INGENIO WORKING PAPER SERIES

Resolving tensions of research utilization: The value of a usability-based approach

Paul Benneworth, Julia Olmos Peñuela

Working Paper Nº 2014-10

INGENIO [CSIC-UPV] Ciudad Politécnica de la Innovación | Edif 8E 4º | Camino de Vera s/n | 46022 Valencia
tel +34 963 877 048 | fax +34 963 877 991 | innco@ingenio.upv.es

Resolving tensions of research utilization: The value of a usability-based approach

Paul Benneworth [a], *Julia Olmos Peñuela* [b]

[a] Center for Higher Education Policy Studies, University of Twente, the Netherlands.
[b] INGENIO (CSIC-UPV), Valencia (Spain)

Abstract: This is a position paper addressing the debate about the nature of how research is utilised and measured that questions the prevalent practice of measuring terminal use transactions (TUTs) – i.e. patents, spin-outs or license income – for measuring research impact. In so doing, our starting point is that a science system is a progressive business in which any piece of research builds on a whole set of antecedent research and knowledge. We contend that the extent of research utilisation across this science system is determined by the extent to which antecedent research can feed into research that ultimately feeds into these TUTs. We introduce the concept of 'valorizers' as research users that valorise knowledge by transforming it into the socio-economic domain, for the purpose of defining the 'usability' of antecedent research as the ease with which it may contribute to research that valorizers are able to absorb. We argue that the flow into the pool of 'usable knowledge' is ultimately dependent on the extent to which newly created scientific knowledge is cognate with valorizer needs and that more consideration need to be given to the processes by which research creates knowledge that is usable through the course of the research cycle.

Keywords: research utilisation, research usability, research usefulness, research valorisation, terminal use transaction, antecedent utilisation transaction, research cycle

JEL Codes: I23, O31, O32

1 Increasing imperatives for research utilisation

The last two decades have seen an increasing set of pressures which have seen a new "normal emerge" in which publically funded science is contingent upon producing clear and demonstrable socio-economic benefits. Popp Berman (2011) has argued convincingly that US universities in the 1970s constructed a new economic market logic for university activities based on university patenting, spin-offs, and industry research centres. But this very time- and place-specific set of logics – related to America's need to compete technologically with Japan – have become a universal set of policy prescriptions widely promoted by multilateral agencies (McCann & Ortega-Argilés, 2013; Benneworth, 2014). Today, the creation of socio-economic impact has become intertwined in manifold ways into core public funding for research, grouped into programmes driven by what we here call valorizer (see section 2) interests[1] and prospective economic value, with more fundamental research activities even forced to justify itself in terms of creating impacts.

There is a debate currently raging about the nature of how research is utilised and how that can best be measured, evaluated and managed. The most obvious tensions is between the very narrow scope of readily available and accepted metrics for research impact (e.g. patents, spin-outs, license income), and the recognition that research creates impact across a much broader portfolio of activities (e.g. AWT, 2007; RCUK, 2011). But this focus on the transactions by which particular pieces of research become utilised seems to overlook an important nature of how knowledge is created. Science is a progressive business in which any piece of research builds on a whole set of antecedent research and knowledge co-ordinated through the institutions of scientific governance (Polayni, 1962; Merton, 1973). Thus, what we call the terminal use transactions (TUT: those things most often included in the accepted metrics for research impact e.g. patents, spin-outs, license income) around which debate has become focused are in reality

---

[1] As we will later explain, we see that knowledge is used by many actors in different domains and so we do not refer to social knowledge partners as 'users'. We make a distinction between those who use knowledge to create more value, and those who valorise that knowledge by transforming it into the socio-economic domain. It is this latter group that we refer to as valorizers: this is similar to the idea of knowledge 'users' as sometimes appear in more historical literature (e.g. Lundvall, 1988). A valorizer is a played role not an intrinsic quality – a scientist in a firm may create new scientific knowledge with no immediate application – in that role they are not a valorizer; if they embody that knowledge into a new product or process in their company, then in that knowledge transaction, they are acting as a valorizer.

dependent on a whole set of antecedent interactions which progressively build to create knowledge that flows into research utilisation.

We argue that this lacuna relating to antecedent research has progressively spread to become a dominant feature of the science policy discourse around the public value of research, with policy-makers focusing almost exclusively on what can be done to maximise research utilisation. We contend that in reality, the extent of research utilisation across a science system as a whole is determined not only by these TUTs, but also by the extent to which that antecedent research can feed into research that ultimately feeds into TUTs (sections 2 and 3). We define the 'usability' of antecedent research as the ease with which it may contribute to research that valorizers are able to absorb, using a heuristic of a knowledge pool emerging from science of new research that valorizers can draw upon and use (sections 4 and 5). In this position paper, we argue that flow into the pool of 'usable knowledge' is ultimately dependent on the extent to which newly created scientific knowledge is cognate with valorizer needs (section 6). On that basis, we argue that more consideration need to be given to the processes by which research creates knowledge that is usable through the course of the research cycle (section 7).

2 The complex relationship between final use and the business of science

It is widely recognised by both researchers (Rosenberg, 1994) as well as policy-makers – in their more reflective moments (e.g. Willetts, 2013) – that there is no simple translation from basic/ fundamental research into practical application. It is therefore surprising that that assumption seems to be central within a discourse that has acquired a peculiar traction in contemporary policy debates. To do nothing more than to highlight the level of the problematic and the dissonance between the reality of how use emerges and the contemporary policy consensus, we present an illustrative narrative of the relationship between fundamental nanotechnology research and market applications drawn from the University of Twente (UT)[2]. In particular, we illustrate how a particular artefact demonstrating research utilization, a spin-off company, was enabled by an ongoing circulation of knowledge between Dutch universities, Dutch research funders (the

[2] The research that fed into this stylised example has been published elsewhere as *inter alia* Benneworth & Charles, 2005; Benneworth & Hospers, 2007a; 2007b; Benneworth & Ratinho, 2014.

Netherlands Organisation for Scientific Research (NWO) encompassing the Foundation for Fundamental Research on Matter (FOM) and Technology Foundation STW), leading Dutch R&D companies and a succession of antecedent university spin-off companies.

The University of Twente was in 2013 reported as the most entrepreneurial university in the Netherlands by the annual Elsevier-Science Works report on university enterprise (Van Leeuwen, 2013). It is clear that there has been a steady stream of spin-off companies emerging in recent years from research at the University of Twente, particularly in the domain of nanotechnology (Benneworth & Ratinho, 2014). An example of such a firm is Tide Microfluidics, which in 2014 won the Young Technology Award for the "Commercialization of Micro, Nano, and Emerging Technologies Conference" (Tyrell, 2014, see *TCTubantia*, 2014). The technology had been supported by an exploitation grant from STW in 2012 that provided the means to develop a set of ideas that had emerged in the course of the founder's Ph.D. project to create the prize-winning technology. This seems to provide an example of the new research policy paradigm, not merely investing in excellent basic research (Tide's CEO undertook a Ph.D. in micro-fluidics at the University of Twente part-funded by an existing spin-out company, Medspray *qv*[3]). From this perspective, it can be argued that more applied research funding launched usable concepts into the marketplace, thereby creating an award-winning technology business that was using excellent knowledge.

