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The Missing Link

The Knowledge Filter and Entrepreneurship in Endogenous Growth[1]

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Abstract

The intellectual breakthrough contributed by the new growth theory was the recognition that investments in knowledge and human capital endogenously generate economic growth through the spillover of knowledge. Endogenous growth theory does not explain how or why spillovers occur. The missing link is the mechanism converting knowledge into economically relevant knowledge. This paper develops a model that introduces a filter between knowledge and economic knowledge and identifies entrepreneurship as a mechanism that reduces the knowledge filter. A cross-country regression analysis over the period 1981-2001 provides empirical support for the model. We conclude that public policies facilitating knowledge spillovers through entrepreneurship may be an important new approach to promoting economic growth.

JEL: O10, L10

Keywords; Endogenous growth, knowledge, innovation and entrepreneurship.

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1. Introduction

Endogenous growth theory has provided two fundamental contributions that constitute intellectual breakthroughs. The first is that the formation of knowledge and human capital takes place as a response to market opportunities. The second is that investment in knowledge is likely to be associated with large and persistent spillovers to other agents in the economy. However, empirical evidence supporting the hypotheses derived from these models are ambiguous at best.[3] The simple correlation between R&D expenditure and GDP growth reveals no systematic relationship (Figure 1).[4] Thus, the model seems to offer no explanation as to why countries such as Japan and Sweden with seemingly larger R&D-stocks grew so slowly during the last decades, while other countries less endowed with knowledge – such as Denmark and Ireland – experienced persistent and high growth rates. We believe that the ambiguous empirical support for endogenous growth models is associated with far too mechanistic a view on the spillover of knowledge.[5]

We go back to Arrow's (1962) recognition that knowledge is not the same thing as economically relevant knowledge, suggesting that spillovers may not occur automatically. The endogenous growth proponents (Romer 1986, 1990, Lucas 1988, Rebelo 1991, and others) picked up the thread suggested in the spillover literature a couple of decades earlier. Their aim was to explicitly introduce knowledge into models of growth. Aggregate knowledge capital was defined as a composite of R&D and human capital, not embodied in processes or products. Accumulation of capitalized knowledge assets was then shown to lead to increased growth in a general equilibrium setting. The major contribution – because of the

[3] See Jones (1995a, 1995b), Young (1995) and Greenwood and Jovanovic (1998). Jones proposed a semi-endogenous growth model where it becomes more difficult over time to discover new products. Educational variables have been more successful in explaining growth (Barro and Sala-i-Martin, 1995). See Dinopoulos and Thompson (1998) and Aghion and Howitt (1998) for a discussion of empirical problems.

[4] In Figure 1, changing or removing the time lag does not materially change the results.

[5] Solow (1956) and Cass (1965) are two standard references on neoclassical growth theory. Kendrick (1981) and Maddison (1987) are examples of studies that have studied the importance of technological change as a source of growth.

properties of non-excludability and non-rivalry attached to knowledge – of these models was to analytically demonstrate that since the marginal productivity of knowledge capital does not need to diminish as it becomes available to more users, growth may go on indefinitely.

The first wave of endogenous growth models (Romer 1986, Lucas 1988, Rebelo 1991, and others) gave little attention to how spillovers actually took place and treated the process as exogenous. Their emphasis was on the influence of knowledge spillovers on growth without specifying *how* knowledge spills over. Yet, the critical issue in modeling knowledge-based growth rests on the spillover of knowledge. This was to some extent remedied in the second generation of endogenous growth models (Schmitz 1989, Segerstrom, Anant and Dinopoulos 1990, Segerstrom 1991, Aghion and Howitt 1992, Cheng and Dinopoulos 1993, Segerstrom 1995). These neo-Schumpeterian models design entry as an R&D race where a fraction of R&D will turn into successful innovations.

While this implies a step forward, the essence of the Schumpeterian entrepreneur is missed. The innovation process stretches far beyond R&D races that predominantly involve large incumbents and concern quality improvements of existing goods. As pointed out by Schumpeter (1947) "the inventor produces ideas, the entrepreneur 'gets things done' ….. an idea or scientific principle is not, by itself, of any importance for economic practice." Indeed, the Schumpeterian entrepreneur, by and large, remains absent in those models. We intend to highlight how the introduction of the "pure" Schumpeterian entrepreneur influences knowledge spillover and how knowledge thereby can be more or less smoothly filtered and substantiated into business activity.

The purpose of this paper is to extend the endogenous growth model to explain how knowledge is converted into economic knowledge and how economic knowledge influences growth. First, in contrast to previous endogenous growth models, we explicitly introduce a transmission mechanism that determines the rate at which the stock of knowledge is converted into economically useful firm-specific knowledge. Second, we develop a model that demonstrates the role of entrepreneurship in the exploitation of knowledge. Thus, whether regions or countries experience higher growth depends just as much on the entrepreneurial skills in the economy than on how much resources that are spent on knowledge creation, e.g. in terms of R&D-outlays. Third, we show how the suggested modifications of the endogenous growth model imply a new policy approach.

The paper is organized as follows. In the next section, we outline the basic structure of the knowledge-based growth model and specify how the model can be extended to identify the missing link in the spillover process. In Section 3 we present a model that incorporates a filter in the spillover mechanism determining the link between entrepreneurship and growth. In Section 4 we provide empirical support of the contribution of entrepreneurship to economic growth. The following section 5 discusses the implications of growth policy. Finally, we provide a summary and conclusion in Section 6.

2. The missing link in the endogenous growth models

The Knowledge-Based Growth Model

Endogenous growth theory took off in the later part of the 1980s, with Romer (1986) and Lucas (1988) as the standard references. These knowledge-based growth models have three cornerstones: spatially constrained externalities, increasing returns in the production of goods, and decreasing returns in the production of knowledge (at a given point in time). These provide a micro-economic foundation for explaining the mechanisms that promote growth at the macro level.

More precisely, profit-maximizing firms produce knowledge (A) in one period which is used as inputs in subsequent periods.[6] Production of knowledge is assumed to be characterized by (strongly) diminishing returns to scale. The result is an upper bound of knowledge that can be used in the production of goods, where each firm *i* can appropriate only a portion of the knowledge ($l_{i,R}$) it produces. Thus, knowledge is partially excludable and all firms benefit from spillovers originating in aggregate knowledge investments $(A = \sum_{i=1}^{n} a_i = \sum_{i=1}^{n} l_{i,R})$.

The economic impact of technology (designs) in the growth process was further stressed in Romer's 1990 article.[7] As technology was assumed non-rival and hence could be used by many agents simultaneously, an increase in aggregate technological knowledge was likely to positively influence future productivity in R&D. The combination of partial excludability and non-rivalry thus suggested an important role for technology in explaining growth. Since R&D-production was explicitly modeled and also privately financed in these models, there was scope for growth-enhancing economic policies to maximize externalities due to underinvestment in R&D.[8]

The Missing Link

New knowledge leads to opportunities that can be exploited commercially. But converting new ideas into economic growth requires turning new knowledge into economic knowledge

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[6] Knowledge, denoted A, is frequently assumed identical to R&D-outlays. In a continuous time model assuming labour is set to one, externalities are not internalized, the time path of knowledge is given and capital accumulation is foregone consumption, then the maximization problem is (Romer 1986):

$$\max \; U(c) = \int_0^\infty u(c_t)e^{-\rho t}dt, \quad s.t. \; \dot{K} = \bar{A}K^{\alpha} - c \quad and \quad \dot{K} \geq 0 .$$

[7] Grossman & Helpman (1991) and Aghion & Howitt (1992) are two further standard references in the area. Initially, the endogenous growth models focused on the role of physical and human capital. As Rebelo (1991) showed, endogenous growth can be sustained if the output of capital goods in at least one sector is linear in the stock of (broad) capital.

[8] See Shell (1966) for an early model of R&D-driven growth.

that constitutes a commercial opportunity. For example, only about half of the invention disclosures in U.S. universities result in patent applications; half of the applications result in patents; only 1/3 of patents are licensed, and only 10-20 % of licenses yield significant income (Carlsson and Fridh 2002, p. 231). In other words, only 1 or 2 percent of the inventions are successful in reaching the market and yielding income.

Just as important is that opportunities rarely present themselves in neat packages; rather they have to be discovered and applied commercially. Such discoveries are made in all types of economic activities, not only in R&D-intensive activities. Precisely for that reason the nexus of opportunity and enterprising individuals is crucial in order to understand economic growth (Shane and Eckhardt, 2003).

