Minerva (2012) 50:149–167
DOI 10.1007/s11024-012-9201-y

A Cultural Political Economy of Research and Innovation in an Age of Crisis

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Published online: 22 May 2012

Abstract Science and technology policy is both faced by unprecedented challenges and itself undergoing seismic shifts. First, policy is increasingly demanding of science that it fixes a set of epochal and global crises. On the other hand, practices of scientific research are changing rapidly regarding geographical dispersion, the institutions and identities of those involved and its forms of knowledge production and circulation. Furthermore, these changes are accelerated by the current upheavals in public funding of research, higher education and technology development in the wake of the economic crisis. The paper outlines an agenda for science & technology policy studies in terms of a research programme of a 'cultural political economy of research and innovation' (CPERI). First, the implications of the overlapping crises for science policy analysis are discussed. Secondly, three rough constellations of contemporary approaches to science policy are critically compared, namely: a techno-statist Keynesian governance; a neoliberal marketplace of ideas; and co-productionist enabling of democratic debate. CPERI is then introduced, showing how it builds on the strengths of co-production while also specifically targeting two major weaknesses that are of heightened importance in an age of multiple crises, namely neglect of political economy and the concept of power.

Keywords Science & technology policy · Crisis · Cultural political economy · Governmentality

Introduction

Writing as 2011 closes, even the most casual of observers of science & technology policy (STP) must be struck by the scale, scope and depth of the challenges. Yet the

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shift of science policy to centre-stage is hamstrung by the fact that standard science policy studies are inadequate to the tasks. I explore one agenda for science & technology policy to articulate routes to a brighter future by arguing for a research programme of a 'cultural political economy of research and innovation' (CPERI) (Tyfield 2012a, 2012b).

Science and technology policy is undergoing seismic shifts.[1] First, policy is increasingly demanding of science that it tackles and (it is hoped) fixes a set of epochal and global challenges, including: the global (or trans-Atlantic, with uncertain global implications) economic crisis and stagnation of the knowledge economy; diverse environmental crises (particularly climate change); and overlapping resource constraints, particularly regarding energy, agriculture and food security, and water availability and quality. Moreover, these overlapping crises are themselves intimately bound up with science, in terms of their identification (e.g. climate change) and, via scientifically-enabled technologies, their causal emergence and/or their possible resolution. They thus go beyond the condition of 'risk society' (Beck 1992), in which the very success of science generates new horizons of irreducible uncertainty and risk, by imparting a heightened political urgency that intensifies the demands on science to provide solutions.

On the other hand, practices of scientific research are changing rapidly, as are its geographical dispersion (extending into global networks and new rising powers of science, such as China), the institutions and identities of those involved (through both commercialisation and public participation, now also enabled by social media) and its forms of knowledge production and circulation. Again, this is thus not simply the increasing presence of 'society' in 'science', or 'Mode 2', as discussed over the last two decades (Nowotny et al. 2001); nor the 'democratization' (von Hippel 2005) or 'opening' of innovation (Chesbrough 2005). Rather, whether in transforming processes of scientific peer review (Mirowski 2011b) or the emergence of Do It Yourself bio (Hedgecoe 2011), the various crises are conditioning intensified interest in many collective experiments that are fundamentally redefining science and innovation.

Furthermore, these changes are accelerated by the current upheavals in public funding of research, higher education and technology development in the wake of the economic crisis. That science is simultaneously tasked with resolving the economic crisis (and acting as the core of a new economy) while in some countries public funding is reduced is a curious, indeed paradoxical, development. Such paradox, however, highlights the novelty of the present conjuncture, problematizing any approach provided by past experience.

In short, a major change in context, demands and objects of science policy (and so also STP studies) is unfolding that undermines conventional science policy's understanding of both the nature of science and its relation to policy. It is analytically inadmissible to take any of these terms, with their fixed and reliable definitions, as external variables. The challenge for contemporary science policy studies is thus how to examine, identify and hold to account an assemblage of

[1] Throughout the paper, for brevity and to avoid irritating repetition, I will use the terms 'science' and/or 'science policy' to stand, *mutatis mutandis*, for 'science and technology policy'.

science practices and their political/economic/cultural conditions that is still emerging and of uncertain form.

How is this to be achieved? Once we question the presuppositions of given, dominant and socially-efficacious understandings, a proliferation of alternatives begins to open up. We see a cultural political economy of research and innovation as a possible overarching way forward. First, the implications of the overlapping crises, in general and particular, for science policy analysis and its presuppositions are detailed. This analysis thereby leads to the identification of six issues of science policy that need to be explicitly incorporated and rationally justified but are now generally tacitly presumed.

Secondly, we identify and critically compare three configurations of contemporary approaches to science policy, namely: a techno-statist Keynesian governance; a neoliberal marketplace of ideas; and co-productionist enabling of democratic debate. Dominant paradigms are shown to be *worsening* both the problems they are supposed to address and the predicament of science & technology policy itself. Co-production-inspired approaches can do better, but are inadequate in key respects.

