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Funding policy

Lasting tensions in research policy-making — a delegation problem

Dietmar Braun

A basic paradox in funding policy is that policy-makers want to guarantee maximum welfare benefits without violating the independence of scientists and their organisations. This article contends that this problem can be adequately conceptualised in terms of delegation and principal–agent theory. In the past, blind delegation and incentives were used to resolve the tension: more recently, efforts have been in quite a different direction. The 'steady state' succeeds in realising more society-oriented research but fails to reduce the tensions. 'Delegation by contract' and 'delegation to networks' attack the estimation of costs by scientists linked to the efforts in politically or user-inspired research and can thus reduce the likelihood of moral hazard by scientists. They are 'opening up' the scientific system to user systems by changing the functioning of the basic structures of science whilst embodying two very different solutions. 'Delegation by contract' maintains a strong belief in the rationalisation of funding policy and in political guidance, while 'delegation to networks' makes the state a 'facilitator' helping scientists and their institutions to self-organise networks of co-operation with user systems.

Professor Dietmar Braun is at the Institut d'Etudes Politiques et Internationales, Université de Lausanne, BFSH 2, CH-1015 Lausanne, Switzerland; Tel: +41 21 6923132; Fax: +41 21 6923145; E-mail: Dietmar.Braun@iepi.unil.ch. The author is grateful to Barend van der Meulen and Fabrizio Gilardi for helpful comments.

IN AN ARTICLE on the "central planning of science" published in Minerva in 1977, the famous science policy expert Joseph Ben-David resumed the main problem of funding policy in the following words:

> "The main problem of science policy … today is how to support research from governmental funds and yet to ensure the vigor, initiative, and independence of scientific institutions" (Ben-David in Freudenthal, 1991, page 279).

Twenty-five years later, the problem is still there despite theoretical progress and political experience in dealing with research development. This may be attributed to the fact that the problem is an antinomy or paradox, that is, a problem where equally rational but contradictory views exist and solutions are consequentially hard to come by. The question remains on the agenda of funding policies and each government in each country must often give a pragmatic answer hoping that it can in one way or another implement policies that will respect both sides of the contradicting views.

In the course of funding history, a large variety of political answers has been given. These have moved from one end of the paradox — complete freedom of scientific institutions — to the other — complete planning of scientific activities. I contend, nevertheless, that today we have entered a new period of dealing with the paradox, offering in many ways different answers from before.

While the 'classic' period of funding policy has focused very much on the 'either–or' of state guidance and scientific freedom, we are experiencing nowadays a shift in the discourse on funding policies

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Dietmar Braun, professor of comparative political science at the Institut d'Etudes Politiques et Internationales of the University of Lausanne (Switzerland), has studied political sciences at the University of Amsterdam (PhD) before he worked as a research fellow at the Max Planck Institute for Societal Research in Germany. In 1996, he presented his habilitation thesis at the Institute for Political Science at the University of Heidelberg before he became, in October 1996, full professor in Lausanne. Dietmar Braun has published on labour market, higher education and research policies, federalism as well as on modern political theory. He has published several books, and articles in journals.

attempting to conciliate both sides either by 'facilitating markets' or by 'facilitating networks'. Both discourses offer different recipes in funding policy. I will discuss in this article in what way these discourses and linked strategies have succeeded in appeasing the perennial conflict between the direction of scientific activities by external criteria and the independence of scientific institutions.

I maintain that recent considerations of science policy in terms of delegation and principal–agent theory are a fruitful way to discuss developments in funding policy (see, for example, Braun, 1993; 1998; Rip, 1994; Rip and van der Meulen, 1996; Guston, 1996; 2000; van der Meulen, 1998; Caswill, 1998).[1] The problems of the paradox can thus be analytically sharpened. I will endeavour therefore to describe different periods of funding policy after the Second World War in terms of modes of delegation. In order to do so, I will, first, discuss the underlying rationale of the funding paradox and then introduce the concept of delegation.

Conceptual foundations

The functional differentiation of modern societies is at the base of the lasting tensions in funding policy. The scientific system becomes the place for the advancement of knowledge. To create new knowledge, special procedures, norms, rewarding mechanisms, and institutionalisations are put into place characterising scientific activities and distinguishing them from other professional activities in society. The establishment of such science-specific mechanisms has allowed an unprecedented rise in knowledge of modern societies.

While functional differentiation is necessary for the progress of knowledge, it also means a loss in coordination and interaction between different functions and activities in society, while, at the same time, the interdependence between functions is growing. One of the major problems becomes how to guarantee that societies do not function at cross-purposes and, even more importantly, how to make sure that there are mutual benefits? In our context, this is the perennial problem of how scientific knowledge can be made accessible for users in society, politics and economy and how this knowledge can be made part of activities in other systems (technology transfer and so on). Evidently, the problem of how to integrate the scientific world with other 'worlds' is one of the main, and today perhaps the most important, problem of funding policy-makers.

What does functional differentiation of the advancement of knowledge mean for political decision-makers? Evidently, that the political system does not intend to, nor can it produce the knowledge necessary for its own functioning and that of other systems. It needs the co-operation of scientists to overcome the implicit lack of knowledge or, in other terms, the 'information asymmetry' inherent in functional differentiation. The relationship between policy-makers and scientists becomes therefore a relationship of delegation where the one side, the policy-makers, asks the other side, the scientists, to do something for them that they cannot do themselves, because they lack the capabilities or the knowledge the scientists have (Coleman, 1990).

If we accept this view of formalising the relationships in funding policies between policy-makers and scientists, we observe three fundamental problems for policy-makers:

- Getting scientists to do what politics wants (problem of responsiveness);
- Being sure that they choose the best scientists (problem of adverse selection)
- Being sure that scientists do their best to solve the problems and tasks delegated to them (moral hazard);
- Knowing what to do (decision-making and priority-setting problem).