But when one looks a slightly longer term perspective of what led to the creation of Tide then a different story emerges. The research antecedent to Tide took place in a research environment in Twente that had built up steadily over almost two decades following the creation of the nanotechnology research centre MESA (that became MESA+ in 1998). In 1998, the Netherlands undertook a substantial research Foresight exercise (Ten Wolde, 1998, cited in Van Est *et al.*, 2012) which laid the foundation for a series of strategic national research investment programmes supporting Dutch nanotechnology infrastructure (called NanoNed, MicroNed, and NanoNextNL). All Dutch universities with interests in nanotechnology were actively involved in the Foresighting report. Their researchers contributed over the following decade to an ongoing dialogue between companies facing particular technology challenges, and the community of physicists and chemists working in various elements of nanotechnology.

[3] http://www.utwente.nl/mesaplus/scientists/phd/2011/interview_wim_van_hoeve_2011/ (Accessed 24th October 2014)

The scientific governance system of the Netherlands' nanotechnology research community was not exclusively determined by academic concerns, but one where commercial voices were also central in deciding which questions warranted public investments. Large research programmes were not exclusively academic research programmes – they were actively engaged with and shaped by Dutch "nanotechnology" companies[4]. Alongside the structural infrastructure investments there was a pattern of smaller (FOM and STW) projects involving industrial partners whose involvement varied from rather superficial (such as being involved in a user group) to being joint partners in the activities being carried out. There was a generational effect: firms were formed both from STW and Nanoned/ Microned investments that were specifically seeking application, alongside those created by Ph.D. and post-docs working on FOM-funded 'fundamental' research projects without obvious *ex ante* application.

These high-technology spin-offs partners were working with the university on more basic research projects in the hope of generating interesting new ideas and solutions to their particular technological problems. All the research activities contributed to positioning the MESA+ Laboratory at the time of writing as one of the world's largest and most scientifically productive research laboratories. The relatively high level of spin-off generation was a function of the intertwining of these firms into the MESA+ scientific research programme. The activity also positioned MESA+ as an emblematical entrepreneurial laboratory (visited eagerly by princes and prime ministers) with a high level of 'research utilization' measured in terms of new spin-off companies.

Our point in presenting the narrative of usable nanotechnology in Twente is not to point out that the applications from science do not emerge in a linear flow, which is to our mind rather redundant. Instead, our contention is more modest: if one is concerned with policy for research utilization, then it is important not just to consider the epiphenomena that demonstrate final use – in the case of Twente, the act of the creation Tide Microfluidics. Van Hoeve's Ph.D. was part-funded by an existing UT spin-off company – Medspray – and led to a spin-off company – Tide – via a Ph.D. trajectory (Van Hoeve,

[4] It is unsurprising that the Microned programme involved five of the top ten Dutch companies by investment in R&D, in part because it was in their laboratories, that certainly for much of the period were better or equal to anything in the university sector, that interesting questions and challenges were being generated. Philips was a core partner of the Nanoned programme alongside public research organisations; in Microned, 8 of the 27 businesses, and in NanoNextNL, 14 of the 95 participating businesses were spin-offs (or had spun-out of spin-offs) from the University of Twente.

2011) that involved clearly excellent and fundamental science, as demonstrated by the resultant publications[5]. Although it is in Van Hoeve's Ph.D. project that ideas antecedent to the piece of utilized research were created, the fact that the research even existed, and asked the questions in the way it did, to create that knowledge that was utilized economically, was a result of antecedent fundamental knowledge that created the conditions that enabled that project.

3 Post-normal science as an ecology of heterogeneous interacting agents

We use this observation to illustrate our wider argument, that if policy-makers are really interested in maximising returns from investments by maximising societal research utilisation, then they should not just be concerned with these final utilization activities in which valorizers translate immediately antecedent research into a socio-economic artefact. Rather, policy-makers should also seek to stimulate research that leads eventually to projects that lead to research utilization: it is that that will maximise the eventual flow of knowledge to the valorizer. To clarify the discussion, we here make a clear terminological distinction, between two properties of knowledge: its usefulness and its usability. Useful knowledge is used by a valorizer to solve a problem; usable knowledge has that potential to be used; usefulness is an emergent property for which usability is an antecedent condition – given the nature of knowledge as an uncertain product, we can only be sure that knowledge is useful when it has been used. We therefore argue that policy makers should therefore seek to stimulate higher volumes of that usable knowledge to ensure as much knowledge as possible becomes used in these TUTs.

At the same time, we acknowledge that research has another characteristic, that of its scientific quality; research that is not taken forward by other scientists represents a

[5] E.g. a paper published in Physical Review Letters (the leading journal in the field) with relatively high citations Google Scholar 115, Web of Science 75: http://journals.aps.org/prl/about (Accessed 24th October, 2014)
See also http://scholar.google.nl/citations?view_op=view_citation&hl=nl&user=9CSxTxsAAAAJ&citation_for_view=9CSxTxsAAAAJ:2osOgNQ5qMEC (Accessed 24th October 2014).

knowledge evolutionary dead-end. However, this complex issue is the central subject of the subject of bibliometrics, and to reduce complexity in our argument, we do not further consider the scientific usability-usefulness of knowledge; hereafter, we use usability and usefulness to refer to knowledge characteristics vis-à-vis valorizers. But the case of Twente illustrates a critical point here, namely that knowledge may be created which is not immediately useful, but that nevertheless has the potential to later enable and become incorporated into useful knowledge via other knowledge creation processes which become usable: to this antecedent knowledge we attach the label of usable knowledge.

We therefore argue that to solve the research utilization policy problematic, it makes sense to seek to maximise usable knowledge, as an antecedent to maximising useful knowledge. To conceptualise this, we base our argument around the idea that research utilization transactions flow out of knowledge created within a heterogeneous knowledge community. Agents in this community are all carrying out their own research projects and interacting; mutual interest in each other's knowledge holds the community together. The governance of this community regulates a 'marketplace of ideas'(Menand, 2010) and co-ordinates which research questions are investigated in science – both publically- and privately-funded, what some have referred to as 'post-normal' science (*cf.* Funtowitz & Ravetz, 1993; Ravetz, 1999). A characteristic of post-normal science is that the urgency and uncertainty of particular socio-science problems require trans-disciplinary and even trans-academic knowledge communities to form and to create new knowledge to solve those problems.