This implies that knowledge by itself is only a necessary condition for the exercise of successful enterprise in a growth model. An interesting approach recently presented (Michelacci 2003) focuses on the allocation of societal resources spent on R&D and entrepreneurship. Michelacci concludes that low rates of return to R&D may be due to lack of entrepreneurial skills. Hence, the ability to transform new knowledge into economic opportunities involves a set of skills, aptitudes, insights and circumstances that is neither uniformly nor widely distributed in the population.

In particular, the uncertainty, asymmetries and high transaction costs inherent in knowledge generate a divergence in the assessment and evaluation of the expected value of new ideas (Arrow, 1962). This divergence in valuation of knowledge across economic agents and within the decision-making process of incumbent firms can induce agents to start new firms as a mechanism to appropriate the (expected) value of their knowledge. This would suggest that entrepreneurship facilitates the spillover of knowledge in the form of starting a new firm.

Moreover, empirical findings suggest that entrepreneurial startups are important links between knowledge creation and the commercialization of such knowledge, particularly at the early stage when knowledge is still fluid (see section 4). There are undoubtedly many mechanisms that impede the commercialization of knowledge. By serving as a conduit for the spillover of knowledge that might not otherwise be commercialized, entrepreneurship is *one* mechanism that links knowledge to commercialization and economic growth.

3. Entrepreneurs and the knowledge filter –A simple model

In order to model the filter as well as the mechanism that generates spillovers, we impose the following assumptions:

1. A given set of individuals $\overline{L}$ can either be employed in the goods producing sector (L_M), the knowledge (invention) producing sector (L_R), or in the entrepreneurial (innovation) sector (L_E).
2. Entrepreneurial ability is distributed unevenly (and exogenously) across individuals. They deploy their endowments of entrepreneurial capabilities to evaluate the knowledge accessible to them in reaching a decision how best to appropriate the returns from that knowledge, i.e. they make profit-maximizing inter-temporal choices whether to remain employees or become entrepreneurs (Knight, 1921).
3. There is a filter σ_R in the economy influencing how efficiently knowledge is transformed into economic knowledge, implying that only part of the stock of knowledge (A) is converted into economically useful firm-specific knowledge. The filter depends on policy, traditions and path-dependence and influences networks and technology transfer mechanisms

4. There are two channels to transform knowledge (A) into economically useful knowledge. The first involves incumbent firms and the second involves the entrepreneurial startup of new (Schumpeterian) firms.

5. Incumbent firms transform available knowledge into economically useful knowledge by employing knowledge workers (L_R) which results in new inventions, new varieties of products (x_i) and new knowledge (A). The “thickness” of the filter (σ) determines how efficiently firms can transform knowledge into goods and services (commercialization),

$$0 \prec \sigma_R \prec 1$$

The thicker the filter (σ is close to zero), the less efficient exploitation of knowledge.

6. A start-up (innovation) represents any kind of new combination of existing or new knowledge, where individuals (L_E) draw on their (given) entrepreneurial ability ($\bar{e}_i$) and the aggregate stock of knowledge (A).[9] Also entrepreneurial activities are governed by how efficiently knowledge is exploited and transformed into goods,

$$0 \prec \sigma_E \prec 1$$

7. Knowledge produced by firms is non-rivalrous and partly non-excludable.

These assumptions imply that two conditions are decisive for an increasing stock of knowledge (through R&D and education) to materialize in higher economic growth. First, knowledge has to be transformed into economically useful knowledge, and, second, an economy must be endowed with factors of production that can select, evaluate and transform knowledge into commercial use. If these conditions are not fulfilled, an increase in the knowledge stock may have little impact on growth. Moreover, economies endowed with small

[9] Schumpeter (1911).

knowledge stocks may experience higher growth than regions more abundantly endowed with knowledge due to a less impeding knowledge filter.

The entrepreneurial choice

Consider an economy endowed with a population of L individuals that live for two (or more) periods. In the first period incumbents employ all individuals, but between periods they make intertemporal choices between remaining an employee or becoming an entrepreneur.

Individuals at the higher end of the distribution of entrepreneurial ability identify more opportunities to commercially exploit A as compared to individuals with lower ability. By combining given entrepreneurial capacity $(\bar{e})$ with the aggregate knowledge stock (A) in an economy operating at an efficiency level (σ), a certain share of the population (L_E) will identify profitable opportunities in running their own firms and become entrepreneurs (e_i). Thus, at a given point in time,

$$e_i = f(\overline{e_i}, A, \sigma), \quad \sum_{i=1}^{L} e_i \equiv L_E \qquad (1)$$

where aggregate entrepreneurial ability is increasing in $\bar{e}$, A and σ.

The intertemporal choice between becoming an entrepreneur or remain an employee depends on the expected pay-off accruing to the respective alternative. Suppose that the individuals' preferences are characterized by von Neumann-Morgenstern utility functions allowing a strictly increasing utility representation of the expected utility form. Moreover, assume that individuals are strictly risk-averse and that *u(0)* = 0. The decision whether to become an entrepreneur or not is illustrated in Figure 2. [10]

[10] The concave curve in Figure 2 - the Bernoulli utility function - is associated with certain outcomes and the straight line - the von Neumann-Morgenstern utility function - with uncertain outcomes. The certain utility of π is $u^{\pi}(x)$ and the certain utility of a zero payoff is u(0) = 0. If, as is the case for the entrepreneur, the outcomes are uncertain and can only be described in probability terms, we have to look at the von Neumann-Morgenstern utility function. This utility function gives the expected utility of becoming an entrepreneur as the linear

Figure 2

The individual who choose to remain an employee will receive a wage (w) with certainty, yielding utility,

$$U^{Worker} = u(w) \; = \; u^{w}(x) \tag{2}$$

which we will refer to as the individual's expected utility from remaining an employee, allowing consumption of x goods. If, on the other hand, the individual chooses to become an entrepreneur, expected utility is dependent on the probability of success ($\phi \in [0,1]$) and the expected pay-off (π),

$$U^{Entrepreneur} = \phi \; u(\pi) = \phi \; u^{\pi}(x)\,. \tag{3}$$

To engage in entrepreneurial activities the individual's expected net pay-off from entrepreneurial activities (u^{π}) must be larger than the expected net pay-off from remaining an employee (u^{w}). As shown in Figure 2, if $\pi \;\geq w$ then there exists a probability ϕ^* such that the choice of being an entrepreneur is optimal for the individual for all $\phi > \phi^*$. Assume that there exist a $\pi > w$ and a $\phi > \phi^*$ for a subset of individuals (since $\bar{e}$ is assumed

weighted average of the certain outcomes (wage earner), where the weights are the probabilities of the respective outcomes. The expected utility of the choice to become an entrepreneur is therefore $\phi \; u^{\pi}(x) + (1-\phi)u(0) = \phi \; u^{\pi}(x)$.

to be unequally distributed). Then a share L_E will shift from employees to entrepreneurs, thereby commercializing part of the given aggregate knowledge stock.[11]

At the aggregate level, entrepreneurial activity in the economy (L_E) depends on entrepreneurial ability and factors influencing the filter, assumed to be contained in a vector σ_E. A policy that increases the probability of success (ϕ) – given π – e.g. by reducing the regulatory burden or making knowledge more accessible, increases the expected utility from becoming an entrepreneur. This can be illustrated as a move along the straight line in figure 2 toward the "northeast" corner.

The share of entrepreneurs can also increase due to a policy that increases the expected pay-off (π) for an entrepreneur (e.g. through lowered taxes). In the figure, this implies a shift downwards of the straight line and the intersection with the u-curve would take place further to the "east" in Figure 2. Thus, even though the probability of success is held constant, the expected utility of becoming an entrepreneur may increase through other measures.

A simple endogenous growth model with entrepreneurship

To illustrate the role of entrepreneurs in growth we take the model of Romer (1990) as our departure point. Assume that there are two methods of developing new products; research labs in incumbent firms and entrepreneurs. There exist three factors of production: labour, different varieties of capital goods, and entrepreneurship. Markets are characterized by monopolistic competition. Entrepreneurship is embodied in labour, but in contrast to raw labor, entrepreneurship is distributed unevenly across the population. This means that some individuals are inherently better at performing entrepreneurial activities, whereas all individuals have the same ability to do R&D and to produce final goods.

[11] Compare Murphy, Schleifer and Vishny (1991).