I will focus in this article above all on the problems of responsiveness and of moral hazard. A promising way to deal with this question analytically is the use of utility functions.

The principal–agent literature uses utility functions to describe the dynamics and problems of 'incomplete contracts'. This can be used for our purposes. It needs two utility functions to understand the relationship between principal and agent. The basic rationale of the principal–agent approach is that the principal can only insufficiently observe what the agent does and that the agent has an interest in hiding relevant information about his performance in order to 'defect', that is to reduce his efforts for the principal to a minimum.

By following largely van der Meulen (1998), the basic utility function of the principal can be described as:

$$U = x_{(e)} - f - c$$

where

U = principal's utility (in wealth)
$x_{(e)}$ = the profit for the principal from the effort of the agent
f = the fees paid by the principal to the agent. If the principal chooses to trust the agent,

the fee is fixed. If the principal chooses to monitor, the fee depends on the outcomes and/or the observation of (e). In this case:

$f = f_{(x,e)} = f^*$

c = other costs involved in obtaining the effort of the agent

In order to adapt this basic formula to our purposes we must develop the notions of fees and costs of the principal.

In funding policy, we find two basic ways of allocating money to the scientific system, first, by granting institutional funds to research institutions and second by allocating project funds. The former way will be indicated by 'a' and the latter by 'b'. The scientist profits both from institutional and project funds. We should, however, also distinguish between two different ways of allocating funding money: without conditions attached; and with specific purposes in mind and obliging scientists to respect criteria attached by policy-makers. In the former case, the money is fixed and given to the agent, in the latter case, the money transferred becomes dependent on the effort of the agent for the principal and on monitoring. If there are conditions attached to either institutional or project funding this will be indicated by a star (a^*, b^*).

There are two kinds of cost for the principal. First, costs that are related to decision-making if policy-makers decide to use the directed mode of allocating funds. In this case they have to specify some goals and conditions that scientists have to respect if they want to obtain these funding resources (indicated as '$C_{(D)}$'). Second, if policy-makers decide to control what is done with their money they have 'monitoring costs' (indicated as '$C_{(M)}$'). Introduced into the utility function of policy-makers the formula becomes:

$$U = x_{(e)} - (a + b + a^* + b^* + C_{(D)} + C_{(M)})$$

The 'utility function of the agent' can in broad terms be defined as:

$$V = f - C_{(e)} + Y_{(e)}$$

Funding money can be granted to research institutions or project funds: it may be allocated without conditions attached or with specific purposes in mind, obliging scientists to respect criteria attached by policy-makers

where:

V = agent's utility function (in wealth and effort)

f = fees paid by the principal for the efforts of the agent

$C_{(e)}$ = costs involved in the efforts of the agent for the principal.

$Y_{(e)}$ = The yield of his efforts for the agent in terms of reputation, career etc.

If we adapt this formula to funding policy we need to replace f again by a and b:

$$V = a + b - C_{(e)} + Y_{(e)}$$

The costs of the agent involved in funding policy are for example:

$C_{(T)}$: The time the agent uses for research for the principal. This must be related, however, to the estimated effect this research effort has for the career purposes of the agent. Ten hours used for applied research at the command of the principal instead of undirected, basic research may be a waste for the agent as there is no positive effect for the agent, for example, in the form of a publication in a scientific review. In this case, the agent looses ten hours of his/her time. If, however, there are some positive side effects of this research, the ten hours weigh less heavily. In quantitative terms, we could say that a small positive influence in the form of one article reduces these ten hours to, let us say, only eight hours that are 'wasted'. The expression becomes therefore: $C_{(T)}/Y_{(e)}$

$C_{(A)}$: Costs for the acquisition of funding projects

$C_{(M)}$: Costs stemming from monitoring efforts of the principal.

Taken together the formula becomes:

$$V = a + b + a^* + b^* - (C_{(T)}/Y_{(e)} + C_{(A)} + C_{(M)}) + Y_{(e)}$$

The costs depend on the institutional environment of the agent (embeddedness in a 'mode 1' or 'mode 2' environment, for example).[2] Institutions define the criteria and opportunities of a scientific career. This is why policy-makers have an interest in influencing the institutional environment.

With this analytical tool we are equipped to start discussing how policy-makers have dealt with the paradox in different periods of funding history. We can distinguish two modes of funding policies after the war: blind delegation (based on trust) and delegation by incentives (based on incentive contracting).[3]

How to deal with delegation in science policy

Polanyi (1951; 1962) has perhaps formulated in the most concise way the predominant method in the

funding policy of countries directly after the war until about the 1960s. It may be called 'blind delegation'.

Blind delegation

Polanyi's response to the paradox of funding policy was the proposition to trust scientists entirely and give them all resources and rights to decide and act on their own account.

Trusting science has been, since the early days of science policy (about 1830) the major, but not the only, way in which public money has flowed into the scientific system, among other things because the political system had not yet developed the professional expertise either to take decisions in, or to control, scientific activities. Specific ideas about innovation processes underpinned this kind of delegation. Above all, Vannevar Bush's famous book *Science. The endless frontier* (Bush, 1990 (1945)) has strengthened this option after the Second World War as part of the "compact between science and government" until about the 80s (Guston, 2000; Stokes, 1997; Elzinga and Jamison, 1995). Trusting science meant to finance research institutions (universities included) with institutional funds and to allocate funding money via funding agencies for investigator-initiated projects ('global funding').