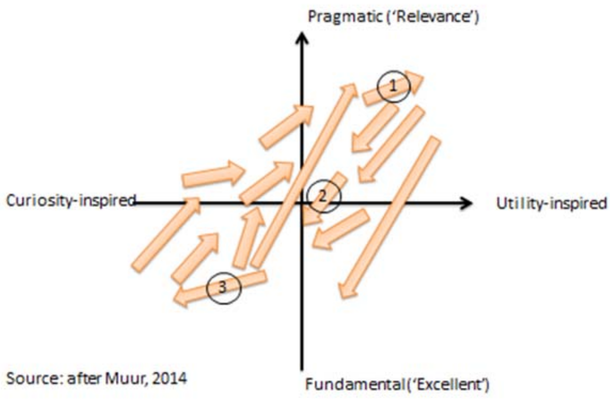
We see in this situation a clear echo of the desires of the first academic journals to actively support those communities by creating a constructive dialogue between scientists and valorizers (e.g. Boyle, 1665). This also echoes ideas of Mode 2 science in which there is a circulation of knowledge between a heterogeneous group of actors (Gibbons *et al.* 1994; Novotny *et al.*, 2003), each with their own interests, needs and reasons for participating in the community. To construct our framework for analysing what we believe to be a problematic policy failure, we seek to typologize those actors involved in creating scientific knowledge. We concur with Sarewitz & Pielke (2007) in utilising the distinction made by Stokes (1997) in actors' research behaviour having two distinctive dimensions:

- Motivation: The extent to which research is motivated by scientific curiosity and the extent to which it is inspired by utility, or indeed the extent to which the generation of questions is driven from what agents in the scientific field find interesting as opposed to agents exploiting the knowledge outside science.

- Practices: What determines what constitutes good research practice, making a distinction between following a scientific approach (reproducible and generalizable knowledge) and between producing a solution to a context-specific problem (applicable and proprietary knowledge).

In figure 1 below, we use these two axes to visualise the way knowledge evolves in the context of Mode 2 science. In the course of solving problems actors with their own interests draw on antecedent knowledge (which need not necessarily be located in an identical part of the knowledge ecology), creating new knowledge. Viewed retrospectively, it is possible to chart how, as knowledge evolves, its characteristics change over time; firms' problems are an important source of inspiration for fundamental research in many areas, as seen previously in nanotech and materials science. Knowledge may evolve through repeated research projects and programmes in the area of fundamental science before some particular knowledge is created that is both generally usable, as well as immediately useful to the firms.

Figure 1. Evolution of knowledge across research projects across two scientific dimensions



Source: authors' own design (after Mur, 2014).

Each of the arrows in the diagram involves a knowledge transaction or creation activity, in the course of which the nature of the knowledge changes as well as its context, changing its fundamental/ pragmatic motivation and curiosity/ utility inspiration. By way of illustration of our meaning of transaction, in this diagram we can see three of the transactions from the narrative in Section 2:

- Transaction 1 represents a standard piece of valorisation activity, whereby a firm wins a government grant to take a pre-competitive piece of research and move it into the pre-market stage.
- Transaction 2 is slightly different, representing a public research laboratory working with a technical university on a joint research project that creates a piece of fundamental understanding about the physical properties of a material characteristic.
- Transaction 3 involves a transaction within the university sector, such as where a piece of basic physics research on the nature of matter is inspired by findings from more applied basic research of physical material characteristics.

Rather than being a linear flow from the general-fundamental to the specific-applied, there is instead a circulation of ideas and knowledge within a field. Much of that knowledge that is created is usable – and at particular moments such as indicated by

Transaction 1 in the figure above, that knowledge is fixed, transformed and becomes useful through a terminal use transaction.

4 Research utilisation as knowledge pool outflow

This idea of a circulation of knowledge within a field which leads to parallel scientific and societal progress provides a useful framework for reflecting on the differences and the connections between usefulness and usability. The current policy paradigm appears to presume that (or to aspire to a situation where) every single research activity has an underlying potential to become useful. This seems to be a conflation of two separate ideas, firstly that public research should prioritise research that creates public value, and also that responsible researchers should seek to find applications for their research as one of the conditions for that public funding.

However, it is possible to regard research utilization as the practical exploitation of what Sarewitz & Pielke (2007) refer to as a metaphorical knowledge reservoir which builds up in the course of knowledge circulation processes. This in turn draws upon Sarewitz's (1996) argument (cited in Sarewitz & Pielke (2007)) that this knowledge circulation process within an extended research community builds up a shared set of knowledge resources, and these form the basis for particular exploitation activities by valorizers who are also active agents in that community. The nature and dynamics of terminal use transactions (particularly commercial transactions) has been widely explored across management literatures. These analyses have demonstrated that these TUTs involve changing the context of the knowledge (Ambos *et al.*, 2008) in its exploitation (Rasmussen, 2011), clarifying the nature of its application (Gruber *et al.*, 2008) and situating it in the commercial domain (Clausen & Rasmussen, 2013).

The policy discourse appears to assume that this is underpinned by a straightforward linear process in which knowledge moves from being curiosity-inspired and pursued for the sake of excellence, to utility inspired and pursued for the sake of relevance. However, Sarewitz (1996, cited in Sarewitz & Pielke (2007)) makes the point very clearly that this is clearly not true: he argues that the history of technological development is littered with examples where researchers seeking to create utility have linked up serendipitously with kinds of knowledge created with no direct regard for the eventual conditions of use. Sarewitz & Pielke (2007) even invert the argument, claiming that downstream, technological-oriented developments play an important role in the dynamics of fundamental knowledge production, stimulating more basic questions on the basis of curiosity-arousing questions emerging from individuals with a know-how of a particular process under very limited circumstances.

"one feature that invariably characterises successful innovation is ongoing communication between the producers and users of knowledge. […] Emerging technological frontiers often *precede* deep knowledge of the underlying fundamental science. It is precisely the demand for better theoretical foundations among those worried about applications that has driven the growth of fundamental science in many areas (e.g. Rosenberg, 1994)" (Sarewitz & Pielke, 2007, p. 7)

The existence of these anomalies, derived from pragmatic, utility-driven searches by commercially-oriented agents, awaken the curiosity of (more) fundamental researchers who seek to place the understanding of that proprietary-context specific knowledge on a general-universalist footing (*cf.* Rosenberg, 1994). Those fundamental researches are inspired by the questions that have emerged from within practice; answering those questions provides a means for that fundamental knowledge to eventually be made useful again, through a series of knowledge creation activities within that community.

