Classifying Technology Policy from an Evolutionary Perspective*

by

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1. Introduction

In 1987 Ergas introduced the concepts of *mission*- and *diffusion-oriented policy designs* to classify and analyse national systems of innovation. According to him, mission-oriented systems are characterised by centralisation and the concentration of policy support on a small number of technologies and larger firms, unlike diffusion-oriented systems which concentrate their policy efforts on increasing an economy's capacity of innovating by concentrating on the scientific infrastructure, technology transfer and cooperation, i.e. formal and informal relationships between different actors etc. Although, on the one hand, we assume this taxonomy well-suited for analysing technology policy in an evolutionary context, on the other hand, it appears somewhat crude, especially regarding the characteristics Ergas identifies in order to assign a specific innovation system to one or the other policy design. To surmount these critics, we suggest to take a closer look at the specific policy measures applied. For this purpose we develop a new classification scheme, based on interviews with political representatives and suggesting four categories spread out between the technology side (high and low technological specificity) and the economic side (high and low market distance). This

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scheme allows for more evident comparisons of different innovation systems. For our discussion we take an evolutionary perspective looking at capabilities of the actors involved, the processes of technological competition and co-operation as well as the connecting feedback during the various phases of innovation processes (in a broad sense). We then apply this concept in an empirical analysis of German technology policy of the last two decades thus demonstrating the basic procedure of our approach.

2. Theoretical Aspects

Asked for the most important driving forces of economic development, most economists do not hesitate to state that technical progress is the main source of quantitative economic growth and qualitative economic change. However, a necessary sequent question is, what kind of innovative activities can be expected in capitalistic societies, and how can policy support or even spur such innovation processes? In order to analyse these issues, some economists left the traditional equilibrium-oriented path of neoclassical economics and turned to an evolutionary theorising. In particular, they argue that the evolutionary paradigm is more adequate for analysing development processes initiated within the system, characterised by strong uncertainty and disequilibrating forces and which is composed of heterogeneous actors.[1] In this perspective, neoclassical economics oversimplifies the issues of innovation processes by drawing on a representative agent who attempts to reach an optimal equilibrium because he acts in a deterministic or quasi-deterministic environment and is endowed with perfect rationality.

Contrariwise, in an evolutionary context the complexity of interactions between heterogeneous agents guided by trial-and-error is considerably increased, and a benchmark for optimal solutions is missing - thus, uncertainty prevails and the optimality of solutions can only be assessed ex post. Therefore, one has to search for other justifications for policy interventions than sophisticated but nevertheless simple market failure analysis.[2] Such a new view on technology policy, although not well-elaborated as yet, will certainly have to be framed by an understanding of innovation processes as search and experimentation (instead of

[1] See e.g. Witt (1987, 1992), Dosi/Nelson (1994).
[2] See Cantner/Hanusch (1997).

immediate optimisation). Policy measures will then aim at the propelling and sustaining forces of these processes (instead of not yet achieved optimal solutions).[3]

Among these forces, the capability, education, and skills of actors are of foremost importance.[4] Absorptive capacities[5] and receiver competencies[6] are required for both the generation and dissemination of technological know-how. In many cases bottlenecks emerge just here, and any market incentives promoting or restricting innovative activities are subordinate. Whatever the policy measure, crucial points should be considered, not in a facultative but in a general and long-lasting manner. This emphasis on non-market factors, of course, is not to be understood as an argument for the total neglect of markets. Markets are here to be considered mainly as selective devices for awarding better and penalising worse technological solutions or performances. Of course in this context policy measures aim at the functioning of markets and still attempt to prohibit monopolisation - not in a static allocative sense, but with a dynamic orientation, keeping in mind the role of heterogeneity *as the fuel* for technological evolution.[7]

Moreover, the evolutionary perspective dispenses with the simple linear-sequential model of innovation[8], where an exogenous inventive stage is followed by an innovation stage in which firms can draw on well-defined new technological opportunities, and finally also a diffusion stage, where the successful innovations spread over the whole economy is no longer adequate. Instead, some authors draw from the notion of *collective invention*[9] where actors in different stages of the innovation process influence each other, to and fro. Thus, in these environments so-called *cross-fertilisation effects*[10] additionally propel technological change. Applying this concept of *looped processes*[11] to the major innovative actors in an economy, the concepts of *national innovation systems*[12] were introduced. There, different actors and institutions (firms, independent inventors, universities etc.) jointly and individually contribute to the exploration of new and the exploitation of given technologies. In this perspective, not only risk (i.e. weak

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[3] See Metcalfe, J. S. (1995).
[4] See Carlsson/Eliasson (1994).
[5] Cohen/Levinthal (1989).
[6] Eliasson (1990).
[7] See e.g. Metcalfe, J. S. (1994).
[8] See e.g. Schumpeter, J. A. (1911).
[9] Allen (1983).
[10] Mokyr, J. (1991), Pyka (1999).
[11] Kline, S.J. (1985).
[12] See e.g. Nelson (1994), Lundvall (1992).

uncertainty), but also strong uncertainty[13] necessitates policy intervention in order to support innovation processes. So, in addition to the question how to provide for venture capital, the problem of suitable or appropriate structures underlying and supporting these evolutionary development processes moves into the centre of interest. Here, new trade-offs have to be solved, e.g. between heterogeneity as a necessary and rich source of innovation and standardisation[14], which is, on the one hand, useful for the diffusion of new technologies, but on the other hand obviously reduces heterogeneity.

