KNOWLEDGE, ECONOMIC GROWTH AND THE ROLE OF POLICY
On the role of 'public-private partnerships' in the new 'knowledge-driven' economy

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Abstract:
The paper examines the economic rationale for "public-private partnerships" to promote technological progress and growth in the new "knowledge-driven" economy. Three main arguments are advanced: First, the present policy agenda is caught up in a mismatch between micro-economic science and technology policies, on the one hand, and macroeconomic growth policies, on the other. While the former rely on an essentially evolutionary understanding of innovative processes which emphasise the need for decentralised public-private co-operation, the latter largely reflect the insights of the New Endogenous Growth Theory (NGT) which, however, advocates a standard market failure approach to economic policy, and innovation policies in particular. Second, the NGT is itself to blame for much of this confusion in that it is unclear with regard to its conceptualisation of knowledge as a *factor of production* and as a (public-private) *good.* Third, for "public-private partnerships" to work the underlying policy direction (privatisation or gradual socialisation) needs to be further specified. This, in turn, requires a clarification of whether knowledge is to be understood primarily as a disembodied factor of production or as embodied in the process of capital accumulation.

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"The puzzle lies in the relationship between making profit and technological innovation. It is often assumed that an economy of private enterprise has an automatic bias towards innovation, but this is not so. It has a bias only towards profit."
E.J. Hobsbawm, Industry and Empire from 1750 to the Present Day (1969: 40)

"*It is the business of economists, not to tell us what to do, but to show why what we are doing anyway is in accord with proper principles.*"
J. Robinson, Economic Philosophy (1962: 25)

1. Introduction

The renaissance of university-industry relations (UIRs) is a centrepiece of the economic agenda associated with Third Way politics. Three concepts are at the heart of this agenda: the exploitation of 'the knowledge driven economy'[1], an explicit recognition of the value of 'social capital' in supporting economic dynamism, and a partner- or sponsorship role of the state vis-à-vis the market. Together, these ideas define the core feature of the Third Way, namely its emphasis on 'newness': the government, in partnership with the private sector, responds to perceived fundamental changes in the economy's resource base which require radically new forms of social interaction. In the economic sphere:

'the industrial order... built on raw materials, heavy industry, unskilled and manual employment, great concentrations of economic power, and antagonism between labour and capital' has given way to the 'new economy.... Services, knowledge, skill and small enterprises are its cornerstones. Most of its output cannot be weighed, touched or measured. Its most valuable assets are knowledge and creativity. The successful economies of the future will excel at generating and disseminating knowledge, and commercially exploiting it' (Blair 1998: 8).

At the core of this 'new economy' is 'human and intellectual capital' (ibid.:10). For this capital to flourish a precarious balance needs to be struck between competition and collaboration, between entrepreneurial and collective spirits. Following Putnam and Fukuyama, proponents of the Third Way agree that in 'the new knowledge driven economy' the transformation of entrepreneurial zeal into wealth creation, or Schumpeterian 'creative destruction', requires the development and nurturing of 'social capital', of informal bonds and norms of trust, to replace the historical antagonism between labour and capital. 'Public-private partnerships' are a central policy tool to achieve this balance between competition and co-operation, between economic and social capital. They also encapsulate the new, essentially pragmatic Third Way view of the state, which rejects both the openly interventionist state and the rigid division of tasks between the state and the market advocated by neo-classical welfare economics. Stiglitz labels this the 'market complementarity view' which he sees as attributing to the state:

'more than a minimalist role, but less than an all-encompassing role, a role in which government *focuses* on areas of relative strength, where there are well defined lacuna in the market. But the market complementarity view goes beyond the simplistic approach which says that certain areas (like defense) should be the domain of the public sector, while others (like making steel) should be the domain of the private. The public and private sectors often need to work in tandem as 'partners' within the same area....' (forthcoming: 11-12, emphasis in the original)[2].

Given the strong emphasis on knowledge and science as the new 'engine of growth', it comes as no surprise that UIRs[3] should be assigned a pivotal role among the 'public-private partnerships' designed to promote and assist the performance of the 'new economy'.

That knowledge and science are an important driver of technical progress and, therefore, also of economic growth is not a new idea. On the contrary, the identification of science with progress is one of the main themes of the Enlightenment and a defining aspect of capitalism. As such, it is one of the few propositions on which neo-classical and Marxist economists can agree. Neither is close direct collaboration between public sector research (PSR) and industry a new phenomenon. As is well-known, both the chemical and the electrical industry made ample use of direct interaction with university laboratories in the nineteenth century and far into the twentieth century. What is new, however, is the systematic propagation of such linkages by governments, or the idea that all (or most) of basic research should directly generate economic value. To put it another way, what is new is that universities should form an intrinsic part of the 'value chain', with commercial exploitation of their output constituting their raison d'être.

Underlying this view of the new economic role of PSR are two assumptions. One is microeconomic in nature, referring to the characteristics of technology transfer from the science base and the role of collaboration. It holds that, given the complexities of modern science and technology, close and continuous collaboration between public research institutes and private companies at all levels of knowledge formation is indispensable to the successful 'commercialisation of knowledge'. The other is macroeconomic in nature, referring to the 'engine of growth' in a modern 'knowledge-driven economy' and the role of the state. It holds that the exploitation of 'human capital', of skills, knowledge, science and ideas, is the key to growth in high-technology economies, and that, in order to promote growth in this 'new economy', the state needs to foster both private entrepreneurship (competitive capabilities) and public partnerships (collaboration):

'In a knowledge driven economy, partnership is essential to competition. To exploit our capabilities in people and technologies, businesses have to collaborate across sectors, throughout regions and with education.' (DTI 1998:3.2).[4]

One of main contentions of this paper is that these two assumptions rely on contradictory models of the economy and of the process of innovation in particular. The first - microeconomic - argument for 'public-private partnerships' in science builds on an evolutionary understanding of innovation processes which stresses the role of 'dynamic inefficiencies', such as the persistence/inertia of behavioural routines, the inevitability of 'waste' in the process of competitive selection (trial and error), the possibility of lock-ins and the realisation of local rather than global optima. Essentially, processes are regarded as irreversible in time and cumulative - that is, path-dependant - evolving within a certain possibility space (paradigm) defined by cognitive constraints (bounded rationality and genuine uncertainty) and a set of co-evolving institutions which themselves undergo continuous change. Increasing returns in the economy are, therefore, regarded as a consequence of increasing complexity in the reorganisation of production and technical change.

The second - macroeconomic - argument draws heavily on the New Endogenous Growth Theory (NGT). The NGT rests its case for the dynamic nature of the 'knowledge-driven' economy on a different characterisation of knowledge. Rather than stressing the role of cognitive constraints and the dynamic 'imperfections' arising from these, it conceptualises knowledge as an accumulable and self-reproducing factor of production which - in a sense to be specified below - is essentially non-scarce. Furthermore, it treats increasing returns as resulting from static knowledge externalities which are dealt with by monopolistic competition-cum-welfarist state intervention to remedy market failure. This economic interpretation of increasing returns in terms of knowledge externalities constitutes an analytical link between two different conceptualisations of knowledge in the NGT. The first concerns knowledge as a *factor of production* with the above mentioned characteristics, the second refers to knowledge as a public-private *good*. The latter concept appears, in particular, in the more recent NGT models, which try to model research activities and innovation processes in high-technology economies more explicitly. The upshot of this implicit conceptual shift from knowledge as a factor of production to knowledge as a good is that, while neoclassical value theory does not escape unscathed, the institutional framework of a private market economy does. Even if the production of knowledge requires monopolistic (or oligopolistic) competition, the underlying concept of knowledge and technology transfer follows the conventional 'linear' neoclassical model, implying that innovative activity can be efficiently handled by a private property rights regime-cum-welfare state. Consequently, the NGT leaves little space for the role of decentralised private-public co-operation, or more generally speaking, for a more complex institutional model such as that envisaged by evolutionary theories of innovation.

Because of the divergent institutional implications and frameworks inherent in these two approaches - the evolutionary view of innovation on the one hand, and the essentially neoclassical conception of 'knowledge-driven' growth advocated by the NGT on the other - the resultant mismatch between S&T and growth policies amounts to more than just another 'storm in a theoretical teacup' with negligible consequences for real world policies. While this does not mean that 'public-private partnerships' are necessarily doomed as an effective policy tool, the main argument developed here is that what is required in order to make them work is a clarification (a) of the precise mechanisms by which knowledge is supposed to promote growth and (b) a specification of the policy direction underlying these partnerships. As will be seen, the first of these questions essentially refers to whether one regards knowledge as a disembodied factor of production or as embodied in the process of capital accumulation, while the second concerns the role of property rights (privatisation or gradual socialisation).

What both approaches to innovation and growth share, at least to a large extent, is a view of knowledge as a disembodied (virtual) entity/factor of production. However, while evolutionary approaches are notoriously unclear as to the property rights implications of knowledge as a prime driver of innovation and growth, advocating the promotion of 'collective learning processes' and decentralised cooperation across private and public sectors without much concrete specification of what such a process of 'collectivisation' and/or 'clustering' might mean in terms of the larger and formal institutional setting, the NGT is simply inconsistent. *If***,** on the one hand, knowledge is not just a disembodied entity but, as will be seen, also a factor of production with the capacity of endless self-recursive reproduction, it is unclear why it should be dependent on private entrepreneurial efforts to flourish. *If*, on the other hand, private entrepreneurial efforts, and with them private incentive/property rights structures are deemed indispensable for innovation occurring at all, it is unclear how knowledge - as both a factor of production and a private-public good - can create the perpetual growth motion generated that is the most basic feature of most NGT models, given the cognitive constraints and complexities of entrepreneurial (as any other individual) decision-making.

As will be argued below, there are essentially two responses to this problem. One is to place emphasis on the role of individual decision-making in economic development and growth and, consequently, to take a more skeptical view on the possibility of perpetual balanced growth in the new 'knowledge-driven' economy, while safeguarding a place for the private entrepreneur in the analysis of modern innovative processes. This route has been advocated in a number of recent contributions, notably the new institutional growth theory (e.g. North, 1990). The other is to cast doubts on the conceptualisation of knowledge as a disembodied and distinct factor of production and to embed recent insights on modern technological progress in a broader theory of the process of capital accumulation and surplus distribution. This latter route builds on a view of capitalist growth dynamics developed in the works of Marx, A. Young, Schumpeter, Kaldor and

Joan Robinson and puts emphasis not so much on the role of entrepreneur, but on the organisational and collective potential inherent in new technologies and their role in lessening the constraints of individual decision-making.

Before entering into the details of the arguments, it should be noted that the particular criticism of the NGT explored in this paper is only a partial one. There are other powerful and important lines of criticism which, for reasons of time and space, can only be mentioned in passing. These concern, in particular, two arguments. First, the device of the representative Ramsey agent, employed by the NGT, is obviously highly questionable (see also footnote 36 below), all the more so in the context of a (self-styled neo-Schumpeterian) theory of innovation and growth of which uncertainty and heterogeneity (of agents) should be an integral element. Apart from well-known technical limitations such as, in particular, the substitution of a non-arbitrary number of periods for a truly infinite intertemporal horizon, the Ramsey model effectively relies on the theory of expected utilities and the concomitant probability view of beliefs, implying perfect knowledge of all future states of the world. More importantly, though, the Ramsey model closes the way to a serious exploration of co-operation in the economy in that its implicit view of the market is Walrasian. Given the two first welfare theorems, a state in which expected utilities are maximised is Pareto-optimal, that is a basic (social) utility function is a good substitute for a real Walrasian n-agent market. In such a market, there is, however, no space for even the smallest need for co-operation since there can only be one single source of information (a single price series or a single auctioneer), and nothing can be said about the way in which agents would adjust or interact, if more than one such source existed. Hence, it is important to note that the real problem with the Ramsey model (and the implied theoretical views of exchange and production) is not so much whether or not a purely competitive equilibrium exists, but what degree of (de)centralisation is permissible.

Second, there is the problem of the notion of aggregate knowledge. All the observations and criticism made regarding the notion of aggregate capital (Harcourt 1972, 1995, 1999) apply to the concept of aggregate knowledge. Not only do questions arise as to how different price weights could be attributed to different types of knowledge and what the implication of a uniform rate of return on investment into knowledge would be, but, as Harcourt has pointed out more than once, the real issue is not so much 'related to the *measurement* of capital as to its *meaning*.' (1995: 41). In other words, the real obstacle to aggregation is not only measurement, but also the (self-recursive) complexities of the process that ties knowledge as capital production into the broader picture of the dynamics of capitalist accumulation and distribution.

Given these caveats, the paper is structured as follows: Section 2 contains a brief summary of the microeconomic argument for direct collaboration between PSR and private companies.[5] Sections 3 to 5 concentrate on the macroeconomic dimension of the argument for 'public-private partnerships' (and UIRs in particular), that is their role in promoting 'knowledge-driven' growth. Section 3 provides a brief review of the empirical literature on the relation between public sector basic research and economic growth. The main focus of the paper is sections 4 and 5. Section 4 discusses the conceptualisation of 'knowledge-driven' growth in the NGT and its implication for the design of growth and innovation policies. Section 5 contains a brief discussion of the different ways in which the apparent contradiction between the nature of knowledge-driven growth (as championed by the NGT) and the Third Way advocacy of 'public-private partnerships' might be resolved. Section 6 concludes.

2. The microeconomics of knowledge transfer from the science base: two views

Economic theory offers two perspectives on the understanding of the private and social benefits and costs of particular modes of knowledge and technology transfer, and of the ways in which these can be influenced by policy.

Neo-classical theory (e.g. Nelson 1959, Arrow 1962a, 1962b) regards basic research as producing a public good: information. Information is a commodity like any other and as such it is codifiable, quantifiable and easily transmissible. However, its tradability is more problematic for a number of reasons. First, because basic science is far removed from industrial production, its commercial benefits are highly uncertain. Secondly, the public good character of information implies that the fixed production costs of information will be much higher than its transfer or imitation costs and, thus, the former will be difficult, if not impossible, to retrieve. Finally, the existence of indivisibilities in the use of information means that producers will find it difficult to appropriate the returns of their private investment in information creation. Neo-classical theory, therefore, predicts under-investment in private R&D and recommends public policy intervention in the form of state funding for basic research ('picking the winner') and legal devices to internalise externalities, such as patents, as an appropriate remedy.

Information Economics, a recent extension of neo-classical theory (e.g. Stiglitz 1996), takes a slightly different position based on its fundamental contention that informational imperfections are pervasive in both markets and state structures. Not only do these imperfections undermine the ability of the state to pick winners and to design optimal legal devices, but they also represent natural barriers to imitation, thereby giving rise to natural oligopolies which are likely to be reinforced by the existence of fixed sunk costs (non-convexities) and cumulative competitive advantages through learning-by-doing. Hence, the danger of under-investment in private R&D appears to be less serious, once imperfect competition is seen to emerge naturally from the existence of informational asymmetries. The most important policy question then becomes one of how much market power should be allowed, given that some degree of genuine competition will still be necessary to provide incentives to innovate through survival pressures. While some broad rationale for collaborative research arrangements could be seen to be compatible at least with the perspective provided by Information Economics, the important point is that the neo-classical argument overall focuses on avoiding *negative spillovers* between private companies by monopolising access to information.