Thirdly, it is argued that along with the significant insights about the nature of science from constructivist co-productionist STS, attention to the six issues of science policy shows the need for synthesis with other perspectives, which is what CPERI attempts to do. Concerted consideration of the dominant economic imperative on science demands an explicit programme of the political economy of science, which currently remains strikingly neglected within STS (Mirowski & Sent 2008; Mirowski 2011a; Tyfield 2012b). This in turn demands a cultural political economy perspective that is capable of working with the insights, and hence philosophical underpinnings, of STS. This cultural political economy is inspired by Gramscian attention to the political economic significance of ideas and discourses etc… for explanation of the diverse strategies of stabilizing capital accumulation, so that political economy is never a purely economic or structural phenomenon (Tyfield 2012a, 2012b). In addition, *explicit* attention is needed to the concept of power and repudiation of its conception as the opposite of (rational) legitimacy in favour of a strategic, productive concept, as in Foucault's studies of governmentality (Hartmann 2011).

Implications of Crises for Science Policy

While science policy has changed considerably in the past few decades (e.g. Whitley 2010: 4–6), a rough 'standard' post-war model remains, built upon a resilient empiricist model of the creation and nature of knowledge manifesting the Enlightenment commitment to rational judgement and techno-economic progress. Hence, science may be distinguished from policy, the former providing accurate, objective understanding of phenomena on which action can be based (epistemologically privileging prediction of actual events or approximations thereof) and the latter responsible for value judgements responsive to an electoral mandate. Similarly, the idea of policy as instrumental, legitimate action looking for clear definitions and implementable solutions remains deeply entrenched in institutional

logics – even as more empirically robust alternatives have long been available (e.g., Lindblom 1979). The default understanding of interaction of scientific expertise and publics remains the 'deficit model' of an ignorant public that must be educated by knowledgeable scientists (Irwin & Wynne 1996). And the relation between science and policy goals is dominated by its supposed role as source of technologies and resulting economic growth (the 'linear model'), again despite thorough scholarly repudiation of that view. Now, each of the presuppositions of this standard model are fundamentally unsettled by the current challenges: the nature of science and its relation to policy and policy goals; a theory of knowledge, including purposes of science policy studies; and the nature of policy(making).

The current challenges have implications at various levels of abstraction. At its most abstract level, following Debray's (1973:113) useful definition of crisis as "objectively over-determined and subjectively indeterminate" – a characterisation true of all the triple crises under consideration – crisis immediately poses fundamental challenges to the standard model. Subjective indeterminacy introduces a causal role for concepts themselves in the shaping of policy responses, perhaps even constructing conditions they purport merely to describe. Moreover, since crises are over-determined and responses to them are subjectively indeterminate, there is no single analysis that is correct and exhaustive, nor therefore any single instrumental policy out of the mess. And this undermines the very framing of the challenges for science policy (studies) as a problem that can be identified with a solution crafted and implemented by an existing institution. Where the *object* of a positivist social science paradigm is in crisis, in short, this generates an epistemic crisis. The established role of policy studies is particularly problematic since the role accorded *by* policy is both strictly limited ('tell me what is true') and *impossible* ('you can't tell me anything').

This is more than pointing to the intractable insolubility of some 'real world' problems for policy, however, which may be managed or deflated during periods of 'normal' policy-making. Even where the object of a whole field of policy (enquiry) is habitually too complex for demonstrably successful policy intervention, this may be overlooked if the functioning of normal politics is not too heavily dependent upon the resolution of those issues. This has arguably been the state of science policy itself for several decades now. Turning to the more concrete level of the *current* challenges, however, shows that this is no longer the case.

First, each of the constituents of the triple crisis – now the dominant concerns of policy/politics, not just a specialized science policy – are intimately related to issues of science and technology in complex ways; hence the intensified demands of policy on science to deliver solutions. Yet this shift of science policy to centre-stage is occurring at the very moment when the basis of this move, the presumption that 'more complex problems need better knowledge', is itself being undermined. Standard science policy and studies thereof, however, are unable to explore these profound conceptual flaws. The urgent demand created by the triple crisis for science policy to rethink concepts and institutions (of 'science') is superseded in practice by the more immediately compelling urgency of the solutions that are hoped for. Science and technology policy studies should respond, but not just bow to the way this urgency is defined by present science and technology policy.

There are significant tensions, antagonisms and complexity in the inter-relation of the various crises. For instance, the economic crisis has posed anew and heightened a supposed trade-off regarding political will and investment to tackle the ecological crisis. The favoured route out of economic crisis, renewed economic growth, need not be compatible with significant decarbonisation of socio-economic life, since economic growth has always increased greenhouse gas emissions (e.g. Ockwell 2008). Conversely, more than a billion people lack access to reliable energy, so that even from an equity-focused perspective the dilemma remains excruciating. Pagano & Rossi (2009) have highlighted the crucial role in the economic crisis of a deepening 'investment strike' in technological innovation related to the over-privatization of knowledge production, epitomized by the drive towards ever-stronger, globally harmonized intellectual property rights. In that case, however, further attempts to stimulate knowledge-based growth with yet stronger IPRs may simply deepen the crisis, while conversely, attempts to loosen IPRs may weaken incentives for investment by large corporations, especially in major technological projects, also prolonging stagnation. In both cases, a new policy settlement that rebalances amongst growth, equity and environment, and/or accumulation/circulation of IP, is certainly imaginable, but will require intellectual and political effort.

These converging crises thus present conventional science policy studies with the existential challenge that, as a problem-solving paradigm, it must presume precisely what is in question *from the perspective of its policy sponsors*, i.e. an established, well-understood relation between science and policy. Conversely, the only way to proceed would appear to be to step back from the urgency of providing solutions and to question what is presupposed by perspectives on these crucial challenges.