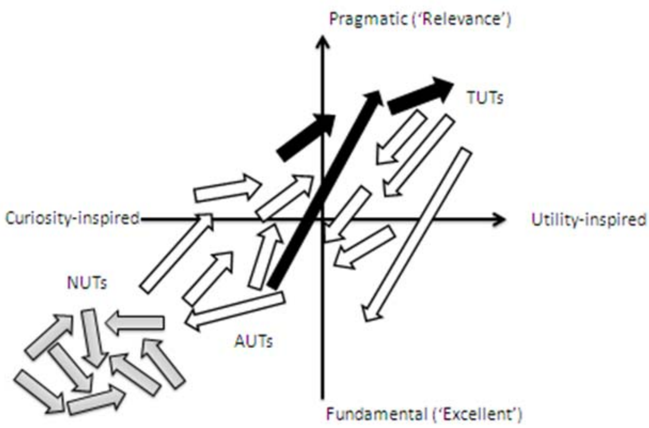
As previously mentioned, in accounting for the issue of what precedes serendipitous link-up, Sarewitz & Pielke (2007) argue that what regulates this can be understood in terms of a metaphorical knowledge reservoir out of which usable knowledge may flow and become useful (in the language of our own definitions in figure 1). Particular knowledge creation activities are influenced both by scholarly concerns (curiosity-fundamental) as well as societal concerns (pragmatic-utility) between interacting agents who share knowledge in various tacit and codified ways; from this reservoir, valorizers are able to draw upon, fix, contextualise and transform the usable-but-general into useful-and-specific (valuable) knowledge (via these terminal utilization transactions). If we represent this along the dimensions used in figure 1 above, we can make a distinction between three kinds of transactions.

- Firstly, shown in the solid black arrows are the transactions by which research utilization takes place, in which usable and then useful knowledge is embodied into products and services in the societal domain: we refer to these transactions as terminal use transactions (TUTs).

- Secondly, shown in the hollow arrows, are transactions which although they do not lead to a new product or service, are themselves ultimately incorporated into – we refer to these as antecedent utilisation transactions (AUTs).
- For the sake of completeness it is possible to imagine a third set of transactions, those which circulate entirely independently of a community which creates knowledge that is *never* incorporated into TUTs (grey arrows): we refer to these as null utilisation transactions (NUTs), and this may be thought of as analogous to ivory tower knowledge created within closed scholarly communities with no wider societal value[6].

These transactions are shown in figure 2 below, which hints at the 'serendipitous' interaction between the aggregating reservoir of usable knowledge, and its serendipitous conversion into useful knowledge via a series of TUTs through which research utilisation is eventually demonstrated.

Figure 2. Research utilisation as terminal use transactions built upon knowledge circulation



Source: authors' own design based on figure 1

[6] Our heuristic for this is an academic citation circle that simply produces papers using a mutually-developed jargon to simulate erudition and sophistication which at the same time did not create any knowledge about real-world phenomena. We are not sure whether such knowledge could meaningfully exist within the political-economy of science (*cf.* Gordon, 1993).

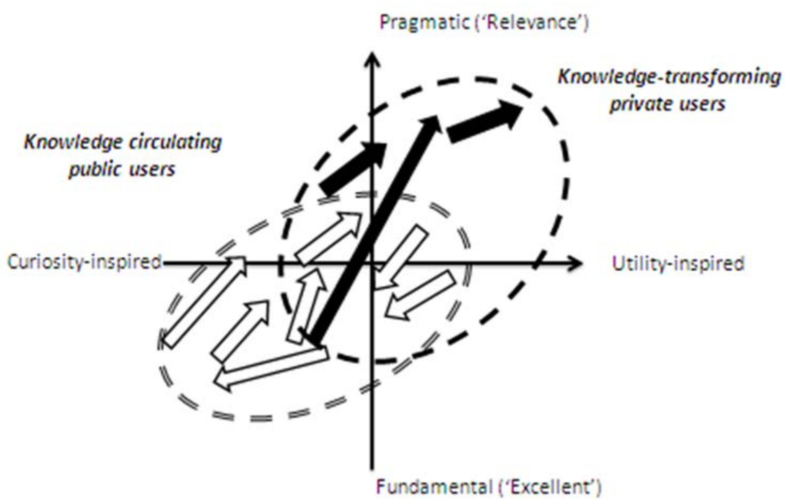
5 Knowledge outflow & coupling 2 circuits

But this situation raises a critical question: under what conditions can post-normal science governance processes affect the rate and speed of TUTs? To date, the answer has been in specifically stimulating those utilization transactions (the moments of creating useful knowledge), rather than considering the feedstock of those transactions, namely antecedent knowledge creation activities that result in new usable knowledge in that reservoir. We argue that this issue of serendipity (an idea cognate to that of chance) has occluded the policy-debate, and this occlusion has been absorbed into academic considerations (because as figure 1 suggests, the science policy academic debate is stimulated and responds – sometimes driven by curiosity and the concerns of excellent science – by policy concerns). The argument that usability is a precursor to usefulness (e.g. Schelsky, 1963) is a difficult argument for policy-makers to address, because it runs the risk of becoming a special-interest argument. It is easy to render this argument as saying that it is sufficient to invest in excellent research to eventually yield dividends (i.e. research utilization transactions). Indeed, some academics argued to policy-makers that it is wrong to demand that eventual use play any consideration judging funding proposals because of the long-term danger of not funding the fundamental breakthroughs that eventually prove to be societally invaluable – such as the MRI Scanner – (*cf.* Collini, 2009; 2011).

The risk that policy-makers evoke, of self-interested ivory-tower scholars seeking public support for research with extremely limited future public benefits, is clearly real, particularly given pressures on academics to publish as widely as possible in academic outlets. But we argue that the simple dismissal of all claims that research with no immediate utilization can still produce long-term benefit is wrong-headed. Indeed, we see as being equally dangerous demands that all research be able to demonstrate TUTs, precisely because of the importance of research that adds to what Sarewitz & Pielke (2007) regard as the knowledge reservoir through AUTs.

These two subsystems (the reservoir and the TUTs) need not be completely decoupled, as we indeed argue in section 2 where we indicate – following Sarewitz (1996), cited in Sarewitz & Pielke (2007) – that knowledge circulating without utility and pragmatism being the guiding principles was nevertheless a relatively rich source for spin-off companies (arguably *the* embodiment of TUTs). In order to aid policy debates, and bring an additional level of resolution to the debate, we argue that maximising the public value of the research base involves managing two flows, firstly the numbers of TUTs, but also the degree of coupling between AUTs and TUTs. Coupling is necessary for that serendipitous transaction to take place: we here define coupling as a connection between knowledge that is circulating within the reservoir without being used, and knowledge which is used. Once coupling is established, then the appropriate goal for a policy intervention seeking to maximise research's socio-economic contribution is to focus as much as possible upon research that contributes into a usable knowledge reservoir. If that research is well-coupled to valorizers, then there will be optimal uptake from the knowledge reservoir into society via TUTs, which demonstrate the usefulness of that knowledge. We represent this in figure 3 below, which shows the issue of optimizing research utilisation as one of arranging coupling between AUTs and TUTs.

Figure 3. Optimising research utilization as optimising coupling between AUTs and TUTs



Source: authors' own design, after figure 2

To understand what influences this coupling process, we focus on one quality of knowledge that determines the ease with which it may be transferred between actors, namely cognitive proximity (see Boschma, 2005). For actors to be able to incorporate knowledge from external sources, there needs to be some kind of shared knowledge base between the various actors involved. Building constructively on someone else's knowledge requires common understandings of problems, common definitions of properties, characteristics and processes, a shared language of communication and indeed a common understanding of the 'rules of the game'[7]. Referring to figure 2, the issue with ivory-tower knowledge circulating for its own sake is that it is not coupled to a usable knowledge reservoir, which might potentially be related to it lacking a suitable common base with valorizer knowledge to eventually become useful through utilization. We therefore argue that a key criterion of usable knowledge – even where it is not immediately 'useful' as measured through TUTs – is that it is 'usable' in terms of having a shared knowledge base and cognateness with valorizer knowledge[8].

