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David B. Audretsch*

Abstract This paper shows how and why the Solow growth accounting framework is useful for linking entrepreneurship capital to economic growth. The knowledge filter impedes the spillover of knowledge for commercialization, thereby weakening the impact of knowledge investments on economic growth. By serving as a conduit for knowledge spillovers, entrepreneurship is the missing link between investments in new knowledge and economic growth. Entrepreneurship is an important mechanism permeating the knowledge filter to facilitate the spillover of knowledge and ultimately generate economic growth. The emergence of entrepreneurship policy to promote economic growth is interpreted as an attempt to promote entrepreneurship capital, or the capacity of an economy to generate the start-up and growth of new firms.

Key words: entrepreneurship, growth, knowledge spillovers, Solow

JEL classification: O4, O3, E0, L26

I. Introduction

In his seminal article, Robert Solow (1956) provided a framework that not only explicitly linked key factors of production to economic growth but also framed the public policy discourse on how best to achieve growth. The Solow growth accounting framework included two explicit factors, physical capital and labour, as well as the implicit factor of technological change. While the specification of these factors has seen considerable evolution, such as the endogenization of knowledge investments generating technological change, public policy for growth has generally remained remarkably constant and focused on these three factors in the decades subsequent to Solow's pathbreaking article.

Thus, it may have come as a startling surprise when Romano Prodi (2002, p. 1), who at the time served as President of the European Commission, proclaimed that the promotion of entrepreneurship was a central cornerstone of European economic growth policy: 'Our lacunae in the field of entrepreneurship needs to be taken seriously because there is mounting evidence

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that the key to economic growth and productivity improvements lies in the entrepreneurial capacity of an economy.' With the 2000 Lisbon Proclamation, the European Council made a commitment to becoming not just the leader in knowledge but also the entrepreneurship leader in the world by 2020 in order to ensure prosperity and a high standard of living throughout the continent.

Europe was not alone in focusing on entrepreneurship as a key factor generating economic growth. From the other side of the Atlantic, Mowery (2005, p. 1) observes,

> During the 1990s, the era of the 'New Economy', numerous observers (including some who less than 10 years earlier had written off the US economy as doomed to economic decline in the face of competition from such economic powerhouses as Japan) hailed the resurgent economy in the United States as an illustration of the power of high-technology entrepreneurship. The new firms that a decade earlier had been criticized by such authorities as the MIT Commission on Industrial Productivity (Dertouzos *et al.*, 1989) for their failure to sustain competition against large non-US firms were seen as important sources of economic dynamism and employment growth. Indeed, the transformation in US economic performance between the 1980s and 1990s is only slightly less remarkable than the failure of most experts in academia, government, and industry, to predict it.

At first glance, the emergence of entrepreneurship as a focus of growth policy would seemingly have little to do with the Solow growth accounting framework. Just as physical capital was generally considered to be best organized for large-scale production to exhaust scale economies (Chandler, 1977, 1990), knowledge capital in general, and R&D in particular, was similarly considered to be a large corporation phenomenon. A generation of scholars had arduously and systematically documented painstaking empirical evidence that supported the conclusion of Joseph A. Schumpeter (1942, p. 106), 'What we have got to accept is that the large-scale establishment or unit of control has come to be the most powerful engine of progress and in particular of the long-run expansion of output.' John Kenneth Galbraith (1956, p. 86) provided a post-war interpretation, 'There is no more pleasant fiction than that technological change is the product of the matchless ingenuity of the small man forced by competition to employ his wits to better his neighbor.'

The purpose of this paper is to show that not only is the recent emergence of entrepreneurship as a central focus of growth policy compatible with the Solow model, but actually to use the lens provided by the Solow growth accounting framework to link entrepreneurship to economic growth. By endogenously facilitating the spillover of knowledge created in an incumbent organization and perhaps for a different application, entrepreneurship makes an important contribution to economic growth.

Confronted with what is termed the knowledge filter (Acs *et al.*, 2004; Audretsch *et al.*, 2006), or barrier impeding the spillover of knowledge from the firm or organization where it was originally generated, for commercialization by third-party firms, public policy instruments to promote investment in knowledge, such as human capital, R&D, and university research, may not adequately generate economic growth. One interpretation of the 'European Paradox', where such investments in new knowledge have certainly been substantial and sustained, while vigorous growth and the reduction of unemployment have remained elusive, is that the presence of such an imposing knowledge filter chokes off the commercialization of those new knowledge investments, resulting in diminished innovative activity and ultimately stagnant growth.

By serving as a conduit for knowledge spillovers, entrepreneurship is the missing link between investments in new knowledge and economic growth. Entrepreneurship is an important mechanism that permeates the knowledge filter, facilitating the spillover of knowledge and ultimately generating economic growth. The emergence of entrepreneurship policy to promote economic growth is interpreted as an attempt to create entrepreneurship capital, or the capacity of an economy to generate the start-up of new firms.

