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The German innovation system: conceptions, institutions and economic efficiency

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Kiel Working Papers

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**The German Innovation System: Conceptions,
Institutions and Economic Efficiency**

Henning Klodt

November 1996



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The Kiel Institute of World Economics

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Abstract

The economic analysis of technology policy suggests non-distortive public support of private innovative activities with a stress upon basic rather than applied research. Actual technology policy in Germany is marked by a high degree of sectoral selectivity which results from the dominance of direct project support. The second main feature of the German innovation system is the strong persistence of the structure of public research institutions, although technological priorities have significantly changed over time. Public support to private R&D should be reoriented towards indirect measures, and public research institutions should be more exposed to competition.

JEL-Classification: O38

I. Introduction*

There is no doubt that science and technology are establishing the central base for growth and economic wealth in modern economies. In order to achieve further growth, a permanent flow of new technologies is required — especially in highly developed countries where natural resources are scarce and the potentials for imitating technologies from other countries are limited. In the framework of a market economy it is the first and foremost task of private investors to develop and to implement new technological knowledge. However, there are good reasons for the assumption that a strictly market-oriented approach to science and technology would result in insufficient innovative activities. Therefore it is widely agreed that there is welfare-enhancing room for public science and technology policy.

Despite this general consensus, there is an intense debate among economists and politicians about the appropriate manner of supporting private innovative activities. On the one hand, it is argued that many basic technologies of today have been initiated by public intervention — last not least from the military sector. A society, which heavily depends on technological development, should not leave the basic decisions about future growth patterns to anonymous and blind-eyed markets. On the other hand, it is argued that creativity and flexibility as the major ingredients of successful innovation processes are rather discouraged than encouraged by state intervention. This latter view was shared for instance by Lord Kelvin, who once wrote: "Had government funding of science existed in the stone age, mankind would now have splendid stone machines — and no metal."

Economic theory will never be able to present an unequivocal and clear-cut answer about the appropriate role of government in the inno-

* Revised version of a paper presented at the workshop on "Productivity and Technological Development Centres", held by the Centro de Estudios sobre Desarrollo Economico of the Universidad de los Andes at Medellin, May 15–16, 1996.

vation process. Theories are too abstract and reality is too complex for such a pretention. Economic reasoning can be helpful, however, for evaluating the soundness and solidity of popular arguments in the policy debate, and it can show up ways and means of how to improve the economic efficiency of actual technology policy measures. Part II of the paper gives a brief accounting of the theoretical foundations of technology policy, part III describes the main elements of the technology policy design in Germany, and part IV draws some policy conclusions.

II. A Brief Sketch of the Economics of Technology Policy¹

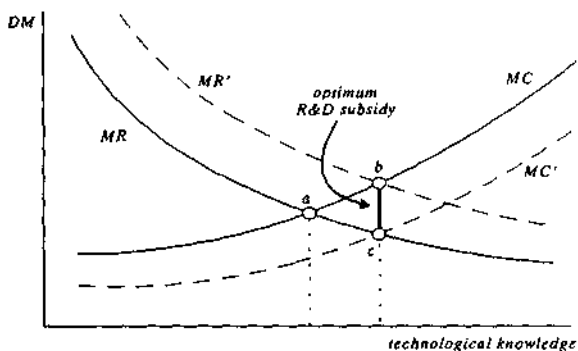
The fundamental point of departure for a theoretical evaluation of technology policy is the notion that innovative activities tend to be associated with positive *externalities*. In general, the results of R&D not only accrue to the R&D-performing firm, but also facilitate the generation of new technological knowledge by other firms without being obliged to pay for it. As a result, a strictly private organization of R&D would not yield a social optimum because the financial incentives for investing in new technologies would be suboptimal. A first-best solution to this type of market failure would require a public subsidy to private R&D which just compensates the difference between private and social returns of R&D (see Box 1).

A second type of market failure in the area of R&D results from the specific properties of technological knowledge as a *public good*. By contrast to private goods, the available amount of technological knowledge does not decline by its utilization. Due to this absence of consumption rivalry, the social marginal costs of utilizing new knowledge are zero. Hence, the static concept of Pareto optimality requires that no potential user should be excluded by royalties or other financial

¹ This chapter mainly summarizes Klodt (1995) where the particular arguments are explained in more detail and extended references to the literature are provided.

contributions from access to the available technological knowledge. Under such conditions, however, no private investor would be ready to spend own money on the generation of new knowledge. A clear-cut theoretical solution to this type of market failure would require a 100 percent financing of R&D projects from public funds. Such a radical solution would conflict, however, with the dynamic requirements of an effective control over the selection of profitable and less profitable R&D project. Due to this conflict between static and dynamic efficiency governments will never be able to perfectly neutralize the inefficiencies arising from the public-good character of technological knowledge.

