

Whitley, Richard

Working Paper

Changing authority relations in public science systems and their consequences for the direction and organisation of research

Manchester Business School Working Paper, No. 556

Provided in Cooperation with:

Manchester Business School, The University of Manchester

Suggested Citation: Whitley, Richard (2008) : Changing authority relations in public science systems and their consequences for the direction and organisation of research, Manchester Business School Working Paper, No. 556, The University of Manchester, Manchester Business School, Manchester

This Version is available at:

<https://hdl.handle.net/10419/50725>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

The University of Manchester
Manchester
Business School

MANCHESTER
1824

Working Paper Series

Changing Authority Relations in Public Science Systems and their Consequences for the Direction and Organisation of Research

Richard Whitley

Manchester Business School Working Paper No 556
June 2008

Manchester Business School

Copyright © 2008, Whitley. All rights reserved.
Do not quote or cite without permission from the author.

Manchester Business School
The University of Manchester
Booth Street West
Manchester M15 6PB

+44(0)161 306 1320
<http://www.mbs.ac.uk/research/workingpapers/>

ISSN 0954-7401

The working papers are produced by The University of Manchester - Manchester Business School and are to be circulated for discussion purposes only. Their contents should be considered to be preliminary. The papers are expected to be published in due course, in a revised form and should not be quoted without the authors' permission.

Author(s) and affiliation

Professor Richard Whitley
Professor of Organisational Sociology
Manchester Business School
Booth Street West
Manchester
M15 6PB
Phone: +44 161 275 6336
E-mail: Richard.Whitley@mbs.ac.uk

Abstract

The governance and organisation of scientific research undertaken for publication have altered significantly since the end of the Second World War in many industrialised economies. These changes have had significant effects on authority relations governing research goals, approaches and the evaluation of results. Such shifts in authority have altered the extent and form of intellectual competition, innovation and coordination in the public sciences. However, the nature and consequences of these governance changes have varied considerably between differently organised public science systems. The changing direction and organisation of scientific research in different societies can be analysed by comparing governance changes in six ideal types of public science systems that differ in the relative authority of the state, intellectual elites and employers. Variations in the stratification of higher education systems and public research organisations and in the diversity of funding agencies additionally affect the consequences of governance changes

Keywords

Public science systems; authority relations; research goals and evaluation; intellectual competition, innovation and coordination; state science policies; stratification; diversity of funding.

How to quote or cite this document

Whitley, Richard (2008) Changing Authority Relations in Public Science Systems and their Consequences for the Direction and Organisation of Research. *Manchester Business School Working Paper, Number 556*, available: <http://www.mbs.ac.uk/research/workingpapers/>

Introduction

Over the past six or so decades since the end of the Second World War the formal system for producing, evaluating and coordinating published scientific knowledge - the public science system (PSS) - has undergone a number of major changes in most industrialised capitalist societies that are members of the OECD. In addition to the rapid and large-scale expansion of certified public knowledge published in refereed journals, books and other scientifically legitimate media, and the proliferation of ever more specialised research fields, the conditions governing the production, coordination and control of formal knowledge have altered considerably. In particular, the state and other collective actors have become more proactive in seeking to steer the direction of academic research, employment organisations such as universities are being encouraged to be more accountable and strategic in their behaviour, and the commercialisation of research has taken new forms.

While continuing growth in the number of research papers and journals has been a feature of the modern sciences for a number of centuries, and close connections between technological developments and academic research have been commonplace in many fields at least since the rise of the chemical and electrical engineering industries (Homburg, 1992; Lenoir, 1997; Murmann, 2003; Shinn, 1979), these postwar changes represent significant shifts in the overall size, organisation and governance of the public sciences and the context in which research is carried out. They can be expected to have substantial consequences for the direction and organisation of research.

However, these general changes in the size, governance and organisation of PSS have occurred in different ways in differently organised systems of higher education, state funding regimes and labour markets (Clark, 1983; Whitley, 2003). While many OECD countries rapidly expanded the public provision of tertiary education and funding for scientific research, and more recently have imitated each others' attempts to reform how these activities are managed and evaluated in a more steady-state funding regime (Whitley and Glaeser, 2007; Ziman, 1994), how they have done so and with what results have varied considerably between states (see, e.g., Braun and Merrien, 1999).

In analysing the impact of recent changes in the governance of public science systems on the direction and organisation of scientific research, it is therefore critical to take account of the major differences between national public science systems and variations in how such changes have been implemented. This involves identifying the key features of their major components, such as funding arrangements, universities and other public research organisations (PROs) and the role of intellectual elites, and their changing interrelationships within the broader context of the dominant institutions governing state-science relations, labour markets and political economies in each country. Particularly important are the nature and policies of the state in sponsoring, licensing, funding and controlling universities and public research institutes, which continue to vary considerably between the Americas, Europe and Asia (Kruecken et al., 2007).

The changing role of the state in organising the public sciences in the postwar period has been especially marked with regard to the organisation of support for academic research and the governance of universities. These latter have been encouraged to become more significant strategic actors with increasing control over "their" resources, and more accountable to the state for their performance through various research evaluation systems (Whitley, 2007b, 2008; Whitley and Glaeser, 2007). Additionally, the combination of declining public financial support for scientific research in real terms, and widespread belief that academic knowledge can, and should, be a significant resource for economic competitiveness, has intensified pressures for PROs to seek revenues from the commercialisation of research results and to collaborate with private companies (Owen-Smith, 2001).

These developments highlight the changing nature of authority relationships governing the selection of scientific goals and evaluation of results that have occurred since 1945 in many OECD countries. Both the variety of authoritative agencies involved, and their willingness to attempt to steer research strategies and knowledge development, have increased, as has the differentiation of the reputational communities integrating research results and rewarding contributions. The goals of such agencies, their internal structures and their relative importance in affecting the direction and coordination of scientific research differ between PSS and over time in ways that influence both the generation of intellectual innovations and how they are assessed and incorporated into established knowledge.

In particular, the variety of new ideas, research goals, approaches and fields, the extent of their novelty relative to currently dominant frameworks, and how they are evaluated as useful contributions to knowledge are affected by the changing nature and influence of these kinds of agencies. In dealing with questions about how particular kinds of PSS have changed in the postwar period and what these changes mean for scientific development, it is important, then, to analyse variations and shifts in the importance, structure and behaviour of these authoritative agencies and their consequences for the direction and organisation of research.

Accordingly, in this paper I suggest how we could analyse changes in public science systems in terms of the varying influence of key groups and organisations in different countries, and their likely effects on the development of novel intellectual goals and the establishment of new scientific fields. This involves, first, summarising the major changes that have occurred in many PSS since the 1950s and considering how these might generally be expected to affect the conduct and direction of scientific research. To understand how these broad changes are likely to affect research priorities, outcomes and coordinated in different kinds of PSS, the key characteristics of the authoritative agencies most influencing scientists' goals and performance standards are then described.

Variations in these characteristics can be combined to constitute six distinct ideal types that differ in the relative authority of the state, intellectual elites and employers. These ideal types differ in: a) the intensity of competition for resources based on intellectual prestige, b) the ease of establishing new fields, c) researcher discretion over goals and approaches, d) the strategic autonomy and capabilities of PROs, and e) the strength of reputational coordination of goals and results across PROs.

Finally, I examine how the key features of these different kinds of PSS seem likely to affect the impact of the postwar governance changes on the generation and selection of intellectual innovations in different societies. Overall, while some of these changes have increased the authority of research foundations, scientific elites and university administrators at the expense of research team autonomy and discretion in some PSS, this is not always the case, and the degree of stratification of universities and other PROs and diversity of funding sources for research are key intervening factors in such relationships.

Changes in the Governance of Public Science Systems and their Implications for Knowledge Production and Development

Public science systems have changed in quite a number of ways since the 1950s, but there are perhaps six major developments that have had significant influence on the organisation and development of research in many countries. First, there has been a rapid expansion of the number of qualified scientists and resources for research followed by a period of much more limited growth in the public funding of scientific research in what Ziman (1994) has termed a dynamic steady state. This reduction in the rate of growth of state funding has often been accompanied by, second, a shift away from relatively stable recurrent support for research institutes and universities towards more competitive project-based funding. Third, states have developed a series of relatively proactive policies for steering the direction of research as part of a more general recasting of science-society relations (Drori et al., 2003; Guston, 2000).

Additionally, many states have undertaken a substantial restructuring of higher education systems following the rapid expansion of students and staff (Braun and Merrien, 1999; Clark, 1983; 1995). This has involved, fourth, the formal delegation of some administrative and financial authority to the managers of universities and other PROs, as well as, fifth, the institutionalisation of various procedures for assessing their performance and auditing their outputs. Finally, there has been a reorganisation of relationships between the public sciences and private business, which has led many PROs to become more actively concerned with the management of intellectual property rights and the encouragement of academic entrepreneurship, especially in biomedical fields (Cohen et al., 2002; Hughes, 2001; Kleinman and Vallas, 2001; Owen-Smith et al., 2002). The expected effects of these six changes on intellectual competition, innovation and coordination are summarised in table 1, and will now be further discussed.

TABLE 1 ABOUT HERE

Considering first the rapid growth of: a) certified researchers producing knowledge for publication, b) published research reports and, c) journals and books devoted to them between the 1950s and the 1980s, this produced PSS that are massively larger than those typical of the first half of the 20th century, and encompass many more areas of study. In terms of the internal organisation of scientific fields, this expansion has accelerated the specialisation of the reputational organisations coordinating published research as well as reinforcing the prestige hierarchy of many publications (Weingart, 2003; Whitley, 2000).

While the sciences in general have become more narrowly focused since the 17th century as natural philosophy was divided up into distinct intellectual disciplines that became entrenched in academic labour markets in many countries in the 19th and 20th centuries (Lemaine et al., 1976; Torstendahl, 1993), the speed and extent of such specialisation grew dramatically in the postwar period as states invested more resources in public scientific research, research training, and higher education more generally. As a result, the prevalent organisational units controlling scientific reputations and the publication of results became more restricted in their intellectual goals and approaches than the established disciplines, as well as overlapping less and less with the boundaries of academic departments, schools and teaching programmes. In the case of English language and literature in Germany, for instance, Weingart suggests (2003: 189) that: "the field which in the mid-1950s could still be seen as a discipline has within thirty years become a mass conglomerate of specialties."

The differentiation of ever more narrowly specified fields of scientific research has additionally been accompanied by their extension to new sets of problems and areas of human experience in what some observers have characterised as the growing "scientification" of everyday life in the knowledge society (Boehme and Stehr, 1986; Drori et al., 2003). This use of formal knowledge to deal with a large variety of social, economic, political and environmental "problems" is not, of course, new, but has become much more widespread and led to a proliferation of new research fields focused on particular policy concerns. It has also encouraged the expansion of university-based training programmes for new specialist skills that are supposed to equip experts for solving such problems (Clark, 1983; Frank and Meyer, 2007).