The starting point of this paper, presented in the second section, revolves around the link between knowledge spillovers and economic growth. Why knowledge might not automatically spill over is attributable to the knowledge filter, which is explained in the third section. The fourth section analyses the role of entrepreneurship as a conduit of knowledge spillovers to penetrate the knowledge filter.

The fifth section shows how measures of entrepreneurship capital have been included along with the traditional factors in the Solow growth accounting framework to link entrepreneurship to economic growth. The emergence of entrepreneurship policy, which is interpreted as the attempt to create entrepreneurship capital, is the focus of the sixth section. In the last section a summary and conclusions are provided. In particular, this paper concludes that the lens provided by the Solow growth accounting framework has proven remarkably robust and flexible, enabling an interpretation of the recent emergence of public policy to create entrepreneurship capital as a means for generating economic growth.

II. Knowledge spillovers and economic growth

Robert Solow (1956, 1957) was awarded the Nobel Prize for his model of economic growth based on what became termed as the neoclassical production function. There are two key factors of production in the Solow model, physical capital and (unskilled) labour. Solow, of course, did acknowledge that economic growth was influenced by technical change. However, in terms of his formal model and the econometric estimation, it was considered to be an unexplained residual, which 'falls like manna from heaven'. As Nelson (1981, p. 1030) points out, 'Robert Solow's 1956 theoretical article was largely addressed to the pessimism about full employment growth built into the Harrod–Domar model. . . . In that model he admitted the possibility of technological advance.'

Solow's pathbreaking research inspired a subsequent generation of economists to apply his growth accounting framework based on the model of the production function to link various measures of physical capital and labour to economic growth. As Nelson (1981, p. 1032) pointed out,

> Since the mid-1950s, considerable research has proceeded closely guided by the neoclassical formulation. Some of this work has been theoretical. Various forms of the production function have been invented. Models have been developed which assume that technological advance must be embodied in new capital. . . . Much of the work has been empirical and guided by the growth accounting framework implicit in the neoclassical model.

Growth policy, if not shaped by the Solow theoretical growth model, certainly corresponded to the view that inducing investments in physical capital in particular was the key to generating economic growth and advances in worker productivity. Both the economics literature and the corresponding public policy discourse were decidedly focused on instruments designed to induce investment in physical capital and ultimately promote growth. While these debates may never have been satisfactorily resolved, their tenacity reflected the deep-seated belief about the primacy of capital investment as the fundamental source of economic growth.

It would be a mistake to think that knowledge was not considered as a factor influencing economic growth prior to the 'new endogenous growth theory'. In fact, one of the main conclusions of the Solow model was that the traditional factors of physical capital and labour did not account for much of the variation in growth performance. Rather, most of the variation in economic growth was explained by the residual, which was considered to reflect technological change. As Nelson (1981, p. 1033) concludes, the research 'provided evidence that neoclassical variables do not account for all of the differences among firms in productivity'.

The explicit introduction of knowledge into macroeconomic growth models was formalized by Romer (1986) and Lucas (1993), who argued that as a result of externalities and spillovers, knowledge was particularly important. In the Romer (1986) and Lucas (1993) models of endogenous growth, knowledge is assumed automatically to spill over from the firm or organization generating that knowledge for commercialization by third-party firms. While the more traditional concept of technology transfer identified knowledge as flowing across different organizations for a market price, knowledge spillovers could be procured for free.

Including the spillover of knowledge in growth models shifted the focus of policy to knowledge, which became particularly potent in terms of its impact on growth when compared to the traditional factors of physical capital and labour, where no such spillovers and free access by third-party firms was possible. Thus, while knowledge was characterized as falling like 'manna from heaven' in the Solow model, the analogous characterization in the endogenous growth models is that it blows over from the neighbours.

The endogenous growth models are consistent with the predominant theory of innovation at the firm level. Rather, than falling like manna from heaven, in what Griliches (1979) formalized as the model of the knowledge production function, innovative output is the result of systematic investment by firms to create knowledge and new ideas, and subsequent efforts to appropriate the returns accruing from those investments through commercialization. Such investments to create new knowledge involve R&D and the enhancement of human capital through training and education. Thus, according to the model of the knowledge production function (Griliches, 1979), innovative opportunities are endogenously created by purposeful and dedicated investments and efforts by firms. As in the macroeconomic models of endogenous growth, Griliches (1992) also recognized that knowledge would spill over from the firm making the investments in new knowledge for use by third-party firms at low or no cost.

Corresponding to the explicit recognition that investments in knowledge were a driving force of economic growth, particularly because of the propensity for knowledge to spill over, the policy debate accordingly shifted away from instruments to promote physical capital and focused increasingly on knowledge capital, such as university research, R&D, and education. Policy focusing on knowledge was increasingly viewed as the key to generating economic growth.