In terms of property rights (see, for example, Demsetz, 1967) this practice of allocating funding money means that policy-makers are willing to transfer all property rights — the right to decide, to act, and to control — to the scientific system: Decisions on the contents of science policy are taken by scientific policy-advisors, scientific-oriented funding agencies and research institutions and their researchers. External criteria do not play an important role. Scientific institutions and scientists implement science policies.

Policy-makers have neither the knowledge nor the means to control the outcomes of these policies and do not aspire to do so. In general, they trust the scientific community to establish their own peer-review system of control. Scientific quality is accepted as a sufficient standard for using public money in research. Science is trusted to deliver, in the medium and long term, what society needs ('science-push model').

Political intervention imposing external criteria would seriously disturb the innovativeness of science.[4] In taking up recent discussions on delegation, this kind of delegation seems to correspond to the theoretical notion of the 'fiduciary' (see particularly Dixit, 1996; Majone, 2001) where policy-makers deliberately abstain from any intervention into the affairs of 'independent agencies' so as not to disturb their functioning.

To describe the relationship between policy-makers and scientists after the War only in terms of the fiduciary is not doing justice to the different forms of organising this relationship, but, without any doubt, this delegation form has been primordial. Even today we find this principle in the mode of institutional funding without obligations and in 'investigator-initiated' project funding where only scientists may choose topics and implement their research according to rules conducive to their liberty of action. Money is given to scientists without attaching a sanction to these payments. It is given "risk free and unrelated to performance or outcomes" (Milgrom and Roberts, 1992, page 208).

In terms of utility functions this delegation mode boils down to the simple expressions:

$$U = x_{(e)} - (a+b)$$

$$V = a+b+Y_{(e)} - C_{(A)}$$

Fees are paid to the 'agent', the scientists, without specific conditions attached. As the government does not engage itself in deciding on the future road of science policy nor on priorities, no decision-making costs are involved and political monitoring is not taking place.

For the agent, there is income, most of the time from institutional funds. As he/she can pursue his/her scientific activities without taking into consideration external criteria, there are no major costs for the agent in accepting the money. The government hopes that there is a convergence of the scientific activities of the agent and political interests in the medium and long term.[5] There are, however, no constraints on moral hazard and no guarantee that scientists will behave responsibly.

Delegation by incentives

Since the 1960s, another mode of delegation in funding policy is shifting to the foreground juxtaposed with blind delegation: the setting of 'incentives' in the form of 'price signals'. This has been the start of 'science for policy' and the development of a science policy by most governments. Moreover, we can contend that this way of allocating funding money represents the original principal–agent model.

In his famous article on the "Republic of science", Polanyi (1962, page 56) demonstrated that the scientific system did not obey the prices on a market but had similar mechanisms to co-ordinate action and to innovate, that is, signals in the form of publications and "current professional standards". Publications are not only the signal that a scientist is doing work the scientific community judges as valuable, they are also the interconnecting points for the co-ordination between otherwise isolated actions of scientists.

Polanyi did not consider the point that policy-makers could also give signals to research institutions and scientists, by offering money for activities in priority fields of research defined by external political criteria alongside the 'normal' funds flowing into the scientific system without conditions attached. Scientists and their organisations can be tempted to direct their work into the thematic direction formulated by funding agencies and political

departments. By choosing a certain research area, these agencies and departments are communicating that they are prepared to pay an extra price for people working in these fields.

These external price signals increasingly co-existed alongside the 'publication signals' circulating within the scientific system. Whether these price signals were heard by scientists depended on a number of factors, not least the financial position of research institutions the scientists were working in, or, in general, their possibilities of financing the research work they would like to pursue.

To organise delegation in the form of price signals to scientists increases political decision-making costs in order to formulate priorities. Special peer-review systems must be organised without always having the guarantee that moral hazard and adverse selection can be overcome. However, political risks can be somewhat reduced in comparison to the trust model of delegation.

In terms of property rights, the government takes the responsibility of organising priority-setting in research and developing politically induced program funding.[6] There are prescriptions as to how to proceed in general terms in implementing the research programme but most of the decisions in the execution of research remain at the operational level. The government maintains the right to control though. Particularly in the beginning, control was usually delegated to the peer-review system of science with some special conditions attached.

We can put the utility functions in the incentive mode of delegation like this:

$$U = x_{(e)} - (a + b + b^* + C_{(D)} + C_{(M)})$$

$$V = a + b + b^* - (C_{(T)} / Y_{(e)} + C_{(A)}) + Y_{(e)}$$

The incentive model comes nearer to the genuine principal–agent features discussed in the literature than the previous model: the principal (the policy-maker) is attempting to formulate priorities that should serve as instructions for the agent (scientists) in the execution of research. Scientists maintain relatively high independence in executing the instructions. They have a genuine interest in pursuing their scientific career, which is not flexibly linked to the exigencies in political program funding. This means that there are clear costs involved for scientists in executing political research and incentives to hide information from the principal and to reduce their efforts for the principal. The principal is therefore forced to think about good monitoring procedures and measurements of the research output.

The principal has two options to be sure that the agents will do their best to comply with the goals and therefore to overcome moral hazard: augmenting the relative share of the money with conditions attached (*b**) (which has been the strategy of the 'steady state', see below); and/or reducing the costs for the efforts of the agent in program research. The incentive mode of delegation has used the strategy of giving scientists the choice between scientific and politically inspired research by adding program funding to the already existing global (institutional and project) funding. The consequence was that incentives for scientists were not very strong as often there was sufficient funding to do undirected research and the scientific career was firmly anchored within the scientific system. The incentive model was, therefore, not able to raise the efforts of scientists linked to political considerations in a significant way.