Box 1 - Optimum R&D Subsidies in the Face of Positive Externalities



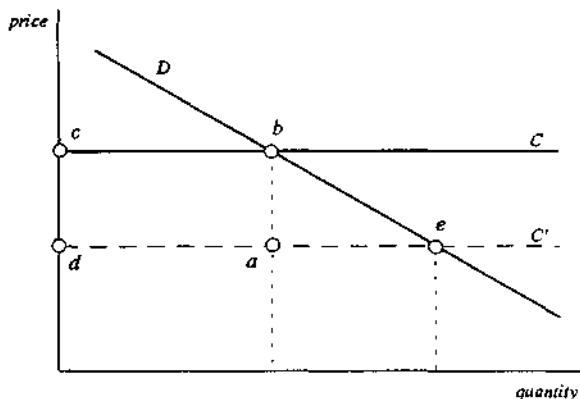
It can be assumed that the marginal costs of generating new technological knowledge will rise with an increase of innovative activities (MC), whereas the marginal revenue for the private investor (MR) and for the economy as a whole (MR') will decline (the vertical distance between MR and MR' displays the positive externality of R&D). A strictly private organization of R&D would result in point a as the market equilibrium, whereas the social optimum lies in b . In order to attain a social optimum, government should contribute to private R&D by subsidizing a share of \overline{cb} / b of total R&D costs, which brings private marginal costs down to MC' .

Patent protection only provides an incomplete solution to this dilemma. On the one hand, it enables private investors to earn at least part of the positive external benefits of their R&D projects by imposing royalties on other users. On the other hand, patent royalties will exclude those potential users who are not willing to pay the royalties, but could derive at least some benefits from the utilization of the new knowledge (Box 2). Moreover, patent rights may be abused for monopolizing product markets and for blocking the technological development of other firms (strategic patenting). This calls for a termination of patent protection to a limited number of years, which in turn reduces the private appropriation of the social returns of R&D. Finally, patent protection provides an imperfect solution to market imperfections because only a fraction of relevant R&D results can be patented under current patent laws. Hence, patent protection is no perfect substitute for public R&D subsidies.

Further types of market failure in the area of R&D may result from the high risk of innovation projects, which leads to an under-investment of *risk-averse innovators*, and to the *credit-rationing* of small- and medium-sized firms, which is most significant in R&D where no physical collaterals can be offered to the banks for guaranteeing credits for innovative projects.

On the other hand, intense competition among private investors may also result in an over-investment in R&D. The basic reason behind this type of market failure is the existence of positive innovation rents which will attract other competitors until all the rents are competed away. In the markets for ordinary private goods, this outcome of competition is socially desirable because monopoly rents are in general associated with welfare losses. In the area of R&D, however, innovation rents are welfare-enhancing, and *rent dissipation* by unrestricted private competition may result in aggregate welfare losses.

Box 2 - Welfare Effects of Patent Protection



It is assumed that a process innovation reduces marginal costs for a specific good from C to C' . With competitive markets and demand D , the pre-innovation market equilibrium is represented by b , whereas the social optimum after the innovation lies in e . If the innovator is granted an exclusive patent right, he may either completely monopolize the product market or give licenses to his competitors for a maximum royalty of \overline{ab} . In both cases, the innovation has increased social welfare by the rectangle $abcd$, whereas a socially optimal free access to the new technology would have yielded additional welfare gains of abe .

Basically, three types of rent dissipation can be identified:

- First, private investors may have socially inefficient incentives for duplicating the R&D projects of other firms (parallel research).
- Second, it pays for private investors to speed up ongoing R&D projects if the innovator who is first in the market will be able to reap the whole innovation rents (patent races).
- Third, the establishment of new innovative monopolies may not only create new innovative rents, but may also destroy monopoly rents of previous innovators (business stealing).

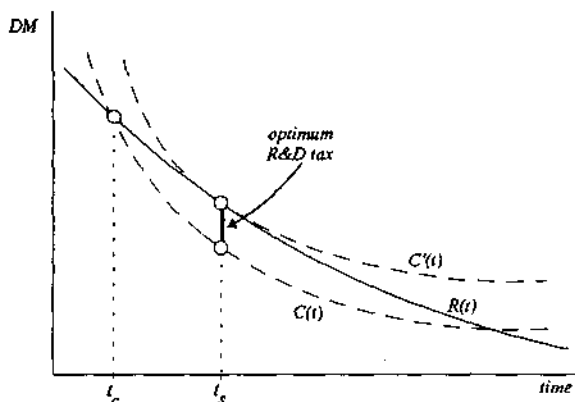
The theoretical background of these cases is extensively discussed in Klodt (1995, chapter B.II). The case of rent dissipation by patent races is illustrated in Box 3. Together with the other two cases, it provides theoretical arguments for taxing instead of subsidizing private R&D in order to achieve a socially efficient market solution.

At first glance, it may be somewhat disappointing that economic theory does not provide a more precise and ready-to-use answer to the role of government in the innovation process. However, a careful look at the different lines of argument presented above allows to derive at least some tentative and pragmatic policy conclusions:

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- The arguments in favor of subsidizing are rather strong if the particular R&D project is oriented at generating basic technological insights which are not directly related to introducing specific new products or processes into the market. In this case, positive externalities can be expected to be quite high, the specific knowledge may exhibit significant public good properties, and the prospects for patent protection are rather low.
- The arguments against public support are rather strong if the particular R&D project aims at direct implementation of new products or processes at existing markets. The use of such knowledge for other technological fields will probably be rather limited, and the capacity for patenting will be quite high.