III. The knowledge filter

As Griliches (1992) pointed out, investments in new knowledge by firms and other organizations not only generate the inputs for innovation for the organization making those investments, but also because of the propensity for knowledge to spill over, for other third-party firms as well. Such externalities are consistent with the basic properties inherent in what Arrow (1962) referred to as information. According to Arrow (1962), information is distinct from the traditional factors of production in that it is non-exclusive and non-rivalrous. Thus, not only does such information generate externalities, but it also incites what has become known as the appropriability problem for any firm generating that new information. Responding to Arrow's distinction between information and traditional factors, scholars have generated a daunting literature exploring the role of various intellectual property regimes and strategies optimally to ensure firm appropriation of its investments.

Writing back in 1962, it would have required extraordinary prescience to realize that information would become a concept distinct from knowledge. Information refers to facts that can be codified. By contrast, knowledge involves tacit ideas that not only defy codification, but whose economic value remains highly uncertain and asymmetric. The expected value of any new idea is highly uncertain, and has a much greater variance than would be associated with the deployment of traditional factors of production. After all, there is relative certainty about what a standard piece of capital equipment can do, or what an (unskilled) worker can contribute to a mass-production assembly line. However, when it comes to potential innovation, there is uncertainty about whether the new product can be produced, how it can be produced, and whether sufficient demand for that visualized new product might actually materialize.

In addition, new ideas are typically associated with considerable asymmetries. For example, in order to evaluate a proposed new idea concerning a new biotechnology product, the decision-maker might not only need to have a Ph.D. in biotechnology, but also a specialization in the exact scientific area. Differences in education, background and experience can result in divergences in the expected value of a new project or the variance in outcomes anticipated from pursuing that new idea, both of which can lead to divergences in the recognition and evaluation of opportunities between economic agents and decision-making hierarchies. Such divergences in the valuation of new ideas will become even greater if the new idea is not consistent with the core competence and technological trajectory of the incumbent firm.

Thus, the expected economic value of a new idea, or knowledge, varies significantly across economic agents. What seems like a good idea to one economic agent may not seem so good to her boss or her boss's boss. New ideas, technical or otherwise, are likely to generate a divergence of assessments about their potential value. While information tends to converge to a singular expected value across economic agents, by contrast new knowledge can generate a divergence in expected values across diverse economic agents.

Thus, because of the conditions inherent in knowledge—high uncertainty, asymmetries, and transactions costs—decision-making hierarchies can reach the decision not to pursue and try to commercialize new ideas that individual economic agents, or groups or teams of economic agents think are potentially valuable and should be pursued. The characteristics of knowledge distinguishing it from information, a high degree of uncertainty combined with non-trivial asymmetries, combined with a broad spectrum of institutions, rules, and regulations, impose what Audretsch *et al.* (2006) and Acs *et al.* (2004) term *the knowledge filter*. The knowledge filter is the gap between knowledge that has a potential commercial value and knowledge that is actually commercialized. The greater is the knowledge filter, the more pronounced is the gap between new knowledge and commercialized knowledge.

Thus, the knowledge filter serves as a barrier impeding investments in new knowledge from spilling over for commercialization. In contrast to the assumption implicit in the Romer (1986) model that knowledge will automatically spill over from the source generating that knowledge for commercialization by third-party firms, incorporation of the knowledge filter suggests that knowledge spillovers are at least partially impeded. Investments in new knowledge do not automatically spill over, thus dampening the impact that such investments in new knowledge, such as university research, R&D, and human capital, have on generating economic growth.

IV. Knowledge spillover entrepreneurship

According to the Griliches (1979) model of the knowledge production function, the firm will invest in knowledge inputs, such as R&D and human capital, in order to generate innovative output. The knowledge filter can impede such knowledge investments from resulting in commercialized new products and/or processes. In some cases the firm will decide against developing and commercializing the new ideas emanating from its knowledge investments, even if an employee, or group of employees, think they have a positive expected value. As explained above, the inherent conditions of uncertainty, asymmetries, and high transactions costs leading to the knowledge filter can result in a divergence in the expected value of a new idea between the incumbent firm or organization creating that knowledge and a worker, or economic agent employed by the firm.

While Griliches's model of the knowledge production function focuses on the decision-making context of the firm concerning investments in new knowledge, Audretsch (1995) proposed shifting the unit of analysis from the firm to the individual knowledge worker (or group of knowledge workers). This shifted the fundamental decision-making unit of observation in the model of the knowledge production function away from exogenously assumed firms to individuals, such as scientists, engineers, or other knowledge workers—agents with endowments of new economic knowledge. Shifting the lens away from the firm to the individual as the relevant unit of observation also shifts the appropriability problem to the individual, so that the relevant question becomes how economic agents with a given endowment of new knowledge can best appropriate the returns from that knowledge. If an employee can pursue the new idea within the context of the organizational structure of the incumbent firm, she has no reason to leave the firm. On the other hand, if she places a greater value on her ideas than does the decision-making hierarchy of the incumbent firm, she may face forgoing what she has evaluated as a good idea. Such divergences in the valuation of new ideas force the worker to choose between forgoing her idea or else starting a new firm to appropriate the value of her knowledge.

