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Commodified science and social wellbeing

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Abstract This paper explores the increasing trend towards the commodification of public research and development (R&D) and the impact of this on social wellbeing. In many developed countries, the changes introduced by governments to funding mechanisms for universities and public research institutions has led to a fundamental shift in the focus of public R&D. The focus has shifted from creating useful public, codifiable knowledge to creating a knowledge commodity driven by commercial imperatives. Although there may be an economic argument to be made for the virtues of such change, we argue here that the potential costs to social wellbeing have been largely, and dangerously, ignored.

Keywords Public R&D · Science · Commodification · University funding · Neo-liberal

1 Introduction

This paper addresses the complex relationship between states, economies, and science and attempts to explore some of the consequences of recent shifts in the relationships between these three actors. Two concurrent and intertwined globalised processes, the emergence of a so-called knowledge economy and of the neo-liberal state, have combined in recent years in such a way so as to produce a dramatic shift in the nature and products of publicly funded scientific research and development. The chief characteristic of this transformation, it is argued, has been a shift from science being for the *public* good to being for *private* good. This shift has, we argue, as well as directly impacted on the social utility of science, increasingly led the public to revise their acceptance of a vision of science and scientists as independent and neutral with consequent effects on public trust in science.

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In Section 2, we describe these developments in general and conceptual terms. Our aim here is to map out major transformations that have occurred within the past 25 years in order to contextualise the detailed material that we present in the rest of the paper. In Section 3, the reform of the UK public sector research establishments is analysed and in Section 4 we explain the changes that have occurred with regard to public support for science in universities. This is followed, in Section 5, with detailed statistical data demonstrating the financial effects of these shifts. In Section 6, we discuss the actual and potential social ramifications of these developments. This is followed by conclusions.

2 Science, states, and economies

During the past 25 years, the complex interrelationship between science, states, and economies has been radically transformed. In particular, and perhaps uniquely in the history of science (Boden et al. 2004), the development of the knowledge economy and the burgeoning of neo-liberal states have generated new exogenous policy-led pressures for change in the vision, institutions, and practices of science.

Traditional conceptualisations of science construe it as a discrete, independent, and 'objective' social practice, delineated by the norms that were outlined by Robert Merton in 1942: *communalism*, *universalism*, *disinterestedness*, *originality*, and *scepticism* (Merton 1973, 267–278). Until the late 1970s, the production of scientific knowledge was marked by its organisational, cultural, and financial separation and independence from the sites of its ultimate consumption or exploitation (Dasgupta and David 1994). Consequently, science was relatively free from economic pressures. The wider public, as represented by the public or state sphere, might be seen as stakeholders in the activities of such science, with a social contract existing between the two whereby, in return for recognition and status, the public sphere is the recipient of knowledge. This 'gift' of scientific knowledge might or might not be utilised by the social or economic worlds.

But economies change and 'knowledge,' including scientific knowledge, is the principal commodity in the rapidly expanding global 'free market knowledge economies.' 'Commodification' denotes a process whereby things that have social or cultural meaning are ascribed a financial value in order to facilitate ownership and exchange. An economy of commodity exchange and consumption is a means by which people and organisations acquire financial or cultural capital. As such, in knowledge economies, knowledge is ascribed a value, exchanged and made subject to ownership and/or control. Consequently, the imperative for scientific knowledge production is increasingly becoming the capacity of such knowledge to create wealth through trading in the knowledge economy (Baskaran and Boden, in press).

Thus, under knowledge economy conditions, a new vision of what science is expected to be emerges: it becomes a commodity-producing production process that has the direct capacity to generate wealth. This is quite a different conceptualisation of the social practice of science from the Mertonian ideal. Moreover, because science is a social practice, science knowledge products cannot exist independently from the processes that make and shape them. If scientific knowledge production embodies commodification, we reason then the resulting knowledge product will reflect that commodification. Law and Akrich (1994) demonstrated how the commercialisation of scientific 'machines' such as a particle accelerator may shape the resulting knowledge products. Thus not only is what science *is* transformed, but also what it *does* and the knowledge that it *produces*.

The shift in science is now viewed by some as so marked that Ziman (2000) has argued that Merton's principles have now been replaced with new ones: *propriety* (knowledge that is not necessarily made public), *local* (focused on local technical problems rather than on general understandings), *authoritarian* (researchers acting under managerial authority rather than as individuals), *commissioned* (to achieve practical goals rather than in the pursuit of knowledge for its own sake), and *expert* (researchers perform as expert problem-solvers rather than exercising their creativity).

Alongside the development of the knowledge economy, and facilitating its growth, states in developed countries have lurched rightwards towards neo-liberalism as a political ideology. Classical liberal ideologies espoused the restriction of state activities to the minimum necessary to achieve a stable arena within which the free market could operate. In these conditions, classical Mertonian science was an activity often characterised as needing, or a suitable candidate for, state support and intervention because it was a public good and susceptible to market failure. For instance, not all Mertonian science leads demonstrably, either in the short or long term, to technological, commercial outputs. Nor is it always possible to discern at the outset which scientific knowledge products will prove useful in the development of technology.