Such intense specialisation was facilitated by the postwar growth of public support for scientific research and higher education in many countries, which made it easier for young scientists to establish new research goals and approaches without having to supplant existing intellectual elites. When this public support ceased to grow at the same rate as the production of qualified researchers, competition for posts, research funds and reputations intensified in most OECD states.

Since access to these resources and positions is usually dependent on the merits of individuals' contributions to scientific goals as assessed by current elite groups, this move to a more steady-state pattern of funding has increased scientists' dependence on the reputational elites that govern intellectual standards, and has reduced the scope of researchers' discretion to pursue their own ideas. It has also made it more difficult to create novel research programmes, particularly those that threaten established intellectual priorities and boundaries. Depending on how PSS and labour markets are organised in each country, such competition for public research support has encouraged some researchers to gain funding from non-public sources and many PhDs and post-doctoral researchers have sought employment outside the PSS.

Overall, then, the slowdown in growth of state funding for public scientific research can be expected to increase scientists' dependence on current intellectual elites who control the standards for evaluating the scientific worth of contributions to knowledge, as well as intensifying the reputational coordination of research strategies around disciplinary goals. It will also make it more difficult to establish new scientific fields that

cross established intellectual boundaries and rely on novel techniques drawn from different areas of expertise, as well as limiting what Fuller (2000: 143-145) has termed the "epistemic fungibility" of new research projects that could contribute to a variety of different fields.

As well as the level of such funding being reduced in real terms, and sometimes nominally as well, many governments have also reduced the proportion allocated on a block grant basis relative to that awarded competitively to research projects. Depending on how such assessments are made, and on the proportion of funding for published research that comes from the state, this shift in the prevalent mode of allocating research resources seems likely to intensify the consequences of moving to a steady-state funding regime. Making scientists compete for resources to conduct discrete projects whose outcomes can be reliably predicted can be expected to: a) reduce researcher autonomy and discretion, b) increase their dependence on established disciplinary elites and c) restrict the variety and novelty of new ideas being pursued (Ziman, 1994: 107). By limiting resources for generating intellectual novelty and tightening the selection environment through such reforms, states are in danger of reducing the flexibility and innovativeness of PSS, as may have happened in Australia and some other countries where researchers depend very heavily on a small number of state funding agencies (Glaeser and Laudel, 2007; Laudel, 2006).

Such dependence on established scientific elites may be modified by the third major change in the governance of the public sciences since the end of World War II, the increasing willingness of state agencies and policy elites to steer public scientific research towards particular policy objectives. As many commentators have suggested, relationships between politicians, bureaucratic elites and scientists have undergone several changes since 1945 in most OECD countries, but most have involved greater state attempts to ensure policy payoffs from public investment in research (see, e.g., Guston, 2000; v d Meulen, 2007; Martin, 2003). From the initial postwar compact between policy makers and scientific elites, whereby increased public funding was provided for research on the basis that it would eventually lead to both public and private benefits, many governments have intensified their efforts to ensure that publicly funded scientific research contributes to specific policy goals.

In some cases, this has led to an increased emphasis on project-based funding from public research foundations being tied to particular policy focused programmes that are initiated, developed and coordinated by public officials, such as those of the US National Institutes of Health (Cozzens, 2007; Stokes, 1997). As many states have reduced the amount of research support provided through block grants to PROs, and thus increased the dependence of scientists on research foundations and their peer review panels, this has further encouraged the growth of research combining the search for fundamental mechanisms with contributing to social purposes in what Stokes (1997) termed "Pasteur's quadrant".

Depending on how states and research foundations manage the implementation of such policy objectives in resource allocation procedures and decisions, and the general diversity and munificence of sources supporting research in the public sciences, this kind of state steering of research priorities can encourage the proliferation of new fields and approaches, as arguably has happened in the case of

the US investment in computer science and health focused research. Insofar as this encouragement of policy-related research goals provides opportunities for researchers to pursue diverse intellectual projects across established disciplines, it should increase their independence from current scientific elites and broaden their choice of research problems to investigate. This seems less likely to happen when resources are more limited and researchers are highly dependent on a small number of foundations that rely on the judgements of a narrow elite to make decisions. In these latter PSS, the variety of intellectual innovations and willingness to pursue what might be regarded as deviant goals are likely to be quite constrained, particularly those that focus on long term fundamental processes.

The importance of such public policy goals and their incorporation into research foundation procedures and practices has grown with the fourth and fifth sets of changes to many PSS in the postwar period, the restructuring of universities and other PROs, especially their governance, financing and evaluation. As many governments increased their expectations of how these organisations could contribute to social and economic welfare, states initiated a variety of reforms that altered their formal status, powers and responsibilities. These became more systematic and widespread in their impact as the expansion of state funding of higher education began to slow down and change its basis.

In some countries these new demands and complexities have led to increasing state coordination and direction of universities in exchange for public funds, while in others they have encouraged states to separate them formally from the civil service and to delegate more administrative authority to their management. In both cases, though, there has been a considerable increase in political and bureaucratic monitoring of PRO performance and the establishment of novel procedures for evaluating this (Whitley and Glaeser, 2007). In principle, such delegation of authority to the central administrations of universities and other PROs should encourage them to develop some strategic autonomy and capabilities, but this varies greatly between states and organisations, as well as being inherently limited by the uncertainties involved in producing new knowledge and academic teaching processes and the influence of scientific elites (Musselin, 2007; Whitley, 2008).

Often premised on the assumptions of the "new public management", and the view that universities producing new scientific knowledge could be managed and assessed in the same way as other publicly-supported organisations (Schimank, 2005), such demands for accountability, transparency and "excellence" (Weingart and Maasen, 2007) have encouraged many university managers to imitate what are considered to be best practices in the private sector. In a few cases this has led them to attempt to follow the prescriptions of management consultants and popular managerial self help books, but many have formalised authority structures, improved reporting procedures and systems and publicised mission statements.

As van der Meulen (2007) has emphasised in the case of Dutch universities, various state initiatives to link funding to group research programmes and to encourage national evaluations of research performance have provided the basis for university administrations to standardise the unit of analysis in comparing the achievements of departments and faculties in relation to the resources consumed. Such rationalisation

of scientific research activities - at least formally - has occurred quite widely amongst OECD countries and facilitates the management of PROs as project-based organisations in which managers can allocate resources between competing components of investment portfolios (Whitley, 2006; 2007a).

In principle, such standardisation and evaluation can lead to increased employer coordination of research goals and control over resource allocation with a consequent reduction in the powers and independence of senior academics, especially in higher education systems previously dominated by academic "oligarchies" (Clark, 1983; Schimank, 2007; Whitley, 2007b). This strengthening of the middle organisational layer between state ministries and researchers has often been seen by policy makers as a way of emulating certain characteristics of the postwar US high education systems and thereby gaining some of its perceived advantages for the wider society. It has also enabled states to delegate responsibility for managing the consequences of reduced public funding of higher education to universities and similar organisations (Trow, 1999).

An important feature of this restructuring of state-university relationships in the last few decades has been the active encouragement of closer university links with private industry and greater academic involvement in commercial activities (see, e.g., Geiger and Sa, 2005; Woolgar, 2007). While not uncommon in many countries such as France, Germany, Japan and the USA before the Second World War (Odagiri, 1999; Metlay, 2006; Homburg, 1992; Shinn, 1979), such connections have become more institutionalised at the organisational level with many universities and other PROs playing a more systematic and strategic role in commercialising research results since the 1970s.

One of the more visible of this increased institutional commitment is the widespread establishment of technology transfer offices and similar administrative units in many research universities in the Americas, Europe and Japan towards the end of the 20th century, despite their limited success in contributing to university funds in most cases (Kruecken, 2003; Kruecken and Meier, 2006, Kneller, 2008; Siegel et al., 2003). Another has been the expansion of university patenting activity, particularly in the USA since the passage of the Bayh-Dole Patent and Trademark Act Amendments of 1980 (Powell et al., 2007). As Mowery et al (2004) and others have found, though, such patents vary greatly in their commercial payoffs, with many failing to recover the costs involved (Geuna and Nesta, 2006).

This growing emphasis on the commercialisation of research outcomes, especially in the biomedical fields, in many PSS has led some to see the increasing role of private business interests in guiding research strategies and university policies as a significant shift in their governance, and to criticisms of "academic capitalism" and the commercialisation of higher education (see, for example, Bok, 2003; Croissant and Restivo, 2001; Krimsky, 2003; Owen-Smith, 2003; Slaughter and Leslie, 1997). Depending on how such growing influence of private interests and concerns takes place in different national contexts, it could reduce the power of established reputational elites to control research priorities and the coordination of research, increase the flexibility of PSS in adapting to new research agenda, and limit researchers' ability to pursue long term fundamental intellectual goals. It may also

restrict the powers of universities as employers to coordinate research strategies when individual star scientists become able to establish successful spin off companies that generate significant revenues (Powell and Owen-Smith, 1998), just as the growth of federal funding in the USA increased the bargaining power of Dr "Grant Swinger" (Greenberg, 1966).

These six changes have taken place in different ways and to varying degrees in very differently organised PSS and higher education systems. As a result, their impact on the organisation of knowledge production, intellectual innovations and authority relations can be expected to differ considerably between countries. In order, then, to understand how these sorts of very general alterations in the governance and funding of PSS have affected the direction and coordination of research in different societies, we need to compare their key characteristics and consider how these are likely to influence both the implementation of such changes and their outcomes. Accordingly, I now suggest a framework for comparing differently organised PSS and analysing the consequences of these major changes.

Contrasting Authority Relationships in Different Public Science Systems

Despite the growing "denationalisation" of many sciences in the late 19th and 20th centuries (Crawford et al., 1993), and the increasing influence of international scientific elites on reputational judgements and reward allocation processes, the coordination and control of research goals and results remains dominated by nationally organised higher education systems and patterns of financial support. How states manage their relationships with universities and faculties, how authority is allocated between different groups and administrative levels within universities, and how they are connected to different groups and organisations in the wider society continue to vary greatly between countries (Trow, 1993;1999; Wittrock, 1993), as does the general financing of PROs for different purposes (Lenoir, 1997; Torstendahl, 1993).

These variations reflect both historical contrasts in state-society relations, such as the different roles of practitioner elites, universities and state bodies in determining the training, assessment and conditions of practice of professional experts (Burrage, 1993), and differences in educational systems, especially in the funding and governance of pre-industrial universities. As a result, the ways in which cooperation and competition between researchers and their employers are organised, the structure of authority within PROs, the relationships between research and teaching activities, the structure of scientific and technological labour markets and careers, and the ways in which resources for scientific research are allocated and performance evaluated continue to differ greatly between states (Whitley, 2003; Whitley and Glaeser, 2007). These differences affect dominant patterns of setting and changing research priorities, coordinating results and establishing new fields, as well as relationships between scientific and technological research and markets (Gittelman, 2006).