From this evolutionary perspective, policy designs now have a straightforward process-orientation instead of solely repairing market failures which is a target-orientation (bench mark-based). Following this, the well-known mission- and diffusion-oriented policy designs may be seen in a different light. Quite obviously, diffusion-oriented policy with its missing clear target perspective serves more to the aim of sustaining an appropriate degree of heterogeneity. At the first sight a mission-oriented policy appears quite the contrary, by favouring one specific development path, this being a severe disadvantage for alternative technological trajectories. However, one might also argue that mission-oriented policy is able to bring ex-ante seemingly unrelated technologies together by exploiting cross-fertilisation effects. In this sense, mission-oriented policy also has to be seen as a policy instrument for sustaining evolutionary development.[15]

Within this analytical and interpretative framework we discuss i) whether the Ergas taxonomy of technology policy is appropriate for identifying evolutionary policy, ii) based on the criticism raised we extend the classification using a direct method, and iii) apply this to the German federal technology policy from 1975 - 1996.

3. Mission- vs. Diffusion-Oriented Policy Design - Some Taxonomical Considerations

In order to judge the efficiency of specific technology policy measure, Ergas (1987) introduces his often cited taxonomy, where he differs between mission- and diffusion-oriented policy designs. Following his arguments, a national innovation system is connected to state

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[13] Knight (1921).
[14] Cowan/Foray (1997).
[15] Conesa, E. (1997).

interventions for two main reasons: On the one hand, in nearly all industrialised countries technology and innovation are promoted due to considerations of national sovereignty and international competitiveness. On the other hand, technology policy measures are invoked by the awareness of significant ‘imperfections’ of the market, e.g. among others in neoclassical terms the public-good nature of technological know-how, and in more evolutionary terms, the intrinsic uncertainty of innovation processes.

The attribute *mission-oriented* seems to be justified, in a rough sketch, in those cases of technology policy, which aim at national sovereignty, e.g. the development and introduction of new generic technologies. Here a clear target is given and the respective funds are granted to fulfil specific technological aims. Whereas measures aiming at a broad spreading out of new know-how, including measures to promote the utilization of this know-how or even the respective transfer, are classified as *diffusion-oriented*. Quite typical is the furthering of so-called key technologies which are assumed to exert positive influence on a broad group of industries and firms.

Ergas (1987) had already emphasized the rough nature of every taxonomy, because a classification of countries or even specific technologies to one or the other policy design obviously disguises single measures which follow the respective other policy design. Anyway, Ergas (1987, p. 52) claims „*But the focus of policy differs in the two groups, and this allows a clearer examination of the relation between technology policy and innovation performance.*“ Although we agree to this statement, in the following we will introduce an alternative to Ergas’ *indirect method* which should in a way reduce shortcomings resulting from roughly classifying whole countries to a specific policy design. However, first, we will take up Ergas’ procedure.

3.1 The Indirect Method

According to Ergas (1987), the technology policy of a country can be classified as mission- or diffusion-oriented by examining several criteria concerning i) the state of the technology life-cycle of a specific technology, ii) the share of public funded research institutions as well as private recipients, iii) the specific design of the educational system, iv) the opportunities for co-operative R&D, v) standardisation efforts, and finally vi) the share of military research. These criteria are applied to a group of seven countries (United States, France, United Kingdom, Germany, Sweden, Japan).

With respect to the first criteria, Ergas claims that *mission-oriented policy* concentrates on a small number of technologies in an early phase of the technological life cycle. Thus, a specific feature of mission-oriented measures is concentration: first, only a small number of technologies is selected for public funding and second, also most often only large corporations have the adequate infrastructure necessary for these programmes. „*A few bets are placed on a small number of races; but together these bets are large enough to account for a high share of each country's total technology development programme.*“[16]

On the contrary, *diffusion-oriented policy* aims at a broader spectrum of technologies in a more advanced phase of the life cycle. In order to distinguish phases of the technology life cycle Ergas draws on the assumption of declining R&D intensity going hand in hand with advances in that technology. His results are summarised in table 1.

	1980		
Country/R&D intensity	high	medium	low
United States	88	8	4
France	91	7	2
United Kingdom	95	3	2
Germany	67	23	10
Sweden	71	20	9
Japan	21	12	67

Table 1: Public funding for R&D in the high, medium and low R&D intensity industries as respective percentage of total public funding (approximate estimates); [a] Defined as industries where the ratios of R&D to sales are respectively more than twice (high intensity), between twice and a half (medium) and less than a half (low) than those of the manufacturing average. Source: OECD, Ergas, H. (1987), p. 54.

By this Ergas implicitly assumes a direct relationship between the number of furthered industries or technologies and the specific policy design[17] applied. However, in order to

[16] Ergas, H. (1987), p. 55.
[17] Of course a large number of firms furthered by technology policy contradict the aim of decreasing parallel research of a mission-oriented design.

classify technology policy the decisive criteria is the design of the specific measure and not the number of technologies chosen. The indirect procedure neglects this.

According to Ergas' second criteria, a high share of public funded research performed 'in-house' i.e. by public research institutions is another distinguishing feature of a mission-oriented policy. For evidence this, the share of public-financed R&D performed within public institutions is invoked (see table 2).

	1983 (%)
France	46,8
United Kingdom (1981)	38,9
Germany	31,6
United States (1981)	25,7
Switzerland (1981)	24,7

Table 2: Share of government-financed R&D carried out within the government-financed sector; source: OECD, Ergas, H., 1987, p. 58.

Again, this is to be regarded as only a considerably rough procedure, because following Ergas' definition of mission-oriented policy, it is the specificity of a measure and not the recipient that is constituent for the respective policy design. So, there are technology policy programmes aiming at technology transfer including public institutions e.g. universities which can be clearly classified as diffusion-oriented, as well as programmes aiming at the development of a specific technology by private firms (e.g. Transrapid in Germany) which are clearly designed as mission-oriented.