Researchers and entrepreneurs develop new varities of (patented) capital, which can be thought of as either new types of physical capital, blueprints or “business models” that are being rented or sold to final good producers thus increasing the efficiency of production of final goods.[12] Specifically, new varieties of capital goods and new knowledge are produced as:

$$\dot{A} = \sigma_R L_R A + \sigma_E Z\left(L_E\right) A \tag{4}$$

where the $\sigma : s$ are efficiency parameters in invention activities (R&D) and innovation (entrepreneurship). Labour is distributed between personnel involved in R&D and those engaged in entrepreneurial activities, whereas A is the stock of available knowledge at a given point in time. Entrepreneurial activities are assumed to be characterized by decreasing returns to scale ($\gamma \prec 1$),

$$Z\left(L_E\right) = L_E^{\gamma}, \gamma < 1 \tag{5}$$

since entrepreneurial skill is unevenly distributed among the population. Hence, doubling the number of people engaged in entrepreneurial activities will not double the output of new knowledge and varieties. Rewriting (4) as

$$\frac{\dot{A}}{A} = \sigma_R L_R + \sigma_E Z\left(L_E\right) \tag{6}$$

[12] As e.g. Grossman and Helpman (1991) have shown, the new varieties of capital goods can just as well be thought of as new varieties of consumer goods entering consumers utility function directly.

shows that the rate of technological progress is an increasing function in R&D, entrepreneurship and the efficiency in these two activities. Combining equations 4 and 5 with a standard consumer optimization problem and a production function for final goods yields a well-defined balanced growth path (see Appendix 1).

It can be shown that in steady state some entrepreneurial activities will always be profitable ($L_E > 0$), while R &D may or may not be profitable, depending on parameter combinations. Moreover, growth is increasing in both efficiency parameters (σ_R and σ_E) and in both R&D and entrepreneurial activities. However, the latter effect depends in a non-trivial way on a range of parameters. The degree of entrepreneurial activity is, for instance, decreasing in the productivity of R&D as long as R&D is profitable. Thus, R&D and entrepreneurship are to some extent substitutes. But overall an economy endowed with a labour force having high entrepreneurial skill enjoys higher growth rates. Apart from these model-specific properties, the model shares a number of characteristics with previous models (e.g., growth is decreasing in the discount factor but increasing in a larger labour force).

The model implies some (testable) predictions. First, a country with relatively low spending on R&D may grow faster than one with high spending on R&D if entrepreneurship is much more prevalent in the first country. Second, the amount of labor engaged in entrepreneurship may not necessarily be the best indicator of the level of entrepreneurial efforts in a country, as the distribution of entrepreneurial skill may differ across countries. Finally, R&D and entrepreneurship may be substitutes in growth. Consequently, policy conclusions derived from standard endogenous growth models (taxes and subsidies to influence R&D), may not suffice to enhance the rate of growth.

The neo-Schumpeterian growth model and ”pure” entrepreneurial start-ups

The first versions of the so called neo-Schumpeterian growth models appeared a few years after Romer presented his work on endogenous growth. The objective was to insert entry and exit into the Romer model through innovation races. Basically the neo-Schumpeterian models built on the later Schumpeter's (1942) view on entry through the introduction of new ways of producing goods (processes) and production of higher-quality versions of already existing goods.

Notwithstanding that the neo-Schumpeterians extended our knowledge on growth by introducing an entry mechanism, the problem is that the mechanism they suggest (R&D-races) is hardly compatible with stylized facts: R&D-races occur predominantly among large, technology-based incumbents. In the model below we will return to the early Schumpeter (1911), emphasizing the combinatorial innovative capacity of entrepreneurs.

Let us first outline the basic structure of the neo-Schumpeterian model (see Aghion and Howitt, 1998) and then introduce our proposed modifications. Individuals' allocation between savings and consumption is based on maximizing their discounted utility over life, and savings are invested in R&D-shares. The return to R&D-investments is related to an instantaneous market interest rate (r), which in equilibrium equals consumers' rate of time preferences, ρt > 0 (the discount rate). The standard utility function can be depicted as,

$$U = \int_0^\infty e^{-\rho t} \ln\left[h(.)\right] dt \qquad (7)$$

where the sub-utility function h describes how utility is increasing in improved quality (a) – i.e. new knowledge - of existing goods (y),

$$h(y_o, y_1, y_2 ......) \quad = \sum_{n=0}^{\infty} a \ \ y_n, \quad a > 1. \qquad (8)$$

Assuming prices on the preceding quality equals one, consumers are willing to pay a (>1) for the quality-enhanced product. As consumers switch to the new products, resources are shifted from production of old to new products; i.e., creative destruction takes place.

New qualities are the outcome of R&D races between firms, where the outcome is stochastic and sequential. Each new race builds on previous investments in knowledge. As firms hire labor to undertake research and augment their firm-specific knowledge ($l_{i,R}$), they enhance their probability of winning the R&D race; that is, commercializing knowledge. A winner of the R&D race will enjoy a temporary monopoly market power, which induces more investment in R&D and new races. Such quality-enhancing innovations enter the market through a Poisson process by probability (μ),

$$\mu = (\sum_{i}^{n} l_{i,t})dt = L_R^{\gamma} dt \qquad (9)$$

where the assumed technology in knowledge production implies decreasing returns to scale ($0 < \gamma < 1$).

The economy's growth is driven by consumer preferences for enhanced qualities of the good x, i.e. $h(y_o, y_1, y_2 ......)$. In steady state income, consumption and knowledge-investment remain invariant over time, but new qualities augment consumer utility. This means that growth (g) is driven solely by the innovative capability to commercialize knowledge investments; $tL_R^{\gamma} \ln a$. Hence,

$$g = dG(t,Y)/dt = L_R{}^{\gamma} \ln a$$

(11)

implying that growth increases in knowledge-investments (hiring more R&D-workers, L_R), i.e. the intensity by which new innovations enter the market (μ) , the degree of quality improvement (a), but decreases in the degree of diminishing returns to scale (γ).

Despite many appealing features of the model it does not capture the characteristic of the "pure" Schumpeterian entrepreneur; combining entrepreneurial skill and the knowledge stock to innovate, thereby reducing the filter between knowledge and economically useful knowledge.

To illustrate our point about the role of the entrepreneur, we relax the assumption of substitutability between research and manufacturing workers. Hence, only the option of entrepreneurship is feasible for a manufacturing worker that wants to shift occupation (see section 3). Assume that knowledge (R&D) workers contribute to an invention (a) that leads to a productivity increase in the final goods sector. If compensation to factors of production is determined by the derived demand in the final sector, the knowledge workers appropriate the whole rent associated with the productivity increase; the increase in marginal productivity of the knowledge input times the final goods price ($w_R = a$), while labor productivity is assumed constant. The final goods worker can then either remain in the manufacturing sector earning $w_M (< w_R)$, or become an entrepreneur.

In the adjustment phase that follows, individuals abundantly endowed with entrepreneurial capability ($\bar{e}$) will combine that with available knowledge (A) to innovate and introduce new products. Thereby they will raise their (expected) income from wage w to entrepreneurial profit π. The reshuffling of labor between sectors implies that a new (temporary) equilibrium is established where marginal productivity in the manufacturing sector – and expected entrepreneurial income – corresponds to marginal productivity in the research sector. In the new equilibrium wages are equalized at a higher level in all occupational categories.

To include the innovative entrepreneur into to the neo-Schumpeterian framework, we propose the following alterations, based in profit-maximizing behavior of individuals.[13] First, start-ups of entrepreneurial new firms occur in the same manner as new qualities enter the market, i.e., a subset of the given population of $\bar{L}$ individuals will randomly appear as entrepreneurial start-ups, governed by a Poisson procedure,

13 See Appendix 2 for details.

$$\eta \; dt = \Big(\sum_{i=1}^{L_0} l_{i,E}(\bar{e}, A, \sigma) \Big) \; dt = \sigma_E L_E^{\gamma} dt \,, \qquad (12)$$

where $0 < \gamma < 1$ implies decreasing returns to scale in aggregate production and σ_E represents the efficiency – or filter – parameter that hampers or facilitates commercialization of knowledge through entrepreneurial activities. For simplicity, we have equalized the degree of diminishing returns to scale in entrepreneurial entry and entry through R&D-races. The intuition for decreasing returns to scale in entrepreneurial activities is that it would be sub-optimal for all economic activities to be undertaken by entrepreneurs; some tasks are better performed by incumbents and large firms.