An alternative view has been put forward by evolutionary economics. Here, the core concept is not information, but knowledge. The difference is that knowledge is not regarded as marketable in the sense information is (e.g. von Tunzelmann 1995). It is not a commodity, but instead is embedded in a variety of learning processes and organisational structures which are specific to individuals, firms or institutions. Because of this embeddedness, and also due to the tacitness of much of knowledge, it cannot be easily transferred. Therefore, the key to innovation is not so much the appropriability of information, but the ability to convert such information into useful knowledge, or, in the language of this school of economics, into a firm-specific competency. Given the embedded nature of all knowledge, the effectiveness of learning (rather than appropriability) processes depends on the quality of social interaction and lines of communication. Hence, the creation of specific competencies by individual firms is likely to involve, to a considerable extent, interactions with, and co-operation between, different sources of knowledge. To put it another way, this school of economics argues that *positive feedback effects* from co-operation (rather than negative spillovers between firms) are at the heart of the innovation process.

However, proponents of this perspective (e.g. Prahalad and Hamel 1990, Foss and Knudsen 1996, Gibson 1994, Faulkner and Senker 1995, Cohen and Levinthal 1989, Callon 1994, Foray et al. 1993) are aware of the trade-off between learning through co-operation and the need to adapt to radical changes in technology and, therefore, the need to un-learn in order to avoid a lock-in into an out-dated technological trajectory. Consequently, positive feedbacks are not associated with just *any* form of co-operation. Rather, what matters are fairly flexible networks with a well-developed capacity to create space for transitions from one technological trajectory to another This condition is most likely to be met by networks which integrate different types of organisational and production logic (long-term vs. short-term orientation) and goals (societal welfare vs. private profitability). Quite obviously, close co-operation between PSR and private companies is a prime candidate for this kind of alliance.

This latter perspective on the nature of innovation processes informs much of current changes in S&T policies, and of their emphasis on high-technology (localised) clusters, public-private research collaborations and other mechanisms to promote collective learning processes. Essentially, these changes mark a gradual shift in innovation policies away from the conventional 'market failure' approach, which mechanically advocates state intervention for those areas of economic activity dedicated to the production of public goods (such as information) or plagued by the pervasiveness of imperfect information and/or externalities, towards a morenuanced and cautious policy rationale with a more attentive eye for the possible long-term dynamic (organisational and learning) effects resulting from the temporary inefficiencies of market-driven innovation (Metcalfe 1998). Thus, the role for policy shifts from 'getting prices right' to 'getting the dynamics right': The main policy task becomes one of balancing the dynamic trade-offs between necessary integration and undesirable organisational inertia, and between the promotion of radically new products and processes (exploration) and the further development of existing product lines (exploitation) (Lundvall and Borrás 1998). This view of innovative processes closely fits the Third Way view of the state as a 'complementary partner' to the market, playing neither the minimal role of the liberal night-watchman nor that of the omniscient interventionist. In this view, 'public-private partnerships' in science are an adequate policy tool to take into account the important interplay of technical, economic and social relations in the process of innovation and to respond to the dynamic and collaborative nature of technological development.

3. Economic effects of basic research: The limits of measurement

Turning now to the macroeconomic role of knowledge as a major driver of economic growth, the first obvious difficulty in conceptualising knowledge as a macroeconomic entity - or a factor of production - is a practical one: how to measure its productivity or, more generally, its impact on economic performance. Of course, this difficulty is not restricted to knowledge as an independent factor of production in its own right, as is amply demonstrated by the 'capital-controversy'.[6] Still, attempts to quantify the 'knowledge-effect' have a fairly long history and the purpose of this section is to recall some basic aspects of the debate on this issue before turning to the theoretical contribution of the NGT.

As is well-known, until relatively recently 'post-Solowian' growth theory has been dominated by 'growth accounting', taking technological progress to be exogenously determined and focusing on the empirical analysis of explanatory variables, such as international trade effects and capacity utilisation, to minimise the famous 'growth residual'. However, even before the advent of the NGT (see section 4 below) brought about a major theoretical shift towards the conceptual endogenisation of knowledge-related and technological growth factors, the empirical outlook endorsed in the context of 'growth-accounting' exercises had already lead to an increasing preoccupation with the measurement of variables directly reflecting the influence of innovation, technology and research on economic growth and productivity. While most contributions have concentrated on the economic benefits of private R&D expenditure, a relatively small number of studies has specifically analysed the effect of basic research and publicly funded R&D on economic performance. Most notable among these is the pioneering work of Mansfield (1977, 1991, 1995) and Griliches (1968, 1979, 1980, 1995).

While these studies establish positive and substantial estimates for private and social rates of return to (basic) research - Mansfield (1991), for example, suggests that the social rate of return to academic research in the US is 28% - perhaps their most important contribution is methodological in that they highlight the manifold practical and theoretical difficulties involved in measuring the economic benefits of research activities. A recent report by the Science Policy Research Unit (SPRU) at Sussex University to the Treasury (Martin et al 1996) on the relationship between public sector basic research and economic performance provides a detailed overview of empirical work in this area and the methodological debate it has prompted. This report argues, in a nutshell, that the benefits accruing from basic research are often too indirect and too long-term, and the mechanisms or routes through which they are captured too complex, to be amenable to reliable quantification.

The report is particularly critical of the use of econometric approaches based on the use of neo-classical production function models. At the conceptual level, these models pose well-known problems, such as the 'adding up problem' (Nelson 1973, 1981, Colander 1996), i.e. the limitation of causal interrelationships to simple functions which are compatible with a linear homogenous production function.[7] In the case of 'research capital', the assumption of a constant output share is even less convincing than it is for the standard process of production ((physical) capital and labour). Further frequent assumptions, such as fixed production techniques among firms and the complete separability of inputs, do not help to make these models more plausible. Finally, practical difficulties abound in measuring the aggregate research (R&D) input and output, such as finding an adequate method for measuring the depreciation of R&D capital as an input or to account for spillover effects in the output measure. In the case of basic research in particular, the pervasive absence of explicit markets, i.e. the 'pricelessness' of information transferred in the process of innovation, obviously aggravates the problem of tractability on both the input and the output side of single-equation models.

Some studies have explicitly addressed the question of spillovers by attempting to establish precise measures for such spillover effects of research. This has led to an extensive, and as yet inconclusive, debate on the suitability of different indicators of innovative output which has centred mostly around patents on the one hand, and more direct number counts of innovations or inventions on the other (Jaffe 1989, Acs et al 1991, Autio and Laamanen 1995). So far, no measure has been found that would not, in some way or other, rely on rather arbitrary mechanisms of bringing research results, innovations or inventions to public attention.

While some of the more conceptual problems specific to econometric studies using simple production function models have been addressed by the NGT's attempt to provide models of the process of technical change taking explicit account of (basic) research as a factor of production, the more practical difficulties relating to the quality of the empirical data used remain and apply equally to survey-based studies, such as Mansfield (1991). The data collected often covers only short time periods, likely to be inadequate to bridge the time-lag separating basic research efforts from any tangible impact they may have on the economic performance of firms, regions or sectors. Cross-country as well as more indirect effects of basic research, such as the development of skills and techniques, are rarely accounted for, and data collected from industrial sources is likely to contain an in-built bias towards under-estimating the contribution of publicly funded research.

Quite clearly, the findings of the SPRU report support the conceptualisation of knowledge advocated by the evolutionary perspective on technology transfer. Not surprisingly, the authors attribute most of the deficiencies they identify, both in conventional econometric and survey approaches to the relationship between (public and private) basic research and economic performance, to a limitation in the underlying understanding of the nature of the benefits from basic research. Essentially, they argue that most of these approaches follow Arrow (1962a, 1962b) and Nelson (1992) in treating basic research as a pure public good, i.e. as non-rival and non-excludable. They therefore regard as its main benefit the production of new codified information readily available for application by industrial and other users. This excludes from the analysis less tangible benefits, stemming from the embodied and tacit character of much of the information/knowledge transferred in the process of innovation. According to this view, much greater importance than commonly assumed adheres to non-traditional forms of benefits from public basic research, such as training and the development of informal communication networks. The full list of these benefits is partly based on Pavitt (1995) and comprises, apart from training and networks, new engineering tools, scientific instrumentation and methodologies, technological problem solving and the creation of new firms. However, reliance on a simplified perception of knowledge as a codifiable entity also tends to disregard considerable learning and other costs involved in the acquisition, imitation and utilisation of such information or knowledge. Hence, while this report seems to suggest that the economic benefits arising from basic research activities are potentially much larger than suggested by mainstream empirical studies, it also points to the fact that the economic costs involved in technology transfer from the science base may be considerable. In conclusion then, the SPRU report sounds a general note of caution: in the absence of an adequate theoretical model of the complex links and mechanisms underlying technology transfer and technical change, as well as of robust empirical measures of research activities, any estimates of and insights into the real economic effects of basic research will, at best, be tentative.

4. Knowledge, economic growth and the role of the state: The New Endogenous Growth Theory

Despite such sizeable obstacles to obtaining a reliable and meaningful quantitative measure of the effective impact of (public sector) basic research on overall economic performance, policy-makers are adamant in their general belief that there *is* a direct link between the accumulation of knowledge and ideas, PSR included, on the one hand, and economic growth and dynamism, on the other, *and* that 'public-private partnerships' in science, and UIRs in particular, are an important policy tool to help unlock the dynamic potential of this new 'knowledge-driven economy'. The theoretical basis for the intuition that modern growth is essentially 'knowledge-driven' and that state intervention can make a difference in promoting the growth performance of the 'new economy' has largely been provided by the NGT. What makes this new branch of growth theory of particular interest for the inquiry into the role and economic significance of UIRs is its emphasis, broadly speaking, on the particular property of human capital to discover or produce ideas and knowledge, and more specifically, the importance of learning and R&D as prime candidates for the explanation of aggregate growth. Furthermore, later contributions (Romer 1990, Grossman and Helpman 1991, Aghion and Howitt 1992), attempt to systematically link advances in aggregate growth theory to the microeconomic analysis of R&D activities and innovation.

As is well known, the NGT represents a renewed attempt to unpack the famous 'growth residual' (Solow 1957) or 'measure of our ignorance' (Abramovitz 1956: 11). The main aim is to 'endogenise' technical progress - the central economic explanation given to the growth residual in the Solowian models - in the rather obvious sense that '(t)echnological advance comes from things people do' (Romer 1994: 12). That is, while the forces and events triggering technical progress may well be beyond the control of individual members of the economy, they, and the rate of economic growth, are still to be conceptualised as the outcome of the aggregate private and social choices of rational agents, or more precisely, of the choices made by a single representative agent, engaged in (infinite-horizon - intertemporal) utility-maximisation. In most models, this microbehaviour determining the rate of technical change, and by extension that of economic growth, is formalised in terms of time preference (discount rates or sometimes also 'required rates of return') and the elasticity of substitution between present and future consumption.

Leaving to one side the very problematic, if not plainly inadmissible, implicit revival of aggregate capital, a key feature of NGT models is the absence of diminishing returns to capital (e.g. Jones 1998: 90; Barro and Sala-i-Martin 1995: 39; Romer 1994: 13-14, Solow 1994: 49). In the Solowian model, the assumption of diminishing returns to both factors of production, labour and (physical) capital, together with the further assumption of constant returns to scale, is instrumental for the outcome of zero growth per capita in the long run (stationary state). On the contrary, in the story told by the NGT, the rate of profit (and, in a one-commodity model with a Cobb-Douglass production function, the marginal product of capital) no longer exhibits a tendency to fall, and, consequently, the major (policy) conclusion of the Solow model appears to be reversed: an increase in the rate of investment now *can* raise the growth rate of the economy permanently. This U-turn on the neo-classical 'investment pessimism' is what makes these models so attractive to the politician-advocates of the new 'knowledge driven economy'.

However, a closer look at a variety of NGT models reveals a certain ambiguity towards the efficacy of state intervention in the context of the promotion of high-technology progress, especially in the diluted form of 'public-private partnerships'. These models seem to offer little space for the pragmatic medium term view of the Third Way in that they oscillate between a very long term perspective focusing on a gradual approach to changes in property rights on the one hand, and wholesale state intervention to raise the rate of investment in the short term on the other.

4.1 Sources of endogenous growth in the new 'knowledge driven economy': Reproducible inputs, knowledge externalities and entrepreneurial efforts

4.1.1. The basic idea: Two interpretations of the AK models

To begin with, the first generation of NGT models, the so-called 'AK models', come closest to spelling out the logic that links knowledge-driven growth to state intervention. The production function, to which these models owe their name, is written as

$$Y = AK, \qquad (1)$$

where K denotes a single factor expression for both human and physical capital, and the positive constant A is generally understood to be an index of factors affecting technology. Essentially, these models are built on the assumption of linearity in the differential equation for the production factor capital K derived from the standard Solowian production function and the equation for capital accumulation.[8] It is mostly assumed that there is only one commodity in the economy. There are two ways of interpreting these models: First, in neo-ricardian fashion, the absence of diminishing returns to capital can be attributed to the elimination of all 'non-accumulable' factors from the production function. If, in the Solowian model, diminishing returns to capital are the logical consequence of taking all other determinants of aggregate output - technology and the employment of labour - as given, thus implying that labour is non-accumulable in the sense that an increase in output will require a more intensive use of physical capital,[9] the NGT can be seen to overcome this problem 'by definition': labour is redefined as human capital and merged with physical capital into a single production factor (i.e. there is no factor substitution). This amounts to the assumption of an unlimited supply of high quality labour, and hence an exogenously given constant rate of real wages and constant rate of profits independent of the amount of (human and physical) capital employed in the production process. In other words, income distribution is purely technologically determined.[10] If this technology only uses self-reproducing inputs (i.e. the depreciation rate of (combined) capital equals zero), perpetual motion or growth is generated, with its rate depending solely on the determinants of saving behaviour and the investment-saving mechanism. This interpretation has been suggested by Kurz and Salvadori (1995, see also Kurz 1997).[11]

Secondly, following Solow (1997), the AK models can be broadly interpreted as a special case of Arrow's 'learning-by-doing' model (Arrow 1962b) assuming a unity learning elasticity. This route provides the economic intuition which underlies the claim to the endogenisation of technological progress in the NGT models. After all, if no consistent (non-ad hoc) economic explanation was given for the assumption of the absence of scarcity (non-accumulable factors of production) in the NGT models, it would have to be assumed that this is due to *exogenous* technological progress.[12] The main element of the explanation is external economies taken to represent a positive learning or knowledge effect arising in the process of production.[13] The basic idea is that these externalities exactly offset the propensity to diminishing returns to physical capital, thus ensuring endogenous steady-state growth.