Consequently, scientists were usually the recipients of public grants rather than subject to commercial contracts to produce specified knowledge. Moreover, the knowledge produced was a public rather than a private good. Until the late 1970s, the combination of a non-commercial status and the perceived importance of science to ultimate wealth generation led national governments to increasingly sponsor science as a producer of public goods (Boden et al. 2000) and then to attempt to facilitate the effective and profitable industrial usage of scientific knowledge so produced. Scientists successfully argued that a well-maintained 'science base,' in which social and economic development could be grounded, was a public good that needed public financial maintenance.

Consequently, science and scientists were perceived by the public to be substantially independent and largely disinterested from the actual economic exploitation of their knowledge products. In other words, there was a clearly identifiable *public input* and a *public output* in the scientific knowledge production process (Baskaran and Boden, in press).

In a subtle contradistinction to classical liberal regimes, neo-liberal states see their role as supporting and sustaining the private, wealth-generating, sector whilst running themselves as economically, efficiently, and effectively as possible by emulating private sector practices and employing their techniques and technologies. Thus, the public realm had become much more like the private in its ethos and practices, shifting its focus to support it rather than simply withdrawing to let the private have free reign. An important aspect of this shift has been the steady dissolution or attrition of the dichotomous divide between the public and private realms (Rose 1996).

In neo-liberal states, science has been reconceptualised in various ways congruent with this political ideology. In contrast to the traditional Mertonian science, where 'the context is defined in relation to the cognitive and social norms that govern basic research or academic science,' in Gibbons et al.'s (1997, 4) so-called 'Mode-2' science 'knowledge results from a broader range of considerations. Such knowledge is intended to be useful to some one whether in industry or government, or society more generally and this imperative is present from the beginning'. Gibbons et al. (1997, 4) argue that 'knowledge is always produced under an aspect of continuous negotiation and it will not be produced unless and until the interests of the various actors are included ... knowledge production in Mode-2 is the outcome of a process in which supply and demand factors can be said to operate.'

Such theorisations as these have heavily influenced policy-makers, who have in turn actively promoted the progressive relocation of scientific knowledge production to the private sphere and/or control by it. Increasingly, government regulators have been perceived to be more keen to promote the interests of industry than those of the public interest because of closer relationship between corporations and the regulators (e.g., Ho 1997; Ferrara 1998; The Guardian 21, 22, and 24 February 1999). Since the 1980s, the conflation of private wealth generation with public good has promoted a significant shift in emphasis on the output side of the public science equation: public input is increasingly shaped by its ability to produce private output (see, e.g., Boden et al. 2004). Public R&D systems have shifted their focus from the creation of useful public and codifiable knowledge to the production of commodifiable knowledge for wealth generation.

This policy shift was justified by reference to an economic discourse. Governments have asserted that publicly funded R&D should meet the needs of industry and help maintain its competitiveness in the new global economic environment. The arguments that publicly funded research should only be governed by its capacity to benefit the industry and economic competitiveness is problematic if public R&D systems are alternatively construed as needing to meet wider socio-economic objectives rather than simply creating wealth (Boden et al. 1998).

Policy-makers increasingly viewed the separation between scientific knowledge production and commercial usage as detrimental to national economic wellbeing. They argued that a lack of synergy between scientists and end-users has resulted in failure to successfully commercially exploit scientific research.

Just as public funding in the liberal states supported and sustained something approximating to the Mertonian ideal of science, funding mechanisms have also been the driving force in this transformation in public R&D. This is especially so in universities and public research institutions. This process began in the US and the UK in the early 1980s. Subsequently, governments globally embarked upon programmes to both reduce public expenditure (thereby attempting to make themselves appear economic, efficient, and effective) and to relocate science within either the private commercial sphere or marketised public sector in order to make it work more effectively for economic ends.

Governments sought to effect this reform through the now familiar new public management remedies of marketisation, commercialisation, and privatisation. In the UK, for instance, government research laboratories became subject to new public management (NPM) regime changes (Boden et al. 1998, 2004). This involved a shift to funding on the basis of contracts by policy customers in government, the devolution of laboratories into executive agencies, and in some instances privatisation, and greater direct control over the activities of universities with moves to make them behave in a more corporate manner.

Ziman (2000, 172) has critiqued these transformations as 'a misty, unknown—even hostile—territory for academic science.' He argued that the delineation between academic and industrial science, characterised by the disinterestedness of the former, is fast disappearing, as academia is obliged through the twin disciplines of management and funding to align itself directly with commercial needs. He argues that this shift 'is signalled by the appearance of words such as management, contract, regulation, accountability, training, employment, etc. which previously had no place in scientific life ... a culture characterised by Weber as essentially "bureaucratic"' (Ziman, 2000, 82).

Thus the knowledge economies and neo-liberal states have, we argue, acted in concert and harmony to effect a radical transition in the vision, institutions, and practices of science. The principal mechanism by which the change has been effected is through the funding mechanisms on which science is so reliant. We argue in this paper that the increasing and extensive nature of commercial control of the scientific knowledge product has ruptured the pre-existing social contract between science and the public sphere.