Assuming independence between entry due to R&D-races and entry due to "pure" entrepreneurship, we can use the additive property of Poisson distributions,

$$\kappa \; dt = \mu \; dt + \eta \; dt = (\sigma_R L_R^{\gamma} + \sigma_E L_E^{\gamma}) dt \,. \qquad (13)$$

In terms of long-run steady state growth (see Appendix 2), the expression would then become,

$$g^* = dG / dt = (\sigma_R L_R^{\gamma} + \sigma_E L_E^{\gamma}) \ln a \qquad (14)$$

which obviously exceeds – given that $L_E \succ 0$ - the expression in equation 10. Hence,

$$g = \sigma_R L_R^{\gamma} \ln a < (\sigma_R L_R^{\gamma} + \sigma_E L_E^{\gamma}) \ln a = g^* \,. \qquad (15)$$

Thus, a higher intensity rate in the commercialization of knowledge generates higher growth. Whether growth is too low or too high from a social welfare point of view depends on the model specifications (markets structure, level and type of spillovers, etc.). Basically, as long as the demand elasticity and innovation levels are not to low, the growth rate will normally be below the social optimum and appropriate policies will be welfare enhancing.

4. An empirical illustration

A series of recent studies have found an empirical regularity in the form of a positive relationship between various measures of entrepreneurial activity, most typically startup rates, and economic growth (Figures 3 and 4). Other measures SMEs, self-employment and business ownership rates in relation to total population or the labor force.[14] For instance, Thurik (1999) provides empirical evidence from a 1984–1994 cross-sectional study of 23 Organization for Economic Co-operation and Development (OECD) countries. He shows that increased entrepreneurship, as measured by business ownership rates, is associated with higher rates of employment growth at the country level. In another study for the OECD, Audretsch and Thurik (2002) undertake two separate empirical analyses to identify the impact of changes of entrepreneurship on growth.

These recent findings also suggest that entrepreneurship can be found in almost any industry. Examples of fast growing entrepreneurial start-ups that do not originate in R&D-intensive activities are Walmart, Starbucks and McDonalds from the U.S., and H&M, Ikea and Securitas from Sweden. It therefore seems reasonable to include all firms when we look at the relation between growth and start-ups, not only the small share involved in R&D-intensive operations.

As an illustration of the model, we present a brief econometric analysis. The estimations basically test equation 14, which could be interpreted as a composite of the contribution to growth from new firms and incumbents. Our R&D-variables refers to research based entry (L_R) by incumbents, whereas the entrepreneurship variable is associated with "pure" entrepreneurs (L_E) . To capture the importance of knowledge (R&D) spillovers for entrepreneurs, the R&D-variables are also interacted with entrepreneurship. The purpose is to examine the contribution of the respective category to annual GDP growth.

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[14] See for instance Callejon and Segarra (1999), Audretsch and Fritsch (2002), Acs and Armington (2004), Audretsch and Keilbach (2004) and Braunerhjelm and Borgman (2004). The Global Entrepreneurship Monitoring (GEM) report has found a similar correlation at the country level (Reynolds et al, 2003).

More specifically, we regress the following variables on annual GDP-growth for 20 OECD-countries in the period 1981-2001: Following Evans and Jovanovic (1989), Evans and Leighton (1989) and Blanchflower and Oswald (1998), we approximate entrepreneurship (ENT) by the share of non-agricultural self-employed as a share of civilian employment.

Our measure of knowledge is based on the share of current R&D in relation to GDP (R&D).[15] Alternatively, we implement R&D-stocks in the estimations (R&DSTOCK), defined as accumulated R&D-flows with an assumed depreciation rate of 10 percent. Since the construction of the R&D-stocks implies a very pronounced accumulation in the beginning of the period (1981-1990), which may influence the results, we therefore also report the results for the period 1991-2001. As mentioned, we interact R&D (flows and stocks) with the entrepreneurial variable to capture the importance of the exploitation by entrepreneurs of knowledge spillover (R&D*ENT). We also elaborate with lagged R&D and entrepreneurship variables (denoted by -1).

In addition two control variables are included; the first relates to factors of production and is measured as a capital/labor ratio (CAP/L). The second is a relatively crude measurement of the "filter" in the respective country, approximated by government expenditure in relation to GDP (GEXP) which is supposed to capture the regulatory burden and the implicit tax pressure. We expect all explanatory variables, except government expenditure (as in Barro and Sala-i-Martin, 1995) to have a positive effect on annual growth. The data cover the period 1981 to 2001 and are taken from OECD sources. All estimations implement fixed effect panel regressions, and the results are shown in Table 1 and Table 2.[16]

Even at this highly aggregate level, some interesting results emerge from the regressions. In Table 1 we refrain from including the R&D-variables and the entrepreneurship

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[15] The overwhelming part of R&D-outlays relate to large, incumbent firms (Braunerhjelm and Ekholm, 1998).

[16] Following previous empirical analyses based on the production function approach, we treat the explanatory variables as exogenous.

variable together with the interaction variable in the regressions, whereas Table 2 includes all variables. The reason is that correlation matrixes reveal potential problem of multicollineraity that may distort the estimations.[17] In Table 1 it is evident from regressions 1 and 2 that R&D flow variables - current or lagged (not shown) - seem to pertain some significance to R&D in explaining growth while the entrepreneurship variable is insignificant. However, when R&D-stock variables are used, entrepreneurship gain in importance while less significance can be attributed (current) R&D-stocks (regressions 4 and 5). Most striking though is the positive and highly significant effect of the interaction variable, indicating that entrepreneurs are important in the exploitation of knowledge. No matter whether flows, stocks or lagged values are implemented, the interaction variable remains strongly significant. Note also that the “filter” variable – share of governmental expenditure – is significant and negatively related to growth throughout the regressions.[18]

Turning to Table 2, where all variables are included into the regressions, we first conclude that the interaction variable remains highly significant and positive. A second observation is that both the R&D-variables and the entrepreneurship variable turn negative – and some time significant – in all regressions. This suggests that R&D by itself is no guarantee for growth or at least that it takes time to convert R&D into growth. Similarly, entrepreneurship alone does not suffice to propel growth, rather it has to exploit knowledge (R&D) in order to for positive growth effects to emerge. Still, the results have to be cautiously interpreted since they may be influenced by the high correlation between the interaction variable, and the R&D and entrepreneurship variables. To account for potential bias originating in such correlations we implemented current R&D and the interaction variable defined in terms of the R&D-stock and entrepreneurship, in regression 7. The correlation is

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[17] The correlation coefficients varies between .89 to .69 depending on the specifications of the interaction variable, and the R&D and entrepreneurship variable.

[18] The variables have only been lagged one period, but similar results were obtained when a lag-structure of two or three years was imposed.

considerably lower between the flow value of R&D and the interaction variable based on R&D-stocks. The results are even stronger in terns of allotting a positive effect to the interaction variable whereas the stand alone R&D and entrepreneurship variables turn out negative and significantly associated with growth. Finally, note also how robust the “filter” variable seems to be: it is significant at the one percent level in five out of seven regressions and the coefficient barely change in the regressions. Furthermore, R^2 - and F-values are at a satisfactory level.

To summarize, the regressions results indicate some positive impact of entrepreneurship on growth but the strongest growth effect relates to the importance of entrepreneurs in exploiting spillovers originating in a country’s knowledge (R&D) stock.

5. Policy Implications

The policy focus of the neoclassical growth models was on capital deepening capital and labor augmenting (Solow, 1956). Thus, the policy debate revolved around the efficacy of instruments designed to induce capital investment, such as interest rates and tax credits, along with instruments to reduce the cost of labor, e.g., reduced income and payroll taxes and increased labor market mobility.

A significant and compelling contribution of the endogenous growth theory was to refocus the policy debate away from the emphasis on enhancing capital and labor with a new priority on knowledge and human capital – in particular through a combination of taxes and subsidies. As Lucas (1993) concluded, “The main engine of growth is the accumulation of human capital – of knowledge – and the main source of differences in living standards among nations is differences in human capital. Physical capital accumulation plays an essential but decidedly subsidiary role.”

Lucas also elaborates on specific policy instruments designed to enhance investments in human capital and knowledge. Thus, the policy debate on how to generate growth revolves around the efficacy of such instruments as universities, education, public and private investments in research and knowledge, training programs, and apprentice systems.

By contrast, the extension of the endogenous growth model suggested in this paper implies the central, although not exclusive, role played by a very different set of policy instruments. This policy focus is on instruments that will reduce the filter that generates a wedge between R&D and commercialized knowledge, or between knowledge and economic knowledge. Such policies are targeted to enhance the spillover of knowledge and focus on enabling the commercialization of knowledge. Examples of such policies include encouraging new-firm startups. The different specific types of policies being implemented to enhance knowledge spillovers are too numerous to be identified and listed here, but Storey (2003) provides a set of examples.

The point emphasized in this paper is that entrepreneurship policies are important instruments in the arsenal of policies to promote growth. As this paper suggests, while generating knowledge and human capital may be a necessary condition for economic growth, it is not sufficient. Rather, a supplementary set of policies focusing on enhancing the conduits of knowledge spillovers also plays a central role in promoting economic growth.