4.1.2 Technical progress as a by-product of other activities

The logic underlying this idea can be seen more clearly if we compare Arrow's original model with later developments in the NGT. Arrow uses a vintage model with fixed coefficients (1962b). He assumes, therefore, that technical progress is embodied and at least as dependent on past investment decisions as on designed research activities. His original addition to this notion of embodiedness is that technical progress is not so much a function of time, but of *individual* learning through experience.[14] Analytically, he conceptualises this learning effect in terms of the integral of gross past *investment* - the higher the rate of investment, the more pronounced the rate of increase of productivity. However, he also assumes that the elasticity of learning with regard to aggregate capital is less than unity. Furthermore, Arrow argues that as technical progress occurs through the act of investment, that is with a time lag, it can be appropriated by competitors. Therefore, the private benefits of investment are taken to be less than its social benefits. Another way to put this is to say that the learning effect is external to the individual firm, but internal to the market. More specifically, it is seen to be internal to an industry due to the close correspondence of particular production technologies with industry boundaries. Hence, while there may be increasing returns to scale at the level of the economy, firms continue to face constant returns to scale and perfect competition prevails.[15] Overall, there are still decreasing returns to capital, i.e. diminishing returns to the physical capital stock are not fully offset by increased knowledge from learning due to an upper 100% boundary of knowledge diffusion. The long-run rate of growth therefore still depends on additions to the labour force (population growth) to raise the marginal productivity of capital:

$$g = \frac{n}{1 - u}, \qquad (2)$$

where n is the population growth rate[16] and u the learning parameter. Hence, as Solow (1997) has pointed out, the assumption of an elasticity of learning of less than unity assures that his model remains well within the realm of the 'old' (Solowian) growth theory, with the difference that instead of assuming technical progress to be autonomous 'manna from heaven' it is now thought of as arising from 'learning by investing'. (ibid.: 10).

To fully endogenise technological progress, the steady-state rate of growth must be independent of population growth, as otherwise long-run growth continues to be determined by (exogenous) production technology conditions (rather than saving and investment). As seen, the simplest form of AK models achieve this simply by assuming constant returns to a hybrid form of capital which includes reproducible inputs.[17] Other models, notably Romer (1986) and Lucas (1988), have gone down a slightly different route by distinguishing sectors according to whether non-reproducible or non-accumulable factors matter or not (i.e. by reintroducing factor substitution) and by using the notion of knowledge or learning externalities to explain constant returns to capital and increasing returns to scale. As in Arrow (1962b), increasing returns to scale do not interfere with perfect competition, i.e. they are based on the conceptualisation of the growth of the productivity parameter A as an unintended consequence of some other activity.

Romer's model centres around the non-rivalry and partial excludability of knowledge as a partially public good, and firms' decisions on the amount of savings they are willing to set aside for R&D. He relates output to conventional inputs, the accumulated stock of public knowledge and the current stock of private (firm-internal) knowledge. The fact, that knowledge is - at least for some time - an excludable good constitutes the rationale for firm R&D, but, ultimately, there will be spillovers which will lead to improvements in the public stock of knowledge. At the level of the economy as a whole, the production function for consumption goods is characterised by constant returns to conventional inputs and firm-specific knowledge, but by increasing returns to all factors taken together, once the accumulated stock of public knowledge is included. Perfect competition, therefore, prevails. However, Romer assumes more specifically that the output elasticity of total human capital (private and public knowledge) exceeds unity.[18] To prove the existence of equilibrium, he then has to further assume that there are diminishing returns to the research technology due to imperfect patent laws, which exactly reduce the effect of knowledge spillovers to establish a unity elasticity of knowledge with regard to capital (i.e. constant returns to capital). Note that population growth is then not only not necessary to achieve growth, but for growth to be steady, it must be absent.

Lucas' (1988) model focuses on the trade-off between the individual agents' decision to add to current production, or to invest in their human capital. A decision in favour of the latter will have a negative effect on current production, but the build-up of human capital will accelerate output in the future. A simplified version of the production function for the single good can be written as follows:

$$Y = a_y K^{\alpha} (L_y H_i)^{1-\alpha} H_a^{\delta}, \qquad (3)$$

where a_y is a positive constant (i.e. a parameter for induced technical progress) L_y is labour employed in the process of the production of real output, H_i corresponds to individual human capital, and H_a denotes the general state of education. While firms face constant returns in capital and labour, the overall production function is characterised by increasing returns to scale because of $\delta > 0$. That is, there is a positive externality associated with the agents' investment in education which accrues to society at large. However, the *formation* of human capital is conceptualised as a self-recursive process yielding a constant average product (i.e. there are exactly constant returns to the *accumulation* of human capital). This can be expressed as follows:

$$\dot{H} = a_H H L_H, \qquad (4)$$

where a_H is a positive constant, H is the given stock of human capital, and L_H is labour employed in the process of building human capital (as opposed to labour employed directly in the production of real output). Hence, both the marginal product of human capital and of labour engaged in the production of such capital are assumed to be constant.[19] Lucas provides an argument for the first of these assumptions - namely that if the marginal product of human capital was decreasing, the formation of such capital would come to a halt over time (1988: 18) - but no explanation is offered for the second assumption.

What this equation ensures, though, is that growth is endogenised, i.e. that there is a steady state with growing per capita consumption and production, even in the absence of autonomous or exogenous technical progress. The bottomline of this model is that it is conceptually similar to the case of labour-augmenting (or Harrod-neutral) technical change at a constant exponential rate in the original Solowian model, with the (important) difference that the existence of steady-state balanced growth is now attributed to human skills and knowledge (or human capital), acquired through intentional learning processes, which are thought of as a disembodied factor that grows indefinitely at a constant rate. Note that owing to this rather startling conceptualisation of skills, learning and knowledge as a non-depreciating disembodied entity, endogenous growth can be generated in this model even if the externality δ associated with human capital is zero (Kurz and Salvadori 1995: 15).

However, as many commentators (e.g. Romer 1994, Solow 1994, 1997, Jones 1998) have pointed out, the main drawback of these models, as well as the simple AK models, is that they lack robustness If, for example, the elasticity of learning in the Arrowian model is even minimally less than unity (or returns to (human) capital slightly less than constant in the models of Romer and Lucas), we are back in the Solowian world:

'Alternatively, if the elasticity of the learning curve exceeds one, the Arrow model - and not only the Arrow model - produces a sort of Big Bang that robs it of plausibility or even of the capacity to represent the world of scarcity. Only if the elasticity of learning is exactly 1 does the model have the New Growth Theory property that a change in the tax rate on income from capital, or anything else that increases the saving-investment rate, will permanently raise the steady-state growth rate' (Solow 1997:14).

Furthermore, these models concentrate exclusively on capital accumulation (referring to the new broader notion of capital), ignoring innovation as an engine of growth. The third generation of NGT models (Romer 1990, Aghion and Howitt 1992, 1998, Grossman and Helpman 1990a, 1991a, 1991b, Jones 1995, 1998) addresses these shortcomings by modelling research activities as well as the innovation process in high-technology economies more explicitly. In doing so, they also abandon perfect competition (at least partially). In other words, externalities here are seen to generate not only increasing returns but also imperfect competition. With the exception of Jones (1995, 1998) all these models assume, in one specification or another, at least constant returns to an accumulable factor (technology, research labour or capital). They are, therefore, *not* different from basic AK models with regard to the basic analytical mechanism through which endogenous growth is generated. Where they differ is in the conceptualisation of technical progress as 'a special resource-using, profit-seeking activity with its own technology' (Solow 1997:17). They are, therefore, also of more potential interest for understanding the rationale underlying the promotion of a new economic role for universities.

4.1.3. Entrepreneurial efforts and innovation

Romer (1990) identifies two sources of increasing returns, namely product differentiation and research spillovers. The main innovation of the model as compared to Romer (1986) is the introduction of an intermediate goods sector characterised by monopolistic competition, arising from a high degree of product variety (following Chamberlain's 1933 large group model and Dixit and Stiglitz 1977), where each individual good is produced by a local monopolist. That intermediate goods will - at best (i.e. depending on the elasticity of substitution between products) - be produced by monopolistic competitors is a consequence of the sunk *fixed* costs incurred in the development of a particular blueprint (that is, the increasing returns associated with it). Furthermore, as opposed to Arrow (1962a), there is free entry to the sector, i.e. there is perfect competition in the research sector. This determines the equilibrium number of intermediate inputs (knowledge A) and ensures that profits to the marginal entrant are driven to zero (i.e. equal the average costs of R&D) whenever innovation takes place.[20] Firms operate in an environment where technological and research knowledge is generally non-rivalrous, but excludable. That is, while researchers can make free use of the accumulated stock of knowledge A, returns to the production of intermediate goods based on blueprints or designs can be made firm-specific in the short run by limiting the use of new designs to a particular intermediate producer. In the long run, general knowledge is both an input into and an output of the production of blue-prints. There is, therefore, a positive externality to the activities in both the intermediate and the research sector.

More specifically, the aggregate production function can be written as:

$$Y = K^{\alpha}(AL_y)^{1-\alpha} \quad (5)$$

The production of ideas and designs (A) is a function of the aggregate research effort (L_i) and the rate of discovery of new ideas (φ) in the following form:

$$\dot{A} = \varphi L_I A^{\delta}, \quad (6)$$

Romer then argues that the rate of technological progress (or the growth rate of A) is:

$$\frac{\dot{A}}{A} = \varphi L_I, \quad (7)$$

What this implies is that the productivity of research (or the rate of discovery of new ideas) is exactly proportional to the existing stock of ideas, i.e. that the externality arising from past innovations/ideas exhibits constant returns ($\delta = 1$).[21] From equation (7), together with the labour-market equilibrium equation and the equilibrium (profit-maximising) value of a design or license (research arbitrage condition), the steady-state growth rate can be written as:

$$g = \frac{\alpha\varphi\bar{L} - \rho}{\alpha + \varepsilon}, \quad (8)$$

where $\bar{L}$ is total labour supply, $1/\alpha$ is the monopoly mark-up, $1/\varepsilon$ is the intertemporal elasticity of substitution between present and future consumption and ρ is the rate of time preference. The equilibrium rate of growth will be less than the social optimal due to the failure of private agents to internalise firms' contribution to specialisation and research spillovers.[22]

Jones (1995,1998) has provided a critique of this model which is of interest in the present context because of its implication for the role of government intervention in the economic system. Jones argues that there simply is no empirical evidence to support Romer's assumption of linearity in the production function for ideas: It is quite clear that, throughout the past decades, average rates of per capita growth in advanced economies have been far lower than the growth rates of resources dedicated to research efforts in these countries (whether measured by the number of scientists and researchers or by R&D shares). Jones, therefore, adjusts Romer's R&D equation to

$$\dot{A} = \varphi(A^{\delta} L_I^{\beta-1}) L_I, \tag{6a}$$

where 0≤β≤1 and 0≤δ≤1. β denotes an additional externality reflecting the likely duplication of research efforts[23]. Therefore, the rate of growth of the stock of ideas A now is:

$$\frac{\dot{A}}{A} = \varphi \frac{L_I^{\beta-1}}{A^{1-\delta}} L_I \tag{7a}$$

Solving the model in the same way as Romer, the steady state growth rate of the stock of ideas or design becomes:

$$g = \frac{\beta n}{1-\delta}, \tag{8a}$$

where n denotes the population growth rate. Provided the share of researchers in the total labour force is constant along a balanced growth path[24], all per capita growth is due to technological progress. Given the standard Solowian capital accumulation equation, the capital-output ratio must be constant along a balanced growth path. It follows from production function (5) that per capita income and per capita capital all grow at the same rate as A. Therefore, g is also the steady-state growth rate of the economy.

The basic economic intuition underlying equation (8a) is that a growing population raises the level of technology (and therefore of income). As opposed to the Solow model, where diminishing returns to capital mean that a higher population growth will reduce the level of income along a balanced growth path with a constant capital-labour ratio, the point here is that conscious research efforts resulting in non-rivalrous ideas provide a counterbalance to this effect.[25] However, given 0<δ<1 (i.e. diminishing returns to the stock of ideas), growth is bound by the rate of population growth, just as in Arrow's model. That is, the growth rate now depends on the rate of growth of the labour force, rather than on its level, and is independent of the saving rate. None of the parameters in equation (8a) is directly affected by changes in the investment rate or the share of R&D, i.e. by policy-sensitive variables. This implies that, for example, a permanent increase in the share of the population engaged in research will produce transition dynamics similar to those of the Solowian model: Just as an increase in the investment rate will raise the growth rate only temporarily, a permanent increase in the research effort (or the number of researchers relative to the population) raises the rate of technological progress only temporarily. Assuming that such an increase occurs in the steady state, the 'research intensity' (or the ratio of research labour to the stock of ideas) will increase and with it the rate of technological progress. Once the rate of technological change exceeds population growth, this will induce a gradual decline in the 'research intensity' and the rate of technological change will gradually return to the balanced growth path.

The main difference with Solow's model is that technological progress is endogenous in the sense that 'profit-seeking individuals who are allowed to earn rents on the fruits of their labours search for newer and better ideas' (Jones 1998: 158). It is not, however, endogenous in the sense that 'it can be easily manipulated at the whim of a policymaker' (ibid.). In other words, growth here is *not* endogenous in the sense that a constant marginal product of capital (independently of the size of the 'capital stock' or of the number of researchers) would ensure that the growth rate is solely determined by the saving-investment mechanism.

The main alternative to Romer (1990) are the so-called 'Schumpeterian' models. The principal difference is that product innovation is modelled not as a process of generating an expanding range of horizontally differentiated products (horizontal innovation), but in terms of a succession of vintages of intermediate goods of ever higher quality (vertical innovation). The Schumpeterian element, thus, refers to the introduction of obsolence (or creative destruction): Every innovation kills off its predecessor.[26] This has consequences for the way in which the intermediate sector is modelled and - via the impact on the amount of research carried out - ultimately, for the relationship between equilibrium and optimal growth rates. There has been a proliferation of 'Schumpeterian' models in recent years, most notably among these are Aghion and Howitt (1992, 1998) and Grossman and Helpman (1991a and b). While these models differ in detail and areas of application, for the present purpose it is sufficient to focus on their basic tenets and conclusions.[27]

At the most basic level of analysis, 'Schumpeterian' NGT models make two assumptions: First, labour is the only input and consists of two types, research labour (n) and labour engaged in the production of the intermediate good (x). Each blueprint or innovation replaces a prior generation of the same product, in the process contributing to technological progress by a constant factor $\gamma > 1$. The intermediate goods sector consists of monopolists (or in a one-sector model of one monopolist), faced with a random arrival rate of innovations λn ($\lambda > 0$).[28] That is, a successful innovator will reap all monopoly profits from implementing the innovation[29] until such time as it is replaced by the next innovation. Second, the dynamics of the research sector are governed by patent-racing. While there is a very large number of innovation production models along these lines (Tirole 1988, Reinganum 1989, Sutton 1998), most 'Schumpeterian' NGT models implicitly adopt a few basic, but rather specific assumptions. As in Romer (1990), there is free entry to the research sector or to the race for the next patent up the 'quality ladder' of an intermediate good.

More specifically, the models usually adopt the route suggested by Lee and Wilde (1980) and Reinganum (1985) in assuming that the date of rival success is drawn from a continuous distribution (as opposed to the basic auction model where a commitment of funds at a certain point in time determines the date of invention) and that the aggregate probability distribution of discovery dates is unaffected by a firm's investment (i.e. there is no incumbent advantage in the race for the next invention/innovation). This ensures that the incumbent innovator will not perform any research (given a perfectly elastic supply of challengers), because the incremental profits from investing in the next blue-print are less for the incumbent than the incremental profits from the new invention accruing to an entrant. Consequently, innovators will lose the entire monopoly profit from their innovation when a new blueprint or design appears on the scene. In other words, Schumpeterian 'creative destruction' is modelled in the form of an 'Arrow replacement effect' (albeit with perfect R&D competition).