A central feature of PSS that continues to vary significantly between countries, and that has altered considerably since the end of the Second World War, is the organisation of authority over the direction and coordination of research in and across different research groups. Authority here refers to the legitimate influence exercised by a variety of groups and organisations over: a) the selection and definition of important

intellectual problems, b) the appropriate ways of dealing with these, c) the interpretation and evaluation of research outcomes, and d) the integration of results into the accepted body of knowledge and subsequent allocation of rewards. In differently organised PSS, such influence is exercised to varying degrees by individual researchers, the head of their research group, department or institute, broader units of employing organisations, such as faculties, divisions or universities, different kinds of funding agencies, peer review panels, national and international disciplinary elites, state ministries, and private companies and interest groups.

These sources of authoritative influence over the production and evaluation of certified public knowledge vary in their importance between countries and over time according to their organisational cohesion and ability to act as distinct strategic actors, as well of course in terms of the resources they control. For example, the autonomy of universities from the state and their ability to exercise relatively independent authority over resources and employment decisions differs greatly between the USA and, say, Germany, and so does their strategic "actorhood" as distinct collective actors (Kruecken and Meier, 2006; Whitley, 2008). The balance of authority between state agencies, universities, department heads and individual project leaders and their interdependent impact on the public sciences have been major distinguishing features of national higher education systems for much of the 19th and 20th centuries (Clark 1983; Trow, 1993).

Additionally, the impact of public and private research foundations on scientific goals and approaches has been considerable in some countries and historical periods, as the example of the Rockefeller foundation in supporting the nascent field of molecular biology exemplifies (Abir-Am, 1993; Kohler, 1979; Yoxen, 1982), while being negligible elsewhere. Such differences suggest that changes in the organisation of PSS and their likely consequences for knowledge production can usefully be analysed in terms of the shifts in influence, purposes and effects of these variously distinct and interdependent authoritative agencies in different countries and internationally.

At least five distinct sets of such agencies can be identified: a) the state and its associated organisations, b) public and private research foundations that vary in their independence from the state, c) local, national and international reputational elites, d) universities and other public research organisations that provide facilities for, and sometimes employ, researchers, and e) private interests, including established and new firms, consortia, trade associations and commercialisation agents. The extent to which members of these sets pursue similar goals and work together to influence PSS obviously varies greatly, but they do distinguish between different kinds of interests and collective actors that can be expected to affect the direction and coordination of research in contrasting ways. Their key characteristics are listed in table 2 and will now be discussed further.

TABLE 2 ABOUT HERE

Considering first the state, in many if not most countries it is the primary agent that establishes, funds and evaluates PROs, often determining the status of universities and allied organisations, their operating procedures and formal structures. While the extent of state control over higher education programmes, student selection,

examination procedures and academic organisation, as well as the appointment and promotion of researchers, continues to vary greatly between countries in addition to changing over time, it remains the dominant institution affecting the organisation of PSS and the prevalent rules of the game governing competition and cooperation between researchers and departments.

However, the organisational cohesion of states in exercising such influence varies considerably. The widespread establishment of ministries and other organisational units of science and technology policy between the 1960s and the 1990s (Jang, 2003) highlights the formal differentiation of state departments dealing with higher education and scientific research in many countries, and the subsequent shifts of such units around state bureaucracies in countries such as Germany and UK suggest some uncertainty as to their role and purposes. As Musselin (1999) describes in the case of France, even in states that exercise strong central control over universities and PROs, the consistent coordination of public science and technology policies around coherent goals can be constrained by bureaucratic fragmentation and political change (see, also, Merrien and Musselin, 1999). Thus, how states exercise authority over scientists, PROs, research foundations and resource allocation more generally, and for what purposes, need to be explored in any comparative analysis rather than being assumed to be identical across countries and periods.

As discussed above, an increasing part of the state's influence over research priorities is being exercised through public research foundations. While these are often sub-units of ministries, many have become more autonomous agencies that are able to exercise some discretion over how they contribute to public policy goals, as in the cases of the British Medical Research Council and the US National Institutes of Health. This is especially likely when they have been established for some time and for wide-ranging purposes, and rely extensively on peer review for proposal evaluations. Their influence over scientific priorities has grown with the relative decline in block grant funding of universities and increasing attempts by state élites to steer research towards public policy objectives (Braun, 1998; 2003).

Additionally, in many countries there are private foundations that provide support for scientific research, although their influence in steering priorities has perhaps lessened since the expansion of public funding in the postwar period. The main significance of these agencies for the organisation of PSS lies in their increasing the diversity of funding sources for research projects and of the purposes for which such support is provided. Such pluralism is important for intellectual innovation since it prevents, or at least mitigates, a small group of reputational elites controlling the standards according to which proposals are judged worthy of support. An important variable characteristic of such foundations is the extent of their reliance on external peer review in making decisions and evaluating performance.

In the case of the USA, the considerable pluralism of public research support that has developed since 1945, with different federal government agencies, congressional committees and other public agencies as well as numerous privately funded foundations providing significant resources for a variety of overlapping purposes, has been considered beneficial for both science and society by allowing multiple and diverse research ideas to be pursued (Stokes, 1997). In contrast, recent changes in

Australia have greatly increased researchers' dependence on the single state funding council and probably limited their ability to pursue unusual approaches (Glaeser and Laudel, 2007; Laudel, 2006). As the role of such agencies and organisations in steering scientific research has grown in most OECD countries since 1945, their organisation, goals and governance have become significant features of PSS that must be taken into account when considering their changing nature.

The considerable authority of reputational elites in directing and evaluating research goals and results is, of course, a central, if not constitutive, feature of the modern sciences that has grown in importance with the institutionalisation of academic careers and labour markets around intellectual reputations and increasing dependence of research funding on peer review judgements (Geiger, 1986; Torstendahl, 1993; Whitley, 2000). While the cohesion and influence of national and international disciplinary elites continue to vary considerably between scientific fields, their role in the organisation of nationally based PSS also varies between countries as well as over time.

First of all, the extent to which, and terms upon which, states delegate authority over resource allocation and rewards to scientific elites differs between PSS, particularly with respect to the establishment of new organisational units and research fields in state institutions such as universities, the appointment of senior academic staff and the organisation and direction of research dedicated to the achievement of public policy objectives. For example, at the new University of Berlin, which served as the model for many 19th century universities that integrated scientific research with teaching, academic appointments were reserved for the state in order to avoid them being dominated by what were seen as parochial guild-like professorial interests. This combination of considerable research autonomy for established professors with formal state powers of approval of such appointments continued well into the 20th century in many European countries (McClelland, 1980; Schimank, 2006; Wittrock, 1993). In contrast, the postwar British state delegated considerable powers to universities and their senior staff, including block grants that supported quite a number of staff research projects (Clark, 1983; Trow, 1993).

Additionally, the way that states rely on intellectual elites' judgements varies greatly between those that defer to peer review judgements of quality and contribution when making resource allocation decisions and those that integrate scientists into policy making processes as much on the basis of their political and personal ties as on the basis of their intellectual distinction. In the latter case, disciplinary authority is less autonomous and strategically significant as an independent influence on research priorities and coordination than it is in the former situation.

Second, scientific élites in some societies are much more concentrated in a few privileged institutions that combine considerable social and intellectual prestige with disproportionate control of resources than in others where they tend to be more dispersed amongst a number of leading research universities and PROs. Often correlated with hierarchically organised higher education systems, such concentration enables intellectual elites to: a) exercise considerable authority over PSS as a whole, b) wield patronage over key appointments and, c) influence the allocation of resources between and within sciences. In less vertically centralised PSS, authority is more

widely distributed between separate groups and elite status is more open to challenge, often because resources are more readily available from a variety of sources. Overall, we would expect the diversity of intellectual innovations to be greater in the latter case than in the former.

Third, intellectual authority in the sciences differs in its flexibility and ability to adapt to changing contexts. In some PSS, it is tied to relatively stable disciplinary communities that control journals, careers and resources as distinct and separate reputational organisations, while in others such authority is less firmly bounded and differentiated between discrete and cognitively integrated specialisms. Such variations partly reflect the extent to which scientific labour markets and resource allocation processes are governed by disciplinary elites' goals and the segmentation of careers between different kinds of organisations (Whitley, 2003).

In particular, when intellectual authority is entrenched in university hierarchies and controls administrative units, it is difficult for radically innovative approaches that challenge current intellectual and social boundaries and priorities to gain adherents and resources. On the whole, then, the more that the primary units of knowledge production overlap with administrative units in PROs controlled by members of disciplinary elites, the less easy will it be to establish new research fields as distinct reputational organisations.

The fourth set of authoritative agencies coordinating and directing scientific research consists of employment organisations, which differ greatly in their ability to influence intellectual priorities and developments. In the case of universities, which remain a key, if not the dominant, organisational location for researchers, their strategic capability and independence continue to be highly variable between national PSS. Some still function largely as hollow organisations in the sense that they have little administrative autonomy and capacity to allocate resources, monitor performance and reward staff, while others have much greater discretion over employment policies and investment priorities (Clark 1983; Schimank, 2006; Whitley, 2008).

Additionally, within PROs the distribution of authority between the central administration, department and institute heads and individual researchers varies across national boundaries. In countries dominated by the institute model (Clark 1995), research strategies and resources are largely controlled by institute heads and individual researchers have relatively little autonomy to develop their own projects. Academic careers are highly stratified, with many scientists unlikely to become senior professors with their own institutes (Trow, 1993; 1999).

In what Clark (1995) terms more departmental academic systems that are characteristic of many Anglophone countries, in contrast, careers are less strongly stratified and many junior researchers can reasonably expect to become senior academics through their own research prowess. This is especially likely in PSS where they are able to raise funds for their own research projects from a variety of agencies that are advised by diverse groups of peer reviewers. While, then, internally centralised and stratified university systems enable the elite to pursue substantial coordinated research programmes with junior colleagues, more pluralist departmental authority structures permit a wider range of topics and approaches to be pursued.

These differences in the internal and external authority of PROs mean that the broad changes in the organisation of PSS discussed above are likely to have variable effects depending on these and other features of national PSS. Increasing state delegation of authority over administrative and financial matters to universities, for example, might lead them to develop greater strategic capabilities and control resource allocation between different fields, as well as reducing the independence of institute heads. However, if commercialisation pressures and general availability of funds from diverse sources enable scientists to pursue individual projects and control their own resources, such organisational direction and integration will be limited. Attempts to turn PROs into strategic actors comparable to private companies not only fail to take sufficient account of the uncertainties involved in scientific research, but also ignore the limitations on their authority resulting from the influence of reputational elites and funding agencies.