6. Conclusion

A careful examination of the basic structure of the knowledge-based endogenous growth theory reveals that the model is limited by the assumption that knowledge not only exogenously spills over but also that it is automatically transformed from knowledge to economic knowledge. Such an assumption violates the basic premise of Arrow’s (1962) insights into the economics of knowledge. These misspecifications may account for the somewhat ambiguous empirical results the model has generated in explaining growth differences across countries.

Recent literature on entrepreneurship suggests that the process of starting a new firm commercializes knowledge that might otherwise not be commercialized. By serving as a conduit for the spillover of new knowledge, entrepreneurship is one mechanism that may reduce the knowledge filter. This is certainly consistent with the recent wave of statistical regularities that provide compelling, systematic empirical evidence linking measures of entrepreneurship to economic growth.

We suggest that the endogenous growth model needs to be modified in order to incorporate the knowledge filter constituting a wedge between knowledge and economic knowledge. To achieve this end, we have suggested an extension to the endogenous growth model that we believe will narrow the gap between the model and real world behavior. The role that entrepreneurship plays in reducing the knowledge filter and increasing the arrival intensity of innovations, thereby generating economic growth, implies a whole new policy approach. Hence, growth is enhanced through individual entrepreneurs exploiting knowledge even though they are not producing knowledge. Policies that generate entrepreneurship facilitate economic growth by reducing the filter between knowledge and commercialized knowledge.

As we have emphasized throughout this paper, entrepreneurship is just one type of mechanism reducing the knowledge filter. We look to future research to empirically identify and analyze other mechanisms that can also serve to reduce the knowledge filter and thus enhance the impact of investments in knowledge on economic growth. In this paper we have made a first preliminary attempt to separate the contribution to growth that emanates from entrepreneurial spillovers relative to the commercialization by incumbent firms. Future research needs to more rigorously identify the different contributions to growth by entrepreneurial and incumbent firms.

Appendix 1: Entrepreneurs in the Romer model

Entrepreneurs and researchers engage in knowledge production in order to develop a new variety of a differentiated capital good that is used in final production. Different varieties of capital goods compete in a monopolistic competition fashion, meaning that they never become obsolete and earn an infinite stream of profits. As a side effect of their efforts, researchers and entrepreneurs produce new knowledge that will be publicly available for use in future capital good development. Equation (A1.1) describes the production of new knowledge, i.e. the evolution of the stock of knowledge, in relation to resources channelled into R&D (L_R) and entrepreneurial activity (L_E).

$$\frac{\dot{A}}{A} = \sigma_R L_R + \sigma_E Z\left(L_E\right) \tag{A1.1}$$

Entrepreneurial activities takes the following form

$$Z\left(L_E\right) = L_E^{\gamma}, \gamma < 1 \tag{A1.2}$$

Production of final goods (Y) takes place using labor and the different varieties of capital-goods:

$$Y = L_m^{\alpha} \int_0^A x(i)^{1-\alpha}\, di \tag{A1.3}$$

Given the symmetry of different varieties in (A1.3), demand for all varieties in equilibrium is symmetric, i.e. $x_i = \bar{x}$ for all $i \le A$. We therefore rewrite (A1.3) as

$$Y = L_m^{\alpha} A \bar{x}^{1-\alpha}$$

(A1.4)

Assume that capital goods are produced with the same technology as final goods and that it takes κ units of capital goods to produce one unit of capital (See e.g. Chiang, 1992). Then it can be shown that

$$K = \kappa A \bar{x} \tag{A1.5}$$

(A1.4) and (A1.5) then gives

$$Y = L_m^{\alpha} A^{\alpha} K^{1-\alpha} \kappa^{\alpha-1} \tag{A1.6}$$

Labour market equilibrium implies that employment in R&D, entrepreneurship and final production equals total labor supply.

$$L = L_m + L_R + L_E \tag{A1.7}$$

Finally, we assume that consumer preferences can be described by constant elasticity utility

$$U(C) = \frac{C^{1-\theta}}{1-\theta} \tag{A1.8}$$

We form the Hamiltonian for the representative consumer

$$H_C = \frac{C^{1-\theta}}{1-\theta} + \lambda_A\left(\sigma_R L_R A + \sigma_E L_E^{\gamma} A\right) + \lambda_K\left(\kappa^{\alpha-1} A^{\alpha} K^{1-\alpha}\left(L - L_R - L_E\right) - C\right) \tag{A1.9}$$

Maximizing (A1.9) gives the first-order conditions

$$\lambda_K = C^{-\theta} \rightarrow \frac{\dot{\lambda}_K}{\lambda_K} = -\theta\frac{\dot{C}}{C} \tag{A1.10}$$

$$\Delta = \frac{\lambda_A \sigma_R A}{\lambda_K \alpha}\left(L - L_R - L_E\right) \tag{A1.11}$$

$$\Delta = \frac{\lambda_A \gamma \sigma_E L_E^{\gamma-1} A}{\lambda_K \alpha}\left(L - L_R - L_E\right) \tag{A1.12}$$

where $\Delta = \left(\kappa^{\alpha-1} A^{\alpha} K^{1-\alpha}\left(L - L_R - L_E\right)\right)$. Combining (A1.11) and (A1.12) gives

$$L_E = \left(\frac{\sigma_R}{\gamma\sigma_E}\right)^{\frac{1}{\gamma-1}} \tag{A1.13}$$

Thus, on a balanced growth path, where both R&D and entrepreneurship is profitable, the amount of resources engaged in entrepreneurial activities is independent of consumer preferences. As γ is less than 1, entry into entrepreneurship is increasing in σ_E and decreasing in σ_R. The maximization of (A1.9) also gives the equations of motion for the shadow prices of knowledge and capital as

$$\frac{\dot{\lambda}_K}{\lambda_K} = -(1-\alpha)K^{-1}\Delta + \rho \tag{A1.14}$$

$$\frac{\dot{\lambda}_A}{\lambda_A} = -\sigma_R L_0 - \sigma_E L_E^{\gamma} + \sigma_R L_E + \rho \tag{A1.15}$$

where ρ denotes the subjective discount rate (rate of time preferences). On the balanced growth, knowledge, final production and consumption all grow at the same rate, while $\frac{\dot{\lambda}_K}{\lambda_K} = \frac{\dot{\lambda}_A}{\lambda_A}$. Combining (A1.10) and (A1.15) gives

$$L_R = \frac{1}{\theta\sigma_R}\left(\sigma_R\left(L_0 - L_E\right) + (1-\theta)\sigma_E L_E^{\gamma} - \rho\right) \tag{A1.16}$$

Combining (A1.16) with (A1.13) and (A1.1) gives

$$g = \frac{1}{\theta}\left(\left(\sigma_R L - \rho\right) - \sigma_R^{\gamma}\gamma^{\gamma-1}\sigma_E^{\gamma-1} + \sigma_E^{\frac{2\gamma-1}{\gamma}}\gamma^{\frac{\gamma-1}{\gamma}}\sigma_R^{\frac{\gamma}{\gamma-1}} \right) \qquad \text{(A1.17)}$$

where it can be shown that the growth rate is increasing in L, σ_R and σ_E but decreasing in ρ. It should be noted that (A1.17) only applies when both R&D and entrepreneurship is profitable. The given specification implies that some entrepreneurial activity will always be profitable as long as $A > 0$. This does not apply to R&D activities however. If R&D is not sufficiently profitable (following from A1.16), then we can combine (A1.10), (A1.12), (A1.14) and (A15) to derive the reduced-form growth rate. The resulting expression however provides little new insights and is not shown here.

Appendix 2: Schumpeterian endogenous growth

Standard basic assumptions apply; labor is the only production factor, one unit of labor is required to produce one unit of output (goods or knowledge), wage rates (w) are normalized to unity and uniform across sectors due to labor mobility. Sequential innovation takes advantage of positive spillovers from knowledge introduced through market entry, but there are also negative spillovers from the fact that each new innovation makes the current innovation/product obsolete.[19]

Demand side: Subject to a budget constraint, consumers maximize linear intertemporal utility,

$$U = \int_0^{\infty} e^{-\rho\, t} \ln\left[h(\quad) \right] dt, \qquad \text{(A2.1)}$$

where ρt > 0 equals consumers rate of time preferences (discount rate). h is the sub-utility function,

$$h(y_o, y_1, y_2......) \quad = \sum_{I=0}^{\infty} a^{\ I}\, y_I, \quad a > 1. \qquad \text{(A2.2)}$$

where products (y's) are assumed perfect substitutes and and I refers to the innovated, new quality. If $a\ \ p_{t-1} > p_I$, then all consumers will prefer the new product (product obsolescence).