Aghion and Howitt (1998:53-60) show that given these assumptions, plus the usual assumptions about savings behaviour, profit maximisation, frictionless labour markets and total mobility of labour, the following expression for the average steady-state growth rate can be derived:

$$g = \lambda \hat{n} \ln \gamma , \qquad (9)$$

where $\hat{n}$ is the steady-state equilibrium level of research, λ a frequency parameter indicating the productivity of research ($\lambda \hat{n}$ is the corresponding arrival rate of innovations) and γ is the size of an innovation. This growth rate is an increasing function of the research productivity (relating R&D employment to the expected arrival rate of innovations), of the propensity to save (since savings behaviour is determined by a representative Ramsey household with linear preferences[30] and $\hat{n}$ can be shown to be a decreasing function of the rate of interest which, in the steady state, is the rate of time preference) and of the degree of market power of a successful innovator (since $\hat{n}$ can be shown to be a decreasing function of the elasticity of the demand curve faced by the intermediate producer). Hence, in this basic formulation of the model *product market* (or price) competition (as opposed to competition arising from freedom of entry) is unambiguously bad for growth, confirming Schumpeter's (and Marx's) argument, that in capitalist economies innovation is driven by rents or 'super-profits'.

However, compared to Romer (1990) and Jones (1998), the model offers a slightly different perspective on the relationship between the equilibrium and the optimal growth paths. As seen, in Romer (1990) the former will always be lower than the latter, while in Jones (1998) the equilibrium and the optimal growth rate will be the same, but the R&D share will differ depending on the relative significance of the various externalities (consumer-surplus effect, research spillovers, duplication effect). 'Schumpeterian' models distinguish between slightly different types of externalities: First, there is, of course, also the positive intertemporal spillover effect (Aghion and Howitt 1992, 1998) from innovation. Monopolists will only capture the immediate benefits of an innovation, not its benefit for research on future innovations (intertemporal spillovers). Second, this positive externality is counterbalanced by a negative one, arising from the fact that an entrant firm will not internalise the loss caused by its entry to its predecessor, what Aghion and Howitt (1992, 1998) call the business-stealing effect. Finally, consumers will continue to pay the same price for a higher quality product, so that monopolists will fail to capture all of the immediate social benefits arising from an innovation. This is termed the appropriability effect by Aghion and Howitt (1998) and the consumer-surplus effect by Grossman and Helpman (1991a).

The relationship between the optimal growth and the equilibrium growth path will depend on the size of these effects. While the business-stealing effect will tend to generate more research than is socially optimal, intertemporal spillovers and the appropriability effect work in the opposite direction. Intuitively, the larger is the size of an innovation, the stronger will be the combined effect of the latter two externalities. However, if innovations are small and there is a high degree of monopoly power, the business-stealing effect might be more dominant. Hence, as opposed to Romer (1990), where the equilibrium growth path will always be less than socially optimal, in this model the reverse is possible (Aghion and Howitt 1988:63). And other than in Jones (1998), the externalities account for a possible gap between the growth *rates*. Accordingly, the role of state intervention is more ambiguous. While scale effects are possible, suggesting that government intervention can have a *direct* effect on the rate of growth (not just the level of income), the design of policy tools aiming at the level of research is complicated by the conflicting ways in which the externalities affect the growth rate.

Aghion and Howitt (1998) extend this basic model in a variety of ways, including the role of (physical) capital accumulation, price (or product market) competition, human capital (learning-by-doing and education), and firm R&D organisation. For lack of space, a detailed discussion of these extensions is not possible. What should be stressed, though, is that none of these themes alters the basic argument in a qualitative sense. Hence, (physical) capital accumulation may be 'complementary' to research and knowledge through its effect on the profitability of research, but not because capital goods *embody* new technologies. Similarly, product market competition may be growth-enhancing in some instances without, therefore, invalidating the overall argument for monopolistic (entry-based) competition. In short, Aghion and Howitt's basic model - according to which knowledge and research are the *direct* drivers of growth via monopolistic competition in the intermediate sector - can be extended to accommodate the insights of other NGT models (human capital) as well as essentially neo-classical arguments on forms of competition and firm organisation in the presence of incomplete contracting. It cannot, however, be extended to include either a heterodox understanding of the dynamics of capital accumulation (investment and embodiment of labour) or evolutionary models of firm organisation and technological trajectories (including heterogenous forms of knowledge).

4.2 The 'new knowledge-driven economy' and 'public-private partnerships' in science

What then are the implications of the NGT for the use of 'public-private partnerships' in science to promote growth in the 'knowledge-driven economy'? In order to fully grasp these implications it is necessary to have a closer look at the way in which the NGT conceptualises knowledge as a factor of production *and* as a good. As a *factor of production*, knowledge - in whatever specification, i.e. ideas, human capital or research - has the particular property of ensuring that the NGT production functions are characterised by (at least) constant returns to the accumulable factors of production, and thus that there exists a steady-state equilibrium in which both income and capital (in the 'broad' sense) grow at the same rate. One basic interpretation of this particular property is that 'there are no scarce inputs like labour or natural resources' (Kurz and Salvadori 1995: 6). To put it another way, what makes knowledge a special factor of production is that it can be seen to overcome scarcity constraints with respect to other factors of production. As a *good*, knowledge is conceptualised as partially private (i.e. non-rivalrous but excludable) and, therefore, amenable to private production and allocation through the market, albeit in the form of monopolistic competition. This latter notion of knowledge is what underlies the microeconomic story of innovation presented by the NGT to deal with the increasing returns characterising the production function(s). The analytical link between the two concepts of knowledge as a factor of production and as an economic good is established through the notion of 'externalities' to explain the self-propelling dynamics of endogenous growth in the 'knowledge-driven' economy. As will be seen, the main implication concerns the institutional framework within which knowledge-based endogenous growth dynamics unfold, namely whether or not market allocation can be seen to remain an efficient form of economic organisation in the 'knowledge-driven' economy.

4.2.1 Knowledge as a factor of production and the self-propelling dynamics of high-technology growth

Several authors have pointed out that increasing returns are not central to the mechanism of endogenous growth in the NGT:

'It is frequently maintained that the original novelty of the NGMs [New Growth Models] is that they manage to deal with increasing returns to scale. Scrutiny shows that this is not the case. What really matters is that returns to scale *with respect to the accumulable factors* are *at least constant*.' (Kurz and Salvadori 1995:6, emphasis in the original).

'(T)he presence of increasing returns to scale is not the essence of these newer approaches. It is perfectly possible to have increasing returns to scale and preserve all the standard neoclassical results. What *is* essential is the assumption of constant returns to capital [where capital now stands for 'the whole collection of accumulable factors of production']. The presence of increasing returns to scale is then inevitable, because otherwise the assumption of constant returns to capital would imply negative marginal productivity for non-capital factors.' (Solow 1994:49).

Two things follow from this observation. First, in NGT models increasing returns to scale are a solution concept for an analytical problem arising for neo-classical value theory from the presence of constant returns to capital (in the 'broad' sense). In other words, the main role of increasing returns in these models is that of a 'technical trick' rather than a substantial concept, introduced to explain the dynamics of 'knowledge-driven' growth. Secondly, as was seen in section 4.1.1. there are two ways of interpreting the feature of constant returns to capital or accumulable factors of production: (a) there are no scarce inputs or (b) there are positive externalities to the accumulation of knowledge (human capital, ideas, research), which arise either as unintended consequences of other economic activities and are, therefore, seen to be compatible with perfect competition, or which arise in the context of conscious innovative efforts in an environment characterised by monopolistic competition. [31]

The different ways in which constant returns to scale with respect to capital - or accumulable factors more generally - can be interpreted highlights an important distinction emphasised by Sraffa 75 years ago, namely that the law of decreasing or diminishing returns and the law of increasing returns pertain to fundamentally different problem areas of economic theory. While '(t)he law of diminishing returns has long been associated mainly with the problem of rent (...) but also the cost of the product', 'the law of increasing returns (...) was regarded as an important aspect of the division of labour, and thus rather as a result of general economic progress than of an increase in the scale of production.' (1926: 536-7). As Solow points out, the fact that what is required to endogenise growth in the NGT models are constant returns to capital (rather than increasing returns to scale) implies that what is at stake is not so much the theory of production ('division of labour' and 'general economic progress') but the 'theory of rents'. What really matters is that diminishing returns to capital are absent. If diminishing returns are mainly attributed to the predominance of 'the world of scarcity' - be it that (high quality) land is scarce or that there are diminishing returns to physical capital (and a falling rate of profit) due to the exogenously given limits to the supply of (high quality) labour and/or technology - then constant returns to capital can be seen to imply the absence of scarcity. As Kurz and Salvadori (1995: 6) put it, '(s)een from this perspective, the NGMs [New Growth Models] with constant returns to scale with respect to accumulable factors are comparable to a Ricardian corn model in which *land is a free good*' (emphasis in the original).

In neo-classical parlance, a similar logic is expressed by saying that the marginal productivity of single-factor capital/ human capital/ research - depending on the model specification - is independent of its stock/the number of researchers. What this implies is that partial factor variation between labour and capital is effectively being abandoned, *whether or not* the model is a single factor or a multiple factor one. In the case of the simple AK models, this is self-evident. In the case of all other NGT models, which reintroduce factor substitution by distinguishing between accumulable and non-accumulable factors, the point is that, in order to obtain (at least) constant returns with respect to accumulable factors (i.e. physical capital and some expression for knowledge as a separate factor of production), it has to be assumed that the *quality* of either labour or (physical) capital rises with the increase in input of the corresponding factor. If diminishing returns in Solow's model are taken to mean (in analogy to von Thünen rather than Ricardo) that, as a given amount of labour of the same quality has to service more and more of the same capital, then constant returns to capital are only possible if the quality of labour rises in proportion to added capital. Or else, if the Solowian model is interpreted as meaning that, as the use of capital is intensified, the economy has to bring into use older and older vintages, then constant returns to capital alter the situation such that the quality of capital rises proportionally with the introduction of additional capital to the economy. The most obvious interpretation of this induced rise in quality of labour and/or capital is that of *embodied* technological progress, a concept that underlies the notion of joint production as well as the Kaldorian technical progress function.[32].

The NGT, however, insists on treating the two factors of production as totally separate entities, or more precisely, on treating knowledge as an additional factor of production rather than the product of the interaction between labour and capital. Thus, Aghion and Howitt accommodate (physical) capital accumulation by arguing that it is 'complementary' to innovation (i.e. knowledge production) through its effect on the profitability of research. They admit, however, that 'there are many reasons for thinking that policies that favor capital accumulation will generally also stimulate innovation and raise the long-run growth rate', adding in a footnote that '(a)nother reason, which does not however fit easily into the present framework, is that capital goods embody technologies.' (Aghion and Howitt 1998: 102). Obviously, once the von Thünian logic of partial factor variation is undermined, there is no *logical* reason to assume that the rise in quality of labour or capital occurring with an increase in one of the factors, is *proportionate* to this increase. This is simply an assumption that ensures that growth does not take the form of a 'Big Bang', but is balanced (rather than stationary). Once a production function of the form F (L, K, A, dk/dt, dA/dt) is assumed to be homogenous of degree more than one in all its arguments except L, NGT models 'produce a sort of Big Bang that robs (them) of all plausibility or even of the capacity to represent the world of scarcity.' (Solow 1997:14).[33]

What Solow overlooks, though, is that 'the world of scarcity' is already obsolete in the case of balanced growth, simply because a plausible economic interpretation of balanced growth dynamics has to do away with partial factor variation. While this violates neo-classical value theory - or the symmetry between Gossen's idea of household behaviour and the 'Thünian' theory of (the remuneration of factors of) production - it opens the way to an understanding of knowledge as a *social* entity which results from the continuous technological and organisational interplay of labour and capital. The increasing economic importance of such social knowledge, to the extent that it can perhaps be regarded as a separate productive entity in that it is less and less tied to physical factors of production (individual people and machines), would then itself be a consequence of past technological progress: Both the preservation and passing on of knowledge as well as its transformation into goods and services is facilitated and rationalised *in the course of economic progress based on embodied technical change.*

This is not an interpretation contemplated by the NGT. In fact, the NGT does not provide any economic analysis of the feature of constant returns to capital, or accumulable factors of production. Its substantial - rather than purely analytical or mathematical - treatment of balanced growth dynamics is solely concerned with increasing returns to scale rather than the absence of diminishing returns, that is with the theory of 'economic progress' rather than the 'theory of rent'. As seen, increasing returns to scale are explained in terms of technology or knowledge 'externalities', whether these be a side-product of some economic activity or part of an organised process of innovation. The notion of 'externalities' has meaning only within the neo-classical (zero-rent) benchmark notion of efficient market allocation. Something is an 'externality' because it is external to the market, i.e. cannot be transacted through the market and will, therefore, not be 'properly' compensated.

Another way of saying this is that an 'externality' is the utility of a variable in the production function which is not 'under control' in the sense that it is not reflected in market prices. The efficiency of market allocation (or the pareto-optimality of competitive pricing), in turn, is a function of two factors: that goods be private goods (i.e. that their use is rivalrous) and that goods and factors be scarce. As seen, *as a factor of production* knowledge is not scarce. More precisely, *if* it is argued that knowledge accounts in some way for (at least) constant returns to capital or accumulable factors of production and *if* knowledge is, at the same time, conceptualised as a separate factor of production rather than as a by-product of embodied technical progress, then it must be given in the form of some pre-existing 'public fund' (for each period of production) on which the standard factors of production can draw to achieve the quality (or productivity) increase that accounts for constant returns. This 'fund' may not be limitless, but it will, by definition, always be sufficient to allow (at least) constant returns to all accumulable factors to materialise.

In order to function in this way as a factor of production, knowledge *as a good* must be either free or at least public, depending on whether or nor its reproduction involves opportunity costs. If the assumption is that knowledge somehow reproduces itself costlessly, then it is a free good in the same way as, say, sunshine (on a tropical island). This is an analogy highlighted by Kurz and Salvadori (1995) and Kurz (1997): If knowledge is construed as some non-depreciating Crusonian plant/capital growing indefinitely at a constant rate (as, for example, in Romer 1986), it corresponds to land as free good in a Ricardian corn model. A slightly less esoteric interpretation is that the production of knowledge is not free from the point of view of society over time, even though it may appear to be a free good from the point of view of an individual producer at anyone point in time, but that its reproduction over time involves opportunity costs. In this case, the 'public fund' of knowledge would contain a pure public good which is reproduced anew in every period of production.