Specific features of a technology policy design following a *diffusion orientation* can be found in the structure of the education system, standardisation efforts and the furthering of co-operative research summarised under the heading *decentralisation*. As to the education system, Ergas focuses, on the interdisciplinary character of e.g. engineering schools on the one hand, and on the other, he emphasises the combination of theoretical knowledge as well as practical skills, as found e.g. in the German apprenticeship system. „*The most significant feature* [of a diffusion-oriented policy] *is probably the depth and breadth of investment in human capital centering in the dual system of education.*“[18] In order to guarantee an effective

[18] Ergas (1987), p. 67.

flow of information and know-how, standardisation can help to reduce the respective transaction costs.[19] In the same way co-operative R&D including close university-industry links, as well as formal[20] and informal[21] co-operation within firms are necessary devices for increasing the pace of the diffusion of new know-how and technologies. With this, Ergas concentrates on the technological infrastructure[22] responsible for information transfer as well as the building up of receiver competencies[23] or absorptive capacities[24]. Although in most cases the above mentioned elements are obviously closely connected to a diffusion-orientation, the reverse conclusion can not necessarily be claimed to hold also. All difficulties in comparing national education systems aside, many mission-oriented programmes involve co-operation (e.g. in nuclear fusion private firms as well as public research institutes and universities are engaged), and sometimes they even take the initiative to create a new prevailing standard (e.g. HDTV). Again as a consequence, a clear-cut classification is impossible without taking the specific design of a technology policy programme into account.

Finally, Ergas (1987) claims a high share of military R&D as a significant feature of mission-oriented policy dominated countries. For evidence, he draws on the shares of defence-related R&D in total government spending for R&D shown on table 3.

	1981 (%)
United States	54
United Kingdom	49
France	39
Sweden	15
Switzerland	12
Germany	9
Japan	2

Share of defence-related R&D in government expenditure on R&D, 1981;
Source: OECD, Ergas, H. (1987), p. 54.

[19] See e.g. Foray, D. (1995).
[20] See Haagedoorn, J., Schakenraad, J. (1990).
[21] See Pyka, A. (1997).
[22] See Tassey, G. (1991), Justman, M., Teubal, M. (1996).
[23] See Eliasson, G. (1990).
[24] See Cohen/Levinthal (1989).

Obviously, military research is mission-oriented par excellence. But it cannot be compared with most of the civil projects, as very different co-ordination mechanisms are invoked e.g. no true cost-control etc. Therefore, in the ‘direct method’ to be introduced below, we decide to neglect these military research expenditures altogether.

With the criteria introduced above, Ergas concludes to characterise countries according to their respective policy design. So, typical mission-oriented countries are the United States (high funding of R&D intensive industries, high share of military research), the United Kingdom (high funding of R&D intensive industries), and France (high funding of R&D intensive industries, high share of military research). Countries with a dominating diffusion-oriented policy are Germany (education system, standardisation), Sweden (low share of defence-related R&D), and Switzerland (low share of defence related R&D, low share of government in-house R&D).

However, the indicators of this *indirect method* applied by Ergas cannot give more than a first and rough idea of the technology policy of a specific country. In order to obtain deeper insights in the development and structure of technology policy, and thereby still drawing on the useful taxonomy of mission- and diffusion-oriented policy design, we will introduce a so-called *direct method* in the following section.

3.2 The Direct Method

It has already become clear that the *indirect* procedure by drawing on specific characteristics of the innovation system can only provide a rough and distorted sketch of technology policy. Without going into further detail of the design of the specific measures applied any classification tends to disguise the multifaceted character of technology policy. The *direct method* we suggest attempts to avoid these shortcomings by investigating the different measures separately. Classifying them according to the respective policy design also allows heterogeneous policy styles.

For the purpose of classification, we introduce the following matrix with one axis describing the degree of specificity of a policy measure and the other describing the market distance of the respective measure.[25] By this we also distinguish basic and applied research, in order to take the large share the furthering of basic research demands in the public budget of every industrialised nation into account. In the following we achieve four broader fields of technology policy (see fig. 1).