Production: New products (qualities) are innovated by incumbent firms (i's) hiring labor to undertake research. Commercialization of knowledge is defined as market entry and occurs through a Poisson process by probability (μ),

$$\mu\ \left(\sum\nolimits_i l_{i,R}\right) dt = L_R^{\ \gamma}\, dt\,. \qquad \text{(A2.3)}$$

The probability of launching successful innovations is increasing in L_R and production technology is characterized by decreasing returns to scale ($0 < \gamma < 1$).[20] The winner of an

[19] We refer to work by Dinopoulos (1996) and Aghion and Howitt (1998) for details of the standard model and restrict the appendix to modifications required to allow for the inclusion of the "pure" Schumpeterian entrepreneur.

[20] We focus on the knowledge producing sector (the a's). The general production function is $y = A\ f(a)$.

R&D-race enjoys a temporary monopoly market power.

Instantaneous profit maximization for the innovating firm implies,

$$\pi = (p_I - 1)Y / p_I = (a-1)Y / a \quad \text{(A2.4)}$$

where p_I represents price of the new good, corresponding to the knowledge (quality) improvement (a) of new products based in new knowledge, and Y is the derived demand which equals consumption expenditure. First order condition implies that $a \geq p_I \geq 1$. The discounted profits (V) – which could be interpreted as the value of a firm at time t - of a temporary winner (firm i) of the race is equal to,

$$V(l_{i,R} / L_R\ )\mu\ dt - l_{i,r}dt \quad \text{(A2.5)}$$

where the first expression refer to revenues from knowledge production (where the firm's probability of commercialization increases in a larger share of total knowledge production and μ is the aggregate probability of entry of a new variety) and the second expression alludes to wage costs related to that production ($l_{i,R}$) times wage costs (which by assumption equals one). Free entry implies that over time,

$$\mu\ V(t) = L_R \quad \text{(A2.6)}$$

implying that revenue is increasing in higher knowledge expenditure.
Firms' instantaneous profit $(\pi = (a-1)(Y/a))$ and the discounted return (V) is linked through the financial market. Assume that investors (savings by consumer) buy shares in all firms, implying a riskless return of $r(t) = \pi - m$, where m is the costs related to the firms' debt service (mortgage and interest rate). Incumbents run the risk of being replaced by the introduction of new qualities (μ),

$$[\pi(t)/V(t)]dt + \dot{V}(t)/V(t)[1-\mu dt]dt - [(V(t)-0)/V(t)]\mu dt = r(t)dt \quad \text{(A2.7)}$$

where $(1-\mu\ dt)$ is the probability that the firm survive and $\mu\ dt$ represents the probability that the firm will be forced out of business. As dt goes to zero,

$$\dot{V}(t)/V(t) + \pi / V(t) = r(t) + \mu, \qquad \dot{V}(t) = 0$$

$$V(t) = \pi / (r(t) + \mu)\,. \quad \text{(A2.8)}$$

The higher risks associated with an investment in incumbents (because they may become replaced), requires a higher return in steady state. Or, put differently, the discounted value of the firm decreases with interest rate and the risk of being replaced, and increases in profits.

The factor (labor) market, equilibrium is obtained when,

$$L_E + (Y/a) = \overline{L} \quad \text{(A2.9)}$$

where $Y/a\ (= L_M)$ is the production of manufactured goods which equals employment in that sector (and consumer expenditure on manufactured goods). Equilibrium in knowledge production is derived by substituting equations A2.4 and A2.6, using the (Euler) conditions that r(t)=ρ and $\dot{V}(t) = 0$ in steady state, into equation A2.8,[21]

[21] Maximizing the Hamiltonian, $H = \ln C(t) + \lambda\ (t)[r(t)A(t) + 1 - C(t)]$, yields the dynamic optimization where steady state implies, $\dot{C}/C = \dot{Y}/Y = r(t) - \rho$, i.e. over time the rate of (constant) change in

$$(a-1)Y = a\ (L_R^{1-\gamma}\rho\ \ + L_R)$$
(A2.10a)

or

$$L_R = \mu\pi/(\rho+\mu) \qquad \text{(A2.10b)}$$

Consumer expenditure (Y) is thus increasing in new knowledge (a), a higher rate of arrival (μ) and consumers' rate of time preferences (ρ). Alternatively (A2.10b), knowledge production is shown to be increasing profits, and in the arrival rate, but decreasing in higher interest rate (or higher preferences for current consumption). Together with factor market equilibrium (equation A2.9), where production in the residual manufacturing sector is diminishing in increased costs for knowledge inputs (due to productivity increase in the research sector related to augmentation in knowledge, L_R), this determines the balanced growth equilibrium allocation between knowledge production and Y.

Aggregate growth: In steady state income, consumption and R&D-investments remain invariant over time, but new qualities augment consumer utility. Let $G(t,Y) = Exp[\ln(y)]$ represent the expected aggregate utility in the economy at t, where the indirect sub-utility at time t is given by $y(\cdot) = a^I C/a$. The number of innovations (I) as the economy moves along its steady state rate of growth then follows a Poisson process $Exp(I) \equiv \mu\ dt = tL_R{}^{\gamma} dt$. Using that, the expected aggregate utility at time t – expressed in logarithms, is

$$G(t,Y) = \ln C - \ln a + tL_R^{\gamma} \ln a\,, \qquad \text{(A2.11)}$$

where the first two terms on the right-hand side denote the quality-adjusted expenditure level, and the last one represents the rationally expected introduction of new qualities over time. Long-run Schumeptererian growth is defined as,

$$g = dG(t,Y)/dt = L_R^{\gamma} \ln a \qquad \text{(A2.12)}$$

that is, growth rate is expressed in terms of consumption of new goods, weighted by quality (a). Growth increases in knowledge-investments (hiring more R&D-workers), i.e. the intensity by which new innovations enter the market, the level of improvement (the quality a), but decreases in the degree of diminishing returns to scale (γ).

Allowing for "pure" entrepreneurs in the Schumpeterian growth model

As shown above, growth is increasing in the entry rate of new varieties based in inventions that originates in R&D-races (A2.10a). Assume a second mechanism for entry through innovations by "pure" Schumpeterian firms (individuals) where entrepreneurial ability (e_i) depends on given entrepreneurial capacity ($\bar{e}$) and overall knowledge (A) . Also here entry occurs through a Poisson process with probability η (cf eq. A2.3),

$$\eta\ dt = \sum_{i=1}^{L} e_i\ \ Ldt = \sigma_E\ \ L_E^{\gamma} dt, \quad e_i\ =\ f(\overline{e}, A, \sigma) \qquad \text{(A2.13)}$$

where entry depends on the number of individuals engaging in entrepreneurial activities. We also introduce an efficiency – or filter – variable in the economy representing obstacles for entrepreneurial activities. If we assume "perfect" efficiency ($\sigma_E\ = 1$), the A2.13 corresponds exactly to A2.3. Since it would be sub-optimal for all economic activities to be undertaken by

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consumption must equal the rate of change in income. Balanced growth takes place when consumers intertemporal rate of preferences is equal to the interest rate (Euler conditions).

entrepreneurs, $0 \leq \gamma \prec 1$. Allowing for Schumpeterian entrepreneurs alter the expression in A2.5 - discounted profits - to

$$V(l_{i,R} + al_{i,m} / \sigma L\ )(\mu + \eta)dt = (l_{i,r}dt + a_i l_{i,m})dt,$$
$$V(\mu + \eta) = \sigma L = \sigma_R L_R + \sigma_E L_E, \qquad \text{(A2.14)}$$
$$V = \sigma_R L_R^{1-\gamma} + \sigma_E L_E^{1-\gamma} + (\sigma_E L_E)/L_R^{\gamma} + (\sigma_R L_R)/L_E^{\gamma}$$

where $0 \prec \mu + \eta \prec 1$. Profits (or the value of the firm) stem from two sources: ether because a firm engages in successful research activities (inventions) or because of entrepreneurial ability (innovations). The latter type of entry means that an alternative cost is incurred, defined as foregone income from being a wage earner in the residual manufacturing (m) sector. To simplify we set the cross-sectional effects in the last two terms to zero ($((\sigma_E L_E)/L_R^{\gamma} = (\sigma_R L_R)/L_E^{\gamma} = 0)$). Including Schumpeterian start-ups into the economy implies that also expression A2.7 changes,[22]

$$\begin{aligned} &[\pi(t)/V(t)]dt + \dot{V}(t)/V(t)[1-\mu dt]dt - [(V(t)-0)/V(t)]\mu dt \\ &+ \dot{V}(t)/V(t)[1-\eta dt]dt - [(V(t)-0)/V(t)]\eta dt = r(t)dt \end{aligned} \qquad \text{(A2.15)}$$