Hence, if knowledge is regarded as the prime driver behind balanced growth dynamics in the way suggested by the NGT, neither as a factor of production nor as a good can it be efficiently allocated through the market. This accords with the notion of 'externalities' to the extent that knowledge is not just something that generates 'externalities' but *is* itself an externality, i.e. something that cannot be transacted through the market. However, it is only by conceptualising the dynamics of a 'knowledge driven' economy in terms of externalities that the question of market allocation arises in the first place. To put it another way, the notion of 'externalities' is fundamentally a static one, defined in the context and against the benchmark of (zero-rent) market allocation. With this implicit ideal benchmark in mind, the *policy* problem that arises naturally, is one of how to *internalise* externalities. This is essentially a problem of how to design private property rights. With externalities, a wedge is driven between private and social returns, because the provision of a private good affects the provision of a public good (air, water, knowledge). In principle, this wedge can be narrowed or removed by making the system of private property rights more encompassing or complete, in particular if public goods have the property of being (at least partially) excludable. *As a good,* knowledge is, of course, precisely of this nature: In reality, most knowledge is non-rivalrous and, to a large extent at least, excludable.[34] This implies that market allocation is at least possible, if not efficient:

'The feature that makes a good collective rather than private... is the possibility of simultaneous enjoyment of the good, not the possibility of preventing others' enjoyment. The first issue deals with the efficiency of market allocation, the second with its feasibility. Market allocation of public goods may indeed be feasible, but that does not make it efficient.' (Marglin 1984: 467/8).

The fact that (some) knowledge is potentially excludable and that, therefore, market allocation is feasible, though not totally efficient, is precisely what is emphasised by the most advanced NGT models which try to provide an economic analysis of knowledge production (innovation). This emphasis on the possibility to 'privatise' knowledge is, however, difficult to reconcile with its presumed ability - as a factor of production - to generate constant returns to accumulable factors. One of the consequences of introducing private property rights to allow for the private appropriation of returns from knowledge is that this will generate artificial scarcity, certainly with regard to the use (and possible reproduction) of knowledge, and most likely also with respect to its accessibility. As seen, for constant returns to accumulable factors to materialise it is, however, necessary for both labour and (standard) capital to be able to freely draw on a 'public' or 'societal fund' of knowledge such that their quality/productivity can increase independently of their stock. This 'paradox' of the NGT is easily overlooked in the fog created by the notion of 'externality'. It is this notion which functions as a 'bridge' between the dynamic analysis of growth mechanisms (knowledge as a factor of production) and the static analysis of allocative mechanisms (knowledge as a good), and which allows the NGT to ignore the implications arising from its mathematical formulation of balanced growth dynamics (constant returns) in favour of an economic interpretation (increasing returns based on externalities) which opens the way to safeguard, if not neo-classical value theory, at least the institutional framework of a private market economy.

4.2.2 Knowledge as a public-private good: Monopolistic competition and the role of the state

Given, however, that the NGT chooses to conceptualise its economic explanation of growth dynamics in terms of increasing returns to scale based on knowledge externalities of some form, what are the implications for the role of the state in the 'knowledge-driven' economy? To put it another way, does this framework provide a role for 'public-private partnerships' - in science in particular - to promote growth, as is suggested by the current emphasis of the 'Third Way' policy agenda on both 'endogenous (knowledge-driven) growth' and 'public-private partnerships'?

Clearly, 'public-private partnerships' in science, or UIRs, will only be a meaningful form of government intervention where entrepreneurial efforts, i.e. consciously organised innovation processes, play a significant role in knowledge accumulation and growth generation. If knowledge formation is a purely accidental by-product of some other economic activity, such as the accumulation of physical capital (Arrow), human capital (Lucas) or even conscious research efforts (Romer 1986), any government policy which raises the saving-investment rate will have the desired effect on growth. Furthermore, where specific sources of endogenous growth are emphasised, such as learning-by-doing, intentional education efforts, or R&D activities, direct government intervention, such as R&D subsidies and investment in the educational and research infrastructure, appears to be a more obvious candidate for policy design than measures supporting direct and decentralised collaboration - partnership - between public sector institutions and private companies. At the very least, such models do not provide any arguments to suppose otherwise.

The main tenet of later NGT models, which stress the role of innovation, is that the intermediate goods sector is characterised by monopolistic competition and product innovation (rather than process innovation)[35] and is dynamically efficient, that is, the rents earned are 'true' innovation rents rather than static monopoly rents. The critical assumption, independently of the exact degree of imperfection in the assumed market structure - i.e. monopolistic competition in Romer

(1990), oligopolistic in Grossman and Helpman (1991a) or monopolies in Aghion and Howitt (1998) - is that intermediate markets are contestable markets. In other words, with free entry to the research sector, 'super-profits' will be temporary. In Romer's (1990) adoption of monopolistic competition, the restrictive assumptions made by Chamberlin (for his large group model) and repeated by Dixit and Stiglitz (1977) - in particular symmetric CES and identical cost functions - ensure that 'super-profits' will be wiped out in a (short period) equilibrium model with free entry. In the 'Schumpeterian' models, it is the particular patent-racing model adopted which ensures that technological leadership will eventually be killed off by making pre-emptive patenting a non-viable strategy.

More generally, whatever the precise specification of innovation processes in these models, in order for competition in R&D to ensure that monopolies in the intermediate 'product' market will be short-lived, it has to be assumed that the present (local) monopolist will not engage in research. If this is not the case for legal reasons, the choice then is between a symmetric and deterministic auction model where firms are compelled to commit 'once and for all' to an entire research project (i.e. research cannot be sequential to deter *potential* entrants), or an asymmetric stochastic model with a sequence of innovations where incentives are dominated by the difference between the firm's profits before and after the innovation rather than by the speed of innovation vis-à-vis a rival, and where the time interval between inventions is not affected by each firm's investment. (Reinganum 1989).

In both cases, underlying the dynamic efficiency of the innovation sector is a view of knowledge as discernible and correctly valuable. Regardless of whether uncertainty is simply absent from the models (i.e. the date of invention is determined once a firm wins a patent and automatically commits a given fund of R&D), or 'uncertainties' are perfectly correlated because there is only a single research strategy available to all firms (Dasgupta and Stiglitz 1980:11), or these ‘uncertainties’ are totally uncorrelated but all strategies are equally effective or ‘risky’ (Aghion and Howitt 1988, Grossman and Helpman 1991a, Dasgupta and Stiglitz 1980:16, and all models assuming a Poisson process), research strategies are no different from ordinary product strategies. Even if the ‘zero-profit’ condition (i.e. the same R&D functions across firms) and commitment are not the main elements of the ‘temporary monopoly’ case, identical risk levels and non-sequential research efforts suggest that ‘uncertainty’ in the innovation process is at best of a very limited nature. Moreover, such uncertainty arises mainly from beliefs/expectations about rivals’ actions rather than from uncertainties inherent to the production of knowledge. Hence, even if no further (exogenous) assumptions about the duration of research efforts or the correlation of R&D functions between firms are made - that is, even if the main concern is not with the dynamic efficiency of the intermediate goods sector - intermediate input costs (in present discounted value terms) are necessarily taken as given and technological opportunity (across sectors or industries in multi-sectoral models) is simply a given set of production possibilities for translating research resources into new production technologies.

While full knowledge of costs (and prices) is, of course, a standard neo-classical assumption, in the case where inputs consist of research projects, the assumption is that research is a commodity, i.e. it is quantifiable, codifiable and clearly discernible. If the intermediate producer buys his or her inputs rather than producing them in-house, i.e. if technology transfer from a research unit is involved, the underlying model is that of ‘linear’ transfer as in the neo-classical model developed by Arrow (see section 2 above). Technology transfer is conceptualised as a unilinear transformation process of basic knowledge into ‘applied’ blue-prints and final consumption goods. Where the (economic) evaluation of research projects is unproblematic, transfer per se is unproblematic, but tradability (i.e. the appropriability of private returns) may not be. That is, barriers to innovation arise not because knowledge is in any way different from standard commodities, but because innovation, as any other economic activity, is driven by the profit-motive. As seen, the barriers to appropriability are caused by high (uninsurable) risk (due to the distance of (basic) research from final markets), indivisibilities in the use of information (on the demand-side) and fixed costs (on the supply side).

Given this conceptualisation of research as the production of information, the problem faced by the policy-maker in a private market economy is that of solving the trade-off between the protection of the innovators' rights to the exploitation of their innovation and the rapid, socially beneficial diffusion of the new information provided (Hirshleifer 1971). In other words, given that private property rights are deemed to be indispensable to innovation activity taking place at all, the state then has to decide how to design private rights to information such that social welfare is maximised, i.e. social benefit net of the *inevitable* costs society has to incur if it chooses *not* to treat a quintessentially public good (entrepreneurship) as a merit good. Figure 1 illustrates the point in simple terms.

Dynamic social welfare here is defined as the difference between the sum of the discounted present value of the flow of social benefits (innovation rents and consumer surplus) across sectors and the sum of net social costs (static welfare/deadweight losses measured against the zero-rent benchmark model) over time. The graph depicts net social gain as a function of the period of rent protection. The inverse U-shape of the curve representing net social benefits from innovation over time reflects the fact that, under a private property rights regime, the rate of innovation will increase with the degree of protection until a point X* is reached, where protection allows innovators to 'rest on their laurels'. The curve representing the sum of net social costs over time, on the other hand, reflects the assumption that society discounts future losses at a certain rate of time preference so that costs (welfare losses) aggregated over time do not rise at the same rate as the period of protection.

As seen, the central claim of NGT models is that growth is *directly* driven by non-rivalrous knowledge. Barriers to entry are, therefore, not natural, as in Schumpeter and Marx, or the natural elements of such barriers (fixed and/or sunk costs giving rise to non-convexities) are not sufficient to overcome the problem of too rapid imitation for private rents to be appropriable. Hence, the scarcity of innovation has to be artificially created by the state (or at least such artificial rent creation becomes more important). Especially where markets are assumed to be contestable, the main emphasis of policy will be on patent protection as well as financial incentives (tax breaks or credits, R&D subsidies) to encourage innovation rather than on competition policy. The problem of optimising dynamic social welfare subject to the innovators' incentive constraint then has three main elements:

First, the breadth and lengths of rent protection have to be determined. The problems of optimal patent design and effective patent protection are well-known and need not be reiterated here (e.g. Nordhaus 1969, Klemperer 1990, Gilbert and Shapiro 1990). Second, even with optimal patent/rent protection the socially optimal level of R&D expenditure may not materialise. As seen in the NGT models discussed above, the existence of externalities drives a wedge between the equilibrium and the optimal growth paths. These externalities do not result from imperfections in patent legislation or rent protection generally, but from the fact that private innovators are interested in their present profits (including profits expected in the near future). They are unlikely, however, to be much interested in the remote future. Otherwise, they would effectively act as social planners and the whole matter of private innovation incentives would not arise in the first place (at least in the world of neo-classical welfare economics).[36] Whether there will be too much or too little research depends on the specific assumptions of the model (firm behaviour, market structure and form of competition in the research and intermediate sector, demand elasticities in the intermediate and final goods sectors) and their implication for the size of the different types of externalities (i.e. consumer-surplus effect, business-stealing effect and intertemporal spillovers). If the net externality is positive, this provides a rationale for tax credits, R&D subsidies, industrial policies and state investment in the research infrastructure. In the opposite case, financial disincentives may be used to discourage private R&D spending.

Third, with state-created rents there are also potential rent-seeking costs to be taken into consideration. In keeping with the largely unreconstructed neo-classical approach of the NGT, we abstract from economic and political transaction costs. Changes in the rights structure can, therefore, be costlessly implemented, maintained and enforced. Even so, the social costs of innovation rents *may* be higher than the deadweight welfare losses associated with (temporary) monopolies themselves. This is the case if economic resources are being used up (as opposed to simply transferred) in the process of *seeking* the rent (i.e. the patent) which could have been used in production. The possibility of 'wasteful' (R&D) expenditure here does not stem, in the first place, from the inherent short-termism of private investors nor from the pressures of competition (prompting a firm to innovate earlier than is socially optimal), but from the fact that the very existence of (state-created) rents creates the incentive to spend resources on seeking them. There are two sources of such rent-seeking costs: duplication, and a mismatch between the spending (and political) power of a rent-seeker and the absolute value of his or her gain or loss. Where rents are created by a neutral state, for (social) value-enhancing rights to be implemented requires that the persuading ability of the rent-seeking groups is such that the addition to net social value (for gainers) is greater than the reduction in net value (for losers) (Khan 2000:97-108): 'For instance, if the creation of a new rent implies that gainers stand to gain $100 and losers stand to lose $50, the creation of this value-enhancing rent requires that the gainers should have greater (economic and political) persuading power. This will ensure that the value-enhancing rent is created.' (ibid.: 102).

Hence, the state not only has to ensure that the period of rent protection is optimal, but also that (a) the institutional rules regulating the process of seeking (or racing for) a patent are such that the use of resources is minimised and (b) that the patent is awarded to investors with the greatest ability to innovate (which ideally would also be the biggest spender). Of course, even if rent-seeking costs were incurred, these may not be 'wasteful' in an absolute sense, as long as the rights created remain value-enhancing (i.e. innovation rather than static monopoly rents). With zero transaction costs the state could theoretically always implement an optimal rights structure. Even so, two problems remain. First, even costless change might take time (and in the context of 'Schumpeterian' growth models one is presumably not required to abstract from time, too). Second, the demands on the state may be conflicting: an incentive structure that minimises persistence of monopoly might not be also minimising rent-seeking cost in the above defined sense.

Clearly, in this sort of scenario there is little space for 'public-private partnerships', and UIRs in particular. Because of the commodity-character of research (inputs into the intermediate sector), the central difficulty is not the transfer of research from public to private sectors but the creation of an incentive structure to encourage the private commercialisation of knowledge and research (innovation). In a world of non-rivalrous, accessible and codifiable knowledge there is no reason why this should require direct collaboration between decentralised units in the private and public sectors. The main task of the state is to create property rights to such knowledge as can be made excludable, and directly to promote all knowledge which cannot. In other words, given an Arrowian notion of information and 'linear' technology transfer, what the NGT advocates is a *market failure approach to research and innovation*. The main difference with a classical welfare notion of market failure is that the division of tasks is not 'naturally' given, but cuts across the provision of one good - knowledge - which is public in principle (i.e. non-rivalrous), but partially amenable to private allocation (excludable). Following Arrow (1962b), excludability is a function of nearness to market.

Presumably, therefore, research which is basic in the sense that it is furthest removed from industrial production, is a *pure* public good to be provided by the state, while more applied research can be treated as a private good as long as appropriate property rights are put into place.

Secondly, apart from making market allocation possible through the creation of private property rights (rents), a major task of the state is to respond to the externalities (and potential rent-seeking costs) that arise from the (partial) privatisation of the public good. With a neutral neo-classical welfare state (which the NGT implicitly assumes) there is no reason why government should not be able to deal with this task directly, i.e. by adapting its investment in the public research infrastructure to the level and direction of the net externality. What is more, if such a state was to delegate its control over the production of *basic* research to decentralised direct collaborations between universities and private high-technology companies, it could run the danger of encouraging the dismantling of the engine of growth. Recall that the externalities mentioned arise because of the inherent short-termism of private investors. A more 'entrepreneurial' role for universities simply means that such short-termism is encouraged. If the state is able to establish optimal rent protection (which in the NGT models it is), shifting the balance of research activities from basic to applied is tantamount to a move to the right of X* in figure 1 above.

Finally, given that, owing to the commodity-form of knowledge and research, temporary innovation rents are required to encourage private producers to engage in R&D activities and high-technology production, the state may have a role in designing competition policies to prevent dynamic innovation rents from turning into static monopoly rents. In principle, the NGT innovation models are constructed in such a way that the assumptions on the nature and organisation of the research process (non-sequential research, zero-profit conditions, etc.) take care of this. However, Aghion and Howitt (1998: 216 - 220), for example, concede that under certain conditions (e.g. agency problems at the firm-level, some importance of tacit knowledge, too low mobility of workers between new product lines) some degree of product market competition may be beneficial to innovation.