The final set of authoritative agencies affecting research goals and coordination of outcomes are more varied and fluid in their influence and interests. These consist of the wide range of private organisations and groups interested in learning about, supporting and gaining advantages from, scientific research. While the role of firms in supporting academic research has been significant in certain fields such as chemistry and electrical engineering since the last quarter of the 19th century in some countries, both the extent and variety of private funding have grown considerably for many more scientific fields, especially since the 1980s (Geiger, 2004). In particular, opportunities for commercialising research results and gaining significant revenues from licensing products and processes have become more widely available, at least for some scientists and universities (Cohen et al., 2002).

This has been concentrated in biomedical fields where new knowledge has been more directly relevant for technological purposes than has much of that produced in the physical sciences (Powell and Owen-Smith, 1998), despite some doubts about the revolutionary impact of the biotechnology industry on drug discovery methods and results (Hopkins et al., 2007). As a result, private companies and commercial interests, including those of PROs themselves, tend to become more overtly and systematically involved in the research goals, techniques and results of academic scientists in these fields than in those where such connections are more mediated by technological sciences and research skills are as important to firms as published knowledge (Cohen et al., 2002; McCray and Croissant, 2001).

Such close links between new knowledge, technological uses and commercial opportunities have encouraged both researchers and their employers to engage more directly in a variety of fund raising initiatives based on the exploitation of intellectual property rights (IPR) than has often been considered seemly in previous decades (Colyvas and Powell, 2006; Hughes, 2001). This involvement raises questions about the role of private interests in guiding research priorities and the allocation of resources in universities (Bok, 2003; Slaughter and Leslie, 1997). It could severely reduce the authority of reputational elites over research goals and significance standards as scientists and employers focus more on revenue from commercialising results than on seeking scientific prestige (Croissant and Restivo, 2001).

It has additionally focused attention on who controls the IPR from scientific research and manages its exploitation. Where universities and other employers have been granted the right to do so, they could gain more authority over research priorities if they are able to increase the funds at their disposal and allocate them centrally. Where, on the other hand, such revenue streams are more controlled by individual researchers through, for instance, establishing new companies, the authority of employers will be diminished. The effects of intensified commercialisation of publicly funded scientific research on the distribution of authority between research groups, employers and disciplinary elites depends, then, on the institutions governing such activities, as well as on more general features of PSS.

Ideal Types of Public Science System

The effects of the changes in the governance of PSS that have occurred since the war vary according to the nature of these characteristics of authoritative agencies and their interrelationships. In analysing how differences in the organisation of PSS are likely to affect these outcomes, it is useful to distinguish between a number of distinct ideal types of PSS that combine these characteristics in particular ways. As ideal types, they exemplify particular patterns of research organisation and control that have contrasting implications for intellectual development. At least three contrasting pairs of such ideal types can be identified in terms of the relative dominance of state agencies, scientific elites and employers: *state-coordinated*, *state-delegated* and *employer-coordinated*.

The first pair consists of PSS where the state retains considerable levels of control over employment and resource allocation, but differ in the degree to which states share authority with intellectual elites. In *state-centralised* PSS this is lower than in *state-shared* ones. In the second pair of PSS, scientists are employees of universities and other PROs, but these organisations remain largely funded and chartered by the state. The two types of state-delegated PSS differ in terms of the amount of independent discretion that researchers have over research goals and approaches. This is lower in *state-delegated competitive* PSS than in *state-delegated stable* ones because they have to compete intensively to gain research resources from a small number of research foundations, and so are highly dependent on the decisions of a few peer review panels.

The last pair of PSS consist of situations where employers are much more able to determine employment conditions, resource allocation and organisational structures independently of the state, but have to obtain most of their resources competitively from diverse sources. Universities and other employers of researchers in *pluralist employer competitive* PSS are much more concerned to become scientifically prestigious by making major contributions to intellectual goals than are PROs in *employer dominated* ones, and so share considerable authority with scientific elites in making many decisions.

These types are associated with different degrees of institutional stratification in terms of their control over resources and general social prestige, variations in the autonomy of individual researchers within departments and institutes, variety of funding sources, permeability of organisational boundaries and fluidity of labour markets for scientists. As a result, they additionally differ in their openness to radical intellectual innovations,

especially the establishment of new scientific fields, the intensity of intellectual competition, and the coordination of research results around collective intellectual goals.

For example, highly stratified education systems seem likely to exhibit considerable centralisation of influence by scientific elites based in the most prestigious universities over resource allocation standards and procedures and scientific priorities. They can be expected to be successful in resisting the establishment of novel research agenda and approaches that threaten their status, as well as the establishment of new fields of research oriented to different kinds of purposes such as technological concerns. Most attempts by low prestige PROs to improve their social and economic position in such societies find it difficult to challenge the dominant standards of intellectual worth set by these elites, as Trow (1993) suggests was the case for many new UK universities and colleges in the 19th century.

Equally, the sort of competitive pluralism that has developed in the USA in the postwar period seems unlikely to become widely established in the absence of considerable diversity of funding sources, relatively fluid labour markets in which PROs compete for leading researchers, and permeable boundaries between different kinds of research organisations and purposes. For such a system to generate a wide range of intellectual innovations and flexibility in the development of new fields, such as computer science, resources have to be relatively generously available from a varied set of agencies and foundations and the boundaries between different kinds of research conducted within and between employers only weakly policed by intellectual elites.

The key characteristics of these six types of PSS are summarised in tables 3 and 4 and will now be further discussed, before considering how they can be expected to alter as a result of the general changes in the governance of PSS discussed above. For purposes of clarity, table 3 summarises variations in their relative authority of different collective agencies in the six kinds of PSS, while table 4 describes their major intellectual and organisational features. The extent of authoritative influence and their impact on research direction and organisation in each ideal type are characterised in a five-point scale of: low, limited, medium, considerable and high.

TABLE 3 ABOUT HERE

Beginning with the state centralised PSS, this is characterised by high levels of state authority over: a) the employment and reward of researchers, b) the allocation of resources between scientific fields and laboratories, and c) the kinds of research that are most highly valued, usually because universities and other PROs are integrated parts of the state. Such integration means that that they have little or no formal authority as independent organisations. It also usually means that the formal heads of individual laboratories and institutes combine considerable administrative and intellectual authority and are able to develop their own long-term research programmes, although some may choose to delegate a degree of intellectual discretion to individual researchers.

In practice, of course, the actual extent of political and bureaucratic influence on research priorities and individual projects can vary considerably between states and

over time, and the authority of co-opted scientific elites may be considerable, as Clark (1983) suggests has been the case in postwar Italy. However, such intellectual patrons exercise their power through the state machinery and by virtue of their being selected by state officials in these kinds of PSS, rather than as leaders of relatively independent reputational communities.

Being quite integrated into the public bureaucracy, it seems unlikely that such PSS would readily accommodate or support highly novel research goals and approaches, or encourage the establishment of new scientific fields, especially if they challenged the authority and expertise of the co-opted elite. Such relative inflexibility could, of course, be overcome by strong political pressure if public policy goals were deemed sufficiently important to require the commitment of substantial resources to accomplish new research goals, but this would more easily be achieved by adding new laboratories and departments to the existing system than by reorganising the established structure. The high cost of such initiatives limits the likelihood of their being pursued very often.

TABLE 4 ABOUT HERE

In state-shared types of PSS, the state shares authority with research institute directors and department heads, but retains substantial formal authority over resource allocation, employment statuses and facilities. Researchers remain state employees, and senior appointments in universities and other PROs still require state approval, but individual institute heads have considerable autonomy in setting research goals and managing "their" staff to achieve them. Such autonomy is enhanced by the state providing substantial research support through the recurrent grant to PROs and departments, so that the need to obtain additional funding on a short term and frequent project basis from research foundations is limited, as still seems to be the case in Switzerland (Liefner, 2003). The authority of separate reputational elites over research goals and standards exercised through peer review of grant applications relative to that of institute heads is thus constrained in these kinds of PSS.

This combination of state and institute authority over resources and research programmes enables powerful senior academics to pursue long-term intellectual objectives in considerable freedom. When they compete for scientific prestige and funds on a relatively equal basis, as in the German academic system for much of the 19th century according to Ben-David (1972; see, also, McClelland, 1980; Wittrock, 1993), they can develop a variety of intellectual innovations in their fields. However, such autonomy and control also enables such elites to resist the establishment of new areas and prevent researchers from pursuing projects that threaten dominant intellectual boundaries, priorities and expertise. Effective resistance to radical innovations is more likely when research institutes are located in a much more hierarchical and stratified higher education system, such as that of Japan, where elite academics are able to develop strong patronage networks that can inhibit competition between departments and limit the circulation and development of new ideas and skills (Clark, 1995; Coleman, 1999; Kneller, 2007).

In more decentralised PSS, the state delegates control over employment, resource allocation and facilities to PROs and scientific elites, while retaining the right to exercise ultimate authority over the nature and structure of PROs, the award of

qualifications, and processes of resource allocation. The crucial difference between these types and the two just discussed is that these state-chartered higher education systems grant degree awarding rights to universities as separate public corporations that are able to hire their own staff and manage their own financial affairs. They are therefore formally independent from the state, despite being largely funded by it, particularly in the 20th century. Additionally, in the Anglophone world the degree of vertical authority over research projects and approaches within departments and institutes of PROs is lower than in more state dominated PSS.

State-delegated stable PSS in particular are characterised by high levels of researcher autonomy from both state agencies and local administrative hierarchies. Additionally, through a relatively generous block grant funding system that provides substantial and predictable recurrent funding of universities for both teaching and research activities, scientists are here able to pursue their own goals without needing to justify them very frequently to either department heads or disciplinary elites. In these kinds of PSS, individuals' scope of discretion is considerable as they compete for reputations in their specialist fields over the medium term. As long as research facilities and materials do not require extensive external support in such PSS, we would expect them to generate considerable variety of research ideas and results with researchers not being greatly inhibited by established departmental and disciplinary boundaries, as exemplified by the work of Watson and Crick at the Cavendish laboratory in the 1950s. Authority within each field is predominantly collegial and horizontal rather than bureaucratic and vertical.

In contrast, state-delegated competitive PSS constrain the work of individual researchers much more by making them more dependent on gaining resources from a few funding agencies reliant on peer review procedures for allocating resources. In these kinds of PSS, authority over research priorities and approaches is more concentrated in the hands of public research foundations and their advisors from the different sciences. While, then, PROs ostensibly have considerable autonomy from the state and their employees are not highly constrained by administrative hierarchies, in practice both are quite dependent on success in highly competitive contests for limited resources governed by current scientific elites' standards for deciding which projects can be expected to make significant contributions to intellectual goals.