Three Established Configurations of Science & Technology Policy Studies

To characterize three well-established configurations of science policy studies – the first two also well-established in science policy itself – I will use six analytical dimensions, and then apply the same dimensions to my presentation of CPERI:

- The economics of science, including not just how science is and should (not) be funded, but also how science in fact relates to economic concerns and, regarding the present conjuncture, to approaches to the economics of crisis (management), including the role envisaged (or not) for the state;
- The geographical extent of the *challenges* allotted to science, of science *itself* as practice and of policy;
- The relation of science to policy goals of technological change, innovation and economic growth;
- The relations posited between science and policy;
- The purpose and role of science policy studies; and,
- The concept of power (hence policy, politics etc…).

The first two configurations are versions of the standard model from different ends of the conventional contemporary political spectrum. Conversely, co-

production, the third configuration, builds on STS, political philosophy on deliberative democracy and (neoliberalism-conditioned) policy interest in (extra-state) governance to achieve some influence, especially in Europe, but without becoming politically predominant.

We start with the dominant post-war model of science policy: Keynesian technostatism. This configuration, a social liberalism of warfare/welfare nation-states (Jessop 2002; Dean 2010), emerged as bulwark for liberal democracy against the twin challenges of (defeated) fascism and (insurgent) communism. Science had two key roles in this new political economic settlement: basic research underpinning technological advancement (for material improvement to satisfy working populations, and defeat the Soviet Union militarily if necessary); and a cultural sphere of 'free' inquiry characterised by Mertonian norms, as against 'ideological' Nazi/Soviet science, that could also act as liberal democratic break on overbearing government, 'speaking truth to power' (Table 1).

The emergence of a separate institution of science occurred in parallel with the rise of classical liberalism in the late 19th century (Ezrahi 1990). Yet the self-evidence of science (and market as invisible hand) as 'natural' limitations to an overbearing state posited by classical liberalism was no longer credible following its wrenching collapse between 1914 and 1945. Keynesian technostatism thus replaced this self-evidence with an explicit determination to defend the liberal division of society, including science, with a strong national state. The conception was thus of functional, mutually-supportive distinct spheres of state-market-science all underpinned by the state, supporting limited government, free enterprise and free thought respectively. Far from these science-policy relations being 'natural' they were a deliberately crafted political settlement (Thorpe 2008).

While professional scientific expertise was enlisted by politics to preserve and revitalize liberal democracy, however, the actual result was growth in unaccountable technocracy. Large, well-funded technocratic public projects were also manifestly failing by the 1970s, some spectacularly, including the 'war by numbers' in Vietnam or the 'War on Poverty' (Fischer 2003). The large public science budgets that such projects elicited were also becoming increasingly

Table 1 Keynesian Techno-Statism

Economics of Science	'Public good' argument, relatively generous state spending to maximize scientific research against socially sub-optimal market failure for national welfare and security
Geography	National horizons for science, challenges and policy
Science – Technology – Innovation	Science as 'basic research' for subsequent, unpredictable technological advancement – linear model – but with academia responsible for a functionally distinct 'science', not for 'linking up'
Science – Policy	Science as delivering objective fact for policy, policy as democratic value judgements between (scientifically-informed) courses of action
Science & Technology Policy Studies	Objective science *for* or *of* policy, both to improve processes of policy decision-making
Power	Juridico-discursive conception of power – hence 'truth to power' – power is either legitimate/consensual or coercive

politically conspicuous. The complexity and uncertainty of technological society were overrunning the policy-making capabilities of nation-state institutions. And the limitations of the political economic model underpinning the science-policy settlement were also emerging in the face of growing global trade and finance, stagflation, labour and/or social unrest etc… The result was the crisis of the Keynesian welfare state of the 1970s, from which arose the neoliberal regime that dominated the last few decades.

Before we turn to this second configuration, though, where is this first position today? Keynesian technostatism has never been definitively abandoned, and remains strongly present in the underlying design of post-war institutions, despite several decades of neoliberal(izing) reform. Keynesian techno-statism thus remains a science policy orthodoxy. Through the 1990s and 2000s, it was reformed by shifting from centralized national government to a discourse of distributed 'governance' (e.g. Gläser 2010) to tackle the problem of illegitimate, bungling technocracy and to stimulate university-industry connections for national economic competitiveness. Today, its limited resurgence is associated with the seemingly renewed relevance of Keynesian solutions for the current economic crisis. This would especially include major programmes of national investment in S&T, as in Obama's announcement of a new 'Sputnik moment', arguably followed through most clearly regarding funding for green energy.

Yet a genuine resurgence of technostatist science policy looks highly unlikely. The US stimulus package included a major boost for science, and the UK's coalition government also ring-fenced the science budget (following considerable lobbying), so that 'basic science' is arguably amongst the most protected areas from cuts. Yet public science budgets remain tight and industrial policy non-existent given the prevailing economic orthodoxy of austerity, including the closing of the totemic space programme itself. Moreover, Keynesian responses to economic crisis are arguably never more than plasters, buying time in the context of emergencies for more deep-seated political, institutional reforms that actually took place in the US during the Second World War, not the 1930s of the New Deal (Lothian & Unger 2011). Such a weak outlook is also true of another emerging Keynesian discourse of fiscal stimulus, proposing a shift in geographical extent from nation-states to techno-globalist projects for global public goods or technology transfer, to tackle 'global' problems like climate change. The glacial pace of negotiation at the UNFCCC, however, illustrates the difficulty of any such global Green New Deal. Keynesian technostatism thus remains a politically respectable but diminished position, adapting itself somewhat to changed circumstances.