Hence, incumbents may now be replaced by either other firms engaged in a R&D-race (inventions) or by "pure" entrepreneurs (innovations), implying that a higher risk-premium is required in order to invest in incumbents.

$$\dot{V}(t)/V(t) + \pi/V(t) = r(t) + \mu + \eta \qquad \text{(A2.16)}$$

As regards the labour market, individuals can choose between research work, manufacturing work and becoming an entrepreneur,

$$L_R + L_E + (Y/a) = \overline{L}. \qquad \text{(A2.17)}$$

Retaining the assumptions used to derive A2.10a and substituting A2.4 and A2.14 into A2.16,

$$\begin{aligned} &\dot{V}(t)/V(t) + \pi/V(t) = \rho + \mu + \eta, \\ &((a-1)Y/a)/(V) = \rho + \mu + \eta, \\ &(a-1)Y = a(\rho + \mu + \eta)(V) = a(\rho + \mu + \eta)(L_R^{1-\gamma} + L_E^{1-\gamma}) = \\ &\rho(L_R^{1-\gamma} + L_E^{1-\gamma}) + L_R + L_E + (\mu/\eta)L_E + (\eta/\mu)L_R \end{aligned} \qquad \text{(A2.18)}$$

Taking into account that the efficiency (σ) - the filter – may differ across sectors, expression A2.18 becomes,

$$\begin{aligned} &(a-1)Y = \rho(\sigma_R L_R^{1-\gamma} + \sigma_E L_E^{1-\gamma}) + \sigma_R L_R^{\gamma} + \sigma_e L_E^{\gamma} \\ &+ (\mu/\eta)\sigma_E L_E + (\eta/\mu)\sigma_R L_R \end{aligned} \qquad \text{(A2.19)}$$

Consumer expenditure is thus influenced by the rate of consumer preferences, research and entrepreneurial efforts, impediments to research and entrepreneurial activities, and the relative size of probabilities of entry. Difference between countries as regard the filter and the level of the labor force allocated to invention or innovation thus influence growth.

Building on the additive property of Poisson distributions, from A2.3 and A2.11

[22] We assume that cost – though not related to R&D - is associated with market entry by "pure" Schumpeterian entrepreneurs (e.g. marketing costs) and that the portfolios of investors instantaneously include these firms as they enter the market.

$$\kappa\ dt = \mu\ dt + \eta\ dt = (\sigma_R L_R^{\gamma} + \sigma_E L_E^{\gamma})dt\ . \qquad \text{(A2.20)}$$

In terms of long-term growth, the expression would then become,

$$g^* = dG / dt = \sigma_R L_R^{\gamma} + \sigma_E L_E^{\gamma}) \ln a \qquad \text{(A2.21)}$$

which obviously exceeds growth (g) building on entry solely from R&D-races,

$$g = \sigma_R L_R^{\gamma} \ln a < (\sigma_R L_R^{\gamma} + \sigma_E L_E^{\gamma}) \ln a = g^*\ .$$

Table 1. Regression results, fixed effect panel estimations. Dependent variable: annual growth, 1981-2000.

	1	2	3	4[1]	5[1]	6[1]	7[1]
R&D	1.06** (2.40)						
R&DSTOCK				.25 (1.31)			
R&D STOCK (-1)					.90*** (4.46)		
ENT	.06 (.60)			.45** (2.24)			
ENT(-1)					.33* (1.69)		
R&D*ENT		.09*** (3.58)	.				
R&D*ENT(-1)			.10*** (4.05)				.
R&DSTOCK* ENT						.09*** (4.18)	
R&DSTOCK* ENT(-1)							.07*** (6.26)
CAP/L	.01 (.46)	.01 (.62)	.01 (.16)	.01** (2.15)	.01 (.67)	.01 (1.62)	.01 (1.05)
GEXP	-.22*** (-7.26)	-.21*** (7.41)	-.22*** (-7.54)	-.12** (-1.94)	-.16** (-2.46)	-.15** (-2.32)	-.14** (-2.38)
CONSTANT	10.11*** (5.01)	10.84*** (6.16)	11.09*** (6.31)	-4.24 (-.69)	-3.14 (-52)	.32 (.05)	.73 (.16)
Adj. R^2	.18	.18	.19	.23	.30	25	.33
F-value	5.16	5.59	5.84	4.96	6.97	5.71	8.12
No. of obs.	400	400	400	220	220	220	220

Note: t-values within parentheses. *, **, and *** refer to statistical significance at the 10-, 5- and 1-perecnt level, respectively. The capita/labor coefficient obtains a low value in all regressions but is rounded off to .01 in all reported results. All data from OECD Statistical Compendium.

[1]Regressions 5 and 6 only cover 1991-2001. The definition of the R&D-stocks implies that there is a strong growth in the first years which may influence the regressions results.

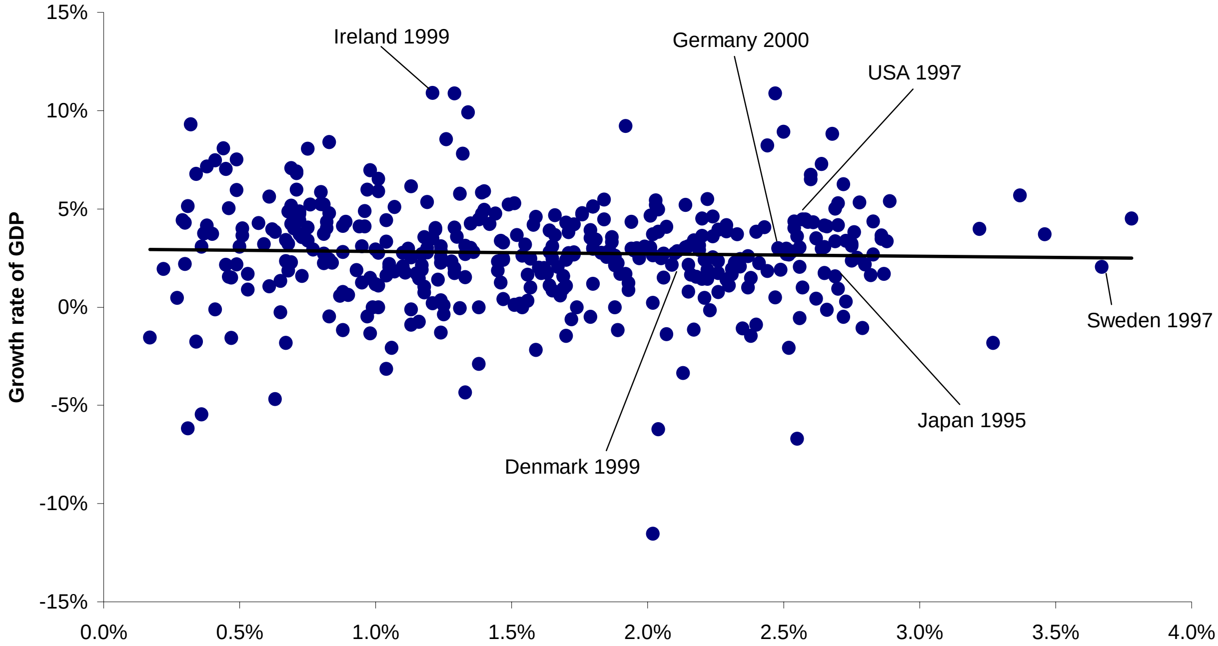
Table 2. Regression results, fixed effect panel estimations. Dependent variable: annual growth, 1981-2000.