Not only do such conditions limit the variety of research goals and approaches followed by most scientists to those likely to fit in with current significance criteria, but they also discourage the pursuit of projects that cross established intellectual and organisational boundaries and are relatively risky in terms of the predictability of expected outcomes. By forcing researchers to compete for resources from one or two agencies that allocate funds through peer review, these kinds of PSS enhance the authority of a small number of reviewers and agency officials who often have to make very fine judgements between a considerable number of proposals competing for limited resources. Both applicants and panels are here likely to focus on projects that are closely integrated with current intellectual goals and can be reliably expected to produce results that contribute to them.

In these circumstances, proposals that aim to deal with highly novel problems with new techniques and concepts from a variety of different disciplines and specialisms are

unlikely to be submitted or supported, especially where politicians and others are concerned with the accountability of scientists and other recipients of public funds. As Laudel (2006) suggests is the case in Australia, intense competition for limited funds coupled with concentration of resources in a single agency encourages decision makers to support applicants who have already demonstrated their ability and the feasibility of the proposed approach. In effect, this often means that much of the work has been carried out before submitting funding applications and is relatively predictable.

The last two types of PSS to be considered here are characterised by limited levels of state authority, usually because universities and other PROs do not have to be formally chartered by the state to award degrees and are not directly regulated in what they can do or how they are organised. As employers, PROs are usually able to establish their own policies and procedures for recruiting, managing and rewarding researchers, to establish their own research priorities, and to shift resources between different fields and topics. They do, though, have to compete for these resources from a variety of sources and to provide a range of services in order to gain them. In such PSS, then, employers are key authoritative agents affecting scientific research through their investment decisions, provision of support and rewards, and organisation of research and teaching activities.

Two different types of such employer influenced PSS can be distinguished in terms of: a) their willingness to share authority with reputational élites in pursuing scientific prestige, b) the strength of research foundations and other funding agencies, and c) the ability of researchers to control their own research resources. Employers in pluralist employer competitive PSS compete for social and intellectual reputations by attracting and supporting research leaders in different fields, as well as for students and funds. They therefore invest in the researchers and faculties that they think will contribute most to disciplinary and specialism goals, and seek resources from a wide range of different agencies and organisations.

As long as there are a considerable number and variety of such sources, competition here encourages organisational and intellectual flexibility and diversity of goals and approaches. Furthermore, the more that individual scientists are able to access research support funds on their own, as quasi-independent entrepreneurs, the more they will be able to pursue different objectives and become relatively independent of their immediate employer. This is especially likely when those funds include substantial contributions to employers' overhead costs, as in the postwar USA (Geiger 2004). In these kinds of PSS, then, employers' ability to allocate resources between competing investments and project teams, and thereby achieve particular kinds of organisational goals is constrained by the specialist knowledge, skills and resource controlling powers of individual scientists and groups.

In more employer-dominated PSS, in contrast, both the level of organisational competition for intellectual prestige and the availability of resources from external agencies are less. Here, scientists are dependent on their employer for funds and facilities required to conduct research. This seemed to have been the case in many US universities in the prewar period (Geiger, 1986), as is illustrated by Terman's encouragement of research activities at Stanford through obtaining funds from local

businesses and supporting new firm formation based on research results (Hughes, 2001; Leslie, 2000).

Such dependence on employers' resources limits both researchers' autonomy and the authority of reputational elites, especially if universities have to compete to attract the best students through the provision of extensive student support services, not to mention the investments needed to be competitive in college athletics and other sporting contests in the USA (Bok, 2003). The search for external funding may, though, enable some private foundations with an interest in science, such as the Rockefeller in the interwar period, to exercise considerable influence on research priorities and approaches, and facilitate the growth of new fields such as molecular biology (Kohler, 1979). In general, the relatively limited control over research priorities and significance standards exercised by reputational elites in these kinds of PSS restricts the degree of intellectual coordination around particular disciplinary goals and allows researchers in different PROs to establish distinct schools of thought that are only weakly integrated.

Changes in Different Types of Public Science Systems and their Consequences

These differences in governance and organisation of PSS can be expected to affect both the scale, and likely consequences, of the six types of change summarised in table 1. It seems improbable, for instance, that political and bureaucratic elites in highly centralised state dominated PSS will delegate substantial authority to the managers of PROs, or to relatively independent intellectual elites, to allocate public resources. Since states would have to grant them greatly extended powers of control over resources, degrees, employment and formal structures, as well as allowing them to pursue a variety of strategies and purposes, if they were to generate significant organisational capabilities and independence, it is difficult to envisage universities becoming autonomous strategic actors in such societies. Equally, many of the changes in state-university relations are of limited relevance to employer dominated PSS where the state already has delegated considerable powers to PROs and there is a strong tradition of organisational independence from national authorities.

In table 5, I suggest how the postwar changes in the organisation of PSS seem likely to affect intellectual innovation and integration in state-coordinated, state-delegated and employer-coordinated types of PSS. It is worth emphasising here that these changes are themselves not independent of the nature of different PSS and the way that they occur does to some extent vary between, say, state-centred and state-shared ones.

TABLE 5 ABOUT HERE

Considering first the impact of reduced state funding of scientific research relative to the number of qualified researchers available to undertake it in different kinds of PSS, the general intensification of competition and reduction in diversity of intellectual goals seems likely to occur in both state-coordinated and state-delegated PSS. As scientists have to compete more for publicly provided resources that are primarily allocated on the basis of intellectual contributions to collective goals, they become more dependent on the judgements of current reputational elites and funding agencies. They are

therefore less likely to invest in "deviant" research strategies and attempt to establish new kinds of scientific fields that use unorthodox techniques.

These effects are less likely to be so strong, though, in PSS where the state delegates only limited authority to scientific elites, and/or where there are a considerable variety of different kinds of funding agencies pursuing diverse objectives. Thus, intellectual integration of research goals and approaches around current disciplinary and specialism significance standards may be less enhanced by such changes in state funding in state centralised and employer-coordinated PSS.

Similar differences in the consequences of changes in funding practices in contrasting PSS can be expected when states implement project based resource allocation processes. As research foundations and peer review panels become more influential in guiding research priorities, scientists become more concerned to demonstrate how their projects contribute to collective goals with reliable methods. This will be especially so when states have delegated substantial authority to intellectual elites in funding decisions and researchers have few alternatives to public foundations. The impact of this change will, then, be particularly significant in PSS where reputational elites play a major role and the variety of different kinds of organisations providing resources for scientific research is limited.

It is perhaps worth mentioning a further "intervening variable" in such relationships, which affects the differentiation of PROs and the reproduction of elite status: the stratification of universities and other PROs. Where this is high, we could expect the effects of reduced funding and growing reliance on competition for project proposals to be strongest for those researchers based in relatively low prestige institutions. Since the intellectual elites determining the criteria according to which research projects are assessed as significant and competent are likely to work in the more prestigious universities where they are also likely to have better facilities, they are also more likely to be successful in gaining resources under the new, more competitive, regime. Again, this outcome will be mitigated in PSS where there are diverse funding agencies with varied goals and groups of advisors. However, in highly state centralised PSS, the same elite is likely to be closely connected to political and bureaucratic elites which may well favour the more prestigious institutions, as seems to have happened in Japan where the former imperial universities have disproportionately become centres of excellence (Kneller, 2007).

When procedures governing the allocation of research funding incorporate public policy goals, these likely consequences of competitive project based funding on intellectual diversity and innovation can be somewhat attenuated. This is especially likely when reputational elites are not so dominant that the consequences of pursuing research contributing more to such purposes than to purely intellectual ones are less negative. Establishing new fields that contribute both to policy goals and to intellectual understanding should therefore be easiest in state and employer coordinated PSS, and rather less so in state-delegated ones. Equally, intellectual diversity should also be greater in these kinds of PSS when public policy goals are incorporated into funding decisions, although this may not be so in state-shared PSS where institute heads retain considerable authority and researchers are less able to raise funds directly for their own projects. As in the previous cases, the effects of such changes in state

funding regimes can be expected to be reduced when resources are available from a variety of non-state agencies and foundations.

Turning next to consider the likely effects of increasing state delegation of financial and administrative authority to PROs in different kinds of PSS, this seems likely to have greatest impact on the more state-coordinated higher education systems. As already indicated, though, it is doubtful if states that have developed highly centralised PSS over many centuries will in fact delegate substantial decision making control to university heads, at least in a few decades, or that many administrators will believe in the permanence of such formal delegation when political and/or financial pressures become significant, as in the case of France (Musselin, 1999; Merrien and Musselin, 1999). The likelihood of universities developing much strategic actorhood and influence over the research priorities of "their" staff as a result of such shifts is, then, limited in state-centralised PSS.

Where the state shares authority with academic élites to a greater extent, this restructuring of state-university relationships is often intended to grant more responsibility for managing resources and activities to universities and to encourage their central administrations to exercise more influence over academics, especially institute heads. To the extent that it does in fact generate and enhance such organisational capability to manage resources and change activities, it could lead to more variety between universities as they compete for resources and prestige, including perhaps their establishment of new departments and research areas.

This would, though, depend on the general availability of resources for such initiatives and the extent to which current reputational elites dominate intellectual standards and resource allocation criteria. Where PROs are highly dependent on their staff obtaining resources for research from a small number of foundations dominated by disciplinary élites, they are unlikely to invest in supporting radically novel projects and skills. This is even more probable when the PSS is highly stratified so that the formal separation of universities from state ministries and of academics from state employment does not really change the dominance of a few elite institutions over the higher education system.

Furthermore, the willingness of the newly empowered deans and presidents of universities to exercise their authority over departments and institutes remains quite limited in many of the European PSS where some formal delegation has taken place (see, e.g., Muller-Camen and Salzgeber, 2005; Schiene and Schimank, 2007). Given the novelty of these changes, and their susceptibility to revision as politicians and bureaucrats change their minds, this is perhaps not too surprising. Such centralisation of organisational authority could increase when new appointments to these roles are not so dependent upon collegial support, and universities begin to function as independent employers, as well being more able to obtain resources from a wider range of funding agencies and organisations.

In the case of more state-delegated PSS where PROs already have some autonomy from the state, are able to shift resources between departments and activities and to make their own employment decisions, the effects of any increase in state delegation seem likely to enhance their strategic actorhood at the expense of individual

researchers and departments. This is especially probable where the political rhetoric associated with such delegation encourages university administrators to act more like private company heads and exercise control over their employees' activities.

