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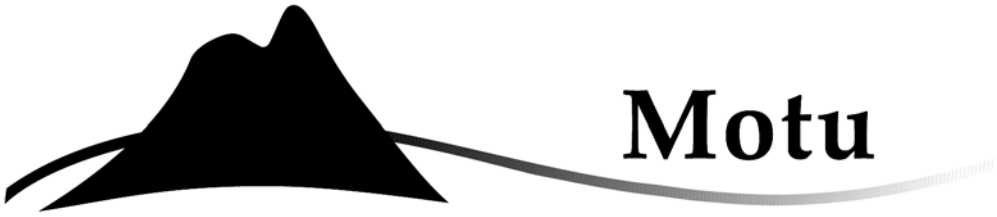

Ideas for Growth?

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Abstract

There is much talk of the knowledge economy, and the central role of ideas and knowledge in generating economic growth. This paper provides a brief review of the economic literature on how skills/ knowledge/ ideas might contribute to higher output or higher rates of growth. Ideas are complementary inputs into production, in the sense that they raise the productivity of other inputs. Some of the complementarities may give rise to externalities—effects that do not have to be paid for. For investments in ideas to generate output growth, these complementarities must be particularly strong. I conclude with some comments on what policy makers can draw from the literature, which is some encouragement but little specific guidance.

JEL classification
E10—General aggregative models—General
O40—Economic growth and aggregate productivity—General

Keywords
Economic growth; Endogenous growth models; Innovation

1 Introduction

There is much talk of the knowledge economy, and the central role of ideas and knowledge in generating economic growth. There may even be some substance behind some of the claims. There are certainly many stories and theories about how such a link may operate. In fact, there are so many different stories that one might be seduced into uncritical acceptance of the general point, even if no single story has been proven. The lack of discrimination between different mechanisms may result in a view that "more is better"—running the risk of having too much investment in ideas, or of investing in the wrong sorts of ideas.

Of course, if we can identify investments that raise the growth rate rather than just the level of economic activity, the implied return on those investments would make them very attractive. Who would not spend a little extra today to generate exponentially higher living standards for future generations?

The existence of a number of relatively recent reviews of human capital and growth[1] is evidence of a keen interest in the issue, within both the economics and policy communities. At the risk of glossing over the distinct contributions of the various papers, the general impression that one gains is that the theoretical approaches to modelling links between human capital and growth have managed to find convenient functional forms to generate a positive relationship, but that the empirical evidence is circumstantial, contentious, or both. There is more than a hint of scepticism about some of the empirical findings, even among those who argue for the existence of a link.

This paper contains a non-exhaustive summary of issues relevant to the discussion of human capital and growth, focusing primarily on insights and evidence from economics. My intention is to provide a non-technical discussion that is accessible to policy advisers, highlighting some of the key analytical distinctions.

[1] I have found the papers by Rebelo (1998), Gemmell (1999), Topel (1999), Sianesi and van Reenen (2000), Temple (2001), Dowrick (2003), and Romer (1994) helpful.

I use the terms "human capital", "ideas" and "knowledge" interchangeably, and somewhat loosely. Education is a commonly used empirical proxy because it is more readily observed and measured than are ideas, knowledge and human capital. Some writers use the term human capital to mean only investments in skills or knowledge that are embodied in an individual. This restriction blurs when we admit the possibility of spillovers (unpriced positive side-effects), or if we accept that human capital investment consists of ideas and knowledge. In essence, I regard any form of learned knowledge, skill, ideas, or education that can generate a stream of future benefits for an individual as human capital.

My discussion starts with a brief account of how ideas can raise the level of output. I then consider the forms and implications of externalities arising from ideas, and finally comment on what is required for investments in human capital to generate a sustained increase in growth rates. In general, it seems that there are too many stories chasing too few facts.

2 Ideas and the *level* of output

A key question in the discussion of the links between human capital and growth is whether a higher level of aggregate human capital raises the *level* of income, or whether it can generate *sustained* increases in the *growth* rate.

Ideas are a productive input to production. Human capital theory formalises this statement by modelling decisions about investment in ideas, and the consequent flow of benefits. For individuals, countless Mincerian[2] wage equations show a positive relationship between earnings and human capital investments (in the form of schooling and experience).[3]

[2] The naming reflects Jacob Mincer's pioneering work in the empirical analysis of human capital models. See Mincer (1974).

[3] There is still, however, considerable debate about the exact size of this effect, and on the best way to obtain unbiased estimates of it. See, for instance, the discussion of education returns in Card (1999). For New Zealand studies on the return to education and qualifications, see Maani (1999), Maani (2000), Gibson (2000), Dixon (1996), and Dixon (1998).

For firms, there are positive returns to investments in new ideas, in the form of research and development (R&D) expenditures. It is therefore highly likely that, at an aggregate level, an increase in the *level* of education or R&D will yield a higher *level* of income.[4]

In a standard human capital model, there are limits to how much investment is desirable. A combination of rising marginal costs and/ or diminishing marginal returns means that beyond some "optimal" level of human capital, the costs of further investment outweigh the rewards to that investment.[5]

We can apply standard production theory to model the way that human capital interacts with other productive inputs. The presence of a greater amount of a complementary input raises the marginal product of human capital. For instance, skilled labour and capital are complements, meaning that skilled labour is more productive when combined with capital inputs. Similarly, research and development expenditures are more productive when combined with skilled labour or capital.

If such complementarities are sufficiently strong, knowledge and other inputs could grow together, without any decline (or rise!) in marginal returns. Formally, this condition is captured with the assumption of constant returns to scale. Doubling all inputs doubles output.[6]

In the standard Swan-Solow neoclassical growth model, aggregate production is modelled as a function of capital and labour. Furthermore, capital is the only factor that can be accumulated, so capital investments are the only accumulation decision that is endogenous (determined within the model).

[4] It is possible that, at very high levels of education, the costs of additional educational investments will outweigh the benefits, due to rising marginal costs and/ or declining marginal returns.

[5] For instance, Ben-Porath (1967) obtains the essential features of the model with constant marginal returns and rising marginal (opportunity) costs.

[6] Rising marginal costs of investment could put a stop to this growth if investment costs (or the productivity of investments) rise with the stock of inputs. In this case the (constant) marginal returns will be insufficient to justify continued investment in one or other of the factors. We will see in Section 4 how these limits can be overcome (at least for the purpose of economic modelling!) by appropriate assumptions.

The accumulation of capital determines the economy's growth trajectory towards the unique steady state. Ideas play no part in the standard formulation. The number of workers is taken as given, possibly with some deterministic growth rate. Any additional growth is treated as "technical change". Investments in education, knowledge and ideas are all subsumed in the technical change term.

Mankiw et al. (1992) added human capital as an additional input to the neo-classical growth model, and endogenised investments in human capital as well as those in physical capital. The resulting model does a better job than the Swan-Solow model of explaining cross-country growth variation, and of generating plausible parameters. Their model is still, however, in the neoclassical growth model tradition, and consequently maps out a growth path towards a unique steady state. Along this growth path, both the capital stock and the human capital stock grow—albeit at decreasing rates, due to overall diminishing returns to the factors that can be accumulated (physical and human capital). Investments in knowledge move the economy closer to the steady state, especially when the stock of knowledge is low, but cannot generate sustained increases in growth. As such, knowledge accumulation has a level effect only, albeit one that may take many years to effect.[7]

Once we take account of the fact that human capital is not homogeneous, the structure of the level effects can become more complex. For instance, low-skilled labour and capital are generally found to be substitutes,[8] meaning that an increase in one lowers the marginal productivity of the other. More generally, we can think of a team of workers contributing different types of ideas to the production process, so the return on ideas will depend on what other idea inputs are present. Knowing where someone works can explain about the same amount of earnings variation as knowing someone's individual characteristics (Abowd and Kramarz (1999)).

[7] The structure of the model implies that the growth rate is ever-decreasing, and it would thus take an infinite time to reach the steady state!
[8] Hamermesh (1993).

As a general principle, returns are higher when complementary inputs are present. In teams, it is usually desirable to have a mix of junior and senior team members. At least within some range, an increase in the number of senior team members will increase the productivity of the juniors. Similarly, an increase in the number of junior members will make the seniors more productive. A similar principle suggests that a mix of general and specialist skills may be preferred to a homogeneous workforce. At an aggregate level, this is one of the key principles in designing immigration policies—immigrants should have a skill mix that is different from (and complementary to) that of current residents.

The range of ways that knowledge can complement other inputs is broader than for inputs other than knowledge and ideas. This is true because of particular characteristics of knowledge. For a start, knowledge is non-rival. If I tell you something I know, I don't (necessarily!) forget it. Having people around with knowledge lowers the cost to others of investing in knowledge. The transfer of knowledge between skilled workers was commented on as far back as 1890 (Marshall (1920)).

Jacobs (1969) emphasises the process of generating new ideas by combining existing knowledge. Interactions between people (especially people with high human capital) can generate new ideas that can lead to increased productivity. If the expected benefits of such interactions are rewarded directly (as would be the case if research team members received salaries that reflected the expected value of innovations), such interactions don't generate externalities. The generation of new ideas in this way by increasing the overall stock of human capital will offset diminishing marginal products (as will any form of complementarity) but will not generate sustained growth (through increasing returns) unless it reverses the decline in marginal products.

Investments in research and development are similarly "generative" in that they create new ways of doing things or discover new things to do, raising the productivity of other workers (and capital). The stock of knowledge arising from research and development investments can be included as an input into production—one that can be complementary with one or more other factors.[9]

High levels of knowledge may also contribute to productivity of other factors by promoting the division of labour. Smith (1904) emphasised the advantages of specialisation, and noted that the extent of the market limited the scope for specialisation. Becker and Murphy (2001) note that costs of coordination may also limit specialisation, and move the balance in favour of having more generalist skills. Uncertainty about the type of skills and knowledge needed for the future would also reduce the attractiveness of specialisation. General rather than specialised skills provide a type of risk-pooling against skill obsolescence.

In summary, there is a wide variety of ways that your investments in knowledge or ideas can raise the return to my investments. Dowrick (2003, p. 7) refers to this as "complementarity of investment" and states that "complementarity is probably more pervasive in the accumulation of skills than in the accumulation of objects. Indeed such complementarity is an essential ingredient in the development of social capital". In this context, social capital can be characterised as a source of complementarity. It lowers the cost of coordinating activities (e.g. through shared knowledge or trust), and the costs of investing are lowered if social capital can be acquired during almost all interactions with others.

[9] Acemoglu (2002) examines (inter alia) the possibility that research and development that is complementary with skilled labour might have supported the increase in skill premia in recent decades.

3 Level effects with externalities ("spillovers")

The existence of complementarities is sometimes (wrongly) used as *a priori* evidence of an externality, and hence as a justification for welfare-enhancing policy interventions. In some cases, the argument for the existence of an externality is reasonable, although it is difficult to isolate external effects from other observationally equivalent phenomena such as selection.[10]

3.1 Private v social returns

The discussion in the previous section described complementarity mechanisms, but without any mention of whether the effects were internalised. In at least some of the cases described, it is feasible that the complementarities are reflected in prices. For instance, a firm may hire highly skilled workers in large part for the positive effect that they will have on the productivity of other workers (e.g. through knowledge transfer). The firm would be willing to pay the skilled worker for the marginal effect that they have on firm productivity, in which case there would be no externality involved.

In many cases, it is harder to see how the private returns to an individual's investments in knowledge will be equated with the social returns. For instance, if knowledge transfers or ideas generation occur at the level of the city (rather than within firms), highly skilled individuals are unlikely to capture the full benefits of their contribution. It would be socially beneficial to effect marginal increases in knowledge acquisition, as long as the marginal social benefit exceeds the marginal social cost of further investment.[11]

[10] For discussions and analyses of knowledge-based external effects, see Lucas (1988), Glaeser et al. (1992), Acemoglu and Angrist (2000b, (2000a), Rudd (2000), Brock and Durlauf (2001), Battu et al. (2001), Ciccone and Peri (2002), Hoxby (2000), Borjas (1995), and Manski (2000).

[11] Without intervention, marginal private benefits equal marginal private costs and marginal social benefits are greater than marginal private benefits. Unless the social marginal cost similarly exceeds the private marginal cost, an increase in investment is justified. Of course, the marginal social cost may be higher than the marginal private cost. This is more likely if expanding knowledge must be financed through distortionary taxes.

Similarly, it would be difficult for individuals to capture the full benefits of their impact on peer or neighbourhood effects. Hoxby (2000), discussing classroom peer effects, claims that peer effects are "by definition, externalities". One final example is that of research and development investments. New discoveries are the platform from which further discoveries are made. The ideas are (patents notwithstanding) non-rival. Furthermore, the knowledge occurs as "disembodied human capital" (Romer (1990)), meaning that it exists permanently and independently of the individuals who created it.

3.2 Where might spillovers arise?

It is difficult to make general statements about whether social returns to knowledge exceed private returns, since spillovers are difficult to isolate empirically. The following section sketches a few (fairly randomly chosen) examples of how complementarities and spillovers may arise at different levels of aggregation. While clearly related, analyses at the different levels have evolved more or less separately, making for a somewhat disjointed set of "accepted wisdoms" about where to look for spillovers.

3.2.1 For individual agents

Complementarity of different forms of knowledge can occur for particular individuals. By definition, the relationships are internalised. Lazear (2002) analyses the degree of specialisation in individuals' skill-sets. People in entrepreneurial roles tend to gain a set of complementary skills, whereas specialists rely on skill complementarity that occurs between them and others and which takes place at the level of the firm or above. Complementarity of skills is also evident at the level of the individual if we consider different forms of literacy. Chapple and Maré (2000), for instance, find evidence of complementarity between three forms of literacy, which is evident in higher wages or employment chances.

3.2.2 Classrooms

There is a well-established literature analysing peer effects that occur in school classrooms. This is relevant to the policy/ school design issue of whether to stream[12] students by attributes such as ability or gender. Externalities arise if a student's performance depends on class composition.[13] The link to aggregate externalities is a bit subtle. As Hoxby (2000) notes, externalities that arise at the level of the classroom may not generate an aggregate externality—streaming is a zero sum game,[14] unless the relationship between individual and class performance is non-linear.[15]

3.2.3 Between firms and industries

A firm's R&D investments are likely to generate knowledge that is of use to other firms in the same line of business. The firm will not, however, capture all the benefits of discoveries, and so will under-invest. A similar dynamic applies to industry-specific training. High investment in knowledge facilitates specialisation—possibly across industries. The benefits of this specialisation will thus accrue to firms in industries other than the one in which the specialised labour or knowledge is generated, again leading to under-investment. In any of these cases, the "social" return (measured across firms) to investments will be greater than the "private" (firm) return.[16]

3.2.4 Within locations: Economic geography/urban economics

There is a good deal of literature attempting to model and estimate the extent of knowledge externalities (generally proxied by education) for geographic areas, usually the city or state. The general approach is to see if a city-level measure of educational attainment has any explanatory power, once individual returns have been taken into account.

[12] Also referred to as "tracking" in the literature.
[13] There is evidence of such a relationship occurring. See the review in Hoxby (2000).
[14] Positive externalities are exactly balanced by associated negative externalities. Moving a positive-externality-generating student from one classroom to another does not change the size of the externality—only who benefits from it.
[15] See also Benabou (1996).
[16] Dowrick (2003) reports the findings of studies that show high estimated returns to research and development expenditures, as well as even higher returns at the country or cross-country level.

Recent work by Acemoglu (1999) and Ciccone and Peri (2002) finds little evidence to support externalities, and concludes that previous positive findings were capturing the impact of production complementarities and supply changes.

Localised externalities may also occur for firms. Research and development externalities have also been found to be localised. Similarly, clusters of firms appear to have higher productivity than they would if they were more dispersed. External effects constitute one of the possible explanations. Similar patterns could also arise from proximity to suppliers or customers, or from "thick labour markets".[17]

3.2.5 Economy-wide

If external effects are widespread, we would expect that social rates of return would exceed private rates of return. The general approach to estimating social rates of return (OECD (1998), Maani (1999)) produces a lower bound on social returns, since it excludes any spillover effects of education—the very effects that are of greatest interest in the current paper.[18] Studies estimating social rates of return in this way usually find rates that are *lower* than private rates of return. Such a finding would be consistent with overinvestment, or with educational qualifications being primarily a signalling device. The evidence from studies that try to pin down spillovers suggests that there are external effects from education, implying that the usual social return estimates are biased downward. For instance, the relationship between education and output appears to be higher at higher levels of aggregation (e.g. economy-wide as opposed to individual or firm-level).[19]

[17] See Henderson (1999) or Krugman (1999).
[18] Estimated social rates of return usually calculate the lifetime internal rate of return on educational investments, net of educational expenditures, and before tax.
[19] This inference is my overall judgement from a reading of a literature containing a wide range of findings. Many reasonable people would disagree.

4 Growth effects (non-decreasing returns)

To find a link between growth and human capital, we need to look beyond level effects. Modelling investment behaviour provides a first link. Intuitively, we can regard human capital as an input into an aggregate production function. At low levels of human capital, the marginal return to investment would be high. As the level of human capital increases, we would expect the marginal return to decline, slowing growth. Investments in other productive inputs (such as physical capital) would temper the impact of diminishing returns on human capital.

There is one special case in which investments in human and physical capital occur together in a way that overcomes diminishing returns. For human capital investments to generate *sustained* growth, we need a particular form of production relationship—one that captures constant (or increasing) returns to scale in factors that can be accumulated. In terms of the sort of complementarities that have just been discussed, we need these to be strong enough to outweigh diminishing returns. As Dowrick (2003) notes, some form of "dynamic feedback" is necessary.

The macroeconomic growth literature has captured these strong complementarities in various ways. An early approach was to simply write down a production function that captured decreasing returns to capital (which could be broadly construed to include human capital—basically anything that could be accumulated) at the firm level, but interactions that were powerful enough to generate non-decreasing returns at the aggregate level.[20]

[20] The production function can be written as $Y = A K^{\alpha} N^{(1-\alpha)} (\overline{K})^{(\gamma)}$ where $\overline{K}$ is the aggregate stock of capital and $\alpha + \gamma = 1$ where there are constant returns to scale. Each firm faces decreasing returns to the capital that it can accumulate (K), but returns are increasing overall.

The subsequent endogenous growth literature has examined in more detail what might lie behind such interactions, and how such interactions might exist in a competitive equilibrium. A number of plausible mechanisms have been identified:[21]:

- Knowledge spillovers within industries (Marshall-Arrow-Romer (MAR) knowledge externalities): Knowledge is shared—as the greater the shared stock of knowledge, the more productive is any given individual's productivity.
- *Knowledge spillovers between industries* (Jacobs-type innovation externalities): Productive new ideas arise as a result of interactions between existing ideas. Scale increases the productivity of interactions.
- Learning by doing (*capital stock spillovers*): Capital inputs are more productive in the presence of a high stock of "disembodied" human capital in the form of technologies. These spillovers may also arise due to specialisation of production, which is limited by the extent of the market.
- Learning by doing (*human capital stock spillovers*): Human capital is more productive in the presence of a high stock of knowledge ("embodied" human capital). These spillovers may also arise due to specialisation of knowledge, which is limited by the extent of the market.
- Learning by doing (*product range spillovers*):
    - Expanding variety: Having a larger range of goods lowers the cost of developing new products (Romer (1990)).
    - Quality ladders and patent races: Grossman and Helpman (1991)) and Aghion and Howitt (1992)) model the development of new goods and the replacement of old ones. Firms have the option of improving the quality of old goods. The potential for doing this is related to the existing range of goods.

[21] Aghion and Howitt (1998) summarises many of the models. Rebelo (1998) also contains a useful set of summaries and discussion. Some of the formal models are consistent with more than one interpretation.

4.1 Evidence

The literature tells us about what sort of relationships or mechanisms would be needed to generate a relationship between the level of knowledge and the growth in output. In particular, there would need to be a high degree of complementarity, which can generate non-decreasing returns in the long run. There are some formally modelled examples of candidate mechanisms but beyond that, the literature is less instructive.

In particular, there is not much guidance on which are the most important or realistic forms of interaction. The theoretical literature has focused on formalising types of interactions that might generate the necessary interactions. The empirical literature has sought to find (often circumstantial) evidence of such interactions, and has so far not been very convincing in isolating the actual mechanisms. Even simple estimates of the growth benefits of education are "imprecisely measured" (Temple (1999, p. 152)). Cautious reviews of the empirical findings in the literature can be found in Temple (2001) and Gemmell (1999), both of which also summarise the problems of drawing causal inferences from the existing studies.

5 Policy choices

To develop policies that might be able to "correct" allocation problems arising from externalities, or to harness the potential that may exist from increasing returns, one would ideally want to be fairly specific about the type of externality, and where it occurs. This is probably asking too much of the literature. Temple, in his review article, notes that:

> "Arcane discussions about the validity of endogenous growth theories are likely to frustrate the policymaker in search of knowledge that can be put to good use. Those forming policies would ideally like to find a set of instructions that is short, clear and easy to implement. It is a foolhardy researcher who responds to this desire by condensing many books and articles into a one paragraph summary, but somebody perhaps ought to try. A quick overview of why growth rates differ is a useful way to close.

> A key reason why growth rates differ across countries is that macroeconomic stability differs across countries. This effect partly acts through capital investment, and equipment investment may have a special role. As yet the growth benefits of education are imprecisely measured."
>
> Temple (1999, p. 152)

A (not uncommon, but often implicit) alternative response to the lack of precise prescriptions is to be persuaded by the overall plausibility of the various externality arguments, and use either a "shotgun" approach (induce some expansion of knowledge investments for a number of plausible types of knowledge), or a "blunt instrument" approach of encouraging more investment without picking any particular forms of investment. Given the uncertainty about the precise mechanisms, these may be sensible approaches.

5.1 Dimensions of choices for policy designers

A greater understanding of (or judgements about) which particular forms of complementarity or dynamic feedbacks lie behind hypothesised growth effects would help policy designers to choose interventions to target the right forms of knowledge or ideas. Choices could then be made along a number of dimensions. The following three dimensions seem to me to be relevant ones. They do not arise directly from the literature(s) discussed above, but are included here to help focus questions about the nature of skill interactions and policy.

Level

Should interventions be aimed at raising the top end of the knowledge distribution or the bottom? Either could conceivably contribute to greater specialisation. Knowledge transfers are more likely if the focus is on the top.

Specificity

Should general or specific knowledge be encouraged? There are benefits of specialisation, but also advantages in having a high level of general skills to aid coordination, insure against risky specialisation, and combat limits to specialisation that arise due to the extent of the market.

Timing

Should interventions be targeted earlier or later in life? This decision depends on the complementarity between different forms of knowledge and learning. How much does a sound basic education lower the costs of subsequent learning? Alternatively, are there complementarities between experience and learning, or skills obsolescence that would justify lifelong learning?

5.2 Are level effects good enough?

The assumptions required to justify a macroeconomic relationship between sustained growth and human capital are fairly particular. Finding credible evidence of complementarities at various levels seems more realistic. If policy were to be targeted at complementarities rather than at growth, it could still generate increases in productivity over probably fairly prolonged periods. Temple notes that:

> "Either growth is endogenous, or it is exogenous and level effects are large. Given the presence of large level effects, distinguishing between exogenous and endogenous growth models is not as pressing as it might seem. The important point is that policy can have a major impact on a country's level of welfare. As pointed out earlier, the debate on whether policy affects the long run growth rate or just the steady state level of income is almost impossible to resolve, and not much of practical importance will turn on it."
>
> Temple (1999, p. 152)

Policies to pursue aggregate level effects will be even more beneficial if their impact is on growth as well as on levels. There is also evidence of 'wider benefits of learning",[22] which would tend to increase payoffs.

Policies to promote clustering, relieve skill shortages, or promote investment could be seen as harnessing complementarities and not even necessarily targeting any particular form of spillover. For instance, addressing current "skill shortages" through training or immigration may be interpreted as encouraging investment in inputs that are in relatively short supply and for which

[22] See, for instance, http://www.learningbenefits.net/.

the marginal return is therefore great. Increasing the stock of skilled labour would raise the productivity of other inputs.

The average expected benefits of this sort of "blanket" policy approach may, however, be small, and must be weighed against the possibility that loosely targeted policies may impose significant costs. For instance, even though skilled labour and capital are, on average, complements, encouraging the wrong sort of skilled labour may be ineffective in raising the productivity of other inputs. It will nevertheless be costly, and will reduce the resources that are available for stronger sources of complementarity benefits. Similarly, raising skills across the entire workforce may be a very costly way to generate level or growth effects if these arise for only a small subset of skills.

As always, it is possible to have too much of a good thing. Unless there really are non-decreasing returns to knowledge investments (which seems unlikely except over a possibly small range at low levels of knowledge), rising marginal costs of investment will mean that there are limits to how much can be achieved without imposing unjustified costs on other parts of the economy.

Policy makers and their advisers searching for ways to stimulate growth (whether sustained or not) can find some encouragement but little specific guidance in the literature reviewed here. Judgements will still need to be made about which forms of complementarity or spillover are most likely to have positive impacts, and about the scale and scope of any proposed intervention.

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