The unilinear concept of technology transfer (and the underlying notion of knowledge as 'information', i.e. a codifiable and transferable commodity), the model of monopolistic competition and, ultimately, the market failure approach to innovation follow directly from the conceptualisation of 'knowledge-driven' growth dynamics in terms of externalities. As has been argued, what this conceptualisation achieves is to brush over the implications arising from the assumption of constant returns to accumulable factors of production, and to shift the emphasis of the analysis to a static framework which takes (zero-rent) market allocation as its ideal benchmark notion. Even if neoclassical value theory does not escape unscathed, the institutional framework of a private market economy does: knowledge production, even if it requires monopolistic competition, can be efficiently handled by a private property rights regime-cum-welfare state, the latter dealing with the externalities arising from knowledge production through a standard market failure approach. What should be pointed out, however, is that this is in stark contrast to Schumpeter who, in tandem with Marx, believed that monopolies stood at the beginning of 'The March into Socialism' (Schumpeter 1949 [1950]). It is small wonder, therefore, that the model of monopolistic competition on which the NGT ultimately comes to rely is Chamberlinian rather than Schumpeterian. Once again, one cannot but agree with Solow:

'... these assumptions [by the NGT]... have important consequences and neither can be said to be so obviously true that one is dragged along by sheer plausibility. The most that can be said is that they do their job.' (Solow 1991:8).

5. 'Knowledge-driven' growth and social organisation:

Decentralised co-operation or gradual 'socialisation'?

What then should one make of the simultaneous emphasis of 'Third Way' economic policies on 'knowledge-driven' growth *and* the need to foster 'social' capital or 'public-private partnerships', in particular in science? The 'paradox' of the NGT points to a contradiction in these policies: *if* knowledge, understood as a disembodied (virtual) entity with the capacity of endless self-recursive reproduction, is the prime driver of growth, it is clearly not dependant on private entrepreneurial efforts to flourish. *If*, though, private entrepreneurial efforts, and with them private incentive/property rights, are deemed indispensable to innovation occurring at all, then it is unclear how knowledge - as a factor of production - can create the perpetual growth motion generated by using only inputs produced by knowledge itself that is the most basic characteristic of NGT models. There are essentially two, rather different, ways out of this impasse. One is to question the possibility of balanced or perpetual growth dynamics of a 'knowledge-driven' economy by emphasising cognitive constraints and the complexities of decentralised decision-making. This route has been chosen by a number of recent contributions which, in turn, form the basis of institutional growth theories as advocated by, for example, Douglas North. The other is to question the disembodied nature of knowledge without necessarily denying the potential growth dynamics inherent in the 'knowledge factor', and to embed recent technological developments in a theory of capitalist accumulation and surplus distribution. This route would build on the conceptualisation of capitalist growth dynamics as present in the works of Marx, Schumpeter, Kaldor and Joan Robinson. The remainder of this paper will briefly summarise the main gist of the arguments involved as the purpose is to highlight different 'routes of escape' from the 'paradox of the NGT rather than to provide an exhaustive account of the theories involved.

5.1 Cognition and decision-making: Complexity to the rescue?

In recent years, mainstream economists have begun to reinstate the study of collective action, institutional arrangements and political structures as a legitimate and important objective of economic research. Much of this effort has been organised around a criticism of the behavioural foundations of neo-classical theory, in particular the rationality postulate, as well as the absence of change and process from the static neo-classical framework. Both aspects are closely related, and have prompted the formulation of institutional growth theory (e.g. Douglas North). The common theme that runs through these approaches is that cognitive constraints, not acknowledged by standard neo-classical theory, introduce organisational complexity into the economy which, in turn, gives rise to static and dynamic inefficiencies. The developmental path of an economy will, therefore, be determined (a) by the institutions (incentive structures or sets of rules) which emerge to deal with the incentive problems arising from cognitive constraints and to minimise the costs associated with these, and (b) by irreversible and cumulative - self-reinforcing - mechanisms and processes which are driven by the inherent inefficiencies of the system rather than by any force of optimisation governing individual choices.

North's (1990) institutional theory is essentially a theory of trade as the major engine of growth. The main novelty of his approach is that he combines this theme with Coase's insight that there are costs to having property rights in place, namely transaction costs. Institutions, both as formal constraints (property rights) and informal constraints (trust, reputation, ideology), matter for growth because they determine the costliness of exchange. Transaction costs arise, in turn, from 'bounded rationality' (Simon) and 'opportunism' (Williamson). While these concepts are closely related, they highlight slightly different approaches to the criticism of the behavioural foundations of neo-classical theory. The notion of 'bounded rationality' refers to the theory of cognition and stresses the role of cognitive constraints in individual agents. These may arise from limitations in the computational ability of individuals (Simon) and/or from the importance of tacit knowledge combined with the fact that most human knowledge formation or perception is abstract in the sense that it is based on selective (and therefore incomplete) theoretical models (Hayek). The notion of 'opportunism' also refers to the presence of imperfect information, but emphasises the fact that, given this constraint, intention and action can no longer be conflated as in standard neo-classical theory (Stiglitz 1996). Therefore, interdependencies between individual actions - what Stiglitz calls 'atmospheric externalities' (ibid.: 29) - are a ubiquitous feature of economic life, and decision-making and enforcement processes, posing problems of monitoring, motivation, compliance and reputation, have to be explicitly considered. As Dahlman (1979) has pointed out, transactions costs are, thus, essentially information costs: if the transaction costs associated with a particular institutional setting could not be avoided, this setting would, by definition, be Pareto-efficient (and, by the first welfare theorem, also output-maximising). If it is not efficient, the only perceivable reason is that high transaction costs were not avoided because economic and political agents lack information about an alternative allocation of property rights associated with lower transaction costs.

Thus, the main reason why a change towards a more efficient (trade- and growth-enhancing) rights and incentive structure may not take place is that the cognitive limitations of individual agents, the resultant separation of intention and action and, ultimately, social and organisational complexity (interdependencies) prevent it from materialising. North explains institutional change, more specifically, as being governed by static and dynamic inefficiencies arising in the *process* of reducing *economic* transaction costs. This process is driven by *political* entrepreneurs who organise to lobby the state for changes in property rights which they perceive to be associated with higher gains from trade. Just as economic entrepreneurs, political entrepreneurs act on the basis of subjective 'mental models' and consequently, second-order transaction costs arise in the process of institutional change, which North calls *political* transaction costs, or the costs of political negotiation. Finally, informational imperfections or cognitive constraints are not only at the root of static inefficiencies (economic and political transaction costs), but they also mean that the dynamic movement of the economy will be path-dependent. Because individuals are endowed with a limited capacity to absorb information and, therefore, tend to revise their intentions on the basis of feedback from their immediate surroundings, their actions are defined by the networks in which they operate. Consequently, the developmental path of the economy will be characterised by increasing returns, arising from network and learning externalities, bandwagon effects and the prevalence of adaptive expectations or beliefs.

Hence, other than with the NGT, the line of reasoning suggested by institutional growth theory emphasises the constraints of human decision-making and cognition. Two things follow from this starting-point of the analysis: First, what is mainly stressed is the inherent unevenness and potential limitations to economic and growth performance, driven by inefficiencies which, while the most important driving force, also tend to keep the system on a less than optimal path. Second, in an environment characterised by informational imperfection and consequent organisational complexity, the main protagonist of change is the entrepreneur, be this the ‘Schumpeterian’ economic entrepreneur hailed by the Austrian tradition, or the political entrepreneur dominating North’s political market, or both in one person. In other words, the ‘price’ paid for replacing the Koopsman-Cass-Ramsey ‘socialist’ household (with unilinear preferences) by truly creative individuals, i.e. entrepreneurs, is that the ‘knowledge-driven’ economy is unlikely to be characterised by the smooth perpetual and balanced growth dynamics modelled by the NGT. Once individual decision-making is taken out of the black box, the fact that the amount of renewable factors of production (capital) available at any one point in time depends on the decisions of consumers and investors means that there is no guarantee that these amounts will be kept constant or will grow at a constant rate, in particular if such decision-making is marred by ‘bounded rationality’ and ‘opportunism’. Growth remains ‘endogenous’ in the sense that it is driven by individual ‘creativity’, i.e. the entrepreneurial spirit, but not in the sense that an increase in the rate of investment will lead to a rise in the rate of growth. It is not surprising, then, that the one NGT model which does *not* adopt the constant returns assumption - Jones (1995, 1998) - emphasises the importance of institutional factors, and North’s growth theory, in particular (Jones 1998: 139, 150). More specifically, the argument is that long-term economic performance will depend not on large-scale state intervention in the provision of the ‘knowledge factor’ (i.e. education and research), but on its ability to foster changes in the property rights and incentive structure so as to improve the ‘appropriation regime’ (or ‘rent regime’) under which entrepreneurs and inventors organise to make the best of new ideas.

A corollary of the emphasis on cognitive constraints and informational imperfections is that decentralised strategic interaction between individuals (and entrepreneurs, in particular) is an important feature of economic life. On the one hand, the existence of ‘atmospheric externalities’, arising from the ubiquity of informational imperfections and asymmetries, implies that strategic interdependencies are pervasive. On the other hand, because of the limitations on human knowledge formation, agency and incentive problems arising from limited information are best dealt with in a decentralised context. The creation of commitment, monitoring and enforcement are all likely to work more efficiently in relatively small groups or networks. There is, hence, also a rationale for direct co-operation, collective arrangements, ‘webs of relations’ and ‘polyarchies’ (Stiglitz 1996: 59 and 157) to promote economic performance and growth:

‘Collusion is nothing more than cooperation to pursue the joint interests of the members of an industry at the expense of others. When there are spillovers (externalities) among the activities of firms within an industry, there is potential for true social and private gains from cooperation. This is most evident, for instance, in joint research ventures...' (ibid.:114).

There is also no reason why such co-operation should not cut across the private and the public sectors, as long as it is decentralised. This is, of course, precisely the case for UIRs and 'public-private partnerships' more generally. To put it another way, within the framework of institutional growth theory and informational economics, 'public-private partnerships' can be regarded as a transaction-cost minimising institution. However, given the emphasis on the individual entrepreneur as the main agent of economic change in an environment characterised by information problems, the purpose of this institution is, of course, to provide a property rights and incentive structure which encourages entrepreneurial behaviour. That is, the emphasis is on 'private', not 'public': If such partnerships are to promote growth, their main role is that of a policy tool for the gradual (re)privatisation of the 'public sphere'.

5.2. Embodied technical progress and the process of 'gradual socialisation'

There is, however, another way to understand and analyse the dynamics of a 'knowledge-driven' economy and the role of 'public-private' partnerships to promote such growth. This approach does not deny or play down the importance of cognitive constraints and informational imperfections, as does standard neo-classical theory and the NGT. Rather, it critically examines another of the main premises of the NGT, namely that knowledge and technological progress are disembodied. As will be seen, as with institutional theory, 'public-private partnerships' have a role to play in such a framework, though a rather different one.

A useful starting point to outline the differences between the institutional approach discussed above and the one suggested here is the concept of the entrepreneur that is central to much of new institutional analysis. As is well-known, this is a concept developed by Schumpeter, and central, in particular, to his 1912/1934 *Theory of Economic Development* (which, in turn, parts of the NGT claim to have developed further). In the *Theory of Economic Development*, Schumpeter provides the following definition: 'The carrying out of new combinations we call 'enterprise'; the *individuals* whose function it is to carry them out we call 'entrepreneurs'. (....) (T)he Marshallian definition of the entrepreneur, which simply treats the entrepreneurial function as 'management' in the widest meaning, will naturally appeal to most of us. We do not accept it, simply because it does not bring out what we consider to be the salient point and the only point which specifically distinguishes entrepreneurial from other activities.' (Schumpeter 1934: 74 and 77). This 'salient point' is that, as opposed to the 'mere manager', the entrepreneur is that individual who is capable of stepping 'outside the boundaries of routine', able: 'to lead, and to organise. Even leadership which influences merely by example, as artistic or scientific leadership, does not consist simply in finding or creating the new thing but in so impressing the social group with it as to draw it on in its wake.' (ibid.: 84 and 88). Hence, what Schumpeter stresses here is more or less what modern institutional theory also identifies with the notion of entrepreneur: entrepreneurial ability is, in the first place, the ability to organise and promote innovation, and this ability is tied to the individual. It can, in this sense, be regarded as in limited supply.

However, in *Capitalism, Socialism and Democracy*, Schumpeter adds an important point that is absent from contemporary approaches emphasising the role of the entrepreneur, namely that the 'entrepreneurial function' is a *historically* specific element of capitalist development which will become obsolete in the course of this development and will be side-lined by the very forces it has helped to develop:

'To act with confidence beyond the range of familiar beacons and to overcome resistance requires aptitudes that are present only in a small fraction of the population and they define the entrepreneurial type as well as the entrepreneurial function.... This social function is already losing importance and is bound to lose it at an accelerating rate in the future even if the economic process itself of which entrepreneurship was the prime mover went on unabated. For, on the one hand, it is much easier now than it has been in the past to do things that lie outside familiar routine - innovation itself is being reduced to routine. Technological progress is increasingly becoming the business of teams of trained specialists who turn out what is required and make it work in predicable ways. The romance of earlier commercial adventure is rapidly wearing away, because so many more things can be strictly calculated that had of old to be visualized in a flash of genius.... On the other hand, personality and will power will count for less in environments which have become accustomed to economic change - and which, instead of resisting, accept it as a matter of course.' (1950: 131).

The only remaining resistance is that of 'interests threatened by an innovation in the productive process' which 'is not likely to die out as long as the capitalist order exists' and which poses a 'great obstacle' to the mass production of some goods, such as cheap housing. Otherwise, however, 'economic progress tends to become depersonalised and automatized. Bureau and committee work tends to replace individual action' (ibid.: 133). Hence, the Schumpeterian entrepreneur, at least, is not some abstract driving force of innovation and growth in an equally abstract society riddled by information problems, but a historical figure with a concrete purpose, created by the developmental dynamics of capitalism and doomed to be obliterated by its inherent drive towards some form of 'depersonalisation', 'collectivisation' or 'socialisation' of economic life. [37]

Evolutionary growth theory,[38] while (at least as far as its macro-theoretical branch is concerned) not explicitly concerned with the role of the entrepreneur or institutional and behavioural assumptions in general, but rather with abstract processes of technological change and self-reinforcing mechanisms in the economy, makes a related point. Whereas most of the new institutional and informational economics remains within a static framework of the comparative analysis of incentive structures best suited to promote innovative activities by firms and individuals, much of evolutionary growth theory emphasises the 'holistic' nature of knowledge formation in high-technology economies, whose dynamic potential can increasingly only be unlocked through collective mechanisms, such as research collaborations, productive and organisational networks and collective learning processes. Hence, while the emphasis of the institutional approach to growth theory is, ultimately, on *individual* creativity, epitomised in the entrepreneur, who acts within the constrains of rules and incentive structures which he or she may help to create, maintain and change, but which do no more than define an opportunity space, evolutionary theory regards knowledge as a *collective* entity that is 'embedded' in structures, routines and habits. Even though some knowledge may still be tied to the individual, what evolutionary theory emphasises is that most knowledge exists in the form of competencies, or combinations of knowledge, which are attached to structures, rather than individuals. Ever more extensive co-operative arrangements, ranging from clusters to the high level of organisational complexity in modern monopolistic complexes, are, therefore, seen to emerge spontaneously in response to this 'new mode of knowledge production' (Gibbons et al. 1994). As seen in section 2 above, this is closely related to the microeconomic rationale for the use of 'public-private partnerships' in the area of Science & Technology.