	1	2	3	4	5[1]	6[1]	7[1]
R&D	-1.38 (-1.40)						
R&D (-1)		-.80 (-.80)					-2.71** (-2.50)
R&DSTOCK			-.35** (-2.50)		-1.07*** (-2.58)		
R&DSTOCK (-1)				-.24** (-1.97)		-.16 (-.36)	
ENT	-.29* (-1.87)		-.12 (-.89)		-.21 (-.78)		
ENT(-1)		-.30* (-1.89)		-.07 (-.58)		-.25 (-.89)	-.48* (-1.84)
R&D*ENT	.22*** (2.75)		.				
R&D*ENT(-1)		.21*** (2.59)					
R&DSTOCK* ENT			04*** (2.71)		.11*** (3.57)		
R&DSTOCK* ENT(-1)				.03** (2.42)		.10*** (2.80)	.13*** (5.23)
CAP/L	.00 (.72)	-.00 (-.02)	.00 (1.23)	.00 (.63)	.00** (1.97)	.00 (-64)	.01 (.56)
GEXP	-.21*** (-7.11)	-.22*** (7.41)	-.20*** (-6.21)	-.20*** (-6.50)	-.16** (-2.39)	-.16** (-2.43)	-.19*** (-3.01)
CONSTANT	14.01*** (5.71)	14.38*** (5.87)	11.82*** (4.29)	12.03*** (4.49)	7.14 (1.06)	4.84 (.74)	9.50 (1.45)
Adj. R^2	.19	.21	.18	.18	.28	.33	.35
F-value	5.46	5.76	5.00	5.10	5.71	7.87	8.41
No. of obs.	400	400	400	400	220	220	220

Note: t-values within parentheses. *, **, and *** refer to statistical significance at the 10-, 5- and 1-perecnt level, respectively. The capita/labor coefficient obtains a low value in all regressions but is rounded off to .01 in all reported results. All data from OECD Statistical Compendium.

[1]Regressions 5 and 6 only cover 1991-2001. The definition of the R&D-stocks implies that there is a strong growth in the first years which may influence the regressions results.

Figure 1: Expenditures on R&D and economic growth in 29 OECD countries 1981-2000



Source: OECD Statistical Compendium on CD, 2002:2. **R&D as percentage of GDP**

Figure 2: Expected utility of becoming an entrepreneur

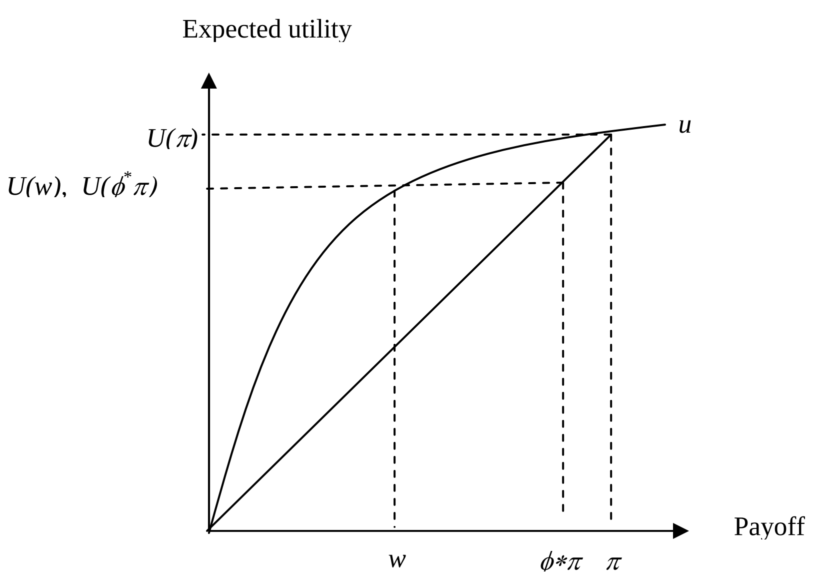
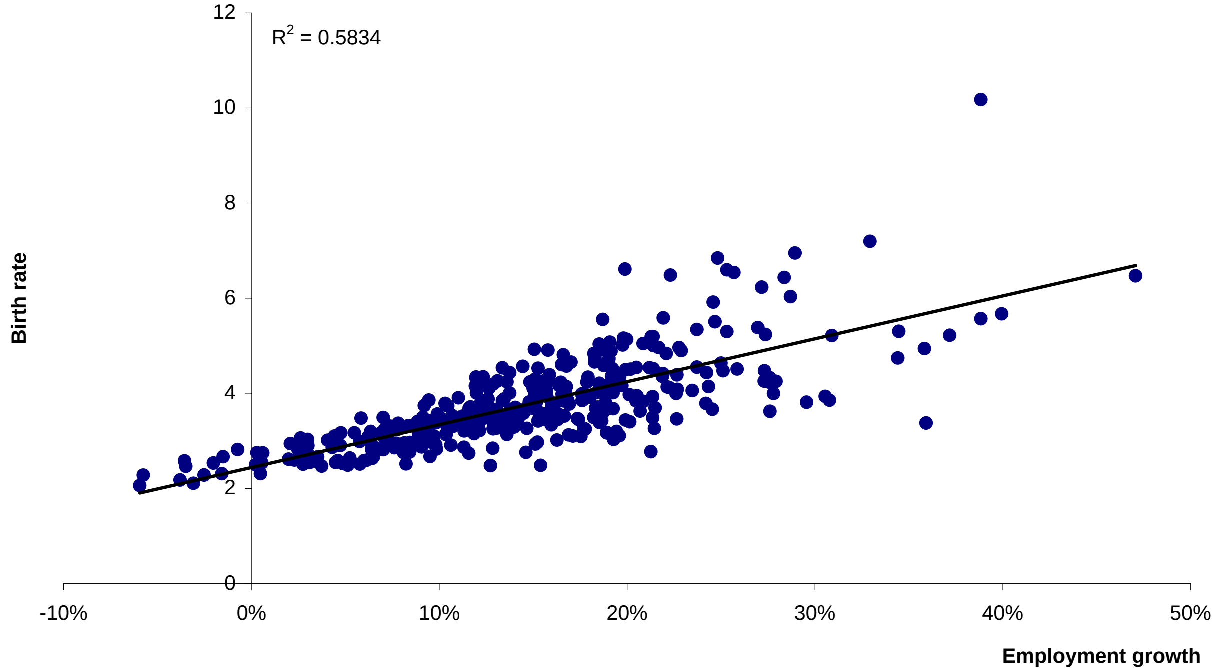
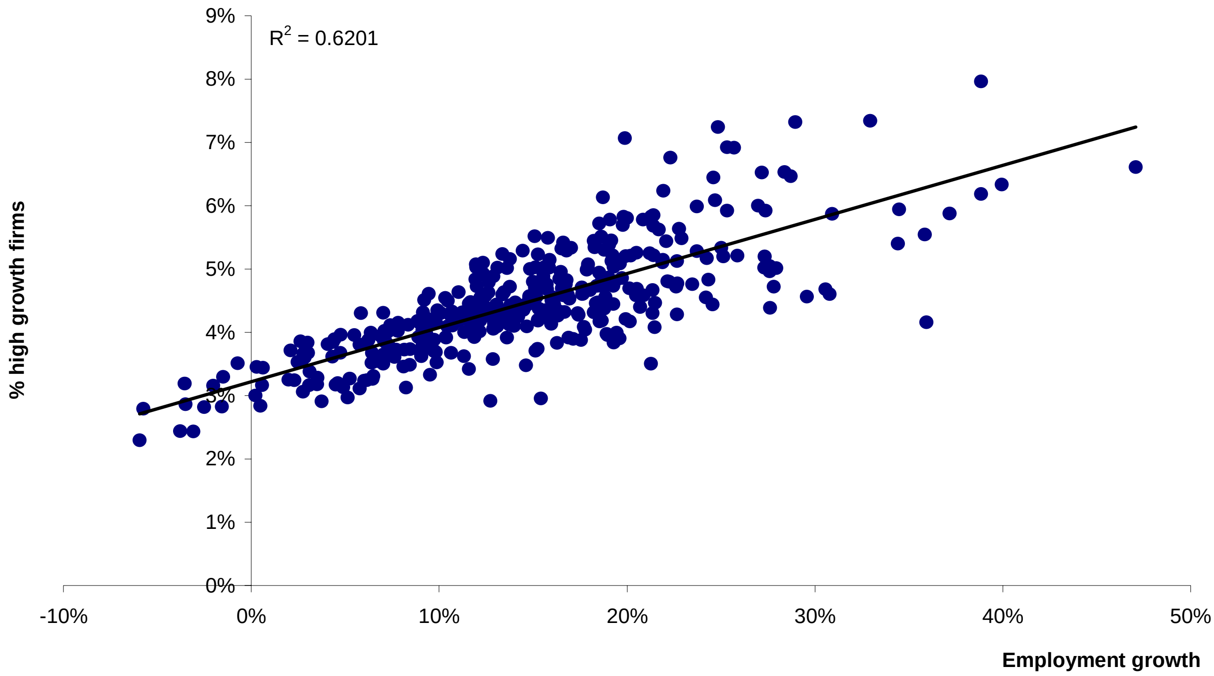


Figure 3: Entrepreneurship and growth 1991-96



Source: Acs and Armington, 2002.

Figure 4: Entrepreneurship and growth 1991-96



Source: Acs and Armington, 2002.

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