Summarising the incentive mode of delegation, funding raises decision-making costs, monitoring costs and increases the danger of moral hazard: certainly, not a very attractive way to solve the paradox

If we summarise this type of delegation, we can state that the incentive mode of funding raises decision-making costs, monitoring costs and increases the danger of moral hazard. Certainly, not a very attractive way to solve the paradox!

Transformation of funding policy

The models that have been described so far have evident deficiencies with regard to attracting the curiosity of scientists to problems of user systems. This changed in the 1980s and 1990s with developments that were most of the time not inherent to funding policies or scientific developments. They were general changes in the way the state governs society with immediate repercussions on funding policies and modes of delegation. I see three such developments that have changed the outlook of delegation today: austerity; contracts; and networks.

Austerity

Politics of budget reduction and austerity have been introduced in most OECD (Organisation for Economic Co-operation and Development) countries since the end of the 1970s. Ziman has discussed the implications for research policy and coined the expression "steady state" to characterise the constraints for research policy making (Ziman, 1987; Cozzens, 1990).

In funding policy, the curbing of public money was above all used to reduce global institutional ('*a*') and project funding ('*b*') (see Senker, 1999), thereby generating a structural incentive for scientists to accept political program funding ('*b**') and to look for financial compensation in other functional systems, notably the economic system. The

choice scientists had had in the incentive mode of delegation (between global and directed funding) was seriously reduced. Without austerity, the foundations for a change from mode-1 science to mode-2 science could not have been laid.

The strengthening of political price signals in the aftermath of reduced public resources provoked at least two effects.

First, the phenomenon of the 'gold rush'. With scarce global funding most scientists interested in research begin to rush into those areas that seem to make the most profit in terms of funding money, that is, where the highest (political) prices are paid (see Bourdieu, 1975; more recently, Bourdieu, 2001). The perverse effects of the gold rush have already been adequately put forward by the OECD in its 1991 report on priority-setting (OECD, 1991). Other areas of research of less interest to user systems suffer from 'malnutrition' and 'exhaustion', with serious consequences for the innovative capacities of a country, given the unpredictability of where future innovations will take place (OECD, 1991). In other words, the more '*a*' and '*b*' are reduced, the more scientists will increase their efforts to comply with the wishes of the government to the detriment of the basic knowledge infrastructure.

Second, established social hierarchies in the scientific system undergo significant changes. The gold rush phenomenon demonstrates this: those researchers that are the quickest and the most successful in finding funding money eventually become leaders as the system is transformed. It is not only the reputation built on publications but increasingly also that generated by the successful acquisition of grants, which begins to determine the 'value' of researchers in the scientific system. This is a long-term process but the 'mode-2' debate adequately points to the changes already accomplished since the 1980s.

The steady state is therefore a means — certainly not conceived as such but strategically used to this purpose by funding policy-makers — for a fundamental re-orientation of scientific activities. It establishes a funding market for program-bound and short-term funding resources forcing scientists to compete for this research money.

The steady state changes nothing in the allocation of property rights compared to the incentive mode of delegation. The main effect is on the 'fee component' of the utility functions. The relative importance of '*a*' and '*b*' on the one hand and '*b**' on the other hand, begins to change considerably. We could state the change like this: while in the incentive mode undirected funds were more important than directed funds ($a + b > b^*$), the steady state reverses this relationship ($a + b < b^*$).

This change in the relative importance of global and directed funding resources puts scientists under strain. As austerity does not change the structure, dynamics and norms of the scientific system, scientists are obliged to continue their scientific career as defined by the scientific community without having the same possibilities of doing so as before. As a consequence, the costs of scientists engaged in politically- or user-inspired research also increase while their return decreases. This is true for all cost components (time used for applied research and also time for applications and for monitoring costs) ($C_{(T+A+M)} > Y_{(e)}$).

The principal must therefore be prepared to be confronted with a considerable dose of shirking by scientists. Moral hazard becomes a likely phenomenon under the regime of the steady state. This is why austerity exacerbates the tensions in funding relations. Other strategies are needed that attack directly the subjective estimation of costs in directed funding by scientists. This can only be done by a change of the institutional embeddedness of scientific research.

Contract

The 'new public management' has given rise to reflections on a more efficient use of public money and a more effective delivery of public services by integrating lessons from the principal–agent debate (see Osborne and Gaebler, 1992). The main rationale of the new public management is the setting up of explicit contracts between the principal and the agent, thereby modifying the authority relationship between policy-makers and bureaucratic agencies into a relationship between contract partners who, before the law, have equal rights and who voluntarily agree to exchange resources. The principal is paying the agent and defines in broad terms what he/she wants while the agent promises to use her/his labour power and organisation to implement the wishes of the principal.

This is not different from what has already been said about the incentive mode of delegation. New public management is not used to revise implicit contracts in programme funding between the government (or its representatives, the funding agencies) and scientists but reorganises the relationship between research institutions and the government. Delegation by contract means therefore the delegation of property rights to institutions instead of scientists. As scientists are part of these institutions, this affects them indirectly. Contracts change the institutional embeddedness of scientists.