3 The new public management of UK public research establishments

We turn now to an analysis of these changes in UK public research establishments as exemplars of how the funding, organisation, ownership, and vision of public science have been transformed.

By 1979, there was a highly diverse range of government science and technology activities taking place within the government research establishments (Boden et al. 1998). Research varied from routine investigation to high-level speculative or strategic research. Services varied from routine testing, policy evaluation to the dissemination of scientific advice to the public. Similarly, organisational form varied from high-security defence establishments to the field officers of the agriculture ministry advising farmers. For the most part, these establishments were quasi-autonomous, generally receiving large block grants of funds with little, real managerial control over how the money was spent. In nature, organisation and ethos they largely conformed to Mertonian notions of the 'Independent Republic of Science' (Dasgupta and David 1994, 487).

Until 1979, state procurement of scientific knowledge for administration and the public good went unreformed and largely unexamined (Boden et al. 2000). However, during the ensuing 25 years, science was caught up in a wave of public sector reform grounded in neo-liberal economics. By 1988, the Government's Chief Scientific Adviser in the Cabinet Office, Sir John Fairclough, had set out the principle that public spending on R&D should be strictly limited to that which was far from the development of marketable products or processes. 'Near-market' scientific knowledge production, it was stressed, should be organised and funded by industry. The government would be left with the residual task where the market would ‘fail to operate to produce maximum benefits to the economy as a whole’ (Wilkie 1991). Thus, the traditional governmental role of supporting (but not particularly controlling) the generation of scientific knowledge as a public good to provide a knowledge fund on which industry could draw was to be dismantled.

For that capacity that was to remain in the public sector, Fairclough reiterated the customer–contractor principle under which providers would compete for public R&D funds in an attempt to create an internal market (Levene and Stewart 1993). That is, greater accounting, accountability, and management controls were to be exercised over that scientific activity that was to be funded by government to ensure that it had a clear ‘customer.’ This management of R&D expenditure was to be enacted through the so-called ‘new public management’ techniques. The principles on which publicly funded R&D were to be reformed were therefore resolutely neo-liberal: science was to be directed by the state as a servant of economic growth.

NPM frequently embodies: a commitment to downsizing the state, cost-cutting, marketisation and competition, the devolution of executive functions to quasi-autonomous agencies, and a commitment to customer–contractor and other quasi-commercial policy-making and management principles. Organisations are viewed as a chain of low-trust principal/agent relationships with the disaggregation of separable functions into quasi-contractual or quasi-market forms. Providers are thus ‘deconcentrated’ into the minimum feasible sized agency, allowing users more scope to ‘exit’ from one provider to another, thereby ostensibly promoting competition (Dunleavy and Hood 1994).

The first NPM reforms that affected science in the UK were general administrative reforms introduced in the immediate aftermath of the Conservative Party victory in 1979. These were mainly confined to the introduction of new budgetary and management control systems (Boden et al. 2004). The government research establishments, being comparatively small-fry within government at this time, did not receive detailed attention until 1987 when the Next Steps Initiative led to a drive to identify those parts of government that could be hived off into executive agencies. Executive agencies are public bodies constituted under a so-called ‘framework agreement’—a contract—by which the agency contracts to provide services to ministries in return for contract payments. In essence, the old block grant funding mechanisms were replaced with a system in which, put simply, ministry ‘customers’ contracted the laboratories for specific pieces of work. Moreover, these contracts were subject to high degrees of monitoring, audit, and management control in order to ensure the ‘three-Es’ of economy, efficiency, and effectiveness.

NPM provided the mechanism by which UK governments progressively sought to abrogate their traditional role of funding the production of scientific knowledge. The net result in terms of the social location of science in government research establishments has been dramatic. Some have had their ownership transferred from the public sector to the private. Those activities that remained in public hands had their relationships recast such that they came to occupy very different ‘spaces’ within government. Table 1 gives some examples of the organisational and ownership outcomes of this reform process. The process of privatisation has been continued under subsequent Labour governments. For instance, the government is currently trying to effect some privatisation or

Table 1 Transformation in the UK public R&D system

Type	Example
Next steps agencies (initially without, and later with, trading fund status)	Defence Evaluation and Research Agency Meteorological Office
Government-owned company-operated entities (essentially, private contractors running a government establishment)	National Physical Laboratory
Companies limited by guarantee (private organisations, but with certain constraints on behaviour, in order to safeguard the public interest or guarantee standards of integrity appropriate to a quasi-judicial function)	Macaulay Land Use Research Institute Scottish Crop Research Institute Building Research Establishment Transport Research Laboratory
Fully privatised companies	Laboratory of the Government Chemist Agricultural Development and Advisory Service AEA Technology National Engineering Laboratory

From Boden et al. (2000)

contractorisation of organisations such as the Forensic Science Service and QinetiQ, a company established and wholly owned by government and enveloping most of the UK's defence technology evaluation capability.