The present dominant position is a neoliberal science policy. Neoliberalism is, of course, a broader political ideology and project but one in which science plays a key role (Mirowski 2011a). Like classical liberalism, neoliberalism confers pre-eminent importance upon the market, but without taking markets as naturally emergent. Rather, they must be deliberately constructed (Lemke 2011; Mirowski & Plehwe 2009). Neoliberalism is thus *not* against the state but is a political project that must itself be *constructed through* a state, which in turn increasingly subjects itself to market discipline. Moreover, markets are primarily valued as the optimal *epistemic*, not just allocative, mechanism, for both natural (technoscientific) and social

(political) judgement. The spontaneous collective ordering of individual choices means that the market necessarily far outpaces the limited capacities for rational judgement of the planner/expert. This is especially the case when set against the proliferating uncertainties of techno-scientific progress. And the market reaches the optimal outcome (regarding success or failure, whether of a technological innovation or a scientific idea) while *also* thereby maximizing (and constituting) individual negative freedom, whereas planners must enforce their decisions on others. Markets (of ideas) alone produce justified knowledge and so are the only legitimate arrangement for knowledge production.

Neoliberalism thus represents the definitive repudiation of conceptions of science as a self-justified 'republic' of rational-empirical argument productive of public knowledge (Tlili & Dawson 2010; Polanyi 1962), by attempting to subsume this republic of science within economic marketplaces. This need not be experienced by scientists as the oppressive imposition of a distinct and alien logic. Instead, the 'marketplace of ideas' transforms the scientific enterprise such that the very criteria by which scientists *themselves* evaluate science are a domesticated version of the criterion of private economic gain, mitigated by the argument of the long-term relevance of basic science to the economy and society (Table 2).

The past decades have witnessed various attempts to neoliberalize science policy, especially in the global North. This has involved prioritizing and intensifying economic demands on science and policy goals, including such tropes as 'national economic competitiveness' (Bruno 2009). In turn, this involves construction of new performance measurement of science, for policy 'accountability' and/or commercial market-based comparison (ibid.). Where controversy about techno-scientific

Table 2 Neoliberal Marketplace of Ideas

Economics of Science	'Marketplace of ideas', strong, global IPRs and the commercialization of academic research. Resonant with an 'Austerian'[a] crisis economics, cutting state budgets and incentivizing the 'private sector'
Geography	Presumptively global, as for a single, unified global market
Science – Technology – Innovation	Revised linear model, with *linkages* between 'science', 'technology' and 'innovation' stressed or even conflated, as in a market for techno-scientific 'ideas'
Science – Policy	Both deconstructed into the marketplace of ideas; policy is depoliticized and procedural, tasked simply with the construction of markets given that the market is *always and in principle* a more informed, more responsive decision-maker
Science & Technology Policy Studies	To illustrate limitations of 'public policy' (as in New Public Management work) and so formulate arguments for construction of markets of science, and STP studies itself organized as a marketplace of ideas (e.g. think-tanks)
Power	Juridico-discursive conception of power in which the superior *epistemology* of the market underpins its superior political legitimacy over that of the limited intelligence of planners and narrower interests of activists and citizens – though these may both be incorporated so long as they are subsumed within markets.

[a] 'Austerian' refers to the combination of an Austrian school of economics approach and crisis policies favouring austerity not stimulus in public finances

developments arises, neoliberalism also tactically counsels a science policy that neutralizes ('ill-informed', 'value-laden') political debate by demanding 'sound science' to furnish the 'facts'; again with the superior epistemology of science as *itself* a self-correcting marketplace of ideas guaranteeing the optimally-informed decision. On the other hand, as the market exceeds the control of any one player,[2] this depoliticized science policy is also seemingly democratic, passing power from the professional technocratic elites to 'consumers' (of science/technology): marginalizing deliberation and maximizing competition (Pestre 2009: 251).

Putative depoliticization and scientification of politics, however, tends merely to politicize science (Levidow et al. 2007), especially as science itself is increasingly commercial and so distrusted by citizens. In recent years, the construction of markets of participation in science politics, involving various NGOs that claim to speak for the public, have emerged to attempt to mitigate this problem. A strong state must also manage the novel risks and uncertainties of neoliberalism's intensely technoscientific economic growth. But in both cases, these developments enflame, rather than allay, a deeper crisis of trust in, and popular sense of disempowered distance from, liberal democratic policy-making and science itself (Tlili & Dawson 2010; Wynne & Felt 2007). This is especially so now, given the repoliticisation of politics due to the economic crisis. A 'new science governance' (Irwin 2006) of experiments with 'public deliberation' is at best a partial solution.

To be sure, the Promethean aspect of neoliberalism – its 'creative destruction' (*Cf* Schumpeter 1976) – has repeatedly led to crises simply being treated as providing further opportunities for the profitable construction of new markets (e.g. Klein 2007; Pellizzoni 2011). This ability to prosper from disorder is not a permanent, intrinsic capacity of neoliberalism *per se*, however, but presupposes certain conditions which are actually necessary for the neoliberal project; in particular, financialized globalization and strong, neoliberalizing nation-states with a relatively docile citizenry, both of which are now in crisis, not least because of neoliberal prescriptions themselves. Whether crisis responses involving *more* neoliberalism are successful – i.e. in terms of neoliberalism's continued political dominance, not in terms of resolution of the crises – thus remains an open question. Regardless of whether or not this spells the end of neoliberalism, however, it has led to enormous inequity, as well as the creation of the global risk society.