The delegation by contract is an indirect way of steering the behaviour of scientists: it changes the 'institutional embeddedness' of scientists in order to avoid moral hazard and to increase the social responsiveness of scientists

In this way, then, the delegation by contract is an indirect way of steering the behaviour of scientists. It changes the 'institutional embeddedness' of scientists in order to avoid moral hazard and to increase the social responsiveness of scientists. As a consequence, the setting of incentives for individual scientists should become more successful in terms of moral hazard, social responsibility and adverse selection because the incentive mode of delegation is embedded in the delegation by contract to research institutions (and the steady state). We have, therefore a kind of 'nested delegation'.[7]

In what way are explicit contracts in the style of the new public management a promising device to guarantee a maximum of effort of 'corporate' agents for the sakes of the principal? This is the question of how to set up the contract so that opportunistic behaviour of research organisations (and their scientists) can be avoided. A contract relationship between policy-makers and scientific organisations

> "could solve the motivation problem [or moral hazard]. It would specify precisely what each party is to do in every possible circumstance and arrange the distribution of realized costs and benefits in each contingency (including those where the contract's terms are violated) so that each party individually finds it optimal to abide by the contract's terms." (Milgrom and Roberts, 1992, page 127)

The problem is that only in ideal circumstances will all information concerning the specification of such a contract be available. Complete contracts are seldom found. This is why the principal–agent literature has focused on 'incomplete contracts' taking into account that actors suffer from 'bounded rationality' and misperception and that there are a large number of contingencies and unforeseen events, which might change in the future and which are not adequately dealt with in the contract. In matters of funding policy, contingencies seem to play a particularly important role. How, then, can contracts, despite their lack of completeness, be set up in such a way that they can reduce the opportunism of agents?

In fact, new public management has used "relational contracting" to overcome problems of incomplete contracts:

- Rather than specifying in detail what to do, principals use "general provisions that are broadly applicable" (Milgrom and Roberts, 1992, page 131);
- The agent is given operational freedom, that is, "no detailed bargaining about what precise action the employee will take in various circumstances" (Milgrom and Roberts, 1992, page 132).

This has two consequences. First, policy-makers are obliged to invest into decision-making even though the political guidelines may remain very general. A certain degree of guidance by the principal is inherent to new public management. Policy-makers have more time to specify guidelines ("steering, not rowing", compare with Osborne and Gaebler, 1992) but bear decision costs to do so. Delegation by contract does not end steering or guidance in science policy, although it is not excluded that research institutions are asked to make proposals in this respect, which are then more or less adopted by policy-makers or among which policy-makers choose. However, there are binding decisions by the government (or its representatives) in the end and research institutions and scientists are required to respect these in their research choices.

In this sense, delegation by contract is not different from delegation by incentives.[8] Both are forms of delegation where decision-making costs exist for policy-makers and where the interests of policy-makers constrain the choices of scientists and their institutions. The choice of what to do is not left to scientists and their institutions. In delegation by contract, the general objectives of the institutions are stipulated in the contracts. In politically inspired research programs thematic priorities are pre-given.

Secondly, new public management has reinforced another component in the utility functions — the costs of monitoring. Although agents are given operational freedom of action, this does not mean that the principal trusts agents completely. On the contrary, new public management is the continuation of modernisation and rationality in the sense of Max Weber only by other means (Frissen, 1998). We find considerable and sophisticated efforts in contract relationships — and this has spilled over to programme funding — to elaborate how exactly the work of research institutions and scientists can be monitored adequately. A large number of evaluation procedures have been established and refined indicators of output measurement have been developed to reassure the principal that there will be no moral hazard.

In comparison to the incentive model of delegation there are three obvious changes:

- Even institutional funds are now partly distributed with a purpose in mind and after negotiations with the government (a^*). The conditions are fixed within the contracts. Both 'a' and 'b' can be curtailed under a regime of the steady state. In this case the expression becomes: $a + b < a^* + b^*$.
- Decision-making costs ($C_{(D)}$) are increasing for the government because global guidelines have to be developed even when this does not mean a stronger form of intervention.
- Monitoring costs ($C_{(M)}$) are rising considerably both for the principal and the agent, at least in the beginning of the 'contract system'.

Although we could guess that the predominance of directed funds will have the same effects as in the case of the steady state (that is, leading to a situation where the costs for the agents are higher than the

return of his actions for the principal) this is not the case. The costs for scientists are decreasing. How?

The answer lies in the 'nested' process: The steady state has started to reduce global funding and obliges both research institutions and individual scientists to accept directed funding resources. A use of these directed funding resources can, moreover, be fixed in the contracts between research institutions and the government. Research institutions become corporate actors obliged to compete on a directed funding market and to open up to the demands of user systems.

At the same time, scientists within these organisations are obliged to work within the confines defined by their research institutions. This forces them to search actively for grants on the directed funding market. As research institutions begin to change, career structures of scientists begin also to change.

Organisational incentives help to create a new scientific élite that is situated more at the junction between the scientific and user systems than in the scientific system alone. This changes '$Y_{(e)}$': the return from activities in applied-oriented research increases. Therefore, the new élites regard the time costs involved in executing politically or user-induced research as less problematic than do old élites. Consequently, the costs for the efforts of scientists to benefit the government begin to decrease, even if application costs and monitoring costs are rising. If the return for the agent increases then the costs depend on how large '$C_{(T)}/Y_{(e)}$' becomes in relation to '$C_{(A)}$' and '$C_{(M)}$'.

There are two points to consider in this respect. On one hand, we can assume that, in the long run, monitoring costs can decrease because changing career structures will diminish the incentive for moral hazard. Diminish monitoring costs would make it more likely that the returns for the agent become higher than costs.

On the other hand, we should not overestimate these developments: There are indications that changing career structures in the direction of 'mode 2' affects only certain parts of the scientific community, mostly working in the rapidly developing areas of biology, biomedicine, nanotechnology and so on. There are large parts of the community not considering it worthwhile to invest into the applied-oriented areas, and universities and other research institutions do not feel obliged to change career conditions for all of their staff. While, therefore, some scientists will evaluate time costs less high than before, others will not. This gives rise to two kinds of agents with different utilities.

This makes the evaluation of changes for the principal ambiguous: although the costs for monitoring and decision-making are rising considerably in the short run, the return from those agents dedicated to 'mode 2' will be higher, but this will not be the case for those agents not integrated into the applied-oriented research developments.