Boden et al. (1998) stress that a number of aspects of the activities of the public sector science establishment made the application of NPM techniques problematic if the character and role of the institutions was to be preserved. That is, they argue, traditional models and locations for the production of scientific knowledge are incompatible with NPM. The range of cognitive skills inherent in scientific work made contracting for specific outcomes problematic. For example, attempts to develop alternative competitive sources of scientific advice outside government might be constrained by availability and fears over lack of impartiality. Moreover, laboratories forced to sell advice elsewhere may give less priority to government or let commercial plans influence the scientific advice given to government. The underpinning argument here is that changes in the ownership and/or governance of these establishments will affect their social location and hence the way in which their knowledge product is used. That is, commodification leads the public to understand things differently.

This relocation of scientific knowledge production processes in the UK has significant implications for ownership, control, governance, and accountability. The new location of and controls over government science laboratories have undoubtedly moved them either into the private sector or much more closely aligned them with it.

4 Fundamental changes in university research (UK)

Since the mid-1980s, the organisation and management of R&D in universities has also undergone fundamental change, particularly in the developed countries.

This trend first began in the US and the UK and soon spread to other countries, including some developing states. Increasingly, university research has been forced to move away from reliance on public funding and towards corporate financing, generating new and tight-knit financial relationships. Some academic scientists have become much more directly involved in the commercial exploitation of their own work, and much work in universities is now undertaken explicitly and directly for commercial ends. Thus the commodification of science is much in evidence.

Since the Second World War, university research has received substantial government funding in the developed countries. Such funding was orientated towards long-term basic research with little or no expectation of a direct commercial pay-off. For example, a UK government report defending public investment in basic research stated:

'Research, more especially basic research, is often a gamble. The working out of imaginative ideas, sometimes on the basis of slight clues, or perhaps just intuition, may lead to whole new fields of knowledge, or to nothing...yet it is at the early uncertain stages of research that help is most necessary and most valuable' (Department of Scientific and Industrial Research 1962, 129).

In the early 1980s, as the Western economies experienced severe recession, a neo-liberal perception developed, particularly in the US, that academic research had failed in its supposed role to help industry to maintain its competitiveness. As a result, governments started forcing universities to work closer with industry by reducing the levels of government funding to university research, thereby incentivising them to seek resources from industry.

Funding mechanisms, as in public sector research establishments, therefore became transformative of science. Although 'the social function of science has always been thought of primarily in terms of the practical human needs that it might serve,' the difference now is that this is 'operationalised' through management routines and financial control (Ziman 2000, 15). Ziman, in critiquing such developments, asserts that the notion that the purpose of research 'can be defined simply as "solving problems" is enshrined in the funding of research in terms of projects,' enabling 'governments, industrial firms, medical charities, and other institutions endeavour to catch hold of science and bend it to their ends' (Ziman 2000, 15).

As basic and applied research were redefined as complementary rather than dichotomous, university research witnessed fundamental transformation. This process first started in the US and soon, other Western countries followed (Corsten and Juginger-Dittel 1988). Many European universities launched initiatives to forge closer relationship with industry (Stankiewicz 1985). This trend has subsequently spread to semi-industrialised developing countries such as Mexico and Brazil (e.g., Waissbluth et al. 1988; Schwartzman et al. 1993). In the UK, the government started putting emphasis on 'getting value for money from...investment in science' and argued that 'industry can judge the requirements of the market far better than the Government, and...[near market] research should be its responsibility' (Baker 1989). The aim of public funding of university research in the 1990s was 'to bridge the gap between the science and engineering base and industry for the benefit of the United Kingdom economy' (Geuna 1999, 90). The government strongly 'believed this as central to achieving a successful knowledge-driven economy' (The Guardian 26 July 2000). Public sector involvement in 'near-market' research was deliberately reduced, and the role of private sector was encouraged to fill in the vacuum. Thus, reduced public funding and other budgetary pressures in the 1980s and 1990s forced universities to seek increased industry funding.

However, serious concerns have been raised over the negative impact of forcing university research too close to the industry, particularly on traditional academic freedom (e.g., Dimancescu and Botkin 1986; Kenney 1986; Roy and Shapley 1985). There is growing evidence that changes in university research funding could influence academic research agendas. For example, some academics appear to have become 'quite eager to reorient their work to make it more commercially relevant and rewarding' (Rosenberg and Nelson 1994, 345). Also, the quality of academic research appears to have declined because of the growth of short-term research aimed at quick results for industry. Consequently, it has become 'difficult to apply scientific checks and balances, resulting in "sloppy science"' (Lee 1996, 858). Furthermore, a survey in the UK revealed that businesses 'were reluctant to support fundamental or core research where immediate benefits in commercial terms were unlikely' (Allington and O'Shaughnessey 1989, 75).

As the UK has been in the vanguard of the transformation of public R&D systems, it is interesting to examine the available data to determine the influence of funding mechanisms in bringing about these changes.

5 Changes in funding of public R&D in the UK

Tables 2–6 illustrate the changes in the public R&D funding pattern over the last 10–15 years.[1] Table 2 clearly shows that the overall government funding of public/academic R&D in the UK has been declining over the years. The total government funding of public/academic R&D has declined from over £3 billion in 1992 to less than £1.3 billion by 2002. At the same time, the business funding of public/academic R&D has increased but fluctuating. That is, it increased from £372 million in 1993 to £571 million in 2000, but has dropped to £445 million in 2002. This trend is also seen in the case of funding from non-European Union overseas sources to non-business sector in the UK.[2] This also increased from £176 million in 1992 to £426 million in 2002. Together, both business and non-EU funding of public/academic R&D has increased from £548 million in 1992 to 871 million in 2002.