While neoliberalism subjugates and trivializes deliberative democracy, and may thus engender deeper crises of legitimacy, the third configuration – built around a framework of STP studies rather than policy itself – starts by criticizing this, as well as the overall view on science, technology and society. 'Co-production' (Jasanoff 2004) refers to analysis of scientific and technological practices as reciprocally conditioning transformations of socio-political institutions. Neither science nor policy may thus be taken as foundational, as institutionally fixed or ontologically isolated from the other. Co-productionist studies explore how scientific knowledge is always politically conditioned, while politics always deploys various knowledges. Hence relatively stabilized settlements of 'science' and/or 'policy' and the boundaries between them (Gieryn 1999) are achievements not pre-given realities.

[2] Though neoliberal thought is explicitly comfortable with monopoly, see e.g. Crouch (2011).

Any techno-scientific problematic, such as the risk associated with a new technology, is also framed by normative and practical visions concerning the optimal organization of society and science itself (e.g. Jasanoff 2004; Fischer 2008). Since there are always such normative presuppositions, however, the only option for science policy is not *whether* or not science is political, but *which* politics is at work. Co-production examines and makes explicit the normative frames presupposed by taken-for-granted ways of producing and deploying knowledge.

Most importantly, since what is at issue in controversies about science and technology actually concerns these broader frames, and not just technical questions of risk assessment, the knowledge that may properly be deemed relevant to such debates is much more widely distributed than a professionalized, scientific/technical elite. Yet without inclusive and informed public debate about these frames, it is unlikely that the politics dominating science & technology policy will reflect the actual concerns of citizens. Since technoscience is also increasingly important in shaping normative trajectories of social change, this is a serious political problem. Contemporary commitment to an inclusive politics, it is thus argued, demands that technoscience itself becomes a sphere of democracy, privileging deliberative conceptions in particular (Wynne 2008; Dryzek 2000). Here it is envisaged that public participation will be a constitutive process of learning, constructing science-democracy and science-citizens (Stirling 2005; Tlili & Dawson 2010). Whereas technostatism aims for *legitimate expert knowledge* and neoliberalism for epistemically *optimal decision-making* by the market despite irreducible uncertainty, the key term here is '*democracy*' (Table 3).

Co-production offers a perspective that is much stronger than studies within the other two paradigms of STP in key respects. First, its foundational insights of the irreducible normative framing of scientific questions and a theory of knowledge mark a fundamental step beyond the first two, looking beyond science as objective facts or sound science respectively. Co-productionist studies offer detailed attention to the messy, contradictory and unintended outcomes of actual changes in science policy. Such analysis is normatively oriented to key and overlooked *qualitative*

Table 3 Co-production of 'science-politics' for (international) deliberative democracy

Economics of Science	Largely neglected beyond abstract expression of co-production of scientific and technoeconomic ordering
Geography	Methodologically cosmopolitan (Beck & Sznaider 2006), using comparative interpretive/institutional analysis
Science – Technology – Innovation	Forward and backward integration. Fuzzy distinctions and only limited boundary work
Science – Policy	Co-produced natural and social ordering of science and politics respectively, as science-politics, with emphasis on constructing public participation in order to *democratize* technoscience
Science & Technology Policy Studies	Focus on distributed innovation and governance; including making explicit tacit normative framings of policy and presenting them for democratic scrutiny
Power	Often explicitly conceived in Foucauldian terms, as productive and dispersed, but juridico-discursive in actual analysis

issues of technoscientific trajectories, such as 'direction, distribution and diversity' (Stirling 2009). It also raises key questions regarding publics and expertise that are simply neglected otherwise, arguing powerfully for a hearing in STP for a broader range of inputs.[3] There has also been some success, in the UK, in affecting policy regarding participatory experiments of 'upstream engagement' (Wilsdon & Willis 2004).

Co-productionist analysis also has some significant weaknesses. First, the key term of 'democracy' is generally under-theorized and prematurely accorded an unquestionably positive tenor (e.g. Irwin 2006; Tlili & Dawson 2010). This also tends to a neglect of the difficulties and problems of public engagement exercises, including how they may act merely as a justificatory gloss for policies already decided; e.g. with policy simply substituting the 'old' deficit model, of public *understanding* of science, with a 'new' one, of public *trust* in science (Irwin 2006).[4]

Moreover, these challenges are exacerbated by the contemporary crises. For instance, in the early 2000s, European science policy was attempting to balance between economic goals and deliberative exercises about broader priorities (Hagendijk 2004), but this effort has been reduced or redirected to become part of the recent strong focus on innovation (cf. the renaming of DG Research to become DG Research and Innovation), with a policy discourse on responsible innovation, up to a code of conduct for responsible nanoscience research (EC 2008). There are also the U-turns on the 'strong funding and strong public support' previously demanded by Tony Blair (Irwin 2006). While we should applaud co-production for its attempts to open up science policy, the limited extent and duration of its successes indicates these were too dependent upon the harmless incorporation of co-production by the neoliberal regime, as a boutique luxury. This suggests that it does not actually provide tools capable of producing the kind of radical transformation of science politics it advocates.