As opposed to Schumpeter, however, the argument for a tendency towards a greater role for co-operation and collective processes in the economy is not a historically specific one. Rather, as with all evolutionary theorising, economic progress is conceptualised as a process governed by the interplay between variation (mutation), transmission (inheritance) and selection, and thus driven largely by some 'natural' (random or stochastic) force. The tendency towards an ever more complex and encompassing organisation of economic processes is ascribed to the increasing pace of specialisation and the technological division of labour which, in turn, is the 'natural' outcome of evolution. The focus on knowledge, in particular, simply arises because, as with the NGT, technologies are equated with knowledge and the technological division of labour is equated with an increase in the specificity of knowledge, requiring a high level of organisational diversity and flexibility. Another way of saying this is that (most) evolutionary theory treats knowledge and technology as some disembodied entity. While 'embedded' in relations between individuals and in organisational structures or institutions, as with the NGT, knowledge is clearly perceived to be a separate driving force in its own right of contemporary economic development. A corollary of this approach to technological progress and change is that evolutionary theories of innovation tend to have a rather different view of the role of monopolies in developed capitalism than did Schumpeter. As has been mentioned, Schumpeter regarded monopolies as a first step on 'The March to Socialism' precisely because they epitomise the changes in the nature of innovation from isolated 'early commercial adventures' to a large-scale centralised and organisationally complex routine undertaking. Hence, for Schumpeter monopolies and monopolistic practices take different forms in the course of capitalist development with the so-called 'Schumpeterian monopoly' - i.e. the temporary and innovative monopoly - being replaced by large bureaucratic and persistent organisations to the extent that natural barriers to innovation disappear and 'innovation itself is being reduced to routine.' Evolutionary theories, on the contrary, do not provide a historical angle to their view of market structure. The prevalent view is that the increasing specificity of knowledge (i.e. the increasing technological division of labour) reinforces the importance of tacit knowledge as well as the heterogeneity of knowledge in general. Consequently, natural barriers to imitation and innovation are seen to persist and to limit the market power of monopolies, making them akin to the 'early' Schumpeterian monopoly.

However, the more basic problem with a disembodied concept of knowledge and technical progress is that it fails to take account of those determinants of economic progress and growth dynamics which are historically specific in that they are governed by the interplay between the political (or distributional) and the economic (or technological) aspects of accumulation. If these determinants are ignored by separating knowledge from standard production factors (capital and labour), no account can be given of the origin of knowledge and technical progress other than in rather vague cognitive or evolutionary, that is, 'naturalised' terms. As a consequence, property rights to the proceeds from economic progress cannot be defined, nor can the implications of the distributional dynamics for the overall process of accumulation be explored: If knowledge is some 'virtual' or 'free-floating' social entity, or a separate factor of production which somehow reproduces itself, its impact on the dynamics of growth in a capitalist economy remain clouded in mystery.

The alternative is, of course, to conceptualise knowledge as embodied in capital, and thus inseparable from the process of capital accumulation which, in turn, is governed by conflictual as well as co-operative elements of socio-economic relations. The best-known approach along these lines is probably Kaldor's technical progress function (Kaldor 1989: 229-281).[39] Kaldor stringently argues against any notion of knowledge or technology as a separate factor of production, because it is like other 'unappropriated agents of production... whose existence causes divergences between the private and the social returns of the *other* factors. This is only another way of saying that we are not free to elevate to the role of a 'factor of production' anything we like; the variables of the production function must be true inputs, and not vague 'background elements', like the sun or the sea or the state of knowledge, any of which may the thought to cause the results to diverge from the hypothesis of the homogenous-and-linear production function.' (ibid.: 262). In his own view:

'(t)he most that one can say is that whereas the rate of technical improvement will depend on the rate of capital accumulation, any society has only a limited capacity to *absorb* technical change in a given period. Hence, whether the increase in output will be more or less than proportionate to the increase in capital will depend, not on the state of knowledge or the rate of progress in knowledge, but on the *speed* with which capital is accumulated, relatively to the capacity to innovate and to infuse innovations into the economic system. The more 'dynamic' are the people in control of production, the keener they are in search of improvements, and the readier they are to adopt new ideas and to introduce new ways of doing things, the faster production (per man) will rise, and the higher is the rate of accumulation of capital that can be profitably sustained.' (ibid.: 263-64).

The reason that the rate of technological progress will depend on the rate of capital accumulation is, of course, that capital accumulation cannot be perceived of as timeless and that, therefore, a shift in the state of knowledge (and consequently a shift of the production function curve) cannot be separated from a change in the quantity of capital, i.e. a movement along the production function curve (or capital deepening).

In this scenario, the 'knowledge-driven' economy can be explained as one in which the *material form* of technical progress is such that it has itself a direct positive impact on the 'dynamism' of society, i.e. its ability to absorb technical change. To put it another way, 'the knowledge factor' does not stem from some perpetual self-recursive motion governing a separate productive entity called 'knowledge', but from the fact that the technologies which result from the process of capital accumulation (i.e. communication and information technologies) increasingly affect society's ability to communicate and organise rapidly and in ever more encompassing organisational arrangements, thus, in turn, speeding up capital accumulation itself. Knowledge and technical progress, thus, remain embodied in capital, but the material form of this capital is such that it directly affects the speed of future accumulation through its effect on the organisational capacity of society at large.

Two things follow. First, the overall growth path of the economy remains governed by the usual determinants of capital accumulation or the rate of (public and private) investment in capital. Within a Kaldorian framework, this means, of course, that what matters is the dynamic between income distribution and demand-induced investment, not just the material form of technical progress (as well as other supply factors). To be more precise, the basic cumulative process identified by Kaldor (following Adam Smith and Allyn Young) as the main driving force of growth in a capitalist economy, namely the interaction between increases in demand, induced by increases in supply, and increases in supply, induced by increases in demand - or a subtle balance of supply and demand regimes (i.e. a limited sensitivity of demand to productivity for any given elasticity of productivity with respect to growth [40]) - is what continues to drive growth even in a 'knowledge-driven' capitalist economy. How far the new technologies - and the organisational potential they embody - will affect the growth path depends on the way in which changes in productivity resulting from the use of these technologies will act upon the various components of demand through price and income effects, and ultimately, on the rate of future investment. Another way of saying this is that increasing returns do not directly and only reflect some intangible knowledge or technology externality, but a far more complex set of *social interdependencies*. As Kaldor (1989: 373 - 398) has argued, increasing returns result both from given physical properties of certain production processes - i.e. manufacturing processes in which a doubling of the linear dimension of equipment increases the surface by the square and the volume by the cube - and socio-economic factors, i.e. the endogenous link between the conflictual (distributional) and the co-operative (technological division of labour) aspects of an economy.

Secondly, if the material form of embodied knowledge and technologies (capital) increasingly facilitates encompassing organisational arrangements, higher levels of communication and, thus, collective processes and organisation, the question asked by Schumpeter arises as to whether the social organisation of a private market economy is appropriate to promote the potential inherent in these new technologies. Put differently, if embodied technical progress in the past has provided the technical and organisational possibilities to carry out and control highly complex and encompassing productive processes, private ownership may provide a barrier rather than an incentive to further promote technical progress, which will depend on the effective use of such inherently collective processes and organisational arrangements. Obvious examples of the relevance of this problem are the current discussion concerning the public or private ownership of new biological technologies (Human Genome Project) and, to some extent, also the debate around the 'American productivity paradox'. One argument to explain the contradiction between a practically unchanged productivity growth rate and the abundance of new technologies holds that it is essentially the inadequate organisational response of capital owners to the new technologies which is at the root of this phenomenon. According to this view, aggregate productivity growth is little affected by the new technologies, because out-sourcing raises the share of low-productivity/ low-paid activities in the economy, while at the same time the manufacturing sector (the main generator of increasing returns for reasons related to the physical properties of production) is shrinking. As a result, high productivity growth based on new technologies is locked into relatively small islands of production for reasons of increased short-term profitability (e.g. Slifman and Corrado 1996).

In any case, given that society's 'dynamism' will also, to some extent, be determined by cognitive constraints, the inertia of habits and the material incentives to innovate, rather than solely by the potential inherent in new technologies, while private ownership may pose 'a great obstacle' to further economic progress, it will also not suddenly become superfluous. The implication is that 'public-private' partnerships may well be a useful policy tool from the point of view that conceptualises 'knowledge-driven' technological change as 'embodied' in capital. However, because knowledge and technological progress is 'embodied' in capital and tied to capital accumulation, and thus neither tied to the individual (entrepreneur) nor a 'free-floating' 'virtual' entity in its own right, and because the main substantial aspect of the new technologies is that they allow for and require an increasingly collective organisation of production, the emphasis should be on 'public', not 'private'. In other words, 'public-private partnerships' may be an appropriate way of fostering growth, if they further the process of the 'gradual socialisation' of production, which capitalism itself has set into motion by greatly increasing the pace of the social and technical division of labour.

6. Conclusions

That '(p)eople are the key input to the creative process' (Jones 1998: 95) is hardly news to anybody other than a neo-classical economist. Both classical political economists (Marxists in particular) and subjectivist individualists of a non-orthodox persuasion (such as adherents to the Austrian school) have claimed this for a long time. However, what matters - and what separates Marxists from Austrians - is the way in which people's creativity is transformed into economic growth. To put it another way, what matters is whether technical progress is conceptualised as embodied or as disembodied.

In the latter case, there are two further options: to regard knowledge as 'embedded' in individuals, and to assign particular value to the ability 'to organise and to lead', i.e. to the entrepreneur; or to regard knowledge as 'embedded' in some sort of structure which, as long as there is no specification of such structures and their relation to economic processes, amounts to the same as saying that knowledge is a 'virtual' or 'free-floating' factor of production in its own right. The revival of the 'entrepreneur' has hitherto proven a rather successful line of defence for a social order based on a private market economy, and has recently been re-invoked by politicians of all mainstream persuasions. It does not, however, easily fit the idea of the 'knowledge-driven' economy in which knowledge, perceived as a self-recursive accumulable factor of production - a kind of non-depreciating Crusonian capital - generates balanced growth in a way that, while not specified, is hardly reliant on the sporadic 'flashes of genius' of entrepreneurs, or more generally, the pitfalls and cognitive limitations of individual decision-making.

Those who advocate a view of knowledge as embodied in capital accumulation, have pointed out that the problem with making knowledge per se a major driver of economic growth is that the process by which knowledge comes to be this driver needs to be specified. This specification of the processes underlying the growth performance of an economy is, after all, what makes a theory of growth an *endogenous* theory. In the case of knowledge, if the exploitation and exploration of knowledge for economic purposes is dependent on the entrepreneur (rather than people generally), then this imposes limits on growth if for no other reason than that individual creativity is unpredictable, essentially driven by randomness and the 'capriciousness' of individual minds. More importantly, if the entrepreneur is to be regarded as an 'ideal type' figure of market organisation, rather than as a historically specific and transient phenomenon of early capitalist development, the limitations of individual decision-making in a world of imperfect information will place a permanent and insurmountable constraint on society's potential for economic growth. If, on the other hand, knowledge is embodied in capital accumulation, it will be the changing interplay between the economic, technical and social forces governing this process which determines the growth potential. While these forces, more often than not, work in opposing directions, there is then no *a* *priori* reason for assuming that the limitations of individual decision-making may not be overcome, or at least lessened, by technological and social developments which open the way to a more effective use of inherently collective forces of production.

Underlying these two views is, of course, a different and largely opposed understanding of what constitutes 'endogeneity'. Mainstream theories of growth (such as the NGT and the new institutional growth theory) 'endogenise' by conceptualising the rate of economic growth as the outcome of the individual choices of economic agents, or one representative agent, engaged in some form of utility-maximisation. Heterodox theories of growth adopt a broader, or more 'holistic', notion of endogeneity: Here, a certain motion, e.g. technical progress, is endogenous to a system if it has arisen as a response to the internal forces of the system. e.g. the supply of resources to an economic system is endogenous if it constitutes a response to demand for them from within the system (e.g. Thirlwall 1972, 66). Obviously, the origin and working of such 'forces' needs to be explained, but there is no reason to assume that they are exclusively driven by tractable individual choices, much less by their aggregate at one moment in time.

Two implications are worth pointing out. First, to say that knowledge is embodied *in capital accumulation* does not imply that measuring the growth of the physical capital stock can account for the growth of total output. Rather, what it does say is that technical progress is governed by the same institutional, technological and economic forces which govern *the process* of capital accumulation, some of which may be quantifiable and some of which may not. Secondly, to explain growth in terms of 'holistic' and historically specific material forces is not to deny the importance of human choice. The realisation of human choices is, to a considerable extent, dependent on the explanatory power of theories designed to render the social and natural environments of human beings intelligible. The explanatory power of 'endogenising' growth by reference to some notion of 'creativity', individual or aggregate, is not obvious. What is more, as long as the origins and workings of such ‘creativity’ are not specified, just as adherents of US corporate liberalism used to find that ‘the laws of trade are stronger than the laws of men’ (Berk 1994: 13), so the adherents of the new ‘knowledge-driven’ virtual economy may well come to argue that ‘the laws of knowledge are stronger than the laws of men.’

The implications for the assessment of ‘public-private partnerships’ as a policy tool for promoting growth in a ‘knowledge-driven’ economy are considerable: their impact on the growth potential of high-technology economies will depend on whether the emphasis is put on the ‘private’ or on the ‘public’ element. In the first case, policy-makers act on the basis of an inherent contradiction. If privatisation is the key to growth, it is difficult to see how the economy can be ‘knowledge-driven’ in the sense suggested by the NGT. Knowledge is *either* a self-reproducing, virtual entity that belongs to nobody and somehow increases the performance of other accumulable factors of production in proportion to its own self-propelled growth, *or* it is dependent on the wit of the individual entrepreneur/monopolist. In the second case, policy-makers at least have a chance of ‘getting the dynamics right’: While they will not be in a position to promise a ‘virtual’ growth miracle, by fostering collective control over the integration of complex lines of production (rather than private control over collective organisation), they may contribute to the further rapid pace of capital accumulation and technological progress.

Notes

1 See Department of Trade and Industry (1998), *Building the Knowledge Driven Economy*, (1998 Competitive White Paper), http://www.dti.gov.uk/comp/competitive/wh_int1.htm.

2 In the Fabian Phamplet on the Third Way, Blair embraces a similar view of public-private relations: 'I fully recognise that the private sector, not government, is at the forefront of wealth creation and employment generation. Yet, government has a vital role in promoting competitive markets, encouraging long-term research and investment, and helping to equip citizens with the skills and aspirations they need to succeed in the modern economy' (Blair 1998:10).