Figure 1 illustrates the government and business funding trends between 1992 and 2002. It is clear that the government funding has fallen sharply between 1994 and 1995 and since then it has been declining steadily. It is also clear from Table 2 that the government funding to Research Councils has seen little increase and the funding to higher education sharply fell from £1,801 million in

[1]Most of these tables are based on current price. However, they provide significant trends and they do not diminish the relevance of various trends analysed below.

[2]The data for non-EU funding of non-business sector in the UK have been calculated by using the total funding by overseas sources and the funding by EU to the business sector (about 4.6% of the total overseas funding). It is presumed that the non-EU funding sources are largely overseas businesses.

Table 2 Government and business funding of public/academic R&D in the UK between 1992 and 2002 (in £ millions)

Year	Funding by Government				Funding by business				Funding by abroad (non-EC)		Business + abroad (non-EC) funding to public R&D
	Public sector	Research councils	Higher education	Total	Public sector	Research councils	Higher education	Total	To business	To non-business	
1992	1,540	–	1,493	3,033	207	–	165	372	1,212	128	500
1993	1,633	–	1,602	3,235	214	–	176	390	1,261	205	595
1994	1,742	–	1,801	3,543	196	–	157	353	1,347	266	619
1995	1,306	83	161	1,550	105	36	170	311	1,645	278	589
1996	1,317	77	157	1,551	129	35	188	352	1,887	299	651
1997	1,166	78	161	1,405	203	37	205	445	1,692	321	766
1998	1,172	76	177	1,425	260	38	221	519	2,119	355	874
1999	1,083	78	258	1,419	308	48	242	598	2,433	343	941
2000	1,138	102	266	1,506	287	35	259	581	2,369	366	947
2001	937	148	237	1,322	191	37	250	478	2,903	363	841
2002	863	150	249	1,262	152	36	257	445	3,390	426	871

Source: Office for National Statistics (On-line Database), UK

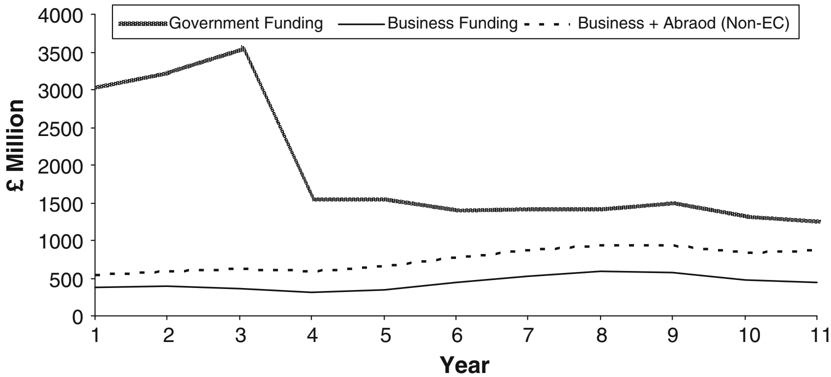

Fig. 1 Government and business funding of public R&D in the UK between 1992 and 2002 (in £ millions)

1994 to £161 million in 1995. It has only marginally increased during 1999 and 2000 (£258 and £266 million, respectively) and has declined since then.

Table 3 shows the R&D expenditure (defence/civil) by sector of funding between 1985 and 2002. It clearly shows that funding by public sector has seen only a marginal increase between 1985 and 1994 and it sharply fell from £4.5 billion in 1994 to £2.5 billion in 1995. This declined further to £2.1 billion in 2002. Table 3 also shows that the funding by higher education and the Research Councils has seen only a marginal increase over the same period. In contrast, funding by business, non-profit, and overseas sources has increased significantly over the years. In 1985, the total business/private sector funding of civil/defence R&D was about one-third more than the total funding by public sector. But the gap increased over the years, i.e., by 2002 total funding by business/private sector is nearly three times that of public sector.

Table 4 illustrates the expenditure on civil R&D by sector of funding. It clearly shows that the R&D expenditure funded by public sector has decreased by about 50% between 1990 and 2002, i.e., £2.4 to £1.2 billion. It is also clear that only the civil R&D funding by the business, overseas, and non-profit sectors has seen significant increase between 1990 and 2002. Since 1989, total business/private funding of civil R&D has been between 2.5 and 3 times that of total public funding.

Table 5 shows the R&D expenditure (defence/civil) according to sector of performance from 1989 to 2003. It clearly shows that the expenditure of R&D performed in public sector has first declined in the late 1980s and witnessed some increase in the early 1990s and remained nearly constant since 1995. It has increased just marginally in the case of Research Councils and the higher education. The expenditure on R&D performed by the higher education sector in each year is significant. Since 1997, it is more than double the amount of expenditure on R&D performed by the public sector. It is also clear that the expenditure on R&D performed in the business sector has seen significant increase over the years.