Preserving co-production's insights, therefore, demands that we attend to, and rectify, its current weaknesses. These evidence inadequate attention to political and political economic conditions. This especially includes neoliberalism as the dominant political project – its implications for science and policy/politics *and* for STS recommendations and their likely effects in that context – *even* as co-production is clearly an STS response to the theoretical and political problems of 'science' and 'society' of a neoliberal age. In the context of the crises *from*, and possibly *of*, neoliberalism, however, this superficial treatment of neoliberalism is no longer tenable. Adequate understanding of the contemporary trajectories and changes in technoscience and science-politics is utterly dependent on similarly adequate accounts of the nature and (non-linear) causes of these crises and their interaction with these techno-scientific issues.

[3] In particular, it highlights the limitations of experts and the capabilities and potential contributions of publics, *not* because of an absolute epistemic superiority but on the critical, relational basis that '"publics know better than you *think they do*" and that "they know *some salient things* better than you"' (Wynne 2008:28, original emphasis).

[4] Though there is a growing body of work associated with co-productionist perspectives that highlights the problems, not just benefits, of citizen engagement (e.g. Lezaun & Soneryd 2007).

In short, while co-productionist studies are strong in that their conception of science, technology and society is more realistic, and can appeal to democratic engagement with science, they only incidentally address the multiple overlapping and systemic crises of the present. This has to do with the neglect of systematic analysis of political economy and the concept of power. It is possible to do better, and this is where the cultural political economy of research and innovation comes in as a complementary perspective.

Cultural Political Economy of Research and Innovation

STS has opened up questions of how given categories (science, policy, etc.) are negotiated in concrete, rather than being established *ex ante* and in the abstract, and has argued for expansion of the range of negotiators to include various publics. In its focus on concrete co-production, however, it backgrounds the question where the structures denoted by those abstract categories come from, and how, as part of the broader project of modernity, they do their actual work – and have causal impact – in the world. The key analytical move is thus to study what is presupposed by, rather than taking for granted the self-presentation of, dominant concepts (Tyfield 2012a). Such research remains situated in a particular social context, but can transcend the context to some extent by showing how abstract categories are performative (and so are 'real') as well as the diverse and messy ways in which these categories condition human action.

This challenge has been taken up by CPERI: explore an historical ontology of the real presuppositions of *other* key categories of contemporary social life, notably markets/exchange value and state/citizen/government, that remain crucial elements of science-politics but are typically backgrounded in STS (Tyfield 2012b). If successful, it will move beyond the overstated philosophical anti-realism, which continues to undermine the critical capacity of STS including its analysis of science-politics/democracy (Tlili & Dawson 2010; Pestre 2009), towards a 'transcendental constructivism' (Tyfield 2012a). Thus, CPERI is a form of analysis that is relational but critical, situated but conditionally able to draw independent conclusions, power-attentive and strategic but still epistemically coherent, allowing for the reintroduction of inescapable *analytical* dualisms between science and politics, epistemic and political reason etc… while acknowledging their *ontological* inseparability.

These are strong claims. Whether CPERI will be able to realize them is not certain, but there is definitely a need to try to do so in STP studies. This is clear from a consideration of the two significant substantive gaps in co-productionist analysis. First, there is the overall approach of STS which is almost constitutionally allergic to issues of political economy. This allergy arguably derives from the focus of the interdiscipline on anti-realist philosophical constructivism, which in turn entails a dismissive attitude to social structures and totalizing social critiques. Comparing the intellectual and empirical vitality of STS and the introverted, moribund stasis of structuralist Marxism provides compelling evidence that STS has chosen wisely – but within limits. STS's neglect of political economy leaves a gaping hole in its analysis that is particularly exposed in times of economic crisis when the political

economic conditions of ongoing technoscience and its politics are undergoing profound change. Co-productionist analysis wants to do better, but finds this difficult when it limits itself to the intellectual resources of STS.

Following the lead of cultural political economy (Sum & Jessop 2009; Jessop 2010), paying attention to these issues can incorporate the insights of STS regarding the importance of relational conceptions of both knowledge and reality for insightful analysis of technoscientific change. An historical ontology approach offers exploration of both the concrete *and abstract* conditions involved in ongoing construction of capitalist political economies. This demands construction of concrete and socio-historically specific 'fixes' (Jessop 2002; forthcoming), involving both technoscientific and institutional innovations, in order to regularize accumulation and allow it to continue relatively unimpeded, albeit only ever temporarily. Given the central importance of technoscience in contemporary capitalism, it follows that not just science and policy is being negotiated in a neoliberal techno-scientific programme (i.e., the subject of STS and STP studies) but the many inherent tensions of neoliberalism itself. As such, in a neoliberal age – one in which science is increasingly tasked with driving economic growth and solving the current economic crisis – social studies of science that systematically ignore political economy are simply of dubious assistance, whether in *resisting* further neoliberalization or in trying to effect change within actual governmental science & technology policies.

Applying cultural political economy to issues of technoscience, and in an age of overlapping crises, yields new perspectives on research questions specifically concerning the parallel development of technoscience, capital accumulation and changing natures, including: how new metrologies are both allowing the direct capitalistic valorisation of new phenomena (e.g. carbon markets) and/or facilitating indirect regularization of new commodities (e.g. international food standards) and markets (e.g. of science-based labour); how innovation constructs new frontiers of capital accumulation (e.g. biotech or ICTs); how technoscience both identifies 'problems' and suggests 'fixes' to regularize continued accumulation, including governance of new technoscientific 'risks' (e.g. geo-engineering) and 'accumulation by dispossession' of practices that may not even be obviously related to technoscience (e.g. of care for the elderly); and how new technological capacities and new technoscientific ontologies afford governmental intervention to assist continued accumulation (e.g. personal genomic medicine).