6 Coupling, cogency & Well-ordered science

What we do not wish to do here is to reduce the property of cognateness to a bilateral property, that is to say that as a scholar, you incorporate the knowledge of a 'valorizer' in your research, and that makes it more usable by that 'valorizer'. Our argument is that knowledge is created in communities that represent the interests of a range of actors, and through research (knowledge creation) processes in those communities arrive at a set of common understandings. Those common understandings create synergies between the individual efforts, which make progress possible across a set of extended epistemic knowledge communities operating globally (Gläser, 2012). The common understandings represent the shared knowledge reservoir which can create societal value through utilization transactions, and the capacity for agents to create common understandings depends on the extent to which their knowledges are cognate.

By inference, knowledge that is cognate with valorizer interest will be generated within communities within which those valorizers have a certain degree of legitimacy in directing research towards particular areas of interest (and away from others), and within the norms and practices of what constitutes good and valuable knowledge. This suggests that cognateness between academic and applied scientists depends upon a more fundamental engagement of valorizers with the governance of knowledge creation which ensure that the processes of setting question and allocating research questions are

[7] Indeed, the contemporary discipline of bibliometrics uses the property of the relative degree of inter-communication between academics (as measured by citation and authorship behaviour) as a means of delineating distinctive academic fields.

[8] We reiterate here that we have already excluded from consideration the question of whether the knowledge has quality in the sense of being novel and coherent; the condition that a shared knowledge base with user knowledge presupposes that the research is of a sufficient quality to contribute to new knowledge creation processes in the user domain, in that it is novel and coherent.

suitably mindful of wider socio-economic demands and interests (Elam & Bertilsson, 2003). Valorizers are embedded into decision-making in the business of science, not necessarily directly dictating questions to researchers, but having the opportunity to shape the way questions are asked and how the knowledge reservoir develops. This increases the level of coupling, and hence enables a higher degree of the serendipitous flow from that knowledge reservoir into TUTs.

Kitcher (2001) describes as "well-ordered science" the societal state in which governance arrangements ensure that there is a balance between valorizer demands for knowledge and producer interests. Sarewitz & Pielke (2007) characterise this argument as being that under the conditions of well-ordered science, that "science is maximally responsive to the needs and values of those may have a stake in the outcomes of the research" (p. 9). Kitcher argues that there are three key deliberative kinds of event in the life of the knowledge circulation community that characterise the state of well-order science. At these three moments, valorizer interests are negotiated into the scientific governance process; firstly, in the stage of agenda-setting and the choice of questions; secondly, in the execution of the projects; and finally, in the transformation of research findings into practical outcomes. As Sarewitz & Pielke note, the concept is an ideal type representation in which outside interests are incorporated into the everyday practices of the scientific endeavour, namely choosing research questions, undertaking research, and disseminating that research. Their argument is that in well-ordered science, grounded on that self-conscious deliberative process, there is the greatest chance for the creation of societal impact. In the language of figure 3, the state of well-ordered science provides the best coupling between the supply side (knowledge-circulating public valorizers) and the demand side (knowledge-transforming private valorizers) of the research endeavour where valorizers are able to co-determine the decisions in the everyday business of science.

As we are concerned with the characteristic of usability, Kitcher's concept provides a means to consider what are the conditions of research that is most usable, that is to say knowledge that will most easily contribute to a knowledge reservoir cognate with valorizers, and hence flow most easily serendipitously into research utilization transactions to generate socio-economic value. Our reading of Kitcher's argument is that the greatest degree of usability occurs when valorizers have the opportunity to exert influence – via scientific governance processes – on the direction (if not the content) of scientific decision-making, and to ensure that it reflects their interest. Hence drawing on Kitcher, we argue that it will be those research projects that have a material dependency on valorizer knowledge that are those that are best cognate to valorizer knowledge and hence coupled to research utilization transactions.

Our argument for the dependency on valorizer knowledge has two rationales. Firstly is because knowledge is highly context dependent and unique, and therefore if a valorizer has knowledge that you require (in whatever form) then you must compromise to their needs to access that knowledge, in contrast to other resources (e.g. financial) that can typically be acquired from a range of sources. Secondly is because acquiring the knowledge from valorizer requires a degree of cognateness with the knowledge base of the valorizer, which in turn suggests that the knowledge eventually arising from the research project will also be cognate with the valorizer. Thus, we argue that those research activities which are the most cognate with valorizer interests are the best coupled to what we call the research utilization subsystem. The research activities most cognate with valorizer interests are those that incorporate valorizer knowledge into their activities through the various stages of individual research activities. And whilst Kitcher envisages that there are three key stages, we instead choose to make a five-fold distinction between the stages of the research process at which valorizer knowledge may be incorporated, reflecting our conception of the business of research as a community of knowledge circulation.

7 Well-ordered science & usability oveR the research cycle

We contend that Kitcher's 3 stages – namely choosing research questions (inspiration), undertaking research (execution) and disseminating that research (dissemination) – might be expanded by considering two additional stages, namely reflection and planning. At the same time, we are not saying that every research process is linear and follows this process, rather that these steps are a way of classifying different kinds of activities, from the individual/ intellectual (inspiration and reflection) to the collective/ practical (execution/ dissemination). To therefore operationalize the idea of usability, we argue that usable knowledge acquires usability by acquiring cognateness with valorizer knowledge through the five different stylised steps in research processes[9]. It acquires this cognateness at each stage by incorporating valorizer knowledge into that stage in various different ways, with more detail provided below:

1. **Reflection**: one's past research agenda is the starting point for future research; researchers whose past research has been affected by external influences starts from a knowledge base of contextualised knowledge.
2. **Inspiration**: the researcher may be inspired by valorizers or external issues to be addressed by creating a new research project.
3. **Planning**: the researcher may design and produce a research project proposal including external knowledge, interests and needs as key research elements.
4. **Execution**: the researcher may undertake a research by actually using external knowledge, making a research project dependent on unique knowledge held by external partners.
5. **Societal dissemination**: the researcher could participate in value-added societal dissemination generating new insights or knowledge for future research orientations.