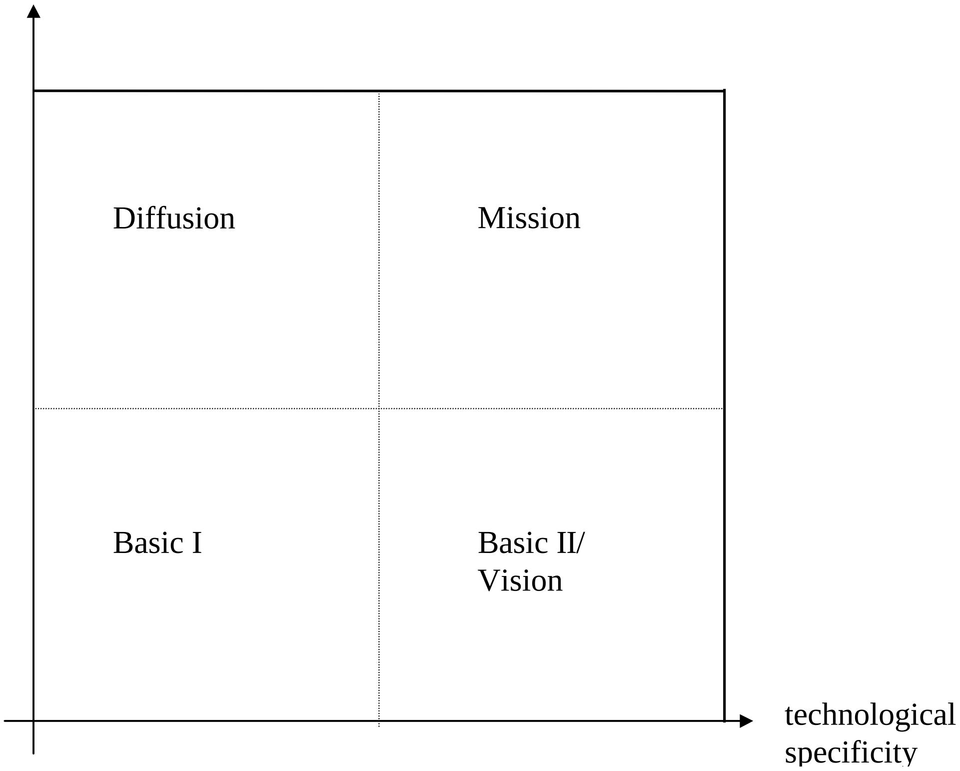

Fig. 1: Classification-Matrix

In *Basic I* we summarise basic research in a narrow sense, meaning there is no commercial orientation. However, still far away from a market introduction, some specific technologies, e.g. nuclear fusion are publicly funded. Here, public funding is combined with a certain degree of technological specificity because a large potential for further development is expected in these fields. Therefore, we call it *Basic II/Vision* as the respective technology policy goes hand in hand with a kind of technological vision or farsightedness or expectation. However, due to the enormous financial efforts necessary to promote innovation and the intrinsic uncertainty in these fields, private actors are normally not expected to engage themselves here on their own. Nevertheless, it is intended to reach higher market vicinity in these fields in the nearer future, so that these promotion areas can be dismissed in the two areas above. With decreasing market distance we approach the mission- and diffusion-oriented fields which differ in the

[25] The respective classification matrix shows some similarities with the so-called Pasteur's Quadrant introduced by Stokes (1997). However, Stokes differs between the motives of researchers, in particular understanding and application, which is why his scheme is not appropriate for our purposes of classifying technology policy.

degree of technological specificity given the single policy interventions. A low degree of technological specificity allows for a broad field of heterogeneous technologies to be furthered in a diffusion-oriented style, whereas this heterogeneity is constrained by increasing specificity following a mission-oriented policy design.

4. Empirics

The *direct method* introduced above we be applied in the following section to data describing the technology policy of Germany over the last two decades. Before presenting the empirical results, we will first briefly introduce the data we draw on and introduce the respective criteria we apply to classify the specific policy measures to the one or the other policy style. Thus, remaining shortcomings, which are unavoidably also associated with the direct method, are also worked out.

4.1 Database

Our data are taken from the annual issues of the Ministry of Research and Technology (BMBF) for the years 1984, 1986, 1988, 1990, 1993, 1996 and 1997. From these we use table 8 as a coherent and topic-oriented scheme out of part VII (Statistics): "Ausgaben des Bundes für Wissenschaft, Forschung und Entwicklung nach Förderbereichen und Förderschwer-punkten" (state expenditures on science, research and development classified by areas and main subjects). The numbers delivered are the aggregated expenditures of the "Bund" for single promoting measures (or ministries) where a further sub-division within the main subject is not provided. Since not all data are available for the whole period under investigation (1975-1996) and because the statistics of 1984 is based on a different classification, the missing values are approximated by appropriate measures. For 1997 there are no actual data available yet so that the planned numbers were taken.

4.2 Criteria of Classification

In order to systematise the specific expenditures with respect to basic research, mission-oriented policy design, diffusion-oriented policy design and also some indirect promotion measures as a subgroup of diffusion-oriented policy, criteria of classification have to be defined. For this purpose in part 3 of the annual report the specific promotion areas and main promotion subjects are evaluated with respect to their objective, the results achieved so far and the applied measures. For this evaluation specific criteria were elaborated and adjusted in personal interviews with the persons in charge at the Federal Ministry of Research and Technology. The specific areas are classified, according to the following criteria:

a) For basic research we follow the OECD definition "Basic research is the experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts without any particular application or use in view." Moreover, the institutional promotion of research institutions within specific promotion areas are also classified as basic research, e.g. within the field agriculture, wood and fishery (R)[26] the promotion of the BML (ministry of agriculture) of the 'Bundesforschungsanstalt für Landwirtschaft' (public institute for research in agriculture) in Braunschweig is summarised.

b) A diffusion-oriented policy design is found when specific promotion measures apply to certain technology fields without a detailed specification of technological aims because e.g. they have an important strategic component or are supposed to be so-called key-technologies with respect to international competitiveness. E.g. in the promotion area L1 'new materials', from a technical point of view, no clear technological objective of the research is specified. Moreover, all measures attempting to accelerate technology transfer are defined as a diffusion-oriented policy design. Additionally, the institutional promotion A3 of the Fraunhofer Gesellschaft (FhG) is taken into account with its specific objective as sustaining applied research and technology transfers from the basic research. Drawing back on Ergas again, the main characteristic of this kind of technology policy is decentralisation.

c) We think of indirect promotion measures as either

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[26] The abbreviations of the promotion areas are explained in the appendix of the paper.

- technology unspecified measures for R&D in firms (e.g. potential oriented measures, such as T1) or
- technology specific measures to further broad application and diffusion of so-called key technologies (e.g. Information Technology T3).