3 In the present context, the term 'university-industry-relations' is used broadly to describe any form of collaborative research arrangement involving public and private partners. The main defining element is the existence of a working relationship concerned with the development and commercialization of a piece of research. The duration and degree of formality of the relationship as well as the distribution of intellectual property rights between the partners may vary substantially, ranging from one-off academic consultancies to university spin-outs and 'embedded laboratories'. UIRs in this sense are a subset of 'private-public partnerships in science', albeit a very important one. If the concept of 'public-private partnerships' is based on the idea that a clear division of labour between the private and public sectors, such as suggested by the standard market failure approach, is not desirable, the reason is (a) that entrepreneurship is regarded as a necessary input into the exploitation of the new source of growth, i.e. knowledge, and (b) that there remain social costs (negative externalities) associated with the private

production and distribution of knowledge. See section 5 below.

4 For more detail see *The White Paper on Competitiveness* (DTI 1998), chapters 2 and 3.

5 For a detailed discussion of the microeconomic dimension of innovation, and the role of UIRs in particular, see Blankenburg, 1998: University-Industry Relations, Innovation and Power: A Theoretical Framework for the Study of Technology Transfer from the Science Base, Working Paper 102: ESRC Centre for Business Research, University of Cambridge.

6 See Harcourt 1972, 1995, 1999. See also above remarks (Introduction).

7 Only if the summation of the marginal products times the production factors equals the total product produced does marginal productivity theory provide a theory of distribution.

8 How exactly linearity generates endogenous growth can easily be seen with reference to the Solow model (Solow 1956). Combining the AK production function ($Y = AK$) with the Solowian capital accumulation function ($\Delta K = \gamma Y - dK$), where γY is the amount of gross investment and dK the amount of depreciation, we obtain: $\Delta K = \gamma AK^{\alpha} - dK$ (where α stands for the elasticity of output with respect to capital K). With diminishing returns to capital ($\alpha < 1$), the smaller α, the sooner the economy will reach the steady state growth rate at which capital accumulation equals depreciation levels. The AK models represents the border case of $\alpha = 1$, characterised by constant returns to capital. If one interprets the basic idea behind the Solow model in terms of transitions dynamics where the economic growth gradually slows down along a transition path from its starting position towards the steady state, the AK

models can be read to describe a state in which the transition dynamics never end (Jones 1998: 151 with reference to Sala-i Martin, X. (1990), 'Lecture Notes on Economic Growth', NBER Working Paper no. 3563, Cambridge, MA: NBER). Examples of 'AK models' of this type are Romer (1987), Rebelo (1991) and, to some extent, Lucas (1988).

9 This, in turn, implies that the labour market is characterized by inflexible prices (in the short period). Of course, this is not a typical assumption in most neoclassical models as full employment here is simply taken to mean that labour earns its marginal product. An alternative way of understanding the 1956 Solow model is in terms of the choice of techniques at one point in time (rather than growth over time). The central idea then is not that a given amount of labour (of the same quality) has to service more and more of the same capital, but rather that, as the use of capital is intensified (a rise in the capital-labour ratio), the economy has to bring into use older and older vintages (that is less and less productive ones). In this case, labour cannot be taken to be 'scarce' or 'fixed' in any absolute sense, but only in terms of its relative price. What is truly scarce is more productive capital. Of course this implies the notion of disembodied technical progress. I owe this point to Mushtaq Khan.

10 Or, if there is a choice of technique as in King and Rebelo (1990), the profit rate will be determined by technology and profit maximisation on the part of producers (Kurz 1997, 10).

11 In a slightly different variant of the argument (where the depreciation rate is taken to equal 1, i.e. circulating capital vanishes at the end of a production period equaling the time unit), they show that AK models can be understood as a simplified version of a Ricardian 'corn model' with land as a

free good (ibid.).

12 Good examples of such an ad hoc approach are King and Rebelo (1990 and 1991) and Jones and Manuelli (1990), where a fall of the rate of profit below the discount rate for investment is simply avoided by amending the aggregate production function in such a way that a lower boundary on private profits is introduced.

13 While Arrow (1962), and also Uzawa (Uzawa, H. (1965), 'Optimum Technical Change in an Aggregate Model of Economic Growth', *International Economic Review*, 6), are commonly recognized as having anticipated the NGT, the same cannot be said of the much more 'Keynesian' neo-classical Trevor Swan. Still, he was perhaps the first to have grasped the basic idea underlying what was later to become the NGT when, in his famous 1956 article on 'Economic Growth and Capital Accumulation', he speculated on possible answers to the investment pessimism inherent in his and Solow's emerging growth theory in the following words:

'First, the rate of technical progress may not be independent of the rate of accumulation, or (what comes to much the same thing) accumulation may give rise to external economics, so that the true social yield of capital is greater than any 'plausible' figure based on common private experience. This point would have appealed to Adam Smith, but it will not be pursued here. Second, the rate of growth of labour may not be independent of the rate of accumulation. That is the distinctively classical answer.' (1956, 338, see also footnote 8).
Essentially, the NGT has explored the first line of argument.

14 As such learning is irreversible, Arrow effectively constructs an analogy to increasing returns (Hahn and Matthews 1964, 845).

15 This corresponds to Marshall's conceptualisation of industry specific increasing returns and, as Sraffa (1925) has shown, constitutes the single case for which perfect competition equilibrium holds in purely analytical terms. It should be pointed out, however, that later authors in the neoclassical tradition (i.e. Dasgupta and Stiglitz 1988) have shown that even this limited notion of increasing returns is ultimately inconsistent with a state of perfect competition.

16 Or, more precisely, the growth rate of full employment and the labour force.

17 Which is why Solow (1994:49) labels these models 'a return to generalized Domar, but with sophisticated bells and rings', although the AK models go much further than Domar by excluding by definition all possibility of a bottleneck in the supply of (skilled) labour.

18 More precisely, Romer assumes that the production function is homogenous of degree one in the current stock of private knowledge and all conventional inputs, but homogenous of degree $\delta > 1$ in the current stock of private knowledge and the accumulated stock of general (economy-wide) knowledge (where δ is the rate of discovery of new ideas or the productivity of research). As he himself pointed out in a later contribution, this assumption contradicts the idea that research knowledge is nonrivalrous (1994: 15).

19 It also worth noting that, therefore, the production function for human capital is homogenous of degree two, i.e. it is assumed that a doubling of all variables will quadruple the value of the function.

[20] In line with the assumptions of the standard literature on product differentiation, Romer actually assumes that average profits are driven to zero. However, as Stiglitz (1996: 145) correctly remarks, all that competition can ensure is that the marginal entrant's profits equal zero, at which point the profits of the inframarginal firm are strictly positive. What the 'zero-profit' condition means then is that there will be no rents or superprofits, but only 'normal' profits or producer surpluses.

[21] I.e. the equilibrium value of A (which is determined by the zero-profit condition of free entry) is such that the production function exhibits constant returns to scale in L and K.

[22] This clear-cut conclusion regarding the relationship between optimal and equilibrium growth paths is ultimately derived from the assumption that the elasticity of substitution between differentiated products is constant, as in this case the contribution of each new product to the consumer surplus equals the aggregate loss of profits inflicted on the existing firms by the marginal entrant. Therefore the only remaining (positive) externality is spillovers (from specialisation and research), implying that equilibrium growth is always slower than (socially) optimal growth.

[23] While the spillover effect, as well as the consumer-surplus effect arising from the monopolistic market structure in the intermediate goods sector, imply that (assuming given research productivity) the amount of research carried out in equilibrium will be less than socially optimal, the duplication effect constitutes a countervailing influence. The basic insights underlying Jones' production function of ideas go back to a paper by Fritz Machlup on 'The Supply of Investors and Inventions' in which he establishes four supply functions (for inventive labour, inventive labour capacity, new raw inventions

and effective (worked) inventions), arguing that all of these functions are unlikely to be infinitely elastic (Machlup 1975).

24 Intuitively, this is the case as otherwise the number of researchers would eventually exceed the population. Formally, from the production function (5) and equation (7a), the labour market equilibrium equation can be derived. Rearranging and from the expression for the rate of interest r (implied by profit maximisation) and the equilibrium price of a new design, it can be shown that

$$\frac{L_y}{L_I} = \frac{r}{\alpha}\frac{1}{g}$$

where L_Y is labour employed in the final goods sector. Because along a balanced growth path r and g are constant, $L_I = sL$ (where s is a constant).

25 To avoid the obvious objection that per capita income is not growing at a faster rate in developing countries with a higher population growth rate relative to advanced countries, the validity of these models is sometimes restricted to the case of advanced economies with a high share of skilled labour only (e.g. Jones 1998).

26 It should be noted that this is as far as the Schumpeterian influence goes. Unfortunately, another rather important insight by Schumpeter, namely that investment determines saving (rather than the other way round), seems to remain permanently beyond the grasp of the more recent wave of 'Schumpeterian' (growth) economists. However, in the Romer (1990) model even the idea of obsolence is absent. In fact, intermediate inputs (A) must be non-depreciating to avoid a return to Solowian 'investment pessimism', i.e. to counterbalance the effect of diminishing returns to conventional inputs.

[27] The following discussion is mainly based on Aghion and Howitt (1998).

[28] Note that this means that every innovation generates a proportionate increase in A and that the (marginal) productivity of research, as measured by λ, is independent of the number of researchers (n) in the economy, i.e. that there are constant returns to scale in research activities.. This is equivalent to Romer's (1990) equation (7) above, and is also conceptually analogous to Harrod-neutral change at a constant exponential rate in a Solowian model.

[29] This is assured by a variety of assumptions, most commonly infinitely-lived patents and the non-feasibility of patent licensing (e.g. Grossman and Helpman 1991a and b).

[30] That is, the equivalent of a utility function in the one-parameter isoelastic class in the Cass-Koopmans-Ramsey model.

[31] See Kurz (1998: 52) for a slightly more detailed typology of NGT models according to their specification of the mechanisms accounting for the 'endogenous' dynamics.

[32] Ultimately, this is also the idea of technical progress and change implied by the labour theory of value (as a theory of production and capitalist accumulation rather than of distribution).

[33] 'Furthermore, if this homogeneity property holds everywhere in a neighbourhood of the balanced path, then the path can be optimal only if the utility function is isoelastic.' (Aghion and Howitt 1998: 65 fn. 9). That is, for the balanced growth path to be optimal, the preferences of the Ramsey household have to be linear, implying infinite elasticity of intertemporal substitution

in consumption. Again, there is no perceivable reason to assume that any household, even a representative one, would cease all consumption as soon as the rate of interest were to rise, even slightly, above the rate of time preference.

34 Obviously, knowledge is not homogenous. While this is implicitly conceded in the NGT literature, because different models emphasise different kinds of knowledge (human capital, research, etc.), in particular the early NGT models do conceptualise knowledge as a homogenous magnitude (e.g. Romer 1986). Later models assume different kinds of knowledge to model innovation - such as Aghion and Howitt (1998) where new knowledge renders previous knowledge obsolete, or Romer (1990), where some knowledge is excludable - but the distinctions drawn are often vague and/or implicit.

35 As Solow (1994:53) remarks, this is a rather narrow notion of innovation. Of course, at a very abstract level of analysis process innovation can always be conceptualised as representing a 'new product', and this is probably the way in which the notion of product innovation is employed in NGT models, i.e. as a 'universal metaphor for innovation' (ibid.). However, as is well known, there are important differences between product and process innovation (e.g. the role of the price elasticity of demand as a determinant of innovative efforts) which, if brushed aside, may well produce misleading results. (An exception is Aghion and Howitt 1992).

36 Given the intertemporally optimising representative Ramsey household generally assumed by NGT models, this is actually what should be the case. As Solow remarks: 'Maybe I reveal myself merely as old-fashioned, but I see no redeeming social value in using this construction, which Ramsey intended as a representation of the decision-making of an idealized policy-

maker, as if it were a descriptive model of an industrial capitalist economy' (1994:49).

37 Interestingly, in the same year of the publication in English of the *Theory of Economic Development* (1912/1934), Kaldor made a very similar point in his article on 'The Equilibrium of the Firm' (1934 (1989): 48-64). In the context of the famous 'cost controversy' and Marshall's device of the 'representative firm', Kaldor argued that the only 'factor of production' which could be thought of being in fixed supply in the long run to the individual firm, thus potentially determining firm size, is a subset of the 'entrepreneurial function', namely the firm's 'ability to co-ordinate' (ibid.:56). His criticism of Marshall, then, rested on the observation that 'the function which lends uniqueness and determinateness to the firm - the ability to adjust and to co-ordinate - is an essentially dynamic function... It is not possible, therefore, to derive the firm's cost function from the economic data...: because the nature of that production function, or, rather, the relative position which the factor 'co-ordinating ability' occupies in that production function, is not given independently of equilibrium, but it is part of the problem of equilibrium itself.' (ibid.: 59, fn. omitted, emphasis in the original).

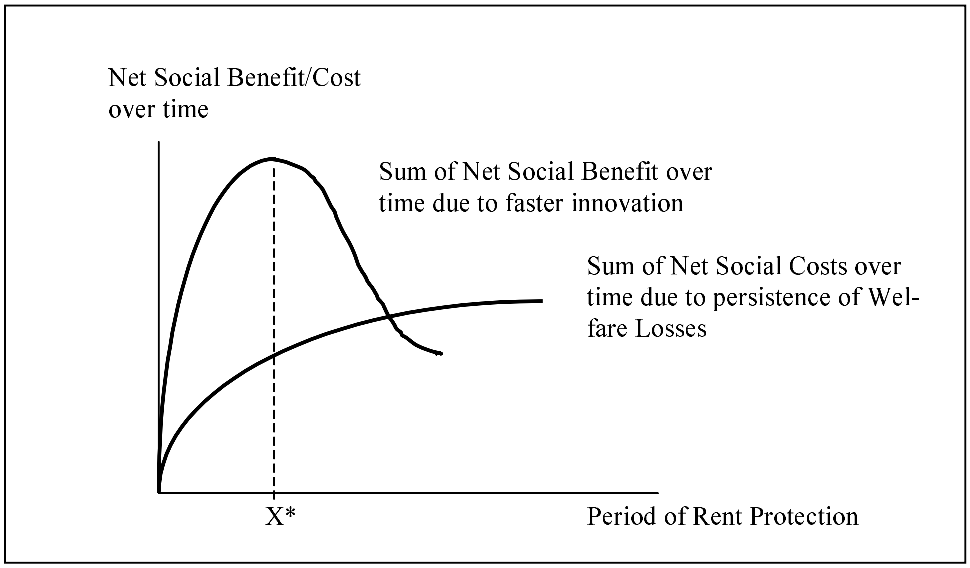
38 Evolutionary growth theory is not, as yet, a well-defined area of growth theory. Models differ considerably with regard to basic assumptions as well as methodologies employed. For a useful overview of evolutionary theorising on economic growth see Silverberg and Verspagen (1995). In the present context, the label 'evolutionary growth theory' is taken to refer mainly to macro-theories (as opposed to 'micro-models' such as Nelson and Winter 1982) which favour a disembodied notion of technological change, as does the NGT. An example is Brian Arthur (1996).

[39] As is well known, Kaldor's model was preceded by Salter's seminal contribution on *Productivity and Technical Change* (1960)

[40] For a detailed analysis see Boyer and Petit (1991).

FIGURE

Figure 1



Source: Khan 2000: 51.

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