The first aspect to consider is that research is an additive activity; researchers build on not only what others have done, but their own past experiences and knowledge, making research a path dependent process (Neff, 2014). Individuals' research trajectories are strongly dependent on past research decisions and outcomes and current practices should be understood in terms of these past its influences – what Knorr-Cetina (1981) characterised as its "decision-impregnatedness". This implies that for researchers whose past research has been conducted within a framework leading to well-ordered science then their own knowledge base has a higher relative degree of usability: the academic's own knowledge is impregnated with valorizer interests (even where these may not immediately be evident). This means that new knowledge that emerges in the course of research building on this usable knowledge base is likewise also impregnated with usability in terms of the general framing and the orientation of that knowledge. Therefore, academics whose past activities have situated them into knowledge generating

---

[9] An earlier version of this argument is presented in Olmos-Peñuela *et al.* (2014), although some of the terminology used has evolved since then in response to feedback.

communities that are well coupled to the research utilization subsystem are likely to take their research further in ways that likewise contributes to this coupled knowledge pool, and hence to be more usable.

In recognition of Kitcher's inclusion of agenda setting (or research question choice), we identify "inspiration" as a second phase in a research cycle. The inspiration phase is where researchers scan the environment to identify a problematic or a tension that they deem as being worthy of further study, generating an overarching research question prior to trying to create a concrete activity to answer that question. Here, we see usability as clearly being reflected by the degree to which individuals are inspired by a practical question as opposed to purely a conceptual challenge identified in scientific literature. Following Stokes (1997) distinction outlined above, it is perfectly possible to undertake fundamental research that is inspired by use considerations, because considerations of use necessarily relate to eventual usability. Therefore we contend that scientists whose research orientation is towards what Stoke terms "considerations of use" whether fundamental or applied scientists, will be better coupled to the research utilization subsystem and hence create more usable knowledge.

The third step of the research cycle is the mobilisation of an activity to address a particular research question, the "planning" stage, where valorizers' knowledge or influences may be included in the research process at the development of the research proposal or plan. D'Este *et al.* (2013) argue that demonstrating what they call 'pro-social' research behaviour at the planning stage implies awareness and sensitiveness of the potential impact of the knowledge that the particular project will create (based on Hessels & Van Lente, 2008, p. 742). They argue that pro-social behaviour does not just relate to the researchers themselves reflecting on potential use in developing a plan (such as writing an impact statement), but also for demonstrating how that potential use will be realised in the course of the project. This involves planning co-creation, knowledge exchange, and interactive activities into the life of the research activity, effectively building well-ordered scientific governance into the project at the micro-scale. The net effect of that is therefore to increase overall usability by ensuring that more research proposals emerge well-coupled to valorizers, and hence increasing the chance for decision-making to decide to proceed with well-ordered projects (rather than those with for example superficial or compliance valorizer dissemination activities).

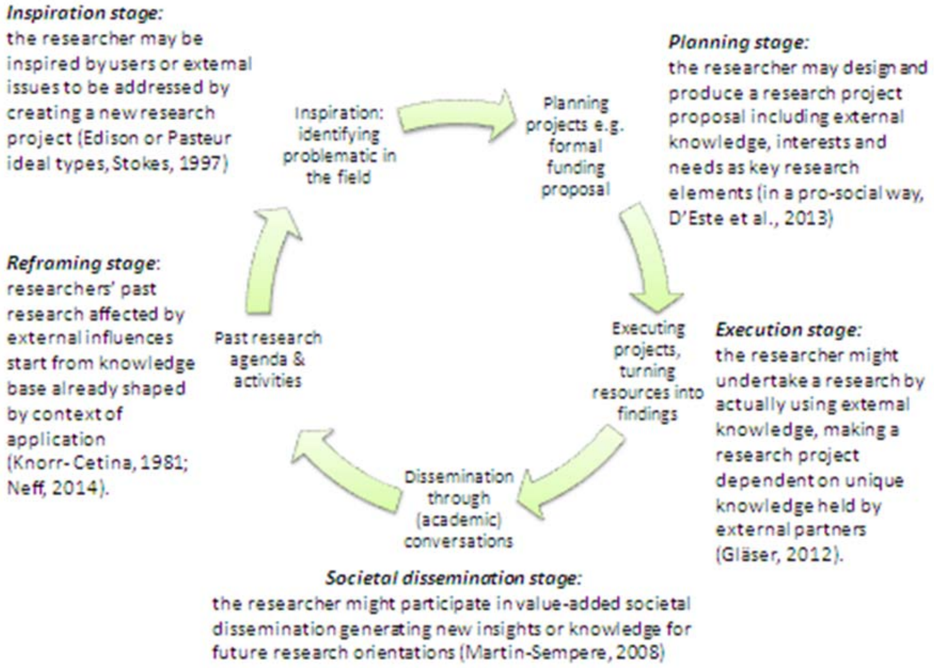
The fourth stage, in Kitcher's words "the pursuit of the investigation" (Kitcher, 2001, p. 122), involves mobilising and distributing already allocated resources in order to create new knowledge to answer a research question and hence produce research outcomes: we term this the "execution" stage. Given that the control of resources is a critical issue in control research content and agendas, (Glasër, 2012, p. 9), as we argued in section 6, we note that in particular the control of knowledge is critical in research processes, because it is context dependent and can be unique, and it is not easily replaced, unlike for example money, which is almost entirely fungible ("*pecunia non olet*"). Indeed, prior research has already identified that access to unique external knowledge is among the most salient reasons motivating researchers' engagement with valorizers (Lee, 2000; Baldini *et al.*, 2007; D'Este & Perkmann, 2011; Lam 2011). This implies that research that includes external knowledge in project execution has to be cognate with valorizer knowledge in order to access, absorb and incorporate that knowledge, and the resultant research outcomes will likewise be cognate with valorizers, making them more prone to be highly usable by others.

Finally, our last stage of the research cycle coincides with the one proposed by Kitcher namely translation of results or dissemination (either scientific or societal). This stage allows research to be open to external influences since it might involve two-way interactions and discussions between scientist and valorizers (Martín-Sempere *et al.*, 2008). A common trope in innovation narratives is of scientists discussing a piece of research with valorizers and those valorizers thinking of new uses for the finding that also raise interesting new fundamental questions that would not necessarily have been the most obvious fundamental questions to ask. Therefore, meaningful two-way dissemination activities with valorizers may contribute to starting new research leading to new knowledge characterised by a higher usability.

Incorporating valorizer (external) knowledge throughout the research cycle – one of the hallmarks of science undertaken within a well-ordered scientific governance framework – provides the coupling of the various interests (Kitcher 2003, p. 218), raising the responsiveness of research outcomes to societal needs. Bearing this in mind, we argue that research usability (and subsequent usefulness) arises as a consequence of well-ordered science in which valorizer knowledge is incorporated at these various stages. We here stress that this process is neither linear nor circular, but rather a way of drawing a line around particular activities that take place within well-ordered science, scientists drawing on past engagement experiences, being inspired by use, planning engagement into projects, accessing valorizer knowledge, and disseminating it in interactive ways. At the same time, well-ordered science involves many knowledge-creating agents undertaking knowledge creation activities in various ways that are clearly not cyclical. With that caveat, we argue that from the retrospective perspective of a research activity, usability as a characteristic can be identified at these five stages, summarised in Figure 4 below[10].