Table 6 shows that the average government funding to R&D performed by the businesses in the UK between 1989 and 2003 was over £1 billion. This is

Table 3 Civil and defence R&D expenditure in the UK by sector of funding between 1985 and 2002 (In £ millions—current price)

Year	Public sector	Research councils	Higher education funding councils	Higher education	Total (public)	Business sector	Abroad (non-EC)*	Private non-profit	Total (business + private)
1985	3,255	–	–	51	3,306	3,644	633	256	4,533
1986	3,357	–	–	55	3,412	4,045	783	234	5,062
1987	3,453	–	–	66	3,519	4,460	817	246	5,523
1988	3,458	–	–	78	3,536	5,115	908	267	6,290
1989	3,804	–	–	82	3,886	5,542	1,098	303	6,943
1990	4,000	–	–	86	4,086	5,886	1,386	365	7,637
1991	3,995	–	–	92	4,087	5,943	1,407	397	7,747
1992	4,089	–	–	99	4,188	6,339	1,340	435	8,114
1993	4,237	–	–	103	4,340	6,815	1,466	477	8,758
1994	4,479	–	–	116	4,595	6,886	1,613	514	9,013
1995	2,514	1,078	1,018	119	4,729	6,765	1,923	511	9,199
1996	2,402	1,092	1,027	120	4,641	6,817	2,186	545	9,548
1997	2,332	1,135	1,033	123	4,623	7,321	2,013	578	9,912
1998	2,535	1,117	1,085	130	4,867	7,356	2,474	621	10,451
1999	2,601	1,185	1,157	142	5,085	8,213	2,775	701	11,689
2000	2,533	1,259	1,276	157	5,225	8,639	2,735	815	12,189
2001	2,440	1,358	1,474	177	5,449	8,740	3,266	888	12,894
2002	2,166	1,466	1,626	196	5,454	9,143	3,806	961	13,910

Source: Office for National Statistics (On-line Database), UKEC funding for both business and non-business sectors is calculated to be about 4.6% of total abroad funding

*It is presumed that abroad (non-EC) funding is mainly from businesses

Table 4 Civil R&D expenditure in the UK by sector of funding between 1989 and 2002 (in £ millions)

Year	Public sector	Research councils	Higher education funding councils	Higher education	Total (public)	Business sector	Abroad (non-EC)*	Private non-profit	Total (business + private)
1989	2,205	–	–	82	2,287	5,025	770	275	6,070
1990	2,356	–	–	86	2,442	5,399	947	337	6,683
1991	2,713	–	–	92	2,805	5,450	1,001	369	6,820
1992	2,845	–	–	99	2,944	5,837	1,050	416	7,303
1993	2,899	–	–	103	3,002	6,389	1,188	471	8,048
1994	3,182	–	–	116	3,298	6,416	1,271	512	8,199
1995	1,128	1,078	1,018	119	3,343	6,374	1,596	511	8,481
1996	1,009	1,092	1,027	120	3,248	6,381	1,916	545	8,842
1997	949	1,134	1,033	123	3,239	6,832	1,707	578	9,117
1998	1,048	1,116	1,085	130	3,379	6,908	2,098	621	9,627
1999	1,105	1,185	1,157	142	3,589	7,728	2,312	701	10,741
2000	1,083	1,250	1,276	158	3,767	8,084	2,247	815	11,146
2001	1,112	1,358	1,474	177	4,121	8,214	2,822	888	11,924
2002	1,212	1,466	1,626	195	4,499	8,669	3,297	961	12,927

Source: Office for National Statistics (On-line Database), UKEC funding for both business and non-business sectors is calculated to be about 4.6% of total abroad funding

*It is presumed that abroad (non-EC) funding is mainly from businesses higher than the funds provided by both the business and other private sectors to the public/academic R&D system (see Table 2). The government funding to business R&D amounted to between 15 and 25% of own funds provided by the businesses.

Overall, it is evident from Tables 2–5 that the funding by and the expenditure on R&D performed by the public sector has declined significantly over the years. The funding by and the expenditure on R&D performed by the Research Councils have seen only marginal increase. In the case of higher education, while the funding by the sector and the expenditure on R&D performed by the sector has only increased marginally, the expenditure on R&D performed by the sector has been relatively significant over the years. It is evident from Table 2 that government funding of public/academic R&D has declined significantly over the years, whereas the funding by business sector has increased significantly. However, the increase in funding by the business sector including the non-EU overseas funding has been inadequate in substituting the decrease in government funding to the public/academic R&D. This suggests that the public and higher education sectors have been competing over an inadequate R&D funding provided by the business sector and they were under significant pressure to seek a share from business R&D funding for their survival. This also suggests that government policy of cutting its funding to public/academic sector to push them closer to business is not working at the rate of speed it expected or it would like to see.