Moreover, we count as indirect measures the main promotion area U ‘Fachinformation’ (‘specific information’) which mainly contains measures to improve the informational infrastructure and the main research area W ‘Technikfolgenabschätzung’ (‘consequences of new technologies’) because in a broad sense both areas serve to further R&D decisions of firms. Indirect policy measures in a somewhat broader definition belong to the diffusion-oriented policy design because decentralisation is also the main characteristic.

d) We classify all measures that further concretely specified technological objectives (e.g. magnetic levitation train Transrapid N) as mission-oriented policy design. Examples for this are also certain national prestige projects, projects which are undertaken under the heading of sovereignty and projects with have a more or less military objective (e.g. nuclear research E3, aeronautics, and hypersonics). According to Ergas (1987), the main characteristic of this policy type is centralisation of decision-making.

4.3 The problem of inclusion

Our classification is not acceptable without particular qualifications. Especially for performing an international comparison, certain problems of inclusion must be taken into account. The following main problems to be considered are:

a) The level of decision in technology policy: Depending on the hierarchic position of any decision maker, every R&D policy measure can be classified as one or the other policy design. On the level of those decision makers who decide on the distribution of funds, the policy measure would be classified rather as a mission-oriented policy design; contrariwise on the level of the ministry the same policy measure will be classified as a diffusion-oriented or still mission-oriented one.

b) The impact of international projects: A number of R&D promotions are funded on the international level (in Europe on the EU level in particular). A classification of these promotion measures into one or the other policy design is quite difficult; in some projects specific countries are only involved by spending money without gaining any influence on the design of the project; in another project decisions are made by several parties each with equal rights; in a third one only the country under consideration has the lead in a certain project.

c) Policy mix: As the statistics we use show a relatively high aggregation level within certain policy areas, there are several measures showing a high proportion of rather mission-oriented design whereas others tend to be diffusion-oriented. An unequivocal classification is impossible on this level of aggregation. In those cases the aggregate is classified to the policy design in which the main measures are classified.

5. Results

- *policy portfolio*

In order to give a first idea of the topography of German technology policy we first draw back on the matrix of fig. 1 introduced above and fill it with data of the most recent (reliable) year 1996 of our database. The different promotion areas are reflected as bubbles where the size of the bubble represents the financial amount invested. This illustration already gives a first hint on the design of policy of this year. The largest share of expenditures of technology policy is located in the fields with high market distance, i.e. those fields representing basic research. Also it becomes obvious that in Germany policy is guided by the vision of large development potentials for space technologies (here also the commitment in multinational programmes as ESA have to be mentioned), as well as nuclear fusion and biotechnologies, where the latter more and more gains in market vicinity. The bulk of expenditures, nevertheless is located in pure basic research in the first quadrant e.g. financing of universities, Max-Planck-Organisations etc. A look at the upper two areas of technology policy reveals a diffusion-orientation of German technology policy for the year 1996. The bulk of measures is located in the quadrant with a low technological specificity. Besides the ‘indirect measures’, which demand a large part of the diffusion-oriented policy measures, also so-called new technologies e.g. ‘new materials’, ‘information and communication technologies’ etc. are located here and are designed without prescribing specific technological features or aims. The large promotion areas with clear technological targets, the mission-oriented fields are ‘nuclear power’, ‘hypersonic’ and ‘environmental technologies’, the first two are also characterised by declining financial budgets in the course of time. From this we conclude the diffusion-orientation to be an intended goal of the design of policy measures in Germany.