[10] It is important to stress here that we are not considering the res process as an endless linear cycle; firstly, individual researchers will be working on several ideas and tracks simultaneously and there will be interplay behind their ideas; secondly, there will be feedback between the different stages. What we say is that in a *completed research activity* that proves to be usable then it is possible to think of the research activity that fed into that as having passed through five discrete stages, from the vague incepting ideas to the dissemination of the final idea, and that usability involves incorporating valorizer knowledge at every stage of this process.

Figure 4. Research openness through the research cycle



Source: authors' own design (based on Olmos-Peñuela et al., 2014).

8

We do not believe that what we are proposing here is particularly radical nor does it rely upon claims that everything that is currently known is false. Rather, we are arguing that a slight misunderstanding in the way that science operates, and policy-makers' concerns with guaranteeing public benefit, have led to a mis-framing of the idea of excellence in reducing it to only research with a potential to contribute to what we call 'terminal use transactions'. We instead argue that what is also important to regulating the level of these TUTs is the existence of knowledge which can feed directly into those final transactions. We therefore argue that the existing studies of research utilization – focusing on these TUTs – should be expanded to consider those AUTs, and that science governance research should likewise expand to better reflect on how governments may direct research towards particular usable and then potential useful outcomes. And the corollary of that is that we are only arguing that policy-makers also seek to promote the research that can in some way clearly demonstrate potential to contribute to the 'knowledge reservoir' by having clear cognateness with valorizer knowledges.

One issue that clearly we need further reflection upon is the relationship between the issue we deliberately set to one side in section 3, that is the characteristic of knowledge in terms of its capacity to be taken forward by others. There is a clear need to use understandings developed within bibliometrics to bring tie together the idea of scientific and societal usability. At the same time, we also believe that bibliometrics itself may benefit from using this distinction between usable and useful knowledge; at the moment what is currently captured is scientific knowledge that is scientifically useful (for example by being cited by others). But at the same time it may be useful to understand the general characteristics of what makes knowledge potentially usable by other scientists, particularly in terms of current policy concerns (e.g. as expressed by Nedeva, 2013; Bloch & Sørensen, 2014; Laudel & Gläser, 2014; Larédo, 2015) with finding ways of funding breakthrough and frontier science (Rosenberg, 1991).

A final issue that clearly arises and requires further reflection is the relation between usability and the various stages; in Kitcher's (2001) model of well-ordered science, it is well-ordered precisely because there is a co-ordination of societal and scientist interests at all three stages of the process. Given the way that our concept of usability has been constructed, what is not clear is the relationship between usability at the different stages. There is an obvious question as to whether usability at all stages is equally important, or whether usability at one stage is critical in ensuring coupling to the research utilization subsystem. Likewise, it is not clear whether building in usability at one of the stages is antecedent to usability occurring at other stages; it is intuitive to think that planning will automatically precede execution and dissemination, and planning for engagement depends on past experience as interpreted through personal reflection. But answering these questions empirically is clearly necessary before any further steps can be taken in implementing the usability concept.

Acknowledgements

The authors acknowledge the EU-Spri Forum for the PhD Circulation grant provided to Julia Olmos Peñuela and to CHEPS as her host institution, and the VALi+d program funding her postdoctoral research. The authors acknowledge the CSIC and other IMPACTO project researchers (INGENIO & IESA) for their hard and very satisfactory work and the CSIC researchers whose questionnaire answers permitted developing the database. The authors would like to thank the anonymous interviewees at the University of Twente that provided the insights contributing to section 2. Finally, the authors wish to thank Jordi Molas Gallart, Ismael Rafols, Richard Woolley and Pablo D'Este for their valuable comments on previous presentations of this work. Any errors or omissions remain the responsibility of the authors.

References

Ambos, T. C., Mäkelä, K., Birkinshaw, J. & D'Este, P. (2008). When Does University Research Get Commercialized? Creating Ambidexterity in Research Institutions. Journal of Management Studies, 45(8): 1424-1447.

AWT (2007) Alfa- en gamma-stralen, the Hague (NL), Adviesraad for Wetenschap en Technologie.

Baldini, N.Grimaldi, R. &Sobrero, M. (2007). To patent or not to patent? A survey of Italian inventors on motivations, incentives, and obstacles to university patenting. Scientometrics, 70 (2): 333-354.

Benneworth P.S & Hospers G-J, (2007a). The new economic geography of old industrial regions: universities as global–local pipelines. Environment and Planning C: Government and Policy, 25(6): 779-802.

Benneworth, P. S. & Hospers, G.-J. (2007b). Urban competitiveness in the knowledge economy: Universities as new planning animateurs. Progress in planning, 67 (2): 99-198.

Benneworth, P. (2014). Tracing how arts and humanities research translates, circulates and consolidates in society. How have scholars been reacting to diverse impact and public value agendas? Arts and Humanities in Higher Education 1474022214533888, first published on May 14, 2014 as doi:10.1177/1474022214533888.

Benneworth, P. S. & Charles, D. R. (2005). University spin off companies and the territorial knowledge pool: building regional innovation competencies?. European Planning Studies, 13 (4): 537-557.

Benneworth, P. S. & Ratinho, T. (2014). Back to the future of high technology fantasies? Reframing the role of knowledge parks and science cities in innovation-based economic development. Environment and Planning C, 32(5): 784-808

Bloch, C., & Sørensen, M. P. (2014). The size of research funding: Trends and implications. Science and Public Policy, scu019.

Boschma, R. A. (2005). Proximity and Innovation: A Critical Assessment. Regional Studies, 39(1): 61-74.

Boyle, R. (1665). The introduction" Philosophical transactions of the Royal Society of London, 1: 1-2.

Clausen, T. & Rasmussen, E. (2013). Parallel business models and the innovativeness of research-based spin-off ventures. The Journal of Technology Transfer, 38: 836-849.

Collini, S. (2009). Impact on humanities: Researchers must take a stand now or be judged and rewarded as salesmen. Times Literary Supplement, 13th November 2009.

Collini, S. (2011). What are universities for? London, Penguin.

D'Este, P., & M. Perkmann. (2011). Why do academics engage with industry? The entrepreneurial university and individual motivations. Journal of Technology Transfer 36 (3): 316-339.

D'Este, P, Llopis, O. & Yegros-Yesgros, A. (2013). Conducting pro-social research: Cognitive diversity, research excellence and awareness about the social impact of research. INGENIO (CSIC-UPV) Working Paper Series. (downloaded on 4 June 2014 from: http://www.ingenio.upv.es/sites/default/files/working-paper/2013-03.pdf).

Elam, M, & Bertilsson, M. (2003). Consuming, Engaging and Confronting Science The Emerging Dimensions of Scientific Citizenship. European Journal of Social Theory, 6(2), 233-251.

Funtowicz, S. O., & Ravetz, J. R. (1993). Science for the post-normal age. Futures, 25(7): 739-755.

Gibbons, M, Limoges, C., Nowotny, H. Schwartzman, S., Scott, P., & Trow, M. (1994) The new production of knowledge: the dynamics of science and research in contemporary societies. London: Sage.

Gläser, J., 2012. How does Governance change research content? On the possibility of a sociological middle-range theory linking science policy studies to the sociology of scientific knowledge. Technical University Berlin. Technology Studies Working Papers, TUTS-WP-1-2012, (downloaded on 1 April 2012 from: http://www. ts. tu-berlin. de/vmenue/publikationen/tuts-working_papers/).

Gordon, R. W. (1993). Lawyers, Scholars, and the "Middle Ground". Michigan Law Review, 2075-2112.

Gruber, M., MacMillan, I. C. & Thompson, J. D. (2008). Look Before You Leap: Market Opportunity Identification in Emerging Technology Firms. Management Science, 54(9): 1652-1665.

Hessels, Laurens K. & Van Lente, H. (2008). Re-thinking new knowledge production: A literature review and a research agenda. Research policy 37 (4): 740-760.Kitcher, P. (2001) Science, truth and democracy. Oxford: Oxford University Press.

Kitcher, P. (2003). What kinds of science should be done? In: Lightman, A., Sarewtiz, D., Desser, C. (Eds.), Living with the Genie: Essays on Technology and the Quest for Human Mastery. Island Press, Washington, DC.

Knorr-Cetina, Karin. (1981). The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science. Oxford: Pergamon Press.

Lam, A. (2011). What motivates academic scientists to engage in research commercialization:'Gold','ribbon'or 'puzzle'? Research policy 40 (10): 1354-1368.

Larédo, P. (2015). Supporting Frontier Research, Which Institutions and Which Processes. In The Changing Governance of Higher Education and Research (pp. 189-205). Springer International Publishing.

Laudel, G., & Gläser, J. (2014). Beyond breakthrough research: Epistemic properties of research and their consequences for research funding. Research Policy, 43 (7 September 2014): 1204–1216.

Lee, Yong S. 2000. The sustainability of university-industry research collaboration: An empirical assessment. The journal of Technology Transfer 25 (2): 111-133.

Leeuwen, A. van (2013). Munt slaan uit kennis: De Universiteit Twente voert de nieuwe valorisatie-ranking aan van elsevier/scienceworks, Utrecht haalt weer het meeste geld binnen. Elsevier 15th June 2013: 46-48.

Lundvall, B.A. (1988) 'Innovation as an interactive process: from user-producer interaction to the national system of innovation', in G. Dosi (ed), Technical Change and Economic Theory, London: Pinter.

Martín-Sempere, M. J., Garzón-García, B. & Rey-Rocha, J. (2008). Scientists' motivation to communicate science and technology to the public: surveying participants at the Madrid Science Fair. Public Understanding of Science 17 (3): 349-367.

McCann, Philip, and Raquel Ortega-Argilés. Modern regional innovation policy. Cambridge Journal of Regions, Economy and Society 6.2 (2013): 187-216.

Menand, L. (2010). The marketplace of ideas: Reform and resistance in the American University (Issues of Our Time). WW Norton & Company.

Merton, R.K., 1973. The sociology of science: Theoretical and empirical investigations. University of Chicago press, Chicago.

Mur, L. (2014). University-Industry collaboration Is it important and is it quantifiable? Paper presented to "Evaluating collaboration and valorisation in the Dutch science system" symposium, Hoofddorp, NL, 30th September 2014.

Nedeva, M. (2013). Between the global and the national: Organising European science. Research Policy, 42(1), 220-230.

Neff, M. W. (2014). Research Prioritization and the Potential Pitfall of Path Dependencies in Coral Reef Science. Minerva, 52: 213-235.

Novotny, H., Scott, P & Gibbons, M. (2003). 'Mode 2' Revisited: The New Production of Knowledge" Minerva 41: 179-194.

Olmos-Peñuela, J., Benneworth, P. & Castro-Martínez, E. (2014). Explaining researchers' readiness to incorporate external stimuli in their research agendas. CSIC-INGENIO Working Paper Nº 2014-08, http://www.ingenio.upv.es/sites/default/files/working-paper/2014-08.pdf (accessed 28th October 2014).

Polanyi, M. (1962). The republic of science: its political and economic theory. Minerva 1: 54–74.

Popp Berman, E. (2011). Creating the market university: how academic science became an economic engine, Princeton: Princeton University Press.

Rasmussen, E. (2011). Understanding academic entrepreneurship: Exploring the emergence of university spin-off ventures using process theories. International Small Business Journal 29: 448-471.

Ravetz, J. (1999).What is Post-Normal Science? Futures 31 (5): 647–53.

RCUK (2011) RCUK Pathways to Impact Frequently Asked Questions, http://www.rcuk.ac.uk/RCUK-prod/assets/documents/impacts/RCUKImpactFAQ.pdf <Accessed 23rd October 2014.>

Rosenberg, N. (1991). Critical issues in science policy research. Science and Public Policy, 18(6), 335-346.

Rosenberg, N. (1994). Exploring the Black Box: Technology Economics and History. Cambridge University Press, Cambridge.

Sarewitz, D., 1996. Frontiers of Illusion. Temple University Press, Philadelphia

Sarewitz, D. & Pielke, R. A. (2007) The neglected heart of science policy: reconciling supply of and demand for science. Environmental Science and Policy, 10 (1): 5‑16.

Schelsky, H. (1963) Einsamkeit und Freiheit. Hamburg. Germany: Rowolt.

Stokes, D. (1997). Pasteur's Quadrant: Basic Science and Technological Innovation. Brookings Institution Press, Washington, DC.

TCTubantia (2014). Internationaal succes voor Twentse ondernemers. Twente Courant & Tubantia, 15th October 2014, pp. 2-3

Ten Wolde, A. (1998). Nanotechnology – Towards a molecular construction kit. The Hague: STT Netherlands Study centre for Technology Trends, STT 60.

Tyrell, J. (2014) "Commercialization of micro, nano, and emerging technologies – COMS 2014" *Translational Materials Research blog*, http://tmrplus.iop.org/2014/10/23/show-report-commercialization-of-micro-nano-and-emerging-technologies-coms-2014-salt-lake-city-utah/ (Accessed 11th November 2014).

Van Est, R., B. Walhout, V. Rerimassie, D. Stemerding, L. Hanssen (2012). Governance of nanotechnology in the Netherlands: Informing and engaging in different social spheres. International Journal of Emerging Technologies and Society (iJETS), 10: 6-26.

Van Hoeve, W. (2011) "Fluid dynamics at a pinch: droplet and bubble formation in microfluidic devices" *Ph. D. Thesis*, Enschede, NL: University of Twente.

Willetts, D. (2013). The 'eight great technologies' which will propel the UK to future growth receive a funding boost. Speech to Policy Exchange thinktank, London 23rd January 2013. https://www.gov.uk/government/speeches/eight-great-technologies (Accessed 24th October 2014).