Box 3 - Rent Dissipation by Patent Races



It can be assumed that the costs of generating a specific innovation will increase if the time period for the innovation project is reduced. On the other hand, also the innovation rents will be higher if it is possible to enter the market earlier. The discounted present values of innovation costs and innovation revenues are depicted by $C(t)$ and $R(t)$ respectively. Presumably, $R(t)$ will be less concave than $C(t)$ because the costs of innovation will always remain positive, whereas the innovation revenues eventually fade out when technological development in other areas will make the specific innovation under consideration redundant. The socially optimal point of time for innovation is t_s , where the distance between C and R and hence the social innovation rents are maximized. However, private competition among innovators will drive innovation time down to t_c , where all the rents are competed away. In order to prevent such a undesirable rent dissipating innovation race, the government should tax R&D expenditures until the cost curve $C(t)$ is shifted to $C'(t)$, where private investors will choose t_s as the optimum point of time for introducing the innovation into the market.

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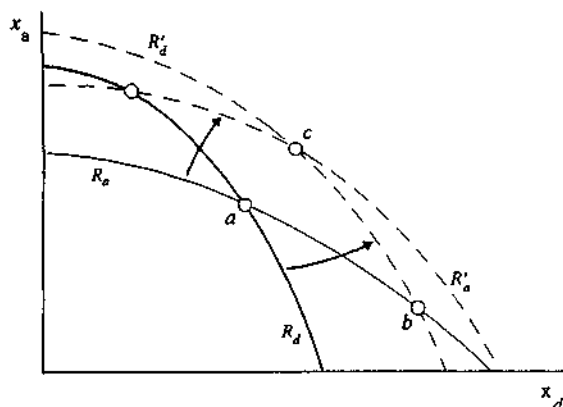
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According to these considerations, public support to private R&D should mainly concentrate on basic research and should be significantly lower for applied research and experimental development.

In addition, governments should refrain from directly intervening into the design of R&D projects, because the relevant information about profitability and risks of research projects can be assumed to be available mainly at private firms exposed to market competition and not at public bureaucracies. This information problem in the sense of Hayek (1945, 1975) also constitutes the main reason why a strategically motivated technology policy is most likely to fail. Although it has been demonstrated within the framework of the new trade theory that strategic technology policy may succeed in shifting innovation rents from foreign to domestic producers (Spencer, Brander, 1983; Helpman, Krugman, 1989), it has repeatedly been shown that such a policy approach will only work if

- the industry under consideration exhibits significant scale economies or learning-curve effects in order to establish barriers to entry as a precondition for sustainable monopoly rents, and

Box 4 - Strategic Technology Policy in the Presence of Foreign Retaliation



The axes of the diagram show the output quantities of a technology-intensive good by a domestic (x_d) and a foreign producer (x_a). If both firms are playing Cournot, the equilibrium will be at the intersection point a of the reaction functions of the domestic and the foreign firm (R_d, R_a). For the home country, it would be welfare-improving if the domestic company would abandon the Cournot strategy and would behave like a Stackelberg leader. If the foreign firm would still play Cournot, the Stackelberg equilibrium would be in b — with higher market shares and higher innovation rents of the domestic producer. Without government support, however, such an attempt of the domestic firm would not be credible. In order to back the position of the domestic firm, the domestic government pays an R&D subsidy which shifts R_d outwards towards R'_d . Although both firms still play Cournot, the new equilibrium exhibits the results of Stackelberg leadership; part of the innovation rents have been shifted from the foreign to the domestic country.

If the foreign government adopts a similar approach and also starts to subsidize its producer R_a shifts outward to R'_a . The new equilibrium lies in c , where the output of both firms is higher than in a and total innovation rents are reduced if not destroyed at all. For the foreign country point c is still superior to point b , but rents are lower for both countries than in a . None of both but no governments is ready to make the first step towards unilateral subsidy reduction because it would slip into the uncomfortable position of a Stackelberg follower. Hence, the subsidy race has established a typical prisoner's dilemma, with subsidies in both countries although because each country would be better off without subsidization.

- governments are able to predict the competitive behavior of firms (Cournot vs. Bertrand), and
- foreign governments do not retaliate, and
- the opportunity costs of withdrawing production factors from other profitable industries are low, and
- monopoly rents of strategic industries are not dissipated by lobbying, strategic investment or other rent-seeking activities of domestic firms.

It can be expected that rent shifting by strategic technology policy will only be successful if all of these requirements are met. The market situation in the presence of foreign retaliation is illustrated by Box 4. Again, the case of strategic technology policy demonstrates that there are only limited opportunities for welfare-improving government interventions into market-oriented R&D activities.