By focusing on the decision-making context confronting the individual, the knowledge production function is actually reversed. Knowledge becomes exogenous and embodied in a worker. The firm is created endogenously in the worker's effort to appropriate the value of his knowledge through innovative activity. Typically an employee in an incumbent large corporation, often a scientist or engineer working in a research laboratory, will have an idea for an invention and ultimately for an innovation. Accompanying this potential innovation is an expected net return from the new product. The inventor would expect compensation for his/her potential innovation accordingly. If the company has a different, presumably lower, valuation of the potential innovation, it may decide either not to pursue its development, or that it merits a lower level of compensation than that expected by the employee.

In either case, the employee will weigh the alternative of starting her own firm. If the gap in the expected return accruing from the potential innovation between the inventor and the corporate decision-maker is sufficiently large, and if the cost of starting a new firm is sufficiently low, the employee may decide to leave the large corporation and establish a new enterprise. Since the knowledge was generated in the established corporation, the new start-up is considered to be a spin-off from the existing firm. Such start-ups typically do not have direct access to a large R&D laboratory. Rather, the entrepreneurial opportunity emanates from the knowledge and experience accrued from the R&D laboratories of their previous employers. Thus, entrepreneurship is an endogenous response to opportunities created by investments in new knowledge that are not commercialized because of the knowledge filter. By resorting to the start-up of a new firm to actualize the commercialization of ideas that otherwise might remain dormant in the incumbent firm, entrepreneurship serves as a conduit for knowledge spillovers.

Knowledge created in one organizational context that remains uncommercialized owing to the knowledge filter provides an important source generating new entrepreneurial opportunities. It is new knowledge and ideas created in one context but left uncommercialized or not vigorously pursued by the organization actually creating those ideas, such as a research laboratory in a large corporation or research undertaken by a university, that serves as the source of knowledge-generating entrepreneurial opportunities. Thus, entrepreneurship can serve as an important mechanism facilitating the spillover of knowledge. The incumbent organization creating the knowledge and opportunities is not the same firm that actually exploits the opportunities. If the exploitation of those opportunities by the entrepreneur does not involve full payment to the firm for producing those opportunities, such as a licence or royalty, then the entrepreneurial act of starting a new firm serves as a mechanism for knowledge spillovers.

Thus, new knowledge generating opportunities for entrepreneurship is the duality of the knowledge filter. The higher is the knowledge filter, the greater are the divergences in the valuation of new ideas across economic agents and the decision-making hierarchies of incumbent firms. Entrepreneurial opportunities are generated not just by investments in new knowledge and ideas, but in the propensity for only a distinct subset of those knowledge opportunities to be fully pursued and commercialized by incumbent firms. Thus, entrepreneurship is important to economic growth by serving as an important conduit of knowledge spillovers.

V. Entrepreneurship capital

The existence of perceived entrepreneurial opportunities resulting from the knowledge filter may be necessary to induce knowledge spillover entrepreneurship, but it is not sufficient. Rather, barriers to entrepreneurship can impede knowledge spillover entrepreneurship. Such barriers range from legal restrictions and impediments to the existence and availability of early stage finance, or to a social and institutional tradition discouraging entrepreneurship and a stigma associated with failed attempts at entrepreneurship. The capacity of an economy to generate entrepreneurial behaviour is shaped by the extent of its underlying entrepreneurship capital.

Entrepreneurship capital should not be confused with social capital. The concept of social capital (Coleman, 1988; Putnam, 1993) injected a social component to the traditional factors shaping economic growth and prosperity. According to Putnam (2000, p. 19),

> Whereas physical capital refers to physical objects and human capital refers to the properties of individuals, social capital refers to connections among individuals—social

> networks and the norms of reciprocity and trustworthiness that arise from them. In that sense social capital is closely related to what some have called 'civic virtue'. The difference is that 'social capital' calls attention to the fact that civic virtue is most powerful when embedded in a sense network of reciprocal social relations. A society of many virtues but isolated individuals is not necessarily rich in social capital.

Putnam (2000, p. 19) extended the standard neoclassical growth model by arguing that social capital is also important in generating economic growth, 'By analogy with notions of physical capital and human capital—tools and training that enhance individual productivity—social capital refers to features of social organization, such as networks, norms, and trust, that facilitate coordination and cooperation for mutual benefits.'

