1-m(t))}{v}-\gamma\alpha}$$

The one-period growth rate of the capital stock, $g_k(t)$, is set by the rate of investment, while the differences between private saving and investment is absorbed by the budget deficit, *d*, and net exports, *x*.

$$(17)\; g_k(t)=\frac{s\gamma[\beta m(t)+\mu(t)-\alpha u^*(t)]+d(t)+x(t)}{\gamma s_P m(t)+s_W(1-m(t))-\gamma\alpha v}$$

The analysis above shows that a lower rate of growth of the capital stock could go with a high rate of profit, but it will require corresponding adjustments either in the government budget, d, or, at the national level, in net exports, x (see Equation (15)). A budget deficit and/or a trade deficit would enable differences between savings plans and investment plans to be realised. A budget deficit and/or a trade deficit would therefore allow savings to take place in excess of investment, while maintaining the current rate of profit and securing high rates of employment. Again, this simple result brings together the crucial question of the sustainability of a low growth-low profit rate capitalist economy together with the necessity and acceptability of a budget deficit or (but only at the national level) a trade deficit.