The debate about technology policy has been stimulated by new developments not only in trade theory, but also in growth theory. In the framework of the new growth theory, it was demonstrated by Lucas (1988), Romer (1986) and many others that market failures resulting from externalities and public-good properties of technological knowledge may significantly repress the aggregate growth performance of an economy if governments refrain from supporting private R&D activities. In traditional neoclassical growth theory, such effects could not occur because technological progress was regarded as exogenously determined. Any inefficiencies resulting from market failure in R&D were supposed to reduce economic growth only temporarily without affecting the long-term growth rate. Hence, there was expected to be rather limited scope for welfare-enhancing public R&D support. In the new growth theory, by contrast, the long-term growth rate of (endogenously determined) technological progress reacts to financial incentives for innovators, which may be socially insufficient without public R&D support. A lack of financial compensation for the positive externalities of R&D is expected to reduce the permanent growth rate of the whole

economy because an appropriate level of R&D activities will reduce the long-term rate of endogenous technological progress.

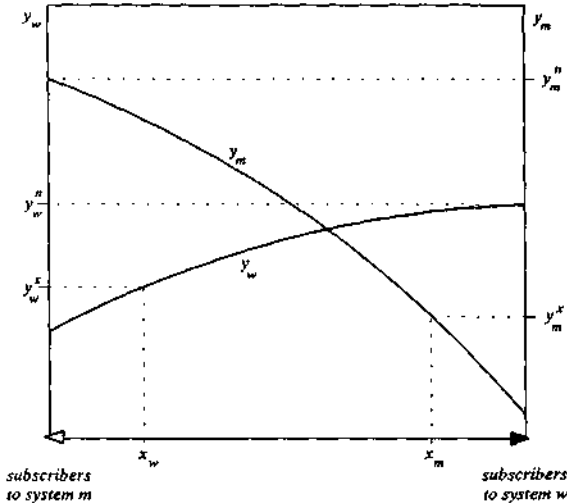
Within the theoretical context of the new growth theory it is also discussed whether aggregate economic growth may be influenced by the sectoral composition of an economy (see, e.g., Arthur, 1989; Stolpe, 1995). Market forces may generate a sectoral production pattern which maximizes economic welfare in the short-term, but drives the whole economy to a rather flat long-term growth path (Box 5). Hence, future growth prospects of an economy may not only depend on factor endowment and technological progress, but also on the sectoral patterns inherited from the past.

Such "path dependencies" may call for government support to industries with high growth potentials in order to improve the growth prospects for the whole economy. As future growth is often supposed to be above average in technology intensive industries, the new growth theory may serve as a new theoretical base for public R&D policy. However, the government is again confronted with a severe information problem which makes it difficult — if not impossible — to identify promising strategic industries which are insufficiently supported by market forces.

In particular, a successful technology policy based upon path dependencies would require

- reliable information available to the government about future growth and productivity potentials of different technology-intensive industries,
- a time horizon of governments that exceeds the time horizon of private investors,
- strong technological or institutional restrictions on switching from one development pattern to another when it becomes apparent that the initial choices of innovators and investors have led to an inferior growth path.

Box 5 - Path Dependency Resulting from Network Externalities



The concept of path dependency can be illustrated for the case of two alternative technologies which both exhibit substantial network externalities. Suppose that buyers of personal computers can choose between the two operating systems w and m , which are assumed to be non-compatible with respect to software application and data exchange. The productivity of an individual personal computer is assumed to depend not only on the technological properties of the particular operating system, but also on the total number of personal computers already installed and equipped with a compatible operating system. The total number of potential users amounts to n , but currently only x persons have actually decided to industrial a personal computer. If these x persons would choose technology m , they would achieve a productivity level of y_m^x , whereas technology w would yield a productivity level of y_w^x . If investors are oriented at short-term profit maximization, they will choose technology w . This decision establishes an irreversible choice for the whole economy, because every new entrant will be better off with technology w than with technology m .

When the diffusion of personal computers is completed, the economy ends up with a productivity level of y_w^n . A far-sighted government could have avoided this path inefficiency by subsidizing early entrants in order to persuade them to choose technology m , which would have resulted in short-term productivity losses, but would eventually have raised the productivity level to y_m^n .

Moreover, such a sectorally differentiated policy approach may seriously be affected by foreign retaliation. If all governments would concentrate their support on the same future industries, they would probably generate over-capacities and allocative inefficiencies which may retard future growth instead of promoting it. Finally, also this type of sectoral intervention may encourage rent-seeking activities which tend to destroy the potential welfare gains of a growth-oriented industrial policy.

All in all, the new growth theory has strengthened the case for subsidising the positive externalities of private R&D because it has demonstrated that insufficient pecuniar incentives for innovative activities may result not only in static, but also in dynamic welfare losses. However, it does not support government interventions into the sectoral structure of private R&D because there is no sound theoretical or empirical base for discriminating between valuable and less valuable innovative activities of different industries.