The development of organisational research strategies and formal procedures for making trade-offs between investment alternatives at central university, faculty and departmental levels that has become such a feature of many PROs in the Anglophone world reflect such pressures, and can be expected to limit the discretion of researchers and groups. While some of these strategies remain largely formal, and are often vague lists of aspirations rather than systematic attempts to allocate resources preferentially to realise specific objectives, they do represent a reduction in the overall independence of scientists from their employers and in the possible diversity of research goals and approaches.

The extent to which such increasing state delegation and encouragement of strategic autonomy additionally enables PROs to make strategic investment decisions that conflict with current disciplinary priorities depends on the concentration of resource control in one or a very few public research foundations and their reliance on peer review advice from scientific elites. Where scientists and universities as a whole depend greatly on research funds that are largely available from a small number of foundations pursuing intellectual goals, the realistic level of autonomy from such elites will be limited. If, on the other hand, universities and other PROs are able to attract funds from, a variety of foundations, private interests, licensing and so on that enhance their discretion over resource allocation, they may well increase their strategic capabilities, at least as far as making differential investments in favoured fields and researchers is concerned (Owen-Smith, 2001).

Increased state delegation to PROs is often accompanied, of course, by growing state surveillance and assessment of their performance, as the rapid growth of evaluation schemes in Europe, Asia and Australasia in the 1980s and 1990s illustrates (Whitley and Glaeser, 2007). In general terms, this can be expected to: a) enhance national and perhaps international reputational authority where such performance is measured in terms of scientific prestige and contribution, b) limit intellectual diversity and, c) facilitate the growth of PROs' ability to monitor the research performance of individuals and groups (van der Meulen, 2007), although the extent of these effects will differ between types of PSS.

They are likely to be most marked in societies where the state continues to provide and control the bulk of resources for research and legitimates the public status of universities and other PROs, while sharing considerable authority with scientific elites over the determination and implementation of the standards used to assess performance. In state-shared and state-delegated PSS, the impact of what can be termed strong research evaluation systems should be greatest (Whitley, 2007b). These combine standardised procedures for assessing the quality of research outputs with the publication of results for each "unit of assessment", as the British Research Assessment Exercise (RAE) construed knowledge production groupings, and with the allocation of resources on the basis of such evaluations.

The more such performance auditing is conducted publicly according to formal and standard procedures that enable policy makers and the public to rank PROs in terms of their research "excellence" (Weingart and Maasen, 2007) and leads to differential funding for research according to such *ex post* evaluations, the more researchers come to depend on the verdicts of the scientific élites that make such judgements. Such dependence can be expected to make it more difficult to establish new fields that combine new techniques from different areas and to pursue radically novel intellectual goals.

This will be especially so in PSS that are so highly stratified that the standards governing evaluations tend to be established and policed by scientific élites based at the most prestigious and well-endowed universities. The stronger are research evaluation systems in these kinds of society, the more likely that they will reinforce such elite standards and the Matthew effect become more marked. To some extent, the insistence on making qualitative judgements of research outputs according to national and international norms of scientific significance in the evolution of the British RAE can be seen as reinforcing the standards and goals of the scientific elite and the institutions where they are mostly located. As a result, it may well have reduced the likelihood of establishing new kinds of research fields and developing novel techniques drawing on ideas and methods from different sciences.

The need to manage such evaluations and compete effectively for resources based on them regularly can be expected to encourage PROs to exert more influence over researcher performance and to ensure that publications contribute to current intellectual goals and are widely recognised to do so. Their authority and capabilities should thus increase in PSS where strong auditing processes are institutionalised, not least because they encourage the standardisation of scientific research around individual projects whose goals and results can be assessed across individuals, departments and faculties (van der Meulen, 2007; Ziman, 1994).

Simply by standardising both the units being evaluated in terms of the nature of the outputs being considered and the intellectual groupings producing them, as well as the results of such assessments on a scale of significance for each subject, these procedures enable administrators to compare the intellectual effectiveness of each group and thereby provide the foundation for making investment decisions between them as well as legitimating them. Where they are relatively autonomous employers and so can implement research strategies through hiring and promotion decisions, this means that PROs could considerably increase their capabilities as project-based organisations.

These outcomes do, though, depend on the extent to which PROs and research groups are affected by the results of such evaluations, particularly in respect of resources. If they are primarily reputational in impact and have little consequences for research funding, either because they are not directly tied to the allocation of public funds or because there are many alternative sources available, and if researchers can access such alternatives themselves, the impact of such auditing will be limited, at least in the short term. Equally, where universities and other PROs incorporate substantial professional development activities and staff can legitimately pursue a

variety of research and teaching purposes, the impact of these changes is likely to be mitigated.

Considering finally the effects of growing encouragement of research commercialisation, insofar as this does result in significantly increased revenue streams for researchers and their employers it should diversify the range of resource providers, and thereby reduce their dependence on the state and scientific elites. In principle, then, it enables researchers to pursue a greater variety of research goals without having to show how much they contribute to current intellectual elite priorities and to establish new areas of concern, as long as such funds are dedicated to the conduct of published research.

However, such funds rarely come without some strings attached, albeit with varying time spans of discretion, and their impact on competition for resources, intellectual innovation and coordination and PROs will vary between differently organised PSS, as well as between scientific fields. Particularly important here is the relative influence of individual scientists, PROs and state agencies on the flow and use of funds from such activities, and the ability of private interests to control the production and dissemination of knowledge, materials and technologies. Where resources from companies are primarily provided to individuals and their research teams for work that contributes to both certified knowledge and private purposes on an informal and largely personal basis, as has been the case for many of the chemical and technological sciences since the last decades of the 19th century in many countries, they reduce the authority of disciplinary elites and enable scientists to undertake a wider range of projects.

On the other hand, if such contacts and resource flows become managed by state agencies and/or by employers, they may reduce the discretion of individual researchers. This would enable the state to pursue particular technology policies and employers to invest in particular scientific fields and groups. This last is obviously dependent on universities and PROs having some discretion over resource allocation and being able to act as employers. In state-delegated and employer-coordinated PSS, then, the active exploitation of commercialisation opportunities by PROs can develop their strategic capabilities and undertake investments in new fields that would be too risky if they were highly dependent on public funds from foundations using peer review to allocate resources.

In PSS that are not very strongly stratified into a stable hierarchy of prestige and resources, gaining resources through working with companies and commercialising research results and technologies additionally enables PROs to invest in the recruitment of new and established research stars and provide high levels of support for their work as a means of increasing their social and intellectual standing (Owen-Smith, 2001). This is especially so in employer coordinated PSS, such as the USA, where they can compete in a relatively fluid scientific labour market and develop distinctive strategic capabilities as separate organisations pursuing varied kinds of intellectual projects. However, the more that they try to control intellectual property rights and use them to raise revenues through licensing and restricting the use of materials, ideas and instruments to organisations that are prepared to pay for them, the more they become similar to commercial organisations and threaten both the

collaborative ethos of the public sciences and their own legitimacy as non-profit charitable organisations (Nelson, 2004).

Concluding Remarks

This analysis of how the major postwar changes in the governance and funding of public scientific research are likely to affect intellectual competition, innovation and coordination in different kinds of public sciences systems suggests a number of conclusions. First, an important feature of such changes concerns the shifting patterns of authority over both the definition and choice of research problems, strategies and approaches and the evaluation and integration of research outcomes into established public knowledge. These involve the development of new kinds of authoritative agencies, such as public research foundations, ministries of science and technology policy and IPR commercialisation agencies as well as the restructuring of existing ones, such as reputational communities, education ministries, universities and other PROs. Differences in the purposes and relative cohesion and influence of these different organisations and communities on scientific research highlight important contrasts in public science systems and provide a means of comparing them.

Second, it is important to recognise that the scale and significance of the six changes discussed in this paper have varied considerably across the OECD economies. How they were introduced and continue to develop differ between states such that many features of their national PSS remain quite distinct. In particular, the recent shifts in state-university relations in many countries are more likely to be far reaching and significant where PROs were fully integrated parts of the state than in societies where the state has only a limited role in their governance, funding and legitimation. Despite states continuing to "learn from abroad" in their educational and science reforms, as they have done to some extent since the French revolution, the organisation of scientific research and its governance still vary greatly between countries in ways that affect intellectual competition, innovation and coordination.

Third, two major factors that vary between countries and affect the impact of these changes concern the degree and rigidity of stratification of universities and other PROs, on the one hand, and the diversity of funding sources for published scientific research, on the other hand. In many ways, attempts to institutionalise a competitive market for resources based on the excellence of individuals' and departments' contributions to collective intellectual goals reinforce existing prestige hierarchies and researchers' dependence on the standards and goals of current scientific elites. This is especially likely when PSS are highly stratified and funding is dominated by a small number of research foundations reliant on peer review evaluations for making resource allocation decisions. The more intense is such competition for limited resources concentrated in one or two public foundations, the less intellectual autonomy and discretion will PROs and their staff have.

Conversely, where there is a variety of different providers of research resources for a range of intellectual and social purposes that rely on the judgements of different sets of peer reviewers and other experts, the effects of many of these changes on intellectual innovation and integration may be less restricting. Furthermore, if such stratification is relatively fluid and not institutionalised through state hierarchies and policies,

considerable diversity of research funding and goals may encourage non-elite universities to support the development of new kinds of research and approaches, including those transgressing current intellectual boundaries and norms.

To an extent, the ability to gain revenues from a variety of sources, including research commercialisation, has enabled some US universities to invest in the pursuit of novel intellectual goals as well as more conventional attempts to poach research stars (Brint, 2005; Owen-Smith, 2003). This may facilitate the establishment of new intellectual enterprises and research specialisms, particularly when the state commits substantial resources to them, as more generally does the incorporation of different kinds of scientific goals and audiences into the activities of US research universities and the relative fluidity of academic and business labour markets in the USA (Casper, 2007). However, the extent of intellectual innovation in such PSS may still be constrained by the dominance of project-based funding.

Fourth, this discussion has emphasised that these six kinds of change in the organisation and governance of PSS often have contradictory effects on intellectual competition, innovation and coordination. While some can be expected to narrow the scope of intellectual novelty and researcher discretion, others could mitigate such consequences depending on the context in which they are introduced. Similarly, while formal state delegation of authority to PROs could enhance their strategic capability in some PSS, this might be constrained by research stars being able to attract significant funds for their own purposes and establishing new firms that provide substantial revenue streams for universities. It may also, of course, be inhibited by intensified state monitoring of performance and reduced public funding to the extent that PROs have effectively very limited freedom of action to determine their futures as independent organisations.

Finally, it is worth emphasising that the ability of research foundations, state agencies and PROs to exert authority over the direction of research projects and the assessment of their outcomes is limited by the inherent uncertainty of most scientific research and the diversity of peer group judgements. In particular, research teams retain considerable autonomy over how research goals are pursued and projects conducted, as well as over the interpretation of results. Although authority over project selection, investment priorities and research strategies may be more formally assumed by PROs, foundations and state agencies than before, it remains shared with peer reviewers and researchers who collectively reconstruct and coordinate results, albeit to varying degrees between scientific fields and different PSS.