However, while Putnam was providing a link between social capital and economic performance, this link did not directly involve entrepreneurship. The components of social capital Putnam emphasized the most included associational membership and public trust. While these may be essential for social and economic well-being, it is not obvious that they involve entrepreneurship, *per se*.

Thus, entrepreneurship capital is a concept distinct from social capital,[1] and involves a number of aspects such as social acceptance and valuation of entrepreneurial behaviour, along with attitudes towards risk and failure.[2] Hence, entrepreneurship capital reflects a broad spectrum of different legal, institutional, and social factors. Taken together, these factors and forces constitute the entrepreneurship capital of an economy, which shapes the capacity for entrepreneurial activity.

The relevant spatial unit for measuring entrepreneurship capital has generally been considered to be a city or region. This reflects a large empirical literature suggesting that knowledge spillovers tend to be localized within a geographically bounded region (Jaffee, 1989; Jaffee *et al.*, 1993; Audretsch and Feldman, 1996; Audretsch and Stephan, 1996). While Jaffe (1989) and Audretsch and Feldman (1996) made it clear that spatial proximity is a prerequisite to access such knowledge spillovers, they provided no insight about the actual mechanisms transmitting such knowledge spillovers. As for the Romer (1986) and Lucas (1993) models, the Jaffe (1989) and Audretsch and Feldman (1996) studies assumed that investment in new knowledge automatically generates knowledge spillovers that lead to commercialization. If knowledge spillovers are spatially bounded within close geographic proximity to the source generating that entrepreneurship, transmitting those spillovers should also be spatially bounded in that local access is required to access the knowledge facilitating the entrepreneurial start-up. Thus, knowledge spillover entrepreneurship will tend to be spatially located within close geographic proximity to the source of knowledge actually producing that knowledge.

An example of a region rich in entrepreneurship capital, Silicon Valley in California, is provided by Saxenian (1990, pp. 96–7), who observed:

[1] According to Putnam (2000, p. 19), 'Social capital refers to connections among individuals—social networks and the norms of reciprocity and trustworthiness that arise from them. In that sense social capital is closely related to what some have called "civic virtue". . . . Social capital calls attention to the fact that civic virtue is most powerful when embedded in a sense network of reciprocal social relations. . . . Social capital refers to features of social organization, such as networks, norms, and trust, that facilitate coordination and cooperation for mutual benefits.'

[2] As Gartner and Carter (2003) state, 'Entrepreneurial behavior involves the activities of individuals who are associated with creating new organizations rather than the activities of individuals who are involved with maintaining or changing the operations of on-going established organizations.'

> It is not simply the concentration of skilled labor, suppliers and information that distinguish the region. A variety of regional institutions—including Stanford University, several trade associations and local business organizations, and a myriad of specialized consulting, market research, public relations and venture capital firms—provide technical, financial, and networking services which the region's enterprises often cannot afford individually. These networks defy sectoral barriers: individuals move easily from semiconductor to disk drive firms or from computer to network makers. They move from established firms to start-ups (or vice versa) and even to market research or consulting firms, and from consulting firms back into start-ups. And they continue to meet at trade shows, industry conferences, and the scores of seminars, talks, and social activities organized by local business organizations and trade associations. In these forums, relationships are easily formed and maintained, technical and market information is exchanged, business contacts are established, and new enterprises are conceived. . . . This decentralized and fluid environment also promotes the diffusion of intangible technological capabilities and understandings.

According to Saxenian (1994), even the language and vocabulary used can be particular to the entrepreneurship capital associated with that region: 'a distinct language has evolved in the region and certain technical terms used by semiconductor production engineers in Silicon Valley would not even be understood by their counterparts in Boston's Route 128' (Saxenian, 1990, pp. 97–8).

Several studies have added measures of entrepreneurship capital to the more traditional measures of physical capital, labour, and knowledge capital, included in the Solow growth accounting framework, to link entrepreneurship to economic growth. The unit of observation for these studies is at the spatial level—a city, region, state, or, in several cases, a country. These studies have tried to link various proxy measures of entrepreneurial capital to economic growth.

Measurement of entrepreneurship capital is no less complicated than is measuring the traditional factors of production. Just as measurement of physical capital, labour, and knowledge invokes numerous assumptions and simplifications, creating a metric for entrepreneurship capital has also presented a challenge. Many of the elements that constitute entrepreneurship capital defy quantification. In any case, entrepreneurship capital, like all of the other types of capital, is multifaceted and heterogeneous. However, entrepreneurship capital manifests itself in a singular way—the start-up of new enterprises. Thus, Audretsch *et al.* (2006) propose using new-firm start-up rates as a proxy indicator reflecting what is essentially an unobservable (i.e. latent) variable. Higher levels of entrepreneurship capital are reflected by higher start-up rates, *ceteris paribus*.