We see that the steady state and delegation by contract create structural conditions that strengthen the position of the government in the paradox of funding policy. While austerity raises tensions between a scientific career and user-inspired research, these tensions are alleviated by the contract mode of delegation, at least for a part of the scientific community. Scientific careers become embedded in a new institutional context that makes the trespassing of the boundaries of the scientific system easier. Scientific institutions lose their independence in the sense of Ben-David, but neither these institutions nor the scientists engaged in the new course seem to deplore this situation.

Delegation to networks

While we can see this reorientation in government policy as a form of 'modernising' funding policy by more information, guidance, operational freedom and monitoring, delegation to networks follows a completely different, 'post-modern' rationale of action (see also Rip and van der Meulen, 1996).[9] The background of this discourse is how to link scientific knowledge production to other user systems without submitting scientific production to the logic of user systems. While the modern approach underlines competition and rationality, the 'post-modern' accentuates co-operation and reflexivity.

The foundations underlying this discourse are fundamentally different from the 'modern' approach. They can briefly be explained by presenting the three major components: systemic thinking, knowledge sharing, and the state as a facilitator.

Systemic thinking

Systemic thinking can be demonstrated by putting forward two main principles — connectivity and indeterminacy.

The debate on "innovation systems" (Edquist, 1997; Lundvall, 1993; Nelson, 1993) is perhaps the best example to illustrate systemic thinking: Technological innovation is understood as part of a wider environment. Funding technological innovation is not any longer just putting funding money in the right way and in the right places in order to pick out the 'winners' but necessitates also a reflection on the political, social and cultural embeddedness of innovation.

Metcalfe and Gheorghiou (1998) therefore demand a new policy rationale recognising the "ambiguity and uncertainty of the policy environment and the futility of picking winners as distinct from encouraging winners". We need the "strengthening of the innovation process in general" by acknowledging the "principle of connectivity — the bridging together more effectively of the different actions and institutions involved in the innovation process." (Metcalfe and Gheorghiou, 1998, page 94). The principle of connectivity becomes therefore a major concern of action in the new funding policies.

In a complex world, we face contingency, recursiveness, and indeterminacy, so we need systems, organisations, or actors capable of learning by doing, of developing structures that can react flexibly and adapt, and of 'self-organising'

Systemic thinking also denounces a notion of rationality characterised by causality, linearity, and reversibility (Bechtle, 1994). In a complex world, we face contingency, recursiveness, and indeterminacy**.** It therefore no longer makes sense to optimise our behaviour by forward planning. A dynamic, non-linear system cannot be controlled. It is better to have systems, organisations, or actors capable of learning by doing, of developing structures that can react flexibly and adapt, and of 'self-organising'. We should not reduce contingencies but attempt to live with them, live with indeterminacy as a basic element of action.[10] We need organisations to be 'open' to the environment but also possessing the capacity of operational closure to reduce complexity (see also Nowotny *et al*, 2001).

This dynamic concept is incompatible with any vision of contracts, even with the remedies offered in the concept of 'relational contracting' discussed above: we cannot predetermine the products to deliver; we cannot oblige organisations any more to do this or that and be accountable for it.

Knowledge sharing

Next to the principles of connectivity and indeterminacy stands the principle of knowledge sharing. While for von Hayek (1945) the set-up of a knowledge-sharing society is still entirely a question of price mechanisms, I would defend the point of view that it becomes a matter of organising interaction spaces and networks (see Ben-David, 1971). It is here that the 'new, post-modern funding policies' are finding their main areas of action.

Knowledge sharing is the quintessence of network forms in research. By networks, I mean the voluntary participation of actors in a research project of common profit for all participants. The notion of network also points to the 'temporary' character of such enterprises: They can be created, used, and dissolved. In this sense, they are perhaps the adequate organisational answer to the problems of complexity and indeterminacy.

Networks are, moreover, non-hierarchical, establishing a win–win situation for all participants. A large number of new funding instruments (such as the Leading Technological Institutes in the Netherlands, the Pôles de Recherche Nationaux in Switzerland, or the Verbundpolitik in Germany) are implementing this logic. Networks are a unique form of linking organisations, of linking actors and of linking systems without perverting their identity or their embeddedness in different environments. This is the difference from the steady state and the mode of delegation by contract where the scientific system is forced to open up to user systems. Instead of establishing the logic of competition, they induce an attitude of openness and trust, which, according to a large number of studies on the 'social capital' are quite effective attitudes for welfare creation (Putnam, 1993; 1995). Networks therefore keep the identity of actors and attempt to find a solution for 'systemic integration'.

State as a facilitator

What does this mean for funding policies? It means above all the willingness to organise, develop knowledge sharing, and thus give the means to research institutions and scientists to self-organise innovation networks with user systems. In the context of organisational complexity, the state loses pretensions of instrumental guidance and "Olympian rationality" (Metcalfe and Georghiou, 1998) and becomes a facilitator of co-ordination processes. The focus of government activities in general and of science policy in particular becomes not the manipulation of the behaviour of scientists but the creation of interaction spaces, the reduction of transaction costs for inter-systemic and interdisciplinary co-operation and the maintenance of vigorous, self-organising systems. "Management of interdependence" (see Mayntz, 1996, page 156) and not steering of scientific behaviour characterises the new funding policy.

More concretely, this means that policy-makers in funding policy abandon pretensions of medium- and long-term priority-setting meticulously laid out in directed funding schemes. The management of interdependence envisages the delegation of the right to decide and act to research networks, which have been constructed with the help of the government but which function independently of governmental influence. Although general topics may have been fixed, such networks should have the possibility of changing topics, adapting to circumstances, and finding idiosyncratic ways of innovation. This means that it is not possible to stipulate all procedures or products in advance. Innovation in networks is an open process and the best that government can do is to guarantee the best conditions of action for these networks (see in particular AWT, 2001a; 2001b).