As a general policy conclusion from microeconomic and macroeconomic theories of innovation it can be argued that basic scientific research deserves special attention of public technology policy because positive externalities are high and the results of this kind of research can often be regarded as public goods. Also market-oriented applied research may deserve some public assistance, but clearly to a lesser extent. And more important, there is strong reason for governments to concentrate on indirect measures of R&D support and to refrain from any direct intervention into specific technologies or product markets.

With this theoretical system of reference in mind, it should be possible to critically evaluate the science and technology policy of specific countries. The following section concentrates on the case of Germany.

III. A Survey of the German Innovation System

The whole area of science and technology policy covers a broad variety of different institutions and measures, ranging from university research

over publicly funded private research agencies to the direct subsidization of private R&D projects. The most important part of public policy towards the promotion of technological development in Germany is concerned with financial support of R&D, which is surveyed below.

1. Funds and Institutions

Total expenditures on R&D in Germany amount to 81 billion DM in 1995, which is equivalent to 2.4 percent of gross domestic product. As compared to the early 1990s, this ratio has somewhat declined due to (1) the almost complete collapse of private R&D activities in Eastern Germany and (2) the cuts in Western German R&D budgets during the recent recession. Nevertheless, aggregate R&D intensity in Germany is still of a size similar to the one in other highly developed countries.

Table 1- Federal R&D Expenditures by Ministry

	1990		1995		1996	
	mill. DM	%	mill. DM	%	mill. DM	%
BMBF (a)	8956	58.8	11008	65.0	11321	64.3
BMVg	3419	22.5	2899	17.1	3240	18.4
BMWi	1077	7.1	1053	6.2	1009	5.7
Other ministries	1763	11.6	1978	11.7	2043	11.6
Total	15215	100.0	16938	100.0	17613	100.0

(a) Prior to 1995: Federal Ministry for Research and Technology (BMFT) plus Federal Ministry for Education and Science (BMBW).

Source: BMBF (1995, 1996).

60.3 percent of total R&D expenditures are financed by the private sector and 39.7 percent by government institutions. Of these public funds two thirds are spent at the federal level and the remaining third at the state level. R&D funds of states are mainly concentrated on university research, i.e. they mainly support science and not technology.

The lion's share of federal funds is spent by the Federal Ministry for Education, Science, Research and Technology (BMBF), which was merged in 1994 from the former BMFT and the former BMBW (Table 1). Further main contributors at the federal level are the Ministry of Defence (BMVg) and the Ministry of Economics (BMWi).

Somewhat more than one quarter of federal R&D expenditures are submitted to private enterprises; these payments can be regarded as the financial manifestation of technology policy in a narrow sense (Table 2). A much larger share flows to private non-profit institutions, which will be further discussed below (see Figure 1). Payments to foreign countries are mainly dedicated to international organizations, above all to the European Union and the European Space Agency.

Table 2 - Federal R&D Expenditures by Sector of Performance (percent)

	1990	1995	1996
Universities and public research institutions	20.2	20.6	20.5
Private non-profit organizations	34.8	41.6	41.1
Business enterprises	34.0	27.6	28.5
Foreign countries	11.0	10.2	9.9
Total	100.0	100.0	100.0

Source: BMBF (1995, 1996).

Public support to public and private non-profit research institutions is mainly granted as "institutional support" which constitutes the financial base of these institutions and is not attached to specific research projects (Table 3). A similar amount is spent on project support, of which two thirds are paid to private business enterprises and one third to public and private non-profit institutions. Project support for private R&D is mainly directed at specific projects (direct) and to a much lesser extend granted in an unconditional (indirect) or almost uncondi-

tional (indirect-specific) manner. The latter programs are mainly addressed to the support of small and medium-sized enterprises. The indirect specific-support programs are currently fading out and will probably not be prolonged.

Table 3 - Federal R&D Funds by Type of Expenditure

	1990		1995		1996	
	mill. DM	%	mill. DM	%	mill. DM	%
1. Institutional support	5177	34.0	6849	40.4	7075	40.2
1.1 Research-supporting institutions	1346	8.8	2111	12.5	2184	12.4
1.2 National research centers	2396	15.7	2555	15.1	2615	14.8
1.3 Federal research institutions	966	6.3	1295	7.6	1363	7.7
1.4 Other institutions	496	3.1	888	5.2	913	5.2
2. Project support	8284	54.4	7641	45.1	8102	46.0
2.1 Direct	7930	52.1	7033	41.5	7425	42.2
of which:						
BMFT/BMBF	3309	21.7	3417	20.2	3559	20.2
BMVg	3090	20.3	2557	15.1	2894	16.4
BMW i	699	4.6	438	2.6	357	2.0
2.2 Indirect and indirect-specific	353	2.3	608	3.6	677	3.8
3. International cooperation	1335	8.8	1592	9.4	1594	9.1
Total	15215	100.0	16938	100.0	17613	100.0

Source: BMBF (1996).