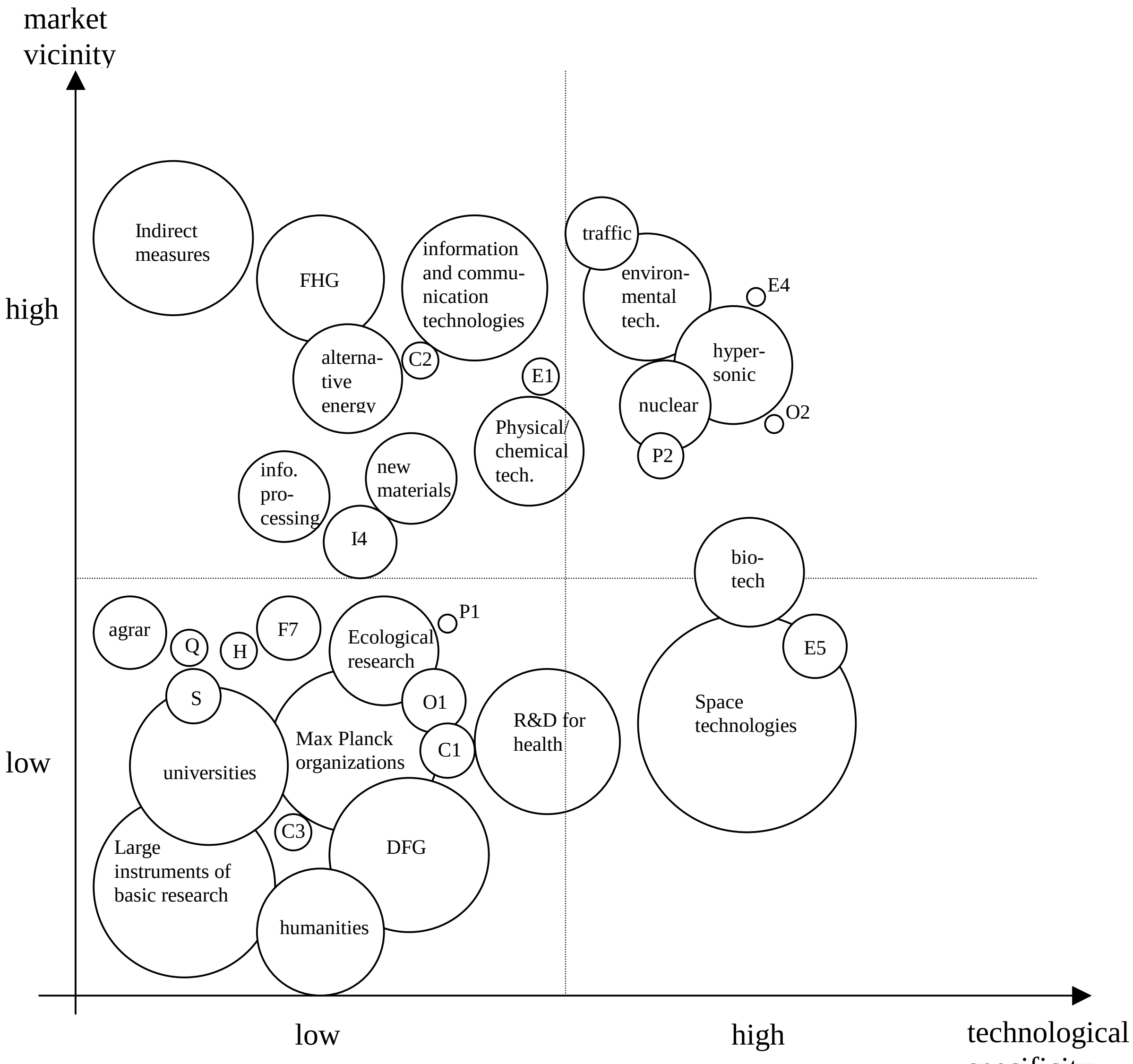

Fig. 2: Classification-Matrix for 1996

- Basic research funding versus technology policy in a narrow sense

In a second step we draw back on our time series of the last 20 years to show the development and changes of German technology policy with respect to the share different policy styles occupy. The following figures are made comparable by deflating them with prices of 1991 taken from the report of the ‘Sachverständigenrat’ (1996). In order to get an idea about the significance of measures aiming at basic or applied research - according to the vertical axis of our classification matrix describing market vicinity - in fig. 3 we summarised the applied fields with a mission- and a diffusion-orientation, as well as basic I and basic II/vision.

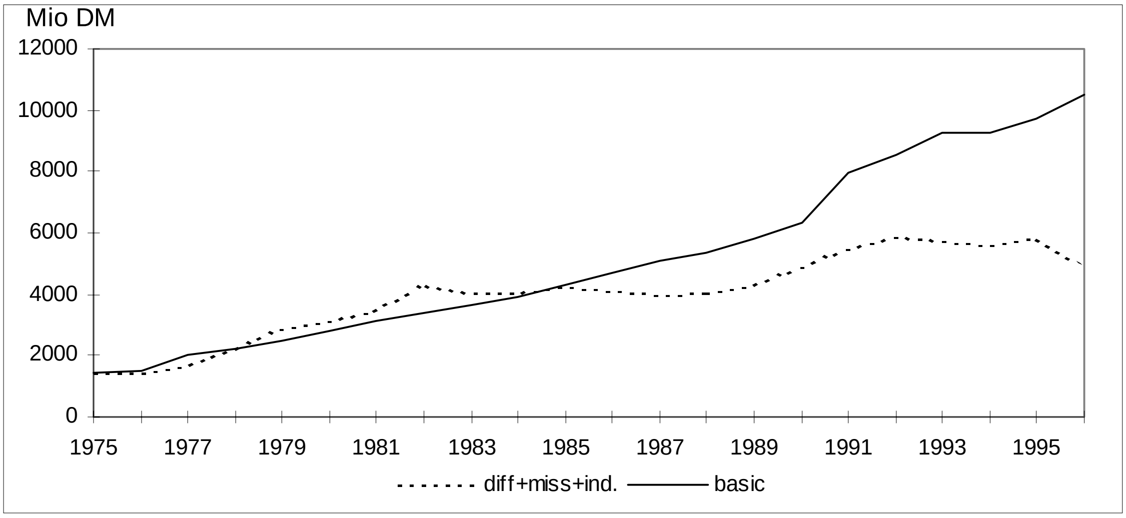

Fig. 3: Development of expenditures according to market vicinity

For the first 10 years of the period observed technology policy located in the basic research areas almost amount 50% of total technology policy, since 1985 this share is even increasing to about 60%. The sharp increase since 1991 is initiated by the German re-unification, demanding large efforts in order to re-structure the institutional research in the ‘Neue Bundesländer’. These figures underline our additional classification differing between a high and low market vicinity, avoiding distortions of immediately including funds for basic research in the classification of technology policy in a narrow sense.