Delegation to networks therefore needs a considerable degree of trust. The right to control remains at the level of the government. Nevertheless, such talks or evaluation cannot refer to goals and indicators in

the same way as in the delegation by contract as they are not *a priori* defined and controllable. An evaluation can only control the process of the working of the network.

What does it mean for the utility functions? The first change that must be introduced in the utility function of the government is that profits depend not only on scientists but also on industry or other users co-operating within the network. This is why we would need to add '$z_{(e)}$' indicating the effort of participants other than scientists in the network. Moreover, we could add a new utility function 'Z' characterising the utility of these other participants. For reasons of simplicity, I will not do this here.

In contrast to the delegation by contract, no conditions are attached here to institutional funds (so, it is 'a' and not 'a^*'). The payments for project funding, however, contain these conditions, though they are much less specific than in the contracting mode of delegation ('b^*'). Decision-making costs ('$C_{(D)}$') for the government are considerably reduced because most decisions are delegated to the network and monitoring costs ('$C_{(M)}$') are considerably reduced because of difficulties in defining adequate measures of control. Nevertheless, they are still there. This makes clear that overall costs for the principal are decreasing while returns are likely to increase ($x_{(e)} < a+b^*+C_{(D)}+C_{(M)}$).

Why are returns likely to increase? This depends on the utility function of the agent. First, we must add costs for co-operation ('$C_{(c)}$') while the costs for monitoring are considerably decreasing. Most importantly, though, we can contend that scientists working in innovation networks consider the research activities within the network not as a loss of time, which is detrimental to their scientific career ('$Y_{(e)}$' is increasing). Participants are a selected group of dedicated scientists analogous to the 'mode 2' scientists we have encountered in the contract mode of funding. Networks have the apparent advantage of being temporary and of respecting the fundamental interests of participants. Networks maintain functional differentiation but permit voluntary co-operation. This reduces the costs for scientists participating in these networks (especially the costs in time and monitoring).

In sum, although time costs used for research in these kinds of networks are increasing and application costs may be high, monitoring costs are decreasing and the expected return '$Y_{(e)}$' is high largely outstripping the costs. Delegation to networks is therefore a way to reduce moral hazard and increase the social responsibility of science while also reducing political costs of decision-making.

Delegation to networks is a new way of dealing with the paradox in funding policy. Scientific independence of institutions and researchers is respected while scientific research is increasingly becoming responsive to the needs of industry and society. The role of the government is limited to the management of interdependence but the co-operation with users within these networks guarantees that scientific behaviour is directed to the needs of society.

Conclusions

I have endeavoured in this article to give an overview of the different ways we find in the history of funding policy to deal with the problem of the functional differentiation of science and the connected problem of delegation. The functional differentiation of science evokes the problem of the linkage of scientific knowledge with contexts of application situated in other functional systems. The delegation of property rights to scientific institutions and scientists is the way government attempts to make scientists contribute to the welfare of society. Delegation provokes typical governance problems, above all how to make sure that delegated scientists and their institutions will do their best in this respect instead of promoting their own welfare, that is, their scientific career. Table 1 summarises the outcomes of each

Table 1. Delegation models in funding policy

Model	Responsiveness	Moral hazard	Monitoring costs/ performance measure	Decision-making costs
Blind delegation	Low	Low	Low Scientific Publications	Low
Incentive mode	Increasing	High	Increasing Practical solutions presented in research reports and advisory bodies	Increasing
Steady state	Increasing	Very high	Increasing Efficient use of resources and practical solutions	Increasing
Contract mode	High	Decreasing	High Thorough evaluation of output defined and operationalised in contract	High
Networks	High	Low	Decreasing Process-related measures concerning network quality	Low

model in terms of responsiveness, moral hazard, monitoring, and decision-making costs for the principal.

It was shown that we find two delegation models in the 'classic', 'mode 1' period of funding policy (blind delegation and incentives) and three delegation models in the more recent 'mode 2' period.

Blind delegation cannot be regarded as a classical principal–agent relationship as all property rights (to decide, to act, to control) are delegated to scientists. In this way, there is simply no moral hazard, as the agents have no motive to shirk. They are required to do what they will do anyway, that is, basic research to promote their scientific career. This is why scientific publications are the main indicator of good performance. The principal pays but he has no other costs. The tension is resolved in favour of the independence of science.

The incentive mode of funding exercises pressure on scientists and attempts to increase responsiveness by using directed funding. As this conflicts with the basic research orientation of scientists, moral hazard becomes likely. The setting up of a science policy in terms of programme funds increases the costs for the principal. Monitoring becomes more costly as now it must be judged to what extent scientists have presented solutions to societal and political problems in their research. The tension begins to exacerbate.

The 'steady state' manipulates the relative importance of global and directed funding, thereby reducing the options of scientists to engage themselves in investigator-initiated research. The simple use of austerity measures sharpens the tension between curiosity-oriented and user-inspired research and polarises positions on the paradox of funding policy. Austerity is not a solution to the paradox but prepares the ground for a stronger orientation of scientists to user systems. Monitoring and decision-making costs remain at the same level as in the former incentive mode of funding but the efficient use of resources becomes an additional dimension of output control.

The delegation by contract, based on the 'new public management' is, in contrast to the 'steady state', another mode of delegation but this time clearly directed to research (and funding) organisations and not to individual scientists. The main point is that the introduction of relational contracting with research organisations has immediate repercussions on the utility functions of individual scientists and therefore on their behaviour. It changes the 'institutional embeddedness' of scientists' actions.