It appears from Tables 2 and 4 that although government funding to higher education has declined from £1.8 billion in 1994 to £161 million in 1995, more R&D have been performed by this sector with the support of business. For example, the expenditure on R&D performed by this sector in 1994 was £2.6 billion, which increased to over £4.5 billion in 2003 (see Table 5). This suggests that significant increase in the R&D expenditure is met by business

Table 5 Defence and civil R&D expenditure in the UK by sector of performance between 1989 and 2003 (in £ millions—current price)

Year	Public sector	Research councils	Higher education	Business sector	Private non-profit	Total
1989	1,534	0	1,689	7,416	196	10,835
1990	1,566	0	1,873	8,054	234	11,727
1991	1,757	0	2,020	7,842	219	11,838
1992	1,846	0	2,129	8,167	224	12,366
1993	1,928	0	2,312	8,717	232	13,189
1994	2,051	0	2,623	8,842	168	13,684
1995	1,462	581	2,696	9,116	177	14,032
1996	1,495	575	2,792	9,297	177	14,336
1997	1,427	590	2,893	9,556	190	14,656
1998	1,487	591	3,040	10,133	203	15,454
1999	1,450	622	3,324	11,302	231	16,929
2000	1,593	646	3,648	11,510	322	17,719
2001	1,160	670	4,034	12,336	423	18,623
2002	1,053	699	4,416	13,110	539	19,817
2003	1,217	788	4,457	13,687	669	20,818

Source: Office for National Statistics (On-line Database), UK

funding. However, from Tables 4 and 5 it appears that although university R&D has succeeded marginally attracting business funding, the public sector R&D institutions have failed to attract increased funding from business sector and they remained largely dependent on government funding.

6 The social implication of commodified science

It is clear from the foregoing that the development of neo-liberal states in which social, human, and technological resources are harnessed for private gain has facilitated the development of knowledge economies in which scientific knowledge is an important, tradable commodity. It is also clear that this transformation has also led to a fundamental shift in the nature, extent, location, and ownership of formerly public scientific activities and indeed in the very vision of what science is and what it is done for.

Many, perhaps including those who are proponents of Mode-2 knowledge production (Gibbons et al. 1997), would argue that such a shift is to the advantage of society and social wellbeing in that it will lead to the effective harnessing of scientific expertise to the benefit of technological and commercial development. However, such a perspective is fundamentally a political and ideological one. In reality, this change may be far more nuanced and complex than can be expressed by a simple assertion that all that has taken place is an effective and efficacious improvement in the management of science such that it is even more useful. Above all, such understandings fail to appreciate the socio-economic reality of science as a social activity.

In the first instance, the effective privatisation of what was previously public science may have an adverse impact on the ability of government to obtain independent and reliable advice for policy purposes.

Table 6 Sources of funds for R&D performed within UK businesses between 1989 and 2003 (in £ millions)

Year	Government	Overseas			Own funds	Other UK businesses	Others	Total
		EC	Non-EC	Total				
1989	1,204	0	0	986	4,768	458	0	7,416
1990	1,269	0	0	1,248	5,147	391	0	8,055
1991	1,053	0	0	1,253	5,134	402	0	7,842
1992	1,021	0	0	1,220	5,467	459	0	8,167
1993	965	82	1,263	1,345	5,885	498	26	8,719
1994	910	63	1,347	1,410	6,030	474	19	8,843
1995	953	93	1,645	1,738	5,723	700	3	9,117
1996	842	131	1,887	2,018	5,742	691	5	9,298
1997	915	108	1,692	1,800	6,198	642	1	9,556
1998	1,094	119	2,119	2,238	6,141	659	0	10,132
1999	1,157	137	2,433	2,570	6,824	750	1	11,302
2000	1,013	101	2,369	2,470	7,244	779	3	11,509
2001	1,101	109	2,903	3,012	7,455	764	4	12,336
2002	884	177	3,391	3,567	7,712	942	4	13,109
2003	1,487	95	3,459	3,554	7,496	1146	3	13,686

Source: Office for National Statistics (On-line Database), UK

Second, a number of major science areas that were originally and traditionally public good activities have now become highly marketised and commodified. This is particularly true in fields such as agriculture and pharmaceuticals (Baskaran and Boden, 2005, in press). Such sciences have been captured and are now controlled by substantial global corporate industries that depend upon the exploitation of scientific knowledge products for commercial gain. In industries such as pharmaceuticals, it is imperative that the corporations attain and retain control of the intellectual property rights relating to scientific knowledge products. This can have serious social welfare consequences, as evidenced by issues such as the pricing of HIV/AIDS anti-retroviral drugs (Baskaran and Boden, 2005). It is, we believe, simply naive to believe that the free market can effectively meet social welfare needs globally in such areas.

Third, the private capture of science has been achieved by global corporations actively seeking research links with universities and other publicly funded scientific institutions. The science institutions have been obliged to co-operate with these new funders as a consequence of the progressive withdrawal of state funding. Global corporations have embarked upon aggressive corporate acquisition strategies and they have resorted to legal action to assert their legal rights over knowledge. This begs the question as to how independent science can be—scientific advice controlled and invoked by regulatory regimes very often now originates with the corporations themselves. Industry's control over scientific knowledge production processes is now becoming comprehensive: for example, an investigation by *The New England Journal of Medicine* revealed that 96% of the scientists who wrote articles supporting 'calcium channel-blocking drugs' to reduce the risk of heart disease received financial support from the pharmaceutical companies that make them (The Guardian 21 February 1999). Such financial relationship between industry and scientists may provoke concerns over the impartiality and objectivity of scientists who decide on approval of drugs.