Public project support to the business enterprise sector exhibits a considerable degree of sectoral concentration. In absolute as well as in relative terms, the main bulk of public funds flows to the aircraft and space industry (Table 4). The relative share of R&D subsidies is high also in the energy sector and in mining. Compared to these industries,

some major R&D performers (such as chemicals, non-electrical machinery and electrical machinery) have only limited access to public funds. It should be noted that the degree of sectoral selectivity is even understated by the figures of Table 4 because the distribution of public funds within industries is rather uneven. For instance, a major focus of public R&D support is laid upon microelectronics, which cannot be identified by Table 4 because microelectronics constitutes only a small fraction of total electrical machinery.

And even within individual technology fields there exists a significant degree of selectivity and discrimination between firms. In the area of information technology, for instance, only one percent of the total number of funded projects accounts for 22 percent of total public funds. Across all civilian technology fields, direct project support is granted to 1,981 firms (1,727 firms supported by the BMBF and 254 firms by the BMWi)², whereas the total number of firms in the German economy amounts to about two million. A more meaningful comparison: according to the statistics of the Stifterverband (1995) about 12,000 firms in Germany are conducting own R&D, i.e., direct project support covers less than 20 percent of firms engaged in R&D.³

² Unpublished data for 1994 from the BMBF. No corresponding data are available about military research, but it can be expected that the concentration of public funds is even higher than in civilian research.

³ An alternative back-of-the-envelope calculation supports this estimate: the regular share of public funds in supported private projects amounts to 50 percent. The total share of public funds in R&D performed by the business enterprise sector is 11 percent (see Table 4). Hence, it can be estimated that about 20 percent of private R&D projects are co-financed by public programs, whereas 80 percent are carried out without any direct project support from the government.

Table 4 – R&D Expenditures of German Business Enterprises by Industry 1993

	Total		Government funded	
	mill. DM	%(a)	mill. DM	%(b)
Energy	177	0.2	29	16.4
Mining	322	1.0	109	33.9
Manufacturing	48194	4.3	4446	9.2
of which:				
Chemical industry	9664	6.1	98	1.0
Rubber and plastics	728	2.5	29	4.0
Stone and clay	474	1.6	42	8.9
Iron and steel	329	1.1	42	12.8
Non-electrical machinery	5135	3.1	219	4.3
Motorcar industry	10467	5.2	93	0.9
Aircraft and space	3259	24.4	2789	85.6
Electrical machinery	12439	6.5	717	5.8
Instruments	778	4.9	102	13.1
Fabricated metal products	877	1.2	97	11.1
Wood, paper and printing	229	1.1	25	10.9
Textiles and apparel	279	2.0	57	20.4
Food and beverages	317	0.6	21	6.6
Other industries	2028	1.1	560	27.6
Total	51236	3.6	5658	11.0
(a) Share in sales of R&D-performing companies. – (b) Share in total R&D expenditures.				

Source: Stifterverband für die Deutsche Wissenschaft (1995).

The sectoral structure of public R&D subsidies is remarkably invariant over time. At first glance, this may be surprising, as individual government programs usually expire within a few years and newly launched

programs often represent changed official priorities of technology policy. However, for implementing the technology programs there has been established a sizable bureaucratic infrastructure which is adapted to specific technology fields and industries. This not only applies to the institutional and personal structures within the BMBW, but also to several technology agencies which are engaged in channeling R&D funds from the government to private and public contractors. It may often be less difficult to accommodate new technology programs to existing bureaucratic structures than vice versa. In addition, informal links between public institutions and large private contractors tend to stabilize the sectoral structure of public R&D funds.

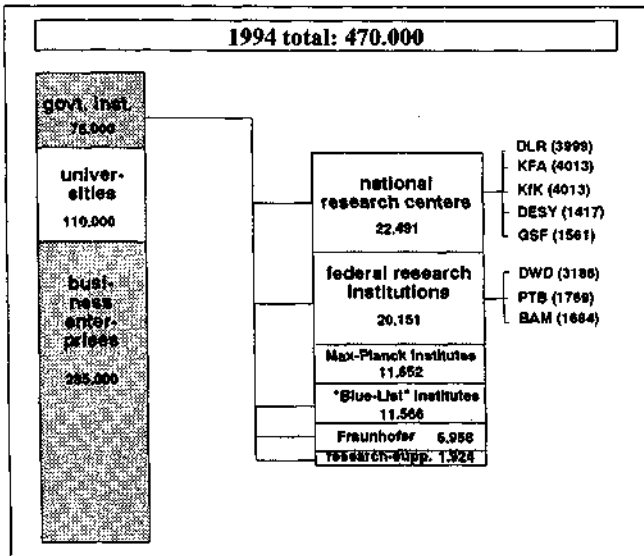
2. Persons Engaged in R&D

In Germany, about 450.000 people are engaged in R&D (full-time equivalent), which amounts to about 1.5 percent of total employment of the economy. More than 60 percent of these scientists, engineers, technicians and other R&D staff are employed by private business enterprises, 20 percent are working at universities (excluding teaching staff), and somewhat less than 20 percent at government institutions (Figure 1).⁴ The latter are mainly to be found in national research centers and federal research institutions. The so-called "blue list" covers a variety of very different research institutions from natural and social sciences, among them the Kiel Institute of World Economics and five additional economic research institutes. The Fraunhofer Society is mainly engaged in supporting innovation projects of small and medium-