This 'nested delegation' provides the basis for a more fundamental reorientation of scientific behaviour and opens the scientific system to user systems. The reason for this is that scientific careers are, at least in part, less straightforwardly anchored within the reputation mechanisms and the credibility cycle (compare with Latour and Woolgar, 1979) of the scientific system but become more strongly connected to the performance at the 'edge' of scientific research with user systems. Consequently, the estimated costs for the efforts of scientists in politically or user-inspired funding are decreasing and moral hazard becomes less likely.

The costs for the principal are, however, very high in terms of monitoring and decision-making but become outstripped by the return from the activities of the agent. The high monitoring costs appear in the thorough and encompassing evaluation procedures of the output of institutions (and scientists), which have been defined *ex ante* in the contracts. The output may now be different: scientific publications but also the innovation of existing procedures and products, or the advice given to different actors in society and the political system.

Delegation to networks follows a completely different rationale from the delegation by contract. Delegation to networks does not follow up the steady state and the delegation by contract but is a "second pendulum swing" (compare with Mayntz, 1997) of funding policies today. This means that all these tendencies co-exist and that they are in many ways opposing each other, in discourses and in the actual practice of policy-making. Delegation to networks is the recognition that government has no serious means or instruments to guide the unpredictable process of discovery and innovation. The delegation of the 'right to decide and act' in funding policy to 'inter-systemic networks' is the consequence of this thinking.

The main difference with the steady state and the delegation by contract is that the delegation to networks builds upon scientists and research institutions, which keep their identity as scientific institutions anchored within the scientific system but which have an inherent interest, based in the changing dynamics of scientific discovery, to engage themselves in networks with users. Maintenance of identity and self-organisation are the main principles. In this way, the costs for the efforts of scientists in politically and user-inspired funding programmes are also decreasing but the background is different from the contract mode of delegation. Monitoring costs decrease as they are no longer output-oriented but process-related, which needs less preparation and less thorough procedures.

Both modes of delegation — by contract and to networks — are powerful ways of reducing the tensions in the paradox of funding policy. They are successful because they are not attempting to steer the behaviour of scientists but rather the institutional environment of scientific action. In this way, the costs for the efforts of scientists in politically and user-inspired research programmes — the most important component with regard to the moral hazard of scientists — are reduced.

I see, nevertheless, a different solution with regard to the lasting tensions in funding policy: delegation by contract is based on 'independent scientific institutions' but only in the sense of operational freedom while delegation to networks trusts in

the self-organisation of independent institution. Delegation by contract envisages a steering by government 'at arm's length' but we find an active role of the government in the prescription of scientific action while the delegation to networks takes the role of the state back.

Government becomes a facilitator of self-organised co-operation networks. It seems to me therefore that delegation to networks embodies, at least in theory, the most adequate way of dealing with the paradox in research policies: reducing the direct influence of the state in funding policies, respect for the independence of scientific institutions, fostering of 'vigorous' scientific institutions, and a strong commitment of scientists to user interests.

Notes

1. Most of this work is directed to the description of the role of funding agencies in science policy. I will deal with the direct relationship of policy-makers and scientists (and their research organisations).
2. See for the distinction between "mode 1" and "mode 2" science: (Gibbons *et al*, 1994). Mode 1 science is characterised by a relatively differentiated scientific system and a comprehension of scientific knowledge in terms of certainty, linearity, predictability and control. Mode 2 science characterises a more open scientific system, interdisciplinary research, and "a multiplication and social diffusion of the sites at which knowledge is produced" (Nowotny *et al*, 2001, page 16) as well as the rise of the notions of 'uncertainty ', 'ambiguity ', 'fluidity ' and 'self-organisation '.
3. Two other ways to deal with the paradox can be mentioned. They are rather exceptions in OECD countries: the Soviet-like 'hierarchical delegation' and delegation based on 'moral obligation', which is found in periods of serious crisis such as wars.
4. In the words of Polanyi: "Controlling, fostering etc. the pursuit of a free scientific inquiry, contradicts the generally accepted opinion that modern science is founded on a total rejection of authority" (Polanyi, 1962, page 67) and "In the case of scientists, the explorers strive towards a hidden reality, for the sake of intellectual satisfaction. And as they satisfy themselves, they enlighten all men and are thus helping society to fulfil its obligation towards intellectual self-improvement" (Polanyi, 1962, page 72)
5. Note that here we do not have a principal–agent problem in the proper sense, as the agent has no reason to hide anything from the principal. They are just doing what they think is best for their own scientific career. Interests of the principal and the agent converge in this respect.
6. It does not mean that scientists are excluded from priority-setting. As a matter of fact, the OECD (1991) reports that priority-setting is an interactive process in which we can hardly distinguish between the different actors contributing to policy formulation. The difference with the trust model and moral obligation is, however, that the government is responsible for the organisation and that it can decide to just choose priorities on its own.
7. In fact, this is comparable to Tsebelis' notion of "nested games" (Tsebelis, 1990): Principal–agent delegation can be seen as one game taking place between a political department responsible for research programmes and scientists about the implementation of a research programme, while this game is embedded into a larger game between the research institution and policy-makers defining the institutional constraints of scientists. In our case, the pay-offs, rules and constraints of the higher-order game (delegation by contract) change the parameters in the lower-order game (delegation by incentives).
8. They are both genuine expressions of the principal–agent model.
9. It is one of the interesting points today that we have at the same time attempts to 'rationalise' policy-making and attempts to overcome the traditional notion of 'rationality' (Frissen, 1998). Mayntz (1997, page 69) sees in a similar way one move to the "market" and a second one to "networks". Both tendencies result in different modifications of the delegation to scientists.
10. This is the essence of chaos theory and "autopoiesis"; see Kiel (1994) and Thiétart and Forgues (1995).

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