Audretsch *et al.* (2006) include measures of entrepreneurship capital along with measures of physical capital, knowledge capital, and labour to estimate a production function for German regions in the 1990s. Their results confirm the positive relationships between physical capital and output, and labour and output, as suggested in the original Solow model (1956). They also find a positive relationship between knowledge capital and output, as suggested by the Romer (1986) model. In addition, entrepreneurship capital is also found to have a positive impact on regional economic growth. Holding the amount of physical capital, knowledge capital, and labour in the region constant, those regions with a greater degree of entrepreneurship capital are found to exhibit a higher level of economic growth.[3] These results suggest that, at least in the German context, those regions exhibiting a greater degree of entrepreneurship tend to have a higher level of economic performance.

There is also evidence from the United States linking entrepreneurship to economic growth. For example, Holtz-Eakin and Kao (2003) examine the impact of entrepreneurship on growth. Their spatial unit of observation is the state. Their measure of growth is productivity change over time. A vector autoregression analysis shows that variations in the birth rate and the death rate for firms are related to positive changes in productivity. They conclude that entrepreneurship has a positive impact on productivity growth, at least for the United States.

Acs and Armington (2006) similarly link the extent of entrepreneurship to growth for US regions in the 1990s. Their evidence shows that, even after controlling for agglomeration effects, those regions with higher entrepreneurial activity exhibited higher growth rates.

The relationship between entrepreneurship and economic growth at the country level is examined by Acs *et al.* (2004). Using OECD country-level data for the 1990s, they find that, holding constant measures of physical capital and knowledge capital, those countries exhibiting higher rates of growth also had higher rates of entrepreneurship.

Thus, considerable empirical evidence is mounting identifying a positive relationship between entrepreneurship and economic growth. This relationship has been found to hold at the regional level for several countries, as well as in a panel of OECD countries. The empirical results are consistent with the view that, by serving as a conduit for knowledge spillovers, entrepreneurship is conducive to economic growth.

VI. The emergence of entrepreneurship policy

Economic growth policy centred on instruments to promote investment in physical capital during the post-war era. This corresponded with the interpretation of the original Solow (1956) model that physical capital was the driving force of economic growth. For example, Charlie 'Engine' Wilson, the one-time General Motors top executive, who went on to become the secretary of defence under President Dwight D. Eisenhower, was widely quoted as declaring, 'What's good for General Motors is good for America.'[4] It seemed to be a capital-driven economy. At the macroeconomic level, public policy revolved around instruments to induce investments in physical capital. At the microeconomic, or industry level, this was the era of targeting of capital-intensive industries in Japan and industrial policies to enhance the competitiveness of capital-intensive industries in Europe.

Public policy towards small firms and entrepreneurship generally reflected the view of economists and other scholars that they were a drag on economic efficiency and growth, generated lower-quality jobs in terms of direct and indirect compensation, and were generally threatened by long-term extinction. Some countries, such as the former Soviet Union, but also Sweden and France, adopted the policy stance of allowing small firms to disappear gradually and account for a smaller share of economic activity.

[3] The positive relationship between entrepreneurship capital and economic growth holds even when the measure of entrepreneurship capital is also estimated endogenously as an instrumental variable.

[4] In fact, Halberstam (1993, p. 118) points out, 'That is what he probably thought, but what he actually said was: "We at General Motors have always felt that what was good for the country was good for General Motors as well."'

The public policy stance of the United States reflected long-term political and social valuation of small firms that seemed to reach back to the Jeffersonian traditions of the country. After all, in the 1890 debate in Congress, Senator Sherman vowed:

> If we will not endure a King as a political power we should not endure a King over the production, transportation, and sale of the necessaries of life. If we would not submit to an emperor we should not submit to an autocrat of trade with power to prevent competition and to fix the price of any commodity.[5]

Thus, in the post-war era, small firms and entrepreneurship were viewed as a luxury, perhaps needed by the West to ensure a decentralization of decision-making, but in any case obtained only at a cost to efficiency. Certainly the systematic empirical evidence, gathered from both Europe and North America, documented a sharp trend towards a decreased role of small firms during the post-war period.

Public policy towards small firms and entrepreneurship in the United States was oriented towards preserving what were considered to be inefficient enterprises, which, if left unprotected, might otherwise become extinct—for example, in creating the US Small Business Administration. In the Small Business Act of 10 July 1953, Congress authorized the creation of the Small Business Administration, with an explicit mandate to 'aid, counsel, assist and protect. . . the interests of small business concerns'.[6] The Small Business Act was clearly an attempt by the Congress to halt the continued disappearance of small businesses and to preserve their role in the US economy.

Nor did small firms and entrepreneurship seem to play any important role with the addition of knowledge capital to the traditional factors of physical capital and labour in growth models. Commensurate with the new emphasis on knowledge as a factor of production, instruments fostering the creation of new knowledge, such as industry R&D, university research, intellectual property protection, education, and human capital enhancement, became central to economic growth policy (Romer, 1986; Lucas, 1993), but there did not seem to be any apparent role for small firms and entrepreneurship.