Study of technoscience in constructing and managing capital accumulation, however, leads to the second major gap in co-production, namely its inadequate conceptualization of power (Hartmann 2011). This too often remains in practice, if not in explicit argument, a 'juridico-discursive' conception, for which 'power' is defined *as against* legitimate (i.e. rationally and consensually accepted) rule. Power is thus something that may be amassed by one party over others, is associated with the capacity to coerce these others and thus is *prima facie bad*.

Technostatism conflates the epistemic authority of science with the political legitimacy of technocracy; while neoliberalism employs an epistemic criterion of legitimacy against abusive (state) power but with the market as optimal and legitimate source of that knowledge. Co-production, on the other hand, is

fundamentally sceptical of the equating of 'true' or 'sound' knowledge with political legitimacy. Nevertheless, like Habermas (Durant 2011; Fischer 2003; Tlili & Dawson 2010), co-production runs the risk of shifting the locus of legitimacy from substantive knowledge to the procedural criterion of public, free deliberation. While stressing the ontological reality of values, culture and practice in construction of both science and politics, the emphasis can too easily be on rectifying a perceived deficit in legitimacy through primarily epistemic means: public deliberation, especially regarding the tacit normative framings of technoscientific issues made explicit by such studies (e.g. Wynne & Felt 2007).

For a juridico-discursive concept of power, legitimate politics is an *epistemic* phenomenon and this effects a tacit and premature conflation of science and politics: 'politics' is 'legitimate' when based on rational, objective knowledge. A residual juridico-discursive conception thus helps to explain co-production's most serious shortcomings. First, where 'politics' equals legitimacy equals rational consensual knowledge, this would underpin a commitment to the presumption of compatibility of, and hence an inadequately analyzed relations of, science and democracy. It would also tend towards an underspecified definition of 'democracy' *per se* and an insufficiently questioned presumption of the efficacy of deliberative science-democracy in the making of better worlds. Finally, it would also support the presumption of the *incompatibility* of science and power ('politics' in the vernacular, pejorative sense of 'making science political'). This, in turn, rules out any role of 'power' in (legitimate) politics and so democracy itself, and at considerable analytical cost.

An alternative exists, however, in the form the strategic and productive conception of power most systematically developed by Michel Foucault (2008) in his later work on 'governmentality' (Dean 2010, Lemke 2011). On this conception, power is not a thing but a relation, not possessed and concentrated but constitutive and (asymmetrically) dispersed, not presumptively bad but normatively ambiguous, not oppressive and destructive but productive and ontologically necessary for the construction of all human creations, and not illegitimate until rationally consented to but strategic and ubiquitous. Hence legitimacy and coercion are simply two possible modes of power relations, not the foundations of 'power' (=domination). It is thus amenable to analysis not in terms of whether or not power is being exercised in legitimate ways or (*per* modern political philosophy since Hobbes) how 'rule' is to be rationally justified (as in the 'political turn' and/or Third Wave of STS, see respectively Brown 2009; Durant 2011; and Collins & Evans 2002). Instead, it offers an analytics of *how* power relations are constituted and in turn constitute the stuff of the world, including institutions, technologies, forms of collective government and subjectivities, that mediate the actual, day-to-day 'conduct of conduct' (Dean 2010). For science & technology policy studies, this involves particular attention to how technoscientific developments in particular interact with and reconstitute power relations (e.g. Pestre 2009; Bruno 2009); including the questions above regarding regularized capital accumulation.

This conception of power is often given explicit attention in co-productionist analysis, but it has yet to be systematically integrated into the framework (Hartmann 2011). The imperative to do so now, however, is clear when considering the

capacity of science policy studies to respond productively to the current crises. Moreover, assuming a cultural political economy perspective helps to ensure that a strategic conception of power is actually used in the analysis, and not merely alluded to, since this framework only makes sense on such terms. This would take the form of a genealogical current history that explores the potential construction by existing power relations and technologies of new techno-socio-political settlements that do not take as given contemporary understandings of politics, democracy, science, etc… and their inter-relations. Importantly, this would also include the key questions of understanding the crises themselves and, in particular, neoliberalism and what may emerge from and/or replace it as the "ecologically dominant" (Jessop 2002) political project. This is thus a resituating of the co-productionist perspective rather than its repudiation. CPERI provides the conceptual underpinnings to help tip the balance of work in a broad co-productionist mould towards that which is (already) more explicitly attentive to a Foucauldian concept of power (e.g. Joly et al. 2010).

What role does this imply for science policy studies? Normatively, its task cannot be to provide objective knowledge, nor just illuminate tacit cultural/normative framings, this then guaranteeing the value of its social contribution on the side of 'knowledge' vs. 'power'. The irreducibility and ambiguity of power is a predicament for STP studies too. Accordingly, it must continually grapple with the strategic problem of how its enterprise, 'knowledge', can best serve normative ends; and these ends cannot be the elimination of 'power' but the construction of power relations, and related technoscience, that minimize *domination*. This strategic conception in turn demands two distinct, but potentially complementary, registers: first, a 'theoretical' discourse addressing academic peers and characterised by critical exploration of current issues (as in this paper); but also 'policy' discourses addressing the world of politics directly and translating findings from the former in ways that are strategically savvy. In short, STP studies can only hope to realize its visions for actual science & technology politics (including, but not limited to, policy) by conceiving of *itself* as a strategic enterprise.