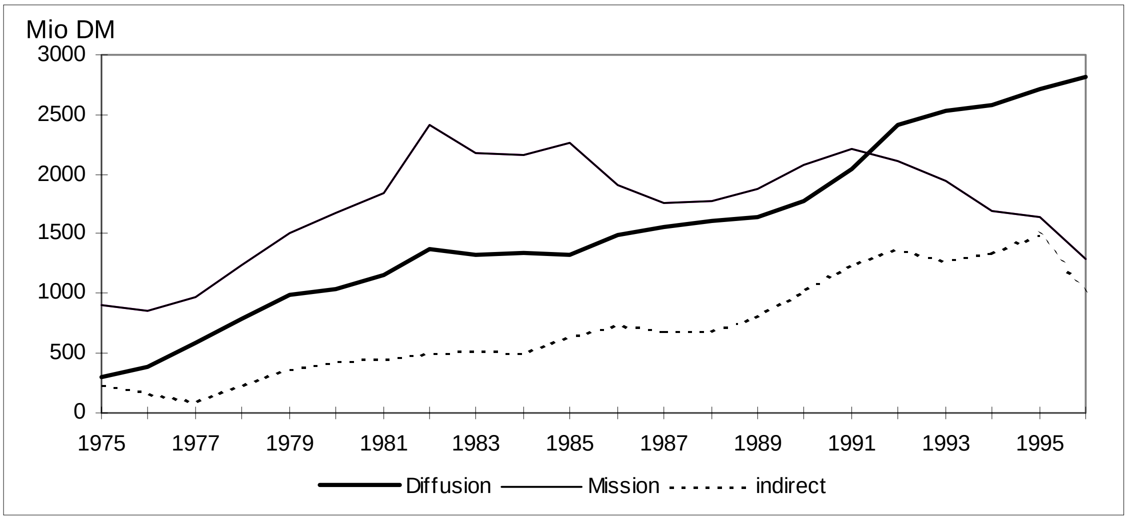

Fig. 4: Development of expenditures in mission-, diffusion-oriented and indirect measures

- Mission- versus diffusion-orientation

To work out the dominating orientation of technology policy in Germany we look at the time series describing the development of funds in the specific policy designs shown in fig. 4. Here, we find a clear dominance of an mission-orientation until the early 90's, which in a way contradicts Ergas' classification of Germany as a diffusion-oriented country. Of course, the Ergas result is a relative one, where Germany is compared to other countries. Our result is based on comparing the absolute values in Germany. But this accepted, it nevertheless is quite remarkable that the share of mission-oriented policy has declined so considerably.

During the years of decline of mission-oriented means, the amount of public funds invested in areas such as 'nuclear power', 'hypersonics' and other mission-oriented fields claimed for the largest shares of public support. However, two developments show a distinct increase in policy measures designed according to the diffusion-oriented policy style. Besides (i) the immediate diffusion-oriented promotion areas, which overtake the mission-oriented measures in seize in 1991, also (ii) indirect measures, such as the building up of a technological infrastructure etc. gain in significance over the whole period observed.

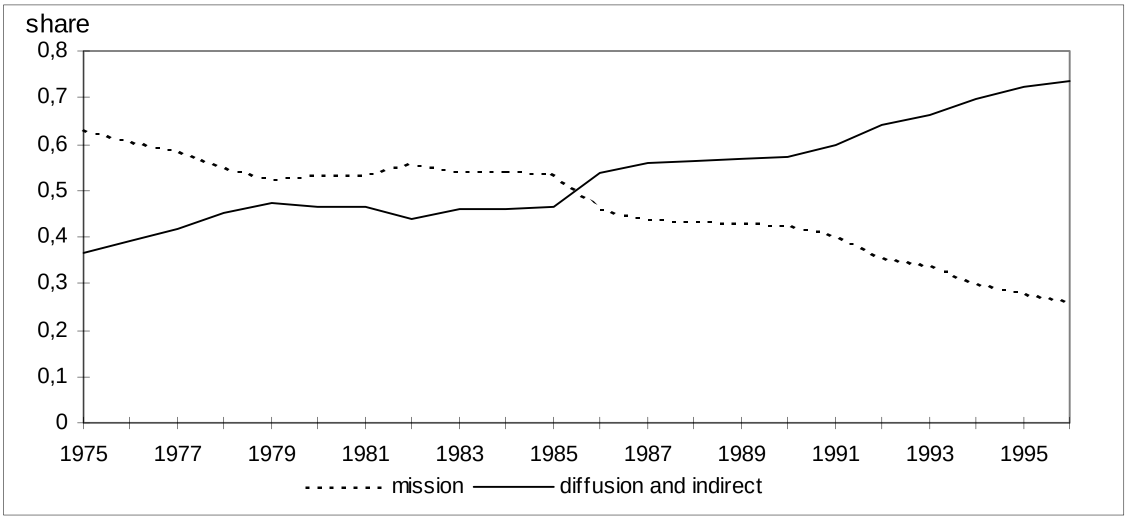

Fig. 5: Relative shares of mission- and diffusion-oriented policy

If we add indirect and diffusion-oriented measures we come closer to Ergas' original classification made in 1987. In fig. 5 the respective relative shares of these two broad categories - diffusion-oriented plus indirect and mission-oriented - are depicted. It becomes visible that the dominance of mission-oriented policy ended already in 1986. So, since the mid 80's an overall diffusion-orientation of German technology policy can be claimed. Additionally, there is a growing trend of the dominance of diffusion-oriented policy measures still lasting since the mid of the 90's. This increasing dominance can be traced back to new promotion areas like 'new materials', 'information and communication technologies' etc., in which the design of the policy instruments more and more gives up the aim of prescribing technological specificities, leaving it to the creativity of market and non-market actors. Taking this development one may ask for the reasons of this policy change. Of course, political reasons (e.g. nuclear power) are to be taken into account. However, furthering diffusion and thus heterogeneity is always an appropriate measure, when the policy makers do not have a clear idea about the direction of further development. However, the insight that the innovativness of a country depends on *collective* innovation, too, might also have induced this policy shift. In this sense policy does not have to lead the development but *only* to manage it - or only to be one actor in the collective process.

- *Collective invention*

Finally, our data allow to test Ergas hypothesis of co-operative R&D as a significant feature of diffusion-oriented policy design. Within the single promotion areas, the 'Förderkatalog' of the BMBF also gives information about the recipients of public funds and whether the research projects are organised in a so-called ‘Forschungsverbund’, i.e. if there is more than one actor involved.