For example, writing in the *Harvard Business Review* shortly before the fall of the Berlin Wall, Ferguson (1988, p. 61), argued that entrepreneurship would actually reduce rather than increase economic growth. He condemned entrepreneurship in the Silicon Valley context for imposing a drag on economic performance,

> because the fragmentation, instability, and entrepreneurialism are not signs of well-being. In fact, they are symptoms of the larger structural problems that afflict US industry. In semiconductors, a combination of personnel mobility, ineffective intellectual property protection, risk aversion in large companies, and tax subsidies for the formation of new companies contribute to a fragmented 'chronically entrepreneurial' industry. US semiconductor companies are unable to sustain the large, long-term investments required for continued US competitiveness. Companies avoid long-term R&D, personnel training, and long-term cooperative relationships because these are presumed, often correctly, to yield no benefit to the original investors. Economies of scale are not sufficiently developed. An elaborate infrastructure of small subcontractors has sprung up in Silicon Valley. Personnel turnover in the American

[5] Quoted from Scherer (1970, p. 980).
[6] http://www.sba.gov/aboutsba/sbahistory.html

> merchant semiconductor industry has risen to 20 per cent compared with less than 5 per cent in IBM and Japanese corporations. . . . Fragmentation discouraged badly needed coordinated action—to develop process technology and also to demand better government support.

Despite the policy implications commensurate with the endogenous growth models, policy-makers increasingly discovered that investments in knowledge capital provided no panacea for stagnant economic growth and sustained high levels of unemployment. For example, throughout the post-war era, Sweden has consistently ranked among the highest in the world in terms of investments in new knowledge. Whether measured in terms of private R&D, levels of education, university research, or public research, Sweden has exhibited strong and sustained investments in knowledge. As recently as 2003, Sweden had the highest share of GDP invested in R&D in the world. Yet, with such massive investments in knowledge, the return in terms of employment creation and economic growth has been modest, at best, and disappointing to the Swedish public policy community. The persistence of stagnant economic growth and rising unemployment, even in the face of substantial and sustained investments in new knowledge, led policy-makers in Sweden to coin a new term—'the Swedish Paradox'. Similar examples of high investments in new knowledge combined with a persistently low performance in terms of economic growth and unemployment could be found throughout Europe, spanning Germany and France, leading the European Union to adapt the term for the European failure adequately to commercialize her massive investments in new knowledge—the European Paradox.

As described in the above section, it is the knowledge filter that impedes investments in knowledge from spilling over for commercialization that leads to the so-called Swedish Paradox and European Paradox. Examples of high investments in knowledge but a low growth performance are not restricted to Europe. An Asian example is Japan. Investments in private R&D and human capital have ranked among the highest in the world. Still, Japan has been bogged down with low and stagnant growth for over a decade. It would seem that Europe does not have a monopoly on the European Paradox.

The United States has also not been able to avoid the knowledge filter. In fact, the knowledge filter impeding the commercialization of investments in research and knowledge can be formidable. As Senator Birch Bayh warned, 'A wealth of scientific talent at American colleges and universities—talent responsible for the development of numerous innovative scientific breakthroughs each year—is going to waste as a result of bureaucratic red tape and illogical government regulations.'[7] It is the knowledge filter that stands between investment in research on the one hand, and its commercialization through innovation, leading ultimately to economic growth, on the other.

Seen through the eyes of Senator Bayh, the magnitude of the knowledge filter is daunting, 'What sense does it make to spend billions of dollars each year on government-supported research and then prevent new developments from benefiting the American people because of dumb bureaucratic red tape?'[8]

[7] Introductory statement of Birch Bayh, 13 September 1978, cited from the Association of University Technology Managers Report (AUTM, 2004, p. 5).

[8] Statement by Birch Bayh, 13 April 1980, on the approval of S. 414 (Bayh–Dole) by the US Senate on a 91–4 vote, cited from AUTM (2004, p. 16).

In an effort to penetrate such a formidable knowledge filter, the Congress enacted the Bayh–Dole Act in 1980 to spur the transfer of technology from university research to commercialization.[9] The goal of the Bayh–Dole Act was to facilitate the commercialization of university science. Assessments about the impact of the Bayh–Dole Act on penetrating the knowledge filter and facilitating the commercialization of university research have bordered on the euphoric:[10]

> Possibly the most inspired piece of legislation to be enacted in America over the past half-century was the Bayh–Dole Act of 1980. Together with amendments in 1984 and augmentation in 1986, this unlocked all the inventions and discoveries that had been made in laboratories through the United States with the help of taxpayers' money. More than anything, this single policy measure helped to reverse America's precipitous slide into industrial irrelevance. Before Bayh–Dole, the fruits of research supported by government agencies had gone strictly to the federal government. Nobody could exploit such research without tedious negotiations with a federal agency concerned. Worse, companies found it nearly impossible to acquire exclusive rights to a government-owned patent. And without that, few firms were willing to invest millions more of their own money to turn a basic research idea into a marketable product.[11]