The first register includes theoretical analysis of the crises and responses, explaining attempts to deflate real, abstract contradictions between and within 'science' and 'policy' into manageable dilemmas (Jessop forthcoming), how they are working or not, and sources and gaps for resistance (e.g. Pestre 2009; Bruno 2009; Tyfield 2012a). The task thus involves identifying and constructing *new concepts for our understanding of new realities*. Thus, this work not only makes tacit frames and realities explicit through criticism of existing power relations, but also directly participates in the construction of concepts and frameworks that themselves enable and constrain certain power relations.

A concrete example is my attempt to explore the strengths and weaknesses of policy for low-carbon agriculture in China (Tyfield 2011; 2012a). This relates to issues of intense GHG emissions and pollution from mineral fertilizer, food security (with global implications given the size of China), agrarian crisis and global knowledge economy/economic crisis. The analysis shows how Chinese science policy has become progressively neoliberal, rapidly increasing commercial funding and patenting, and privileging a model of science that is high-technology and highly

proprietary, with massive investments in agri-biotechnology research. In short, China is attempting to beat the US at its own global, neoliberal game. Yet the Chinese model is also strikingly different to neoliberal prescriptions in the domination of the state and the national project of 'catch-up'.

Implications can then be drawn in several directions. Regarding low-carbon innovation, climate change and food security, China's emphasis on biotechnology is actually having limited success in transforming agricultural practice while simultaneously excluding alternative science, such as agroecology, that could develop a more equitable, diverse, affordable and timely low-carbon agriculture. Secondly, regarding catch-up and political economy, the emphasis on commercializable and hi-tech innovation is also failing to generate the desired results so that China remains relatively excluded from global innovation super-profits, characteristic of neoliberal globalisation, that accrue to transnational corporations. Conversely, a more equitable regularisation of capital accumulation can be traced involving less hi-tech and IP-intensive agricultural innovation. Finally, regarding the future of neoliberalism *per se*, the growing geopolitical importance of China suggests that the ill fit of its political economy with neoliberal prescriptions will likely, in the next few decades at least, shape and undermine neoliberalism's global dominance.

The second policy-oriented register builds on such analyses by taking as given *for strategic purposes* an account of present 'realities' in order to afford direct and more immediate intervention. As Bozeman & Sarewitz (2010) note, no matter how wrong-headed, inadequate or even self-defeating, science policy will continue to be made and so engaged scholars have a duty to intervene in *some* way. Moreover, freed from the scientistic obligation to be certain before intervening, scholars *can* do so on legitimate *epistemic*, and not just *political*, grounds. This would involve presentation of the arguments for an alternative political economy of research and innovation in terms that address the priorities of political agents (including, but not limited to, policy-makers) and using concepts, discourses and forms of presentation that will strengthen their political traction. In the above example of low-carbon agriculture in China, this has involved a policy report (in English and Mandarin) for a high-profile think tank that makes use of Harvard Business School-type concepts, highlights the economic gains for China of an alternative approach to low-carbon innovation and is available for free download (Tyfield et al. 2010). In short, then, the configuration envisaged in this approach is as summarized in Table 4.

Conclusion

The dominant paradigms of science & technology policy studies are unfit for purpose in an age of multiple, overlapping crises and the transformation of science, policy and their inter-relations. By resituating co-productionist STS in a philosophical and substantive programme of historical ontology, however, a broad research programme may yet be able to contribute, in strategic and normatively valued ways, to constructing and guiding an as-yet-unmade post-Enlightenment, and post-triple crisis, future. This research programme was labelled CPERI.

Table 4 Cultural Political Economy of Research and Innovation

Economics of Science	*Regularization of capital accumulation using and/or based upon techno-sciences at the heart of the analysis*
Geography	Methodologically cosmopolitan, at multiple and overlapping scales, themselves under (re)construction – similar to co-production
Science – Technology – Innovation	All within socio-technical and political economic regimes characterised by (strategic, ontologically productive) power relations/technologies
Science – Policy	Relatively autonomous but relationally inseparable and fuzzily bounded emergent institutions characterised by dynamic but relatively persistent intrinsic logics – similar to co-production
Science & Technology Policy Studies	*Strategically to develop new concepts (that simultaneously condition power relations) to enable criticism and mitigation of forms of domination involving technoscience through both theoretical and policy interventions*
Power	*Explicit use of conception of productive, strategic, dispersed power relations, including regarding conception of STP studies itself*

Major differences to co-production are highlighted in italics

By attending to the interaction of technosciences, the regularisation of accumulation and the ongoing reconstruction of political institutions and individuals' sense of self-understanding, CPERI can open up the policy imagination beyond the sterile trade-offs of stimulus vs. austerity, supporting science vs. tackling economic crisis, public vs. private. This might involve substantial policy arguments for a new political economy of research, capable of supporting long-term, cross-disciplinary, user-engaged research and international collaborations (Tyfield 2011). Such research occurs already to some extent, but is under pressure of the neo-liberal tendency to assess the value of research in terms of peer-reviewed publication and economic hi-tech impact alone. In arguing for its continuation and further support, STP studies must step beyond the niche it has carved itself, examining rationales for and implementation of science & technology policies. It must begin to stray into the political and political economic questions that are manifest in the increasingly broad roles played by science and technology in society. CPERI is offered here as a first step in this process.

Acknowledgments I would like to thank Dan Sarewitz, Arie Rip and Kean Birch for comments on earlier versions of this paper and Niklas Hartmann for discussion of some key issues.

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