⁴ The abbreviations on the right-hand side of Figure 1 should be read as follows: DLR — Deutsche Forschungsanstalt für Luft- und Raumfahrt (German Aircraft and Space Agency); KFA — Forschungszentrum Jülich (Research Center Jülich); KfK — Kernforschungszentrum Karlsruhe (Nuclear Research Center Karlsruhe); DESY — Deutsches Elektronen-Synchrotron (German Electron Synchrotron); GSF — Forschungszentrum für Umwelt und Gesundheit (Research Center for Environment and Health); DWD — Deutscher Wetterdienst (German Weather Service); PTB — Physikalisch-Technische Prüfanstalt (Agency for Physical and Technical Testing); BAM — Bundesanstalt für Materialforschung (Federal Agency for Materials Research).

sized enterprises. Usually, all these institutions receive only a fraction of their budgets from government and have to acquire additional funds from private research contracts. The only exception are the institutes of the Max-Planck-Society, which are exclusively devoted to basic scientific research with an extraordinarily high degree of independence from governments, politics and market requirements. If any Nobel-Prizes are awarded to German scientists, they are in general awarded to members of Max-Planck-Institutes.

Figure 1 – R&D Personnel in Germany



Source: Own compilation from BMBF (1996).

There is an intense policy debate in Germany of how to make public research institutions more effective by re-defining their tasks and responsibilities and by cutting public funds and research staff. Above all, it is discussed how to improve the technology transfer from the national research centers to the private sector in order to enhance the efficiency of the German innovation system as a whole. Many of these

exploring the technological potential and safety aspects of nuclear energy. From the centers displayed in Figure 1, this applies to the KFA, the KfK and the GSF, which are equipped with a research staff of almost 10.000 people. After the Chernobyl shock of 1986, however, the social acceptance of nuclear power radically declined. Hence, also scientific research on nuclear energy became more and more redundant. As institutional structures tend to change rather slowly, the major institutions are still in operation without providing adequate inputs to the technological development of the German economy anymore.

The relevance of public research institutions for industrial innovative activities can be assessed by the extent to which private enterprises are conducting external R&D at different institutions. According to this indicator, the national research centers are much less important for the technology transfer between the public and the private sector than the Fraunhofer institutes or other German research institutions, although their research staff is significantly larger (Table 5).

The task of effectively reorganizing the national research centers can probably be regarded as the most challenging topic of German technology policy in the future. As the initial purposes of these institutions have faded away, part of their capacities are currently utilized by the BMBF for designing public research programs, for evaluating project proposals of applicants and for channeling public funds to the contractors. Substantial reductions or reallocations of the research staff are seriously hampered by the particular German labor market regulations for civil servants. Some attempts have been made by German industry to get an increased influence on the research agenda of the national research centers and the BMBF is currently preparing new strategies for partly privatising them, but up to now only limited progress has been achieved. A significant improvement of the economic efficiency of public research institutions in Germany will probably be feasible only if these institutions will be more exposed to competition and will be compelled to earn a higher share of their funds in the market.

Table 5 - Share of German Manufacturing Enterprises Conducting External R&D at Public Research Institutions by Size Class (percent)

Institution	All enterprises	Number of employees			
		20-9	50-99	200-99	> 1000
Universities	53.5	27.1	38.4	39.4	65.5
Colleges (a)	29.7	21.4	20.0	25.9	34.2
National research centers	7.5	3.6	4.3	6.9	8.7
Fraunhofer institutes	27.4	24.4	14.5	18.4	35.2
Other German research institutions	33.8	34.0	36.9	30.7	34.7
Foreign research institutions	8.3	0.0	0.9	7.4	10.8

(a) Fachhochschulen.

Source: van Dijk (1996).

3. Technology Policy of the European Union

Science and technology policy in Germany is increasingly influenced by the European Union (EU), which currently spends about two billion ECU per year (equivalent to about 3.6 billion DM) on research and development projects. As compared to the 30 billion ECU spent by European national governments, it appears to be a small fraction, but the growth rates of EU funds are substantially higher than those of national funds. Moreover, EU programs are highly concentrated on particular technologies, which gives them high significance in certain fields.

According to the treaty on the European Union, the Commission has to establish a multi-annual framework-program which defines budgets and

priorities of European technology policy and which has to be confirmed by the Council of Ministers (Article 130i). The current framework program has a size of about 13 billion ECU (Table 6)⁵. The Commission is responsible for implementing the framework program and for prescribing the details of research contracts. For this purpose, it has released general guidelines which mark out a 50 percent share of EU subsidies in supported private research projects. This level exactly corresponds to the level which is in general applied by the German government for research contracts with private firms.