An even more enthusiastic assessment suggested that,

> The Bayh–Dole Act turned out to be the Viagra for campus innovation. Universities that would previously have let their intellectual property lie fallow began filing for—and getting—patents at unprecedented rates. Coupled with other legal, economic and political developments that also spurred patenting and licensing, the results seems nothing less than a major boom to national economic growth.[12]

As the traditional policy instruments focusing on either physical capital or knowledge capital failed to generate sustainable economic growth, employment, and competitiveness in globally linked markets, policy-makers began to look elsewhere. The political mandate for entrepreneurship capital was to replace or at least augment physical capital, and augment knowledge capital with the missing link—a mechanism facilitating the return on investments made in knowledge that were not being accrued in terms of economic growth and employment by those regions making such knowledge investments. That missing link is entrepreneurship capital.

Schumpeter (1911) had identified entrepreneurship as triggering creative destruction, where the new start-ups displace the large incumbent corporations through innovative activity. However, in a global economy, the destruction of jobs is more typically the result of globalization-induced downsizing, outsourcing, and offshoring. By contrast, because it serves as a conduit of knowledge spillover from investments that might otherwise not have

[9] Public Law 98–620.

[10] Mowery (2005, pp. 40–1) argues that such a positive assessment of the impact on Bayh–Dole is exaggerated, 'Although it seems clear that the criticism of high-technology startups that was widespread during the period of pessimism over US competitiveness was overstated, the recent focus on patenting and licensing as the essential ingredient in university–industry collaboration and knowledge transfer may be no less exaggerated. The emphasis on the Bayh–Dole Act as a catalyst to these interactions also seems somewhat misplaced.'

[11] 'Innovation's Golden Goose', *The Economist*, 12 December 2002.

[12] Mowery (2005, p. 64).

become commercialized, entrepreneurship contributes to growth. Schumpeter's penetrating analysis was generally restricted to a single, closed economy. But in the globalized economy of this century, entrepreneurship may be more about creative construction in that it elevates the return from (knowledge) investments already made. Perhaps this is why entrepreneurship policy has emerged and diffused so quickly throughout the OECD countries. The public policy challenge confronting the leading developed countries in the global era has become how to generate an adequate return in terms of economic growth and employment creation from the massive investments in new knowledge. Entrepreneurship policy has emerged as an attempt to meet that challenge.

Whether or not specific policy instruments will work in their particular contexts is not the point of this paper. What is striking, however, is the emergence and diffusion of an entirely new public policy approach to generate economic growth—entrepreneurship policy.

VII. Conclusions

The seminal contribution of Robert Solow (1956) served formally to link the most salient factors of production to economic growth. His model of growth accounting provided a timeless framework not just for analysing economic growth but also for focusing and framing the ensuing public policy debates.

This paper has shown how Solow's model was sufficiently general and flexible to absorb changes in the world that would have been unimaginable in 1956—the end of communism, the emergence of personal computers and the Internet, and globalization, to name just a few. The Solow growth accounting framework has demonstrated a remarkable robustness to decipher how and why growth policy has evolved over time. The policy focus on instruments to induce investments into physical capital corresponded best to the era in which the original article was published. As globalization shifted the comparative advantage of the advanced industrial nations away from the factor of physical capital and towards knowledge capital, the focus of the growth debate accordingly shifted towards instruments to promote investments in knowledge capital, such as R&D, education, and university research.

This paper has explained the emergence of an additional factor that is important for economic growth—entrepreneurship capital. The knowledge filter impedes the spillover of knowledge investments from automatically resulting in commercialized new products and processes and therefore growth. As the European Paradox suggests, knowledge investments alone will not guarantee high growth and a reduction of unemployment.

Public policy has responded with a new focus on a factor of production not discussed in Solow's original paper—entrepreneurship capital. A growing consensus among policy-makers has emerged that investment in new economic knowledge alone will not guarantee economic growth. Rather, key institutional mechanisms are a pre-requisite for such knowledge investments to become transmitted and transformed into economic knowledge, through the process of spillovers and commercialization. Entrepreneurship has emerged as a driving force of economic growth by serving as an important conduit of knowledge spillovers and commercialization.

Thus, as knowledge has become more important as a factor of production, knowledge spillovers have also become more important as a source of economic growth. Entrepreneurship capital takes on new importance because it serves as a key mechanism by which knowledge created in an existing incumbent organization becomes commercialized in a new enterprise, thereby contributing to the economic growth, employment, and vitality of the overall economy.

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