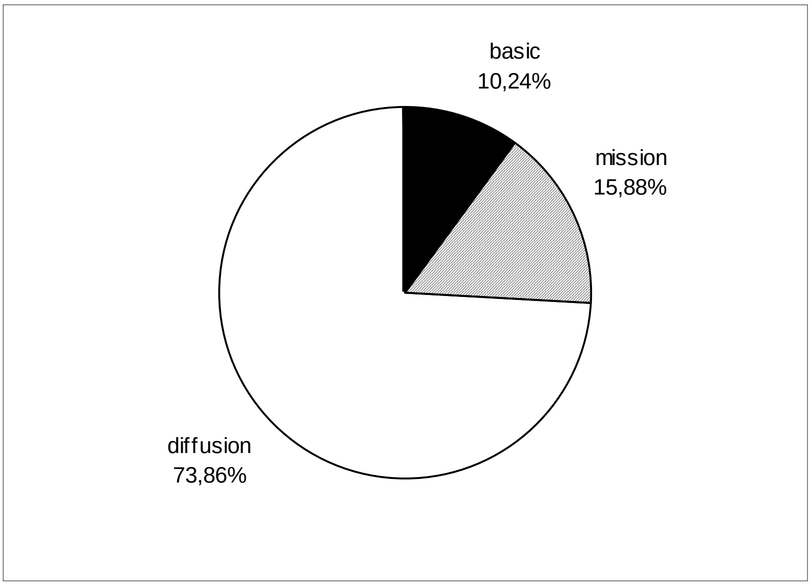

Fig.6: Shares of co-operative measures 1996

In figure 6 the respective shares of co-operative R&D classified to the different policy styles are depicted. Whereas the share of co-operative R&D in the fields of basic research and mission-oriented policy measures are comparatively low, together they claim only about one quarter of all funded co-operative projects, the bulk of co-operative research projects can be found in within the group of diffusion-oriented policy measures. Accordingly, with respect to the number of co-operations, Ergas’ criterion seems to be adequate. However, if this number is weighted with the amount of money spent for single measures, the situation changes significantly especially favouring large-scale basic-research projects.

6. Conclusions

For the classification of technology policy in an evolutionary framework the taxonomy to differ between mission- and diffusion-oriented policy design introduced by Ergas (1987) is useful. In particular this scheme gives a clue whether the policy orientation aims at the realisation of specific goals, thereby neglecting the development potentials arising out of heterogeneous technological approaches, or accepted to be an only imperfect informed actor in an overall search and experimentation process guided by the creativity of a multitude of actors, which also means however, to be permanently threatened by failure. Anyway, Ergas' indirect method is only able to give a first and crude insight of the technology policy of a specific country. Therefore, we developed a so-called direct method aiming at a sound characterisation of single policy measures and giving a more detailed picture about policy orientation. By applying this direct method on data describing German technology policy over the last 20 years, we outlined a significant reorientation in the design of policy measures. In the most recent years a clear dominance of a diffusion-orientation in technology policy in Germany can be stated, which also gives a hint on a kind of *policy learning*. Whereas up to the mid 80's large-scale mission-oriented programmes were in the centre of interest, significant problems and failures in these promotion areas lead to an increasing emphasis on diffusion-oriented and indirect measures.

In this respect also the idea of mission-oriented programmes to spur *intentionally* cross-fertilisation has to be carefully interpreted. Although the amalgamation of specific technological trajectories and/or fields of sciences is intended, issuing such a policy neglects the specific demands of technological development emphasised by evolutionary economics. It is the technological heterogeneity and the interplay of different actors in innovation and diffusion processes which constitutes the cultural and technological evolution. In this respect, mission-oriented programmes unavoidably have to restrict themselves on ex-ante chosen technologies, thereby neglecting consequences of the contingencies going hand in hand with true uncertainty of innovation processes.

In a way the emphasis on heterogeneity of diffusion-oriented policy measures is furthering both: competition, as a selection process between different technological approaches, as well as creating an environment in which cross-fertilisation and with it, the emergence of new technological opportunities can spread out. Therefore and contrary to Ergas' assumption, these measures also concentrate on early phases of the technological life cycle, whereas mission-oriented policy measures aim on technologies in the mid of the technological life-cycle by trying to succeed in getting technological standards accepted in those technological fields which have proven to be successful.

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Appendix

	promotion area
A	research organisations; restructuring institutional research in the new Bundesländer; universities
A1	Max-Planck-Organisation
A2	Deutsche Forschungsgemeinschaft
A3	Fraunhofer Gesellschaft
A4	restructuring institutional research in the new Bundesländer
A5	universities
A6	special university programmes
B	large instruments of basic research
C	research of oceans and the polar region
C1	ocean
C2	sea-technologies
C3	polar
D	space technologies
E	energy
E1	coal and other fossil energy sources
E2	alternative energy
E3	nuclear power
E4	recycling of nuclear power plants
E5	nuclear fusion
F	environment; climate
F1	ecological research
F2	environmental technologies
F5	water
F7	climate and atmosphere
F8	safety
G	health
H	improving labour conditions
I	information technologies
I1	computer sciences
I2	communication
I3	electronic devices
I4	micro systems
I5	manufacturing technologies
K	biotechnology
L	new materials; chemical and physical technologies
L1	new materials
L2	physical and chemical technologies
M	hypersonics
N	traffic
O	geology and raw materials
O1	geology
O2	raw materials
P	regional sciences
P1	urban development
P2	construction/architecture
Q	nutrition
R	agriculture, wood and fishery
S	education
T	innovation infrastructure
T1	R&D employment subsidies
T2	knowledge transfer
T3	venture capital
T4	other indirect means
T8	rationalisation
T9	else (indirect)
U	specific information
V	humanities