Initially, European technology policy was mainly oriented at supporting "pre-competitive" research. However, the Commission increasingly strives for redirecting its programs towards market-oriented projects in order to improve the technological competitiveness of European firms on world markets. The most important individual program is called ESPRIT (European Strategic Programme for Research and Development in Information Technology), which concentrates on the diffusion of microelectronics in various areas. Outside the framework program the EU is supporting nuclear energy research in the fields of nuclear fusion (Joint European Torus) and of light-water-reactors (Joint Research Centres)⁶.

⁵ In response to the integration of Austria, Finland and Sweden into the European Union in 1995, the Fourth Framework Program has recently been enlarged from 12.3 billion ECU to a level of 13.1 billion ECU.

⁶ The four Joint Research Centres of the EU are facing a similar problem as the German national research centers, because the reduced political priority of nuclear research requires a re-orientation of the research agenda, which seems difficult to achieve under the prevailing institutional settings.

Table 6 - Fourth Framework Program of the European Union on Research and Technological Development 1994-1998

	mill. ECU	%
I. Research and Technology	10045	76.7
A. Information and communication technologies	3626	27.7
1. Telematic systems	898	6.9
2. Communication technologies	671	5.1
3. Information technologies	2057	15.7
B. Industrial technologies	2125	16.2
4. Industrial and material technologies	1818	13.9
5. Measuring and testing	307	2.3
C. Environment	1150	8.8
6. Environmental and climatic research	907	6.9
7. Maritime science and technology	243	1.9
D. Biological sciences and technologies	1674	12.8
8. Biotechnology	588	4.5
9. Bio-medicine and health	358	2.7
10. Agriculture and fishing research	728	5.6
E. 11. Non-nuclear energy	1067	8.1
F. 12. Transport technologies	256	2.0
G. 13. Socio-economic research	147	1.1
II. Cooperating with countries and international organizations	575	4.4
III. Diffusion and utilization of results	352	2.7
IV. Education and mobility of researchers	792	6.0
V. EURATOM (nuclear energy)	1336	10.2
Total	13100	100.0

Source: Commission of the European Union (1994).

Less apparent but probably more important for technology policy in Europe is the control of the Commission over national R&D programs. Under this so-called state aid control, which is an integral part of European competition policy, the Commission has the right to prohibit those national R&D programs which can be expected to distort competition among European firms (Article 92 of the EU treaty). For implementing state aid control in the area of R&D, the Commission has released a Common Frame which defines upper limits for subsidizing private R&D by national governments. The respective limits are 50 percent for basic industrial research and 25 percent for applied research. The implementation of these guidelines has repeatedly lead to conflicts with member states — especially with the German BMBF which in general favors a 50 percent share of subsidization for all projects under its responsibility.

Since 1985, the technology policy of the European Union is complemented by the research initiative EUREKA, which is a joint program of 19 European governments and the Commission. EUREKA supports market-oriented high-tech projects executed by private firms from at least two different European countries. Applications for financial support must be addressed to national governments, and there are no common technological priorities or technical arrangements. The coordination of projects is organized at annual meetings of national EUREKA-representatives and by a small EUREKA secretariat at Brussels.

The largest individual EUREKA program is JESSI (Joint European Submicron Silicon), which covers more than 50 projects with participants from six countries and which is concerned with production processes and applications of integrated circuits. From a political point of view, EUREKA can be regarded as an expression of the rising concern of member states about bureaucratic inefficiencies and the awkwardness of the technology policy of the Commission.

IV. Policy Proposals

An evaluation of the actual technology policy described in the preceding section in the light of the theoretical considerations of section II leads to the recommendation that both the German government and the Commission should substantially cut back their direct project support in order to reduce technological and sectoral distortions associated with this type of market intervention. A general reduction of the 50 percent share of subsidies in this area of technology policy would strengthen the market-orientation of private research, would discourage rent-seeking activities of potential innovators and would be in accordance with the rules established by European competition policy. In Germany, reduced funds for project support should at least partly be compensated by enlarged indirect support programs, for instance R&D tax credits or general R&D grants without government interference with technological or sectoral properties of the respective innovative activities.

In addition, a fundamental reorganization of public research institutions is required which properly defines the specific role of each individual institution in the context of the entire German innovation system. The task of position-fixing should mainly be oriented at a distinction between basic science on the one hand and market-oriented applied research on the other hand. The composition of research activities should also be reflected in the financial structure of public research institutions, i.e., institutions engaged in market-oriented research should be compelled to earn a significantly higher share of their budget in the market. Finally, an optimal division of labor between the Commission and national governments would require a concentration of EU funds on basic research, because this type of activities can be expected to yield beneficial results not only for individual countries or enterprises, but also for the European Union as a whole.

And last not least, national and European policy makers should pay more attention to the fact that policy programs for creating or promoting national champions do not make much sense in a globalizing world economy where former national champions are steadily con-

verting into multinational champions and where technological knowledge flows rather freely across national borders in the lee side of international capital flows. In an internationally integrated economy, it is not the national technology base which counts, but the qualification and flexibility of the domestic labor force and the attractiveness of legal and institutional infrastructures for internationally mobile investors. Hence, the relevance of national technology policy for the position of countries in international competition should not be overrated.

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