Fourth, this new regime of science, which is both commodified and marketised and which relies upon a panoply of international law and concerted governmental action to ensure its effective commercial exploitation, generates significant global opposition. The principle grounds for this appear to be the perceived conflict between the aims of commodified science and social welfare needs as perceived by some and the questions raised over independence when funding flows come from the private sector. Like that which it seeks to combat, this opposition is also organised globally. This level of global opposition to the utilisation of scientific knowledge is clear evidence of massive and widespread distrust in what corporatised and commodified science now seeks to achieve.

This level of distrust as evidenced through opposition movements has generated new and ironic forms of governance. Most notably, these have been the public shaming of firms and direct attacks on their profitability. The former, of course, tends to impact the latter in any case. Thus adverse publicity leads to consumer boycotts and a refusal to consume products. Adverse publicity also highlights excessive and inequitable profit making. Direct attacks on profitability have involved engaging, for instance, with companies in the courtroom to challenge them to prove that their profits are not excessive and that pricing structures are justifiable. In a sense, opposition movements have successfully engaged with global corporations on their own territory. It is indeed ironic that one of the most successful lines of attack by opposition groups has been to challenge and compromise the ultimate reason for the existence of these firms: their profits. Thus accounting and accountability have proved to be increasingly useful tools in the development of new forms of the governance of science.

Fifth, and very fundamentally, there are fears that the new regime of commodified science will adversely affect the development and maintenance of the science 'base'—the general fund of fundamental scientific knowledge on which scientists and technologists can draw. This is because as work that is done is increasingly short-term and commercially oriented, so less work is done in underpinning sciences because that has little immediate commercial relevance.

7 Conclusions

This paper relates the unfolding story of how Western science has been progressively shifting from being an activity with an explicitly stated social purpose to one with an explicitly stated economic one. This change in mission has necessitated a fundamental change in the ownership and location of scientific activities as this was necessary to ensure that scientific efforts were appropriately orientated and controlled and that intellectual property could be asserted. The changes in the public research establishments, universities in particular and funding patterns in general demonstrate these commodificatory pressures, exemplifying the systematic private control of the scientific process. The main engine of the commodification of science has been the deployment of new public management techniques and funding mechanisms that effectively shape and control the focus of scientific activities.

This reform of science has been exogenous and policy-led rather than the traditional norm-led endogenous change that has characterised previous periods. This policy-led change is driven by a neo-liberal ideology that dictates that the role of science is to support and serve economic ends first. Neo-liberals would argue that the best way of supporting the social is by strengthening the economic.

We argue in this paper that such a prioritisation of the economic in science in the belief that this will adequately care for matters of social wellbeing is at best naive. There may well be adverse social welfare outcomes of this process in terms of the ability of governments to adequately perform their regulatory functions and inform policy making, and of a number of sciences such as agriculture and pharmaceuticals to help the poor. Thus, we argue, the pre-existing social contract between scientists and the public for knowledge that had both social and economic utility has been fatally fractured.

The consequence of this has been an increasing public distrust of science. The public has come increasingly to view the notion of the independence and neutrality of science and scientists not only with scepticism, but also, in some circumstances, with outright hostility. Central to this shift in public attitude, we posit, is a general perception that science has been progressively relocated within and controlled by industry and that government regulators are more keen to promote the interests of industry than those of the public interest. This change in perception is an indirect result of the efforts of governments worldwide, in general, and in the developed countries, in particular, to make scientists and universities work more closely with the industry.

The refutation of arguments that publicly funded research should benefit the industry and economic competitiveness is problematic. Recent controversies over science suggest that this policy shift has caused increasing public distrust of science and scientists, which may lead to irreparable damage not only to science, but also science's ability to support industry in the long-term. It is, we would argue, in the interest of science, scientists, and industry that the practice of science is relatively independent of economic pressures and is perceived by the public as such. The key to achieving the necessary balance between the roles of science in meeting the economic needs of a nation and serving the public interest lies in its funding and management. The widespread abrogation or marketisation by many states of their funding role in the pursuit of narrowly conceived short-term economic pay-off has fundamentally affected the wider socio-economic objectives of science. If the commodification of science is not in some way reversed, it is likely that the fragile social contract that exists between it and the public will be irreparably damaged.

There are some lessons here for the developing countries which are witnessing a transformation of their scientific research systems as a consequence of globalisation (Krishna et al. 1998). Although some developing countries, such as India and South Africa, appear to be influenced by the policy shift in the funding of academic science, the commodification of science is less advanced in these countries. These countries therefore now have an opportunity to pause and review their policies, drawing on the adverse experience of developed countries. In the developing world, even a large country such as India does not have an industry that could replace the state as primary source of funding and support academic science (Krishna 2001, 15). If developing countries follow the path of their more developed neighbours blindly, the consequences could be far more severe given such infrastructural differences. Further, it is likely that they could find it more difficult and take longer to rectify any negative impact of commodification of science.

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