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The National Innovation System in Germany

Matthew M. C. Allen

University of Manchester, U.K.

Brief history and description of the National Innovation System in Germany

Many aspects of Germany's innovation system have their roots in the 19th and 20th centuries. For instance, characteristics of apprenticeship schemes and universities as well as the origins of important research institutes, such as the Max Planck Society, and large and innovative industrial companies—for example, BASF, Daimler, Hoechst (part of sanofi-aventis since 2004), and Siemens—can be traced back to the first half of the 20th century and, indeed, in many cases to the latter half of the 19th century and beyond. It will not be possible here to describe the various changes that have taken place in the innovation system since then (for more detailed historical accounts see Grupp, Dominguez-Lacasa, and Friedrich-Nishio, 2005; Keck, 1993). This chapter will, instead, focus on more recent changes. This chapter will, of course, draw attention to the historical foundations of those institutions that have been part of the National Innovation System (NIS) in Germany for decades. It will, in addition, cover those aspects of the NIS that have been created or that have come to prominence more recently.

The importance of earlier periods should not, however, be underestimated as Germany's innovative strengths often still lie in those industries that came to prominence in the 19th century. For instance, and as will be shown, Germany continues to have strengths in vehicles, mechanical engineering, and certain electrical and chemical-related industries. However, in other areas, most notably pharmaceuticals, in which early innovations provided the impetus to the establishment of successful companies, Germany has fallen behind similarly advanced economies. The organizations that helped to create these successful companies, such as research institutes, and a strong vocational training and education system, have had to adapt to changing economic and political pressures. This is especially true today as politicians seek to adjust Germany's innovation system to meet heightened competitive pressures in order to ensure the continued strength of that system.

It should be noted at the outset that, because of Germany's Federal political structure, many policies at the national level are influenced by the concerns of the governments of the Federal states, or *Länder*. In addition, the *Länder* can supplement national-level policies with their own at the regional level. This is particularly true in relation to the education system. Therefore, it should be borne in mind that, although what follows depicts the characteristics of the national system, there may be substantial variation between the *Länder* in key areas. Moreover, the still relatively recent unification of Germany in 1990 has meant that many research institutes and industries are, on the whole, less well embedded in eastern Germany than they are in western Germany. There are, however, exceptions as, for example, the *Länder* of Saxony has managed to focus on promoting the establishment of innovation-oriented organizations within its borders. In some instances, it has done this more successfully than many of its peers, regardless of their geographical location.

Current institutional structure and its evolution

There are many important research institutes in Germany. Changes over the last couple of decades, which have arguably accelerated in pace, have sought to streamline the institutional structure in order, first, to promote research excellence; second, to gain the most from those resources that have already been invested; and, finally, to target funds to researchers and institutes that are most likely to produce the desired results. In terms of policy coordination and the channeling of research resources into certain institutes or areas, the Science Council and the German Research Foundation occupy key positions. The most important research institutes are the Hermann von Helmholtz Association of Research Centers, the Max

Planck Society, the Fraunhofer Society, the Leibniz Science Association, and the Centre for Advanced European Studies and Research (CAESAR) Foundation.

The Science Council

The Science Council plays an important role in Germany's innovation system. Established in 1957 following an agreement between the Federal Government and the *Länder* or Federal States, it has a coordination and advisory function with regard to the development of institutions of higher education, science, and research. Some of the most important recommendations that have influenced policy have included the introduction of new degree structures in German universities (see below), the system by which the activities of the Helmholtz Association should be evaluated, as well as proposals regarding the future role of universities in Germany's innovation system. In addition, the Science Council has the task of evaluating research institutes and accrediting, where warranted, newly established private institutes of higher education. It therefore provides guidance within the overall system. Furthermore, it monitors and helps to ensure high research standards within universities, an important element of the NIS.

The German Research Foundation

The German Research Foundation, or *Deutsche Forschungsