What is Impact Assessment? Mechanisms

1. Mechanisms of "impact"

The discussion in the previous section implies that the idea of "impact" is problematic. It imposes an idea of linearity on a more complex reality and it suggests that research is somehow the root cause of changes in society and the economy when research can be an effect as much as a cause. The discussion of innovation theory below will reinforce this idea. Nonetheless, for simplicity, this paper uses the term because it is recognised and widely used.

In the aggregate, our societies tend to assume that research leads to increased welfare, in the form of wealth and quality of life. Intermediate impact mechanisms may be classified reasonably distinctly as:

- Industrial innovation (including innovation in services as well as products and processes);
- Research-influenced changes in policy, agenda-setting;
- Tackling "grand" or societal challenges, that impede social and economic development or provide existential threats (e.g. climate change);
- The provision of improved public goods (and potentially the provision of associated state services);
- The improved exercise of professional skill, for example in research-based improvements in medical practice;
- Human capital development – which is not orthogonal to the other categories but tends to feed into them.

The degree to which these impact mechanisms have been explored varies greatly. Their links to ultimate economic effects are to varying degrees difficult to establish, partly because the way these impact mechanisms operate is variable or not well described. The importance of attempting economic assessment also varies. In some cases, such as with climate change, calculating economic impacts of research is simply irrelevant: unless this grand challenge is dealt with, there will be precious little economy to measure. So, alongside the natural desire to monetarise impacts were possible, we need to recognise that there are potential research impacts that need to be understood in process, rather than monetary, terms.

Industrial innovation

By far, the greatest amount of effort has been put into exploring industrial innovation as a mechanism for realising impacts of research.

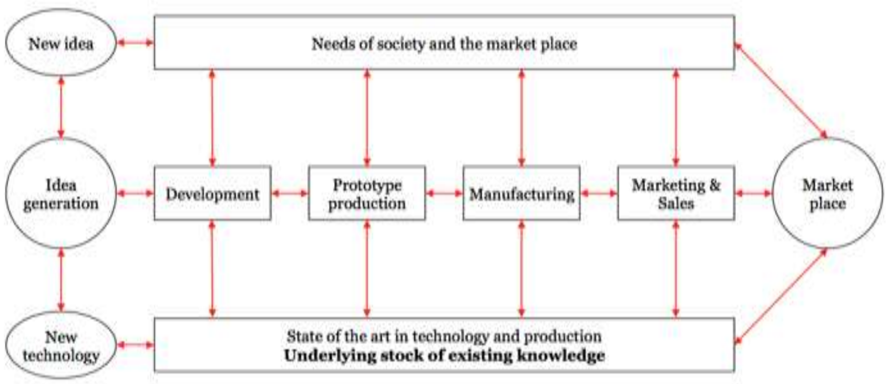
The field of innovation studies is not all that old: we can date its antecedents perhaps from the mid-1950s and its real growth from the second half of the 1960s, building on the work of the OECD in establishing "science policy". One of the persistent debates in the field has been about the relationship between research on the one hand and economic and social development ("impact") on the other.

In the 1950s and 1960s there was a strong belief in a "linear model" of innovation leading from science to wealth production. From the late 1960s, however, thanks to writers such as Carter and Williams (Carter and Williams, 1957), Schmookler (Schmookler, 1966) and Myers and Marquis (Myers and Marquis, 1969), more emphasis came to be placed on the role of the marketplace in innovation, suggesting a linear model where market needs "pull" knowledge out of research and into application.

A key weakness of both push and pull linear models is a failure to conceptualise how the links between successive stages of innovation are supposed to work. They also focus solely on the relationship between **new** knowledge and innovation. In the late 1970s, Mowery and Rosenberg (Mowery and Rosenberg, 1989) reframed the argument between push and pull by stressing the importance of **coupling** between science, technology and the marketplace. A key influence leading to the new focus on coupling was probably research into successful innovation during the 1970s, when studies such as SAPPHO (Rothwell, Freeman, Horsley, Jervis, Robertson, and Townsend, 1974) – which analysed matched pairs of successful and unsuccessful innovations – and the work of Daniel Shimshoni, Morris Teubal, Eric von Hippel and others (Shimshoni, 1970) (Teubal, 1987) (von Hippel, 1976) increasingly emphasised the role of producer-user relations.

Subsequent models of the relation between innovation and research point to a more or less sequential process linking science with the marketplace (via engineering, technological development, manufacturing, marketing and sales), but with the addition of a number of feedback loops and variations over time in the primacy of "push" and "pull" mechanisms. Figure 1 shows an example of such a model.

Figure 1. Modern "Coupling" Model of Innovation



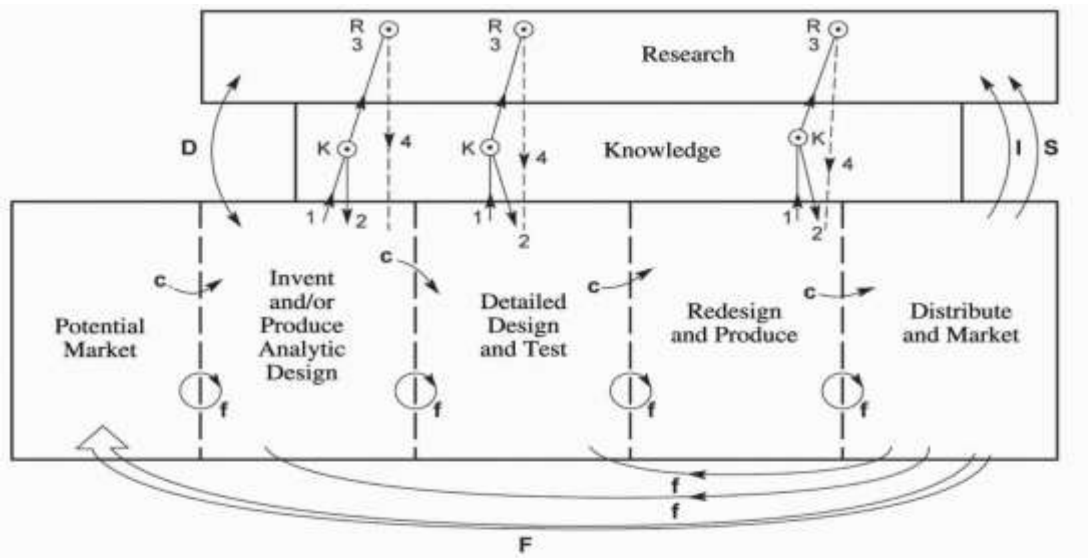
Source: Modified from (Rothwell, 1994)

Key to this perspective is understanding the huge importance of the **stock** of existing knowledge. As, for example, the Community Innovation Survey (and other innovation surveys outside Europe that use a similar methodology) consistently show, the vast majority of the knowledge used in innovation comes out of this stock, and is not created afresh in the project that gives rise to the innovation.

New knowledge often depends upon the existence or the creation of complementary knowledge, if it is to be put into practice. Thus, from a linear perspective there can be “delays” in innovation until the knowledge gap is plugged. Alternatively, new processes of search or research may be triggered in order to plug the gap.

Kline and Rosenberg provide a formulation, focused on **design** (Figure 2.). The process begins with understanding potential demand, moving on to design and then through production towards distribution and marketing. Feedback paths link the innovation stages together. According to this model, scientific knowledge may feed into any stage of the process where it is needed. In turn it benefits from innovation outputs (e.g., new instruments), which in turn lead to new scientific developments and subsequently to new designs.

Figure 2. The Chain-linked model



Source: (Kline & Rosenberg, 1986)

These changes in micro-level innovation models have been accompanied by the emergence of the “innovation systems” paradigm (Freeman, 1987) (Lundvall, 1992) (Nelson, 1993), which emphasises that innovation is predominantly a networked and to some degree collective activity in which individual actors are highly dependent upon other actors and the broader context. Emerging in part from evolutionary economics, this tradition emphasises that individual actors do not have perfect rationality or access to all information. Hence learning is central to their successfulness, they are liable to path dependencies and lock-ins and the extent to which relevant institutions operate well is crucial to their success.

While undoubtedly in many ways a realistic depiction, this paradigm is immensely awkward for impact assessment. Since in the innovation systems view, everything is connected to everything else, everything to a degree also becomes dependent upon everything else. Successful innovators succeed not only as a result of their own efforts but because relevant knowledge is available and transferable, there is a well-functioning supply chain and an intelligent customer to work with, finance is available from the bank despite the apparent riskiness of their project, the patent office is effective in helping them protect their design, and so on. Their own efforts are **necessary but not sufficient** for success; correspondingly, attributing responsibility for their success is problematic. (This issue is discussed further below in connection with the "attribution problem").

Equally awkward is the fact that different kinds of research tend to have different linking mechanisms with society. A study of how industrial R&D managers see the role of publicly funded research in providing knowledge inputs to innovation in their companies (Arundel, van der Paal and Soete, 1995) implies a distinction between "basic" and "transfer" sciences – illustrated in Figure 3 with clearly different impact mechanisms. The work of Pavitt and others focusing on the characteristics of different industries in the acquisition of knowledge tells a similar story from the perspective of the "demand side" (see Figure 4).

Figure 3. Knowledge flows in technological problem solving

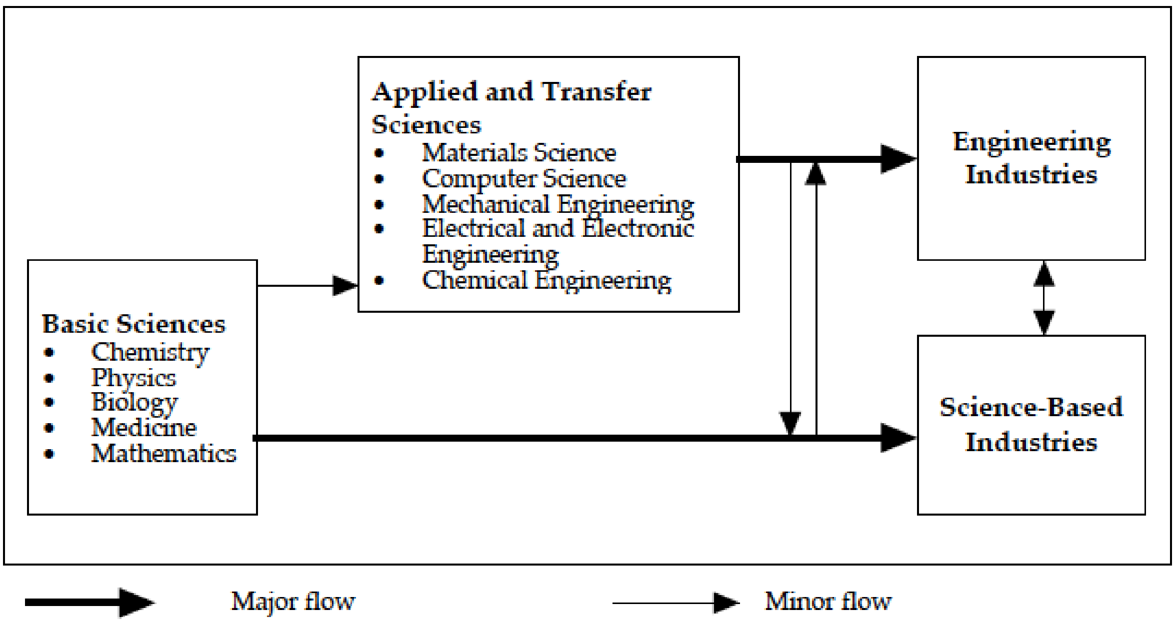


Figure 4. Taxonomy of sector innovation

Category	Main sources of technical change	Focus of innovative activity	Size of innovating firms	Means of appropriation
Supplier-dominated	• Suppliers • Production learning Firms are almost entirely dependent on their suppliers of machinery and other production inputs for new technologies Limited in-house innovation activity is undertaken but some learning from in-house production activities	Main focus is process innovation in pursuit of cost reductions Innovation strategy is to use to technology from elsewhere to support competitive advantage. Process innovations are created in supply sectors and embedded within the inputs to production	Firms are typically small and found within traditional manufacturing sectors such as *textiles, agriculture and services*	Appropriation is rarely based on technological advantage but instead on professional skills: • Design • Trademark • Advertising • Marketing
Scale-intensive	• Production engineering • Production learning • Design office • May include in-house R&D • Suppliers Innovations are largely developed in-house, which may include an internal R&D. Some innovation also sourced from specialised suppliers of equipment and components	Both product and process innovation but a significant focus on production improvements. Innovation strategy is focused on incremental improvements as implementing radical change on complex products and processes is highly risky	Firms are characterised by large-scale mass production where significant economies of scale and division of labour are present. The products & production systems are complex integrations of technologies. Sectors include: *automobiles, extraction & processing of bulk materials & consumer durables*	Appropriation by: • Process secrecy and know-how • Technical leadership • Some patenting
Specialised-suppliers	• Design function • Operational knowledge • Input from advanced users	Innovation focused on product performance improvements. These improvements are often developed to meet the high specification requirements of key users. They are later transferred to other users	They are generally small in size, manufacturing high-performance inputs to other complex products and production processes – inputs such as machinery, components, instrumentation and software	Appropriation by • Design know-how • Relationships with, and knowledge of users • Some use of patents
Science-based	• In-house R&D • Basic research from external sources • Input from advanced users These firms invest heavily in internal R&D to create innovative new products and have close ties to the research base to access new knowledge, skills and techniques	Focus on product innovation where fundamental discoveries (in basic science) lead to new products and markets and corresponding new production and organisational processes Innovation strategy requires monitoring and exploiting developments from the research base	Innovation is highly dependent on developments in the relevant science base and new products are diffused widely as consumer goods or inputs to other sectors Firms are typically large and in sectors such as *pharmaceuticals, chemicals, electronics, materials*	Appropriation by: • R&D know-how • Patents • Process secrecy and know-how • Internal dynamic learning
Information-intensive	• In-house systems & software departments • Suppliers Innovation comes from internal and external sources, and is based on IT hardware improvements, software developments and systems integration	The focus of innovation is to improve, and even redefine, methods of service delivery and to create entirely new service products	Firms are in service sectors that rely heavily on technology to process large quantities of information for efficient and effective service delivery: sectors such as *finance, retail, insurance, travel and publishing, telecoms*	Appropriation by: • Process know-how • Software IP (copyright) • System design know-how

Sources: (Pavitt, 1984) modified and extended in (Tidd, Bessant, & Pavitt, 2001)

Changes in policy, agenda-setting

The role of research in influencing policy is widely discussed but is rarely the subject of impact assessment, despite the flurry of interest – especially in the UK (Solesbury, 2001) – since about 2000 in making "evidence-based policy" (picking up the theme from the "evidence-based medicine" movement of the 1990s). Methods tend to be interview- and survey-based. Arguably the US Government Performance and Results Act has focused the attention of the US impact assessment community towards economic impacts, and away from mechanisms such a policy impacts (Boaz, Fitzpatrick and Shaw, 2008).

Literature reviews indicate that the focus of attention is not much on understanding or measuring the impacts of research on policymaking but rather on developing prescriptions for increasing the impacts of research on policy and practice. The discussion focuses on improvements in practice – the recommendations are rarely based strongly on evidence. Most attention focuses on the health sector (Boaz, Fitzpatrick and Shaw, 2008) (Walter, Nutley and Davies, 2003).

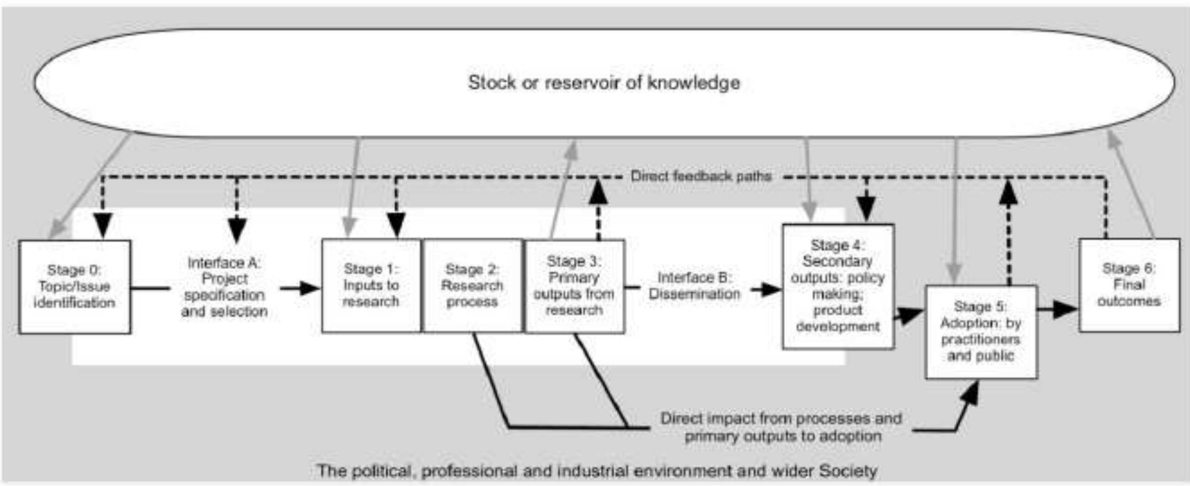
Authors tend to focus on the need to involve potential users of research in project definition, engage them in the execution and monitoring of work and engaging in active dissemination of results (Walter, Nutley and Davies, 2003; Nutley, 2004). (Curiously, this discovery of the need for "coupling" mirrors that in the analysis of innovation, discussed earlier.)

A further echo of the innovation literature can be found in the Brunel Health Services Research Group's "payback model", which spans;

- Knowledge production;
- Research targeting and capacity building;
- Informing policy and product development;
- Health and health sector benefits;
- Broader economic benefits (Donovan and Hanney, 2011).

As Figure 5 indicates, in this model the stock of knowledge plays a central role, as it does in innovation more broadly.

Figure 5. The logic model of the payback framework



Source: (Hanney, Grant, Wooding and Buxton, 2004)

The UK Overseas Development Institute (ODI) has a long-running set of activities (RAPID) aiming to improve the linkage between development research projects and policy practice. Key principles that have emerged are:

- The complexity of policy processes, which makes them intrinsically hard to influence;
- The fact that research-based evidence in practice rarely plays a large role in influencing policy;
- But that such influence is nonetheless possible;
- The need for policy influencers to have a holistic understanding of the policy formulation context and process;
- The need for non-research skills (communications, networking, storytelling, political understanding, etc.) in order to exert policy influence;
- The importance of intent – the researcher wishing to influence policy has strongly to desire to do so and act accordingly (Young, 2008).

A recurring set of observations in the policy impact literature relates policy impact to the development and deployment of research-trained people. For example, the level and type of job into which social scientists move tends to determine the extent to which they can use research evidence to influence policy (Johnson and Williams, 2011). PhD holders tend to rise higher in official hierarchies, exercising greater policy influence than others. Economists play an especially strong role (Juhlin, Tang and Molas-Gallert, 2012).

Tackling grand or societal challenges

The use of "grand challenges" as foci for parts of research policy has been growing over the past two decades. Surveying the US use of the idea across technology challenges (as in high-speed computing) and social challenges such as the Bill & Melinda Gates Foundation's Grand Challenges in Global Health, Hicks argues that these go beyond the mission of a single department of state (so the concept is broader than "mission-orientated research") and tend to involve:

- An intellectual problem;
- A practical problem;
- At a large scale;
- Requiring interdisciplinary research;
- Specification by a committee;
- A public call for suggestions;
- A request for resources;
- Judgment that solution is feasible ;
- A desire to energise a community (Hicks, 2014) .

European policy has seen a different use of the idea of grand or societal challenges, essentially focusing on bigger and broader problems such as climate change, ageing population and so on. As in the USA, these challenges are multidisciplinary and transcend the responsibilities of individual ministries or research performing organisations. Unlike in the USA, EU-level research policy needs to focus at a level of intervention above what individual Member States can do (in line with the "subsidiarity principle"). So European challenges tend to be grander than US ones. Those defined in Horizon 2020 are:

- Health, demographic change and well-being;
- Food security, sustainable agriculture, marine and maritime research and the bio-economy;
- Smart, green and integrated transport;
- Climate action, resource efficiency and raw materials;
- Inclusive, innovative and secure societies .

The use of challenges to organise research and innovation funding has important consequences:

- They focus on problems on the "demand side" of scientific and technological change, so they are inherently governed or steered by society rather than by "science";
- Their breadth (especially in the European variant) means that they often cannot be tackled by a single Department, Ministry or funding agency, creating new issues of governance and opening the question: Who is responsible for impact assessment?
- Their problem focus makes the basic/applied research distinction functionally meaningless in addressing the challenge – there is no way to specify in general the degree of wholly new or fundamental knowledge that is required to solve challenges.

In effect, understanding the impacts of challenge-driven research may require new forms of organisation and institutions, compared with traditional impact analysis.

Providing public goods

The modern state is a large-scale provider of public goods, in the sense of goods that bring social benefits but that are unattractive for the private sector to produce. (This is a flexible and sometimes moving boundary.) While there is some impact assessment work looking at the benefits of providing public goods (e.g. standards), there is little exploration of the impacts of research in connection with these.

Improved professional skills

As with impact assessment of research in connection with policymaking, there is little work that aims to assess or measure the impacts of research on the exercise of professions such as teaching or medicine. (An exception is the question whether university teachers who also do research teach better than those who do not.) Broadly, an equivalent of absorptive capacity – "the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990) – does not seem to have been developed in relation to professions.

Despite the lack of theorisation, however, there is a great deal of activity aimed at increasing the influence of research over practice, for example through improved or more systematic dissemination, techniques for involving research "users" more closely in research project definition (European Science Foundation, 2011).

Human capital

While there are whole literatures about human capital formation through higher education and its economic impacts, the spillover benefits of labour mobility and so on, the role of **research** in human capital building and the role of human capital in effecting research-based technological and social change is rarely considered in impact analysis of research and innovation. This is curious, given the importance placed on it in policy – for example, in Sweden (Sörlin, *En Ny Institutssektor: En analys av industriforskningsinstitutens villkor och framtid ur ett närings- och innovationspolitiskt perspektiv, report to the Swedish Ministry of Industry*, 2006) – and its regular appearance in studies of research-industry links, such as Martin & Tang, 2007.

Scientific and technical human capital has been proposed as an alternative indicator of research impact for the purpose of evaluation (Bozeman, Dietz and Gaughan, Scientific and technical human capital: an alternative model for research evaluation, 2001). The logic is that human capital development is a key outcome of research and that those involved themselves become instrumental in the delivery of further research as well as societal impacts. It follows that the community of people involved represents a fairly durable "reservoir" of capability.

The idea was developed further via the notion of "knowledge value collectives" (Bozeman and Rogers, 2002), namely communities of people across research and industry who work and share an interest in one or more areas of technology. People move from employer to employer and across the research/industry boundary while in effect remaining members of these informal collectives. Bozeman and Rogers examine people who work with Internet technology, there are clearly many others. For example, in Sweden (particularly in the West) there is a community of people who work on diesel combustion and engine technology, which straddles at least two universities, two car companies and two truck companies. Examples in IT include IT researchers and R&D workers in Ireland and telecommunications R&D workers in Stockholm. The Irish community survived the departure of footloose producers such as Apple, going on to establish new companies or work for competitors; similarly, the telecommunications collective in Stockholm survived Ericsson's massive lay-offs in the early 2000s through transfers to competitors and creating new firms. The idea is that the knowledge value collective can be a more durable outcome of research than an individual company. Within reason it can persist beyond the life of the individual firm, continuing to produce and exploit knowledge in a series of new settings and it is therefore a crucial intermediate outcome of research that could usefully be valued in its own right in evaluation. As Bozeman and Rogers themselves point out, a key difficulty is one of quantification or valuation; but the concept is nonetheless powerful because it captures an important impact mechanism that is normally ignored.

2. Realistic impact models

This discussion implies that current impact models tend to be limited in scope, overly linear, liable to under-play "soft" factors such as agenda setting and organisation as well as limited in their ability to handle context.

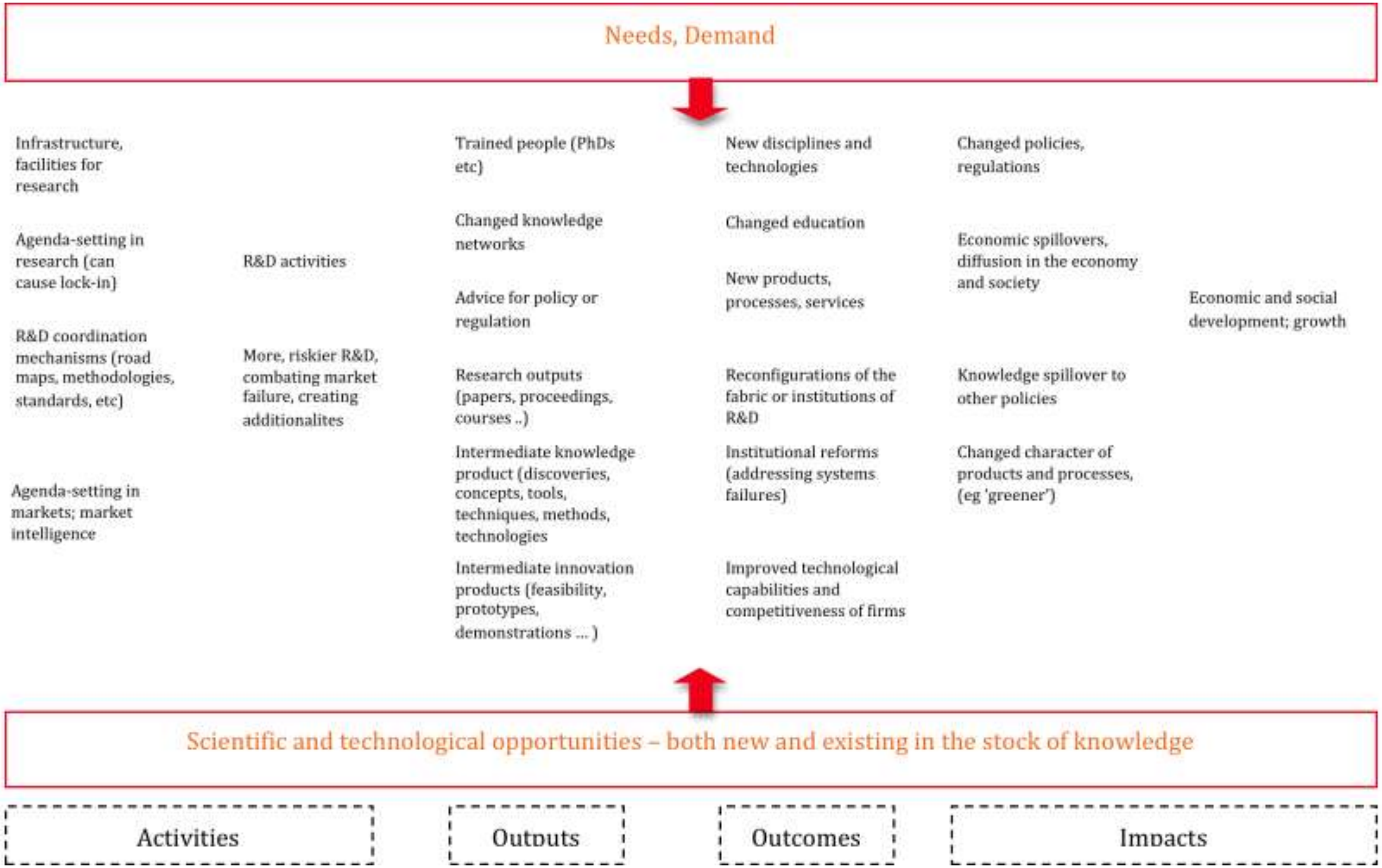
Even when we broaden impact models to incorporate softer factors, they tend to remain linear – as Figure 6 implicitly is. (This is loosely based on a study of the long-term effects of the Framework

Programme, (Arnold, 2012), which highlights the agenda-setting and organisational aspect of impact, in addition to the scientific, technical and economic dimensions.) Like almost all impact assessment frameworks, it suffers from the problem of being **linear**, with the implicit causality running from left to right. Figure 7 overlays a potential non-linear impact process – which could be used as a hypothesis in an impact assessment – to illustrate the type of causality implied by the innovation systems perspective. Here, a change in regulation triggers a change in research agendas and drives innovation – a not uncommon scenario and one which puts in question the extent to which research in this case should be seen as a root cause of innovation. This type of non-linearity is easier to see once social and organisational processes (like agenda-setting) and not only technical relationships are included in the impact analysis framework. Design often proceeds based on existing knowledge and it is only when the potential innovator identifies a knowledge gap that it becomes necessary to trigger new research.

While realistic evaluation seeks a step-by-step understanding of effect mechanisms, the desire for simplicity and for quantification pushes in the other direction via both (micro-)econometric and macroeconomic techniques. Many quantitative impact analyses therefore look at the relationship between input and impact variables without considering the intermediate steps. Normally this is done on the basis of at least an hypothesised effect logic. However, once the data collection and analysis are disconnected from that logic it becomes difficult to use the impact analysis to improve our understanding of impact mechanisms, and vice versa.

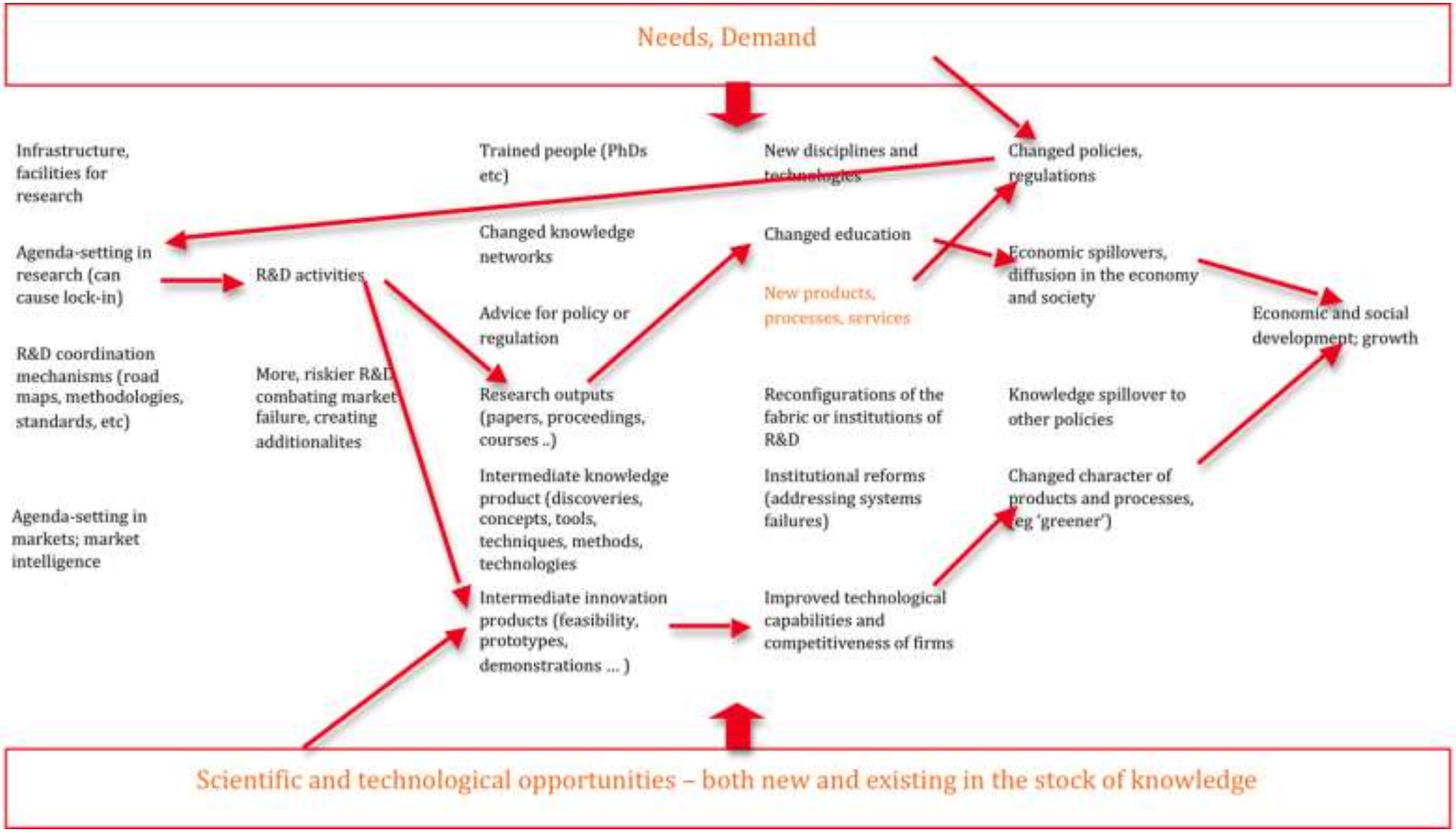
Economic impact analysis therefore suffers, like many other economic analyses, from a difficulty of connecting the macro and micro levels. Establishing such links is important, if impact analysis is to produce results that can be used to design or improve policy interventions.

Figure 6. A linear impact assessment framework



Source: (Arnold, 2013)

Figure 7. The framework used in a non-linear case



Source: (Arnold, 2013)

This document is based on: **OECD Directorate for Science, Technology and Innovation (2014), "Assessing the Impact of State Interventions in Research – Techniques, Issues and Solutions", unpublished manuscript.**

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