References

- Amir-Am, Pnina (1993) "From Multidisciplinary Collaboration to Transnational Objectivity: International space as constitutive of molecular biology, 1930-1970," pp 153-186 in Crawford et al (eds) *Denationalising Science*.
- Ben-David, Joseph (1972) *The Scientist's Role in Society*, Englewood Cliffs, New Jersey: Prentice-Hall.
- Boehme, Gernot and Nico Stehr (eds) (1986) *The Knowledge Society*, Sociology of the Sciences Yearbook. Dordrecht: Reidel.
- Bok, Derek (2003) *Universities in the Marketplace: The commercialisation of higher education*, Princeton: Princeton University Press.
- Braun, Dietmar (1998), 'The Role of Funding Agencies in the Cognitive Development of Science', *Research Policy*, 27, 807-821.
- Braun, Dietmar (2003), 'Lasting Tensions in Research Policy-Making – A Delegation Problem', *Science and Public Policy*, 30, 309-321.
- Braun, Dietmar and F-X Merrien (eds) (1999) *Towards a New Model of Governance for Universities? A Comparative View* London: Jessica Kingsley Publishers.
- Brint, Steven (2005) "Creating the Future: 'New Directions' in American Research Universities," *Minerva*, 43. 23-50.
- Burrage, Michael (1993) "From Practice to School-based Professional Education: Patterns of conflict and accommodation in England, France, and the United States," pp 142-187 in Rothblatt and Wittrock (eds) *The European and American university since 1800*.
- Casper, Steven (2007) *Creating Silicon Valley in Europe: Public policy towards new technology industries*, Oxford: Oxford University Press.
- Clark, Burton (1983) *The Higher Education System: Academic organization in cross-national perspective*, Berkeley: University of California Press.
- Clark, Burton (1995) *Places of Inquiry: Research and advanced education in modern universities*, Berkeley: University of California Press.
- Cohen, Wesley, Richard Nelson and John Walsh (2002) "Links and Impacts: The influence of public research on industrial R&D," *Management Science*, 48. 1-23.
- Coleman, Samuel (1999) *Japanese Science: View from the inside*, London: Routledge.
- Colyvas, Jeannette and Walter Powell (2006) "Roads to Institutionalization: The remaking of boundaries between public and private science," *Research in Organizational Behavior*, 27. 305-353.

Cozzens, Susan (2007) "Death by Peer Review? The Impact of Results-oriented Management in U.S. Research," pp 225-242 in Whitley and Glaeser (eds) *The Changing Governance of the Sciences*.

Crawford, Elisabeth, Terry Shinn and Sverker Sorlin (eds) (1993) *Denationalizing science: The context of international scientific practice*, Sociology of the Sciences Yearbook, Dordrecht: Kluwer.

Croissant, Jennifer and Sal Restivo (eds) (2001) *Degrees of Compromise: Industrial interests and academic values*, Albany: State University of New York Press.

Drori, Gili S., John W. Meyer, Francisco O. Ramirez and Evan Schofer (2003), *Science in the Modern World Polity: Institutionalization and globalization*, Stanford: Stanford University Press.

Frank, David John and John Meyer (2007) "University Expansion and the Knowledge Society," *Theory and Society*, 36. 287-311.

Fuller, Steve (2000) *The Governance of Science*, Buckingham, UK: Open University Press.

Geiger, Roger (1986) *To Advance Knowledge: The growth of American research universities 1900-1940*, Oxford: Oxford University Press.

Geiger, Roger (2004) *Knowledge and Money: Research universities and the paradox of the marketplace*, Stanford: Stanford University Press.

Geiger, Roger and Creso Sa (2005) "Beyond Technology Transfer: US state policies to harness university research for economic development," *Minerva*, 43. 1-21.

Geuna, Aldo and Lionel Nesta (2006) "University Patenting and its Effects on Academic Research: The emerging European evidence," *Research Policy*, 35. 790-807.

Gittelman, Michelle (2006) "National Institutions, Public-private Knowledge Flows and Innovation Performance: A comparative study of the biotechnology industry in the US and France," *Research Policy*, 35. 1052-1068.

Glaeser, Jochen and Grit Laudel (2007) "Evaluation without Evaluators: The impact of funding formulae on Australian university research," pp 127-152 in Whitley and Glaeser (eds) *The Changing Governance of the Sciences*.

Greenberg, Dan (1966) "Grant Swinger: Reflections on Six Years of Progress," *Science*, 154. 1424-1425.

Guston, David H (2000) *Politics and Science: Assuring the integrity and productivity of research*, Cambridge: Cambridge University Press.

Homburg, Ernst (1992) "The Emergence of Research Laboratories in the Dyestuffs Industry, 1870-1900," *British Journal for the History of Science*, 25. 91-111.

Hopkins, Michael, Paul Martin, Paul Nightingale, Alison Kraft and Surya Mahdi (2007) "The Myth of the biotech Revolution: An assessment of technological, clinical and organisational change," *Research Policy*, 36. 566-589.

Hughes, Sally Smith (2001) "Making Dollars out of DNA: The first major patent in biotechnology and the commercialization of molecular biology, 1974-1980i," *ISIS*, 92. 541-575.

Jang, Yong Suk (2003) "The Global Diffusion of Ministries of Science and Technology" pp 120-135 in Drori et al (eds) *Science in the Modern World Polity*.

Kohler, Robert (1979) "Warren Weaver and the Rockefeller Foundation Program in Molecular Biology," pp 249-293 in Nathan Reingold (ed) *The Sciences in the American Context*, Washington, D.C.: Smithsonian Institution Press.

Kleinman, Daniel and Steven Vallas (2001) "Science, Capitalism and the Rise of the 'Knowledge Worker': The changing structure of knowledge production in the United States," *Theory and Society*, 30. 451-492.

Kneller, Robert (2007) "Prospective and Retrospective Evaluation Systems in Context: Insights from Japan," pp 51-74 in Whitley and Glaeser (eds) *The Changing Governance of the Sciences*.

Krimsky, Sheldon (2003) *Science in the Private interest: Has the lure of profits corrupted biomedical research?* Lanham, MD: Rowman and Littlefield.

Kruecken, Georg (2003) "Learning the 'New, New Thing': On the role of path dependency in university structures," *Higher Education*, 46. 315-339.

Kruecken, Georg and Frank Meier (2006) "Turning the University into an Organizational Actor," pp 241-257 in G S Drori, J W Meyer and H Hwang (eds) *Globalization and Organization: World Society and organizational change*, Oxford: Oxford University Press.

Kruecken, Georg, Anna Kosmutzky and Marc Torka (eds) *Towards a Multiversity? Universities between Global Trends and National Traditions*, Bielefeld: transcript Verlag.

Laudel, Grit (2006) "The 'quality myth': Promoting and hindering conditions for acquiring research funds," *Higher Education*, 52. 375-403.

Lemaine, Gerard, Roy Macleod, Michael Mulkay and Peter Weingart (eds) *Perspective on the Emergence of Scientific Disciplines*, The Hague: Mouton.

Lenoir, Timothy (1997) *Instituting Science: The cultural production of scientific disciplines*, Stanford: Stanford University Press.

- Leslie, Stuart W (2000) "The Biggest 'Angel' of Them All: The military and the making of Silicon Valley," pp 48-67 in M Kenney (ed) *Understanding Silicon Valley: The anatomy of an entrepreneurial region*, Stanford: Stanford University Press.
- Liefner, Ingo (2003) "Funding, resources allocation, and performance in Higher Education Systems," *Higher Education*, 46. 469-489.
- Martin, Ben (2003), 'The Changing Social Contract for Science and the Evolution of the University', in Aldo Geuna, Ammon J. Salter and W. Edward Steinmuller (eds.), *Science and Innovation: Rethinking the rationales for funding and governance*, Cheltenham: Edward Elgar, pp. 7-29.
- McClelland, C. E (1980) *State, Society and University in Germany, 1700-1914*, Cambridge: Cambridge University Press.
- McCray, Patrick and Jennifer Croissant (2001) "Entrepreneurship in Technology Transfer Offices: Making work visible," pp 55-76 in Croissant and Restivo (eds) *Degrees of Compromise*.
- Merrien, Francois-Xavier and Christine Musselin (1999) "Are French Universities Finally Emerging? Path Dependency Phenomena and Innovative Reforms in France," pp 220-238 in Braun and Merrien (eds) *Towards a New model of Governance for Universities?*
- Metlay, Grischa (2006) "Reconsidering Renormalization: Stability and change in 20th-century views on university patents," *Social Studies of Science*, 36. 565-597.
- Meulen, Barend van der (2007) "Interfering Governance and Emerging centres of Control: University research evaluation in the Netherlands," pp 191-203 in Whitley and Glaeser (eds) *The Changing Governance of the Sciences*.
- Mowery, David C., Richard R Nelson, Bhaven N Sampat and Arvids A Ziedonis (2004) *Ivory Tower and Industrial Innovation: University-Industry technology transfer before and after the Bayh-Dole Act*, Stanford, California: Stanford University Press.
- Muller-Camen, Michael and Stefan Salzgeber (2005), 'Changes in Academic Work and the Chair Regime: The case of German business administration academics', *Organization Studies*, 26, 271-290.
- Murmann, Johann Peter (2003) *Knowledge and Competitive Advantage: The coevolution of firms, technology and national institutions*, Cambridge: Cambridge University Press.
- Musselin, Christine (1999) "State/University Relations and How to Change Them: The case of France and Germany," pp 42-68 in M Henkel and B Little (eds) *Changing Relationships between Higher Education and the State*, London: Jessica Kingsley Publishers.
- Musselin, Christine (2007) "Are Universities Specific Organizations?" pp 63-84 in Kruecken et al (eds) *Towards a Multiversity?*

Nelson, Richard (2004) "The Market Economy, and the Scientific Commons," *Research Policy*, 33. 455-471.

Odagiri, Hiroyuki (1999) "University-Industry Collaboration in Japan: Facts and interpretations," pp 252-265 in Lewis Branscomb, Fumio Kodama and Richard Florida (eds) *Industrializing Knowledge: University-industry linkages in Japan and the United States*, Cambridge, Mass.: MIT Press.

Owen-Smith, Jason (2001) "New Arenas for University Competition: Accumulative advantage in academic patenting," pp 23-53 in Croissant and Restivo (eds) *Degrees of Compromise*.

Owen-Smith, Jason (2003) "From Separate Systems to a Hybrid Order: Accumulative advantage across public and private science at Research One universities," *Research Policy*, 32. 1081-1104.

Owen-Smith, Jason, Massimo Riccaboni, Fabio Pammoli and Walter Powell (2002) "A Comparison of U.S. and European University-Industry Relations in the Life Sciences," *Management Science*, 48. 24-43.

Powell, Walter and Jason Owen-Smith (1998) "Universities and the Market for Intellectual Property in the Life Sciences," *Journal of Policy Analysis and Management*, 17. 253-277.

Powell, Walter, Jason Owen-Smith and Jeannette Colyvas (2007) "Innovation and Emulation: Lessons from American universities in selling private rights to public knowledge," *Minerva*, 45. 121-142.

Rothblatt, Sheldon and Bjorn Wittrock (eds) (1993) *The European and American University since 1800*, Cambridge: Cambridge University Press.

Schiene, Christof and Uwe Schimank (2007) "Research Evaluation as Organisational Development: The work of the Academic Advisory Council in Lower Saxony," pp 171-190 in Whitley and Glaeser (eds) *The Changing Governance of the Sciences*

Schimank, Uwe (2005) "'New Public Management' and the Academic Profession: Reflections on the German situation," *Minerva*, 43. 361-376.

Shinn, Terry (1979) "The French Science Faculty System, 1808-1914. Institutional Change and Research Potential in Mathematics and the Physical Sciences," *Historical Studies in the Physical Sciences*, 10. 271-323.

Siegel, Donald, David Waldman and Albert Link (2003) "Assessing the Impact of Organizational Practices on the Relative Productivity of University Technology Transfer Offices: An exploratory study," *Research Policy*, 32. 27-48.

Slaughter, Sheila and Larry Leslie (1997) *Academic Capitalism: Politics, policies and the entrepreneurial university*, Baltimore: Johns Hopkins University Press.

Stokes, Donald E (1997) *Pasteur's Quadrant: Basic science and technological innovation*, Washington, D.C. Brookings Institution Press.

Torstendahl, Rolf (1993) "The Transformation of Professional Education in the Nineteenth Century," pp 109-141 in Rothblatt and Wittrock (eds) *The European and American University since 1800*.

Trow, Martin (1993) "Comparative Perspective on British and American Higher Education," pp 280-299 in Rothblatt and Wittrock (eds) *The European and American University since 1800*.

Trow, Martin (1999) "From Mass Higher Education to Universal Access: The American advantage," *Minerva*, 37. 303-328.

Weingart, Peter (2003) "Growth, Differentiation, Expansion and Change of Identity - The Future of Science," pp 183-200 in Bernward Joerges and Helga Nowotny (eds) *Social Studies of Science and Technology: Looking back, ahead*, Sociology of the Sciences Yearbook, Dordrecht: Kluwer.

Weingart, Peter and Sabine Maasen (2007) "Elite through Rankings-The mergence of the Enterprising University," pp 75-100 in Whitley and Glaeser (eds) *The Changing Governance of the Sciences*.

Whitley, Richard (2000) *The Intellectual and Social Organization of the Sciences*, Oxford University Press, second edition (first edition 1984).

Whitley, Richard (2003) "Competition and Pluralism in the Public Sciences: the impact of institutional frameworks on the organisation of academic science," *Research Policy*. 32 (6) 1015-1029.

Whitley, Richard (2006) "Project-based Firms: New organisational form or variations on a theme?" *Industrial and Corporate Change*. 15. 2006. 77-99.

Whitley, Richard (2007a) *Business Systems and Organisational Capabilities: The institutional structuring of competitive competences*, Oxford: Oxford University Press.

Whitley, Richard (2007b) "Changing Governance of the Public Sciences: The consequences of establishing research evaluation systems for knowledge production in different countries and scientific fields," pp 3-27 in Whitley and Glaeser (eds) *The Changing Governance of the Sciences*.

Whitley, Richard (2008) "Universities and Strategic Actors: Limitations and variations," pp - in Lars Engwall and Denis Weaire (eds) *The University in the Market*, London: Portland Press.

Whitley, Richard and Jochen Glaeser (eds) (2007) *The Changing Governance of the Sciences*, Sociology of the Sciences Yearbook, Dordrecht: Springer.

Wittrock, Bjorn (1993) "The Modern University: The three transformations," pp 303-362 in Rothblatt and Wittrock (eds) *The European and American University since 1800*.

Woolgar, Lee (2007) "New Institutional Policies for University-Industry Links in Japan", *Research Policy*, 36. 1261-1274.

Yoxen, Edward (1982) "Giving Life a New Meaning: The rise of the molecular biology establishment," pp 123-143 in Norbert Elias, Herminio Martins and Richard Whitley (eds) *Scientific Establishments and Hierarchies*, *Sociology of the Sciences Yearbook*, Dordrecht: Reidel.

Ziman, John (1994) *Prometheus Bound: Science in a dynamic steady state*, Cambridge: Cambridge University Press.

TABLE 1

Expected Effects of Changes in Public Science Systems on the Direction and Organisation of Scientific Research

Changes in Public Science Systems						
Expected Effects	Steady State Public Funding	Increasing Reliance on Peer-reviewed Project Funding	Incorporation of Public Policy Goals Into Resource Allocation Processes	Increasing Delegation of Authority to PROs	Increased Auditing Of PRO Performance	Encouragement of Research Commercialisation
Intensification of Competition for Resources Based on Intellectual Prestige	Increased where state dominates research funding				Increased where it affects significant amounts of PRO funding	
Ease of Establishing New Scientific Fields and Goals	Reduced	Reduced	Increased		Reduced	Increased where it supports published research
Researcher Discretion over Goals and Approaches	Reduced	Reduced	Increased		Reduced	Increased where it supports published research
Growth of PRO Strategic Autonomy and Capabilities				Enhanced	Enhanced	Enhanced where it is managed by PROs
Strength of Reputational Coordination of Goals and Results across PROs	Increased where state funding dominates and is allocated through peer review	Increased, especially in stratified HE systems	Reduced		Enhanced when judgements based on intellectual quality	Reduced

TABLE 2

Key Characteristics of Major Authoritative Agents in Public Science Systems

Authoritative Agents	Characteristics
State ministries and agencies	Extent of control over: a) employment of researchers, and their careers, b) facilities, c) resource allocation. Delegation of authority to research foundations, reputational elites and PROs. Cohesion and organisational integration.
Research foundations	Diversity of purposes, procedures and standards. Strategic autonomy from the state. Reliance of peer review.
Reputational elites	National centralisation and integration as advisors and resource controllers. Extent of control over resource allocation standards and procedures and over administrative units in PROs. Extent of internationalisation.
Public research organisations	Strategic autonomy and capability in managing academics and resources. Diversity of goals and activities within PROs. Segmentation of goals and activities between PROs. Identity of administrative authority with research groupings under institute heads.
Private interests	Variety of purposes and uses of public knowledge. Directness of use of public knowledge and research skills. Extent and mode of support for public sciences. Extent of researcher and/or PRO control over resources flows and uses.

TABLE 3

Variations in Authority in Six Ideal Types of Public Science Systems

Relative Authority of:	Type of Public Science System					
	State--centered	State-shared	State-delegated stable	State -delegated competitive	Pluralist employer competitive	Employer dominated
The State	High	Considerable	Limited	Medium	Limited	Low
Research Foundations	Low	Medium	Medium	Considerable	Considerable	Medium
PRO centres	Low	Low	Medium	Considerable	Considerable	High
PRO institutes and departments	Medium	High	Limited	Medium	Medium	Considerable
Reputational elites	Limited to co-opted elites	Considerable	Considerable	High	Considerable	Limited, dependent on employers' goals
Private interests	Low	Limited to personal links in a few fields	Low	Medium	Medium	Varies

TABLE 4

Expected Patterns of Research Direction and Organisation in Six Ideal Types of Public Science Systems

Expected Patterns of Research Direction and Organisation	Type of Public Science System					
	State--centered	State-shared	State-delegated stable	State -delegated competitive	Pluralist employer competitive	Employer dominated
Intensity of competition for resources based on intellectual prestige	Limited	Considerable between researchers, low between PROs	Limited	High	Considerable	Limited
Ease of establishing new fields and goals	Considerable where state supports them, low elsewhere	Limited	Medium	Limited	Considerable where there are many diverse foundations	Considerable where employers' have substantial resources for research
Researcher discretion over research goals and approaches	Considerable for laboratory heads where state delegates authority to them	High for institute heads, low for others	Considerable	Limited	Considerable	Depends on employers' resources and delegation
Strategic capabilities and autonomy of PROs	Low	Low	Limited	Medium	Medium	Considerable
Reputational coordination of research goals and results across PROs	Medium	Considerable within research schools, variable between them	Considerable	High	High	Depends on employers' goals

TABLE 5

Expected Effects of Changes in State Support for the Public Sciences in Different Types of Public Science Systems

Effects in Different PSS	Type of PSS	Steady State Funding	Increasing Dependence of Peer Reviewed Project Funding	Incorporation of Public Policy Goals in Research Funding	Increasing Delegation to PROs	Increased Auditing of PRO Performance	Increasing Commercialisation of Research
Intensification of Competition for Resources	State-coordinated State-delegated Employer-coordinated	Positive Positive Limited impact				Positive when it influences funding Limited impact	Negative when it supports public research
Ease of Establishing New Fields and Goals	State-coordinated State-delegated Employer-coordinated	Reduced, except where the state directly invests Limited impact	Reduced Reduced Limited Impact	Increased Less so in highly reputationally controlled PSS Increased		Reduced for all types, especially in stratified systems where reputational elites are strong	Increased for all types where it supports public research
Researcher Discretion	State-coordinated State-delegated Employer-coordinated	Reduced Reduced Limited impact	Reduced Reduced Limited Impact	Increased Increased Increased	Limited impact in state-dominated PSS, reduced in state-shared and state-delegated PSS	Reduced Reduced Limited impact	Increased for all types where it supports public research
Growth of PRO Strategic Capabilities	State-coordinated State-delegated Employer-coordinated				Limited in state-dominated PSS Increased in state-shared and state-delegated PSS where PROs can obtain resources from a variety of sources	Increased, unless the state centralises control Increased Limited impact	Increased for all types when PROs control the flow and use of funds

Strength of Reputational Coordination of Goals and Results	State-coordinated	Limited impact in S-C PSS. Increased in S-S PSS	Limited impact in S-C PSS. Increased in S-S PSS with stratified HE system	Reduced		Enhanced where evaluations rely on scientific elites' judgements	Reduced
	State-delegated	Increased where state funding dominates	Increased, especially with stratified HE system and limited variety of funding sources. Limited impact	Reduced		Enhanced where evaluations rely of scientific elites' judgements	Reduced, except where stratified system is dominated by scientific elites
	Employer-coordinated	Limited impact	Limited impact	Reduced, although limited impact where there are a variety of funding sources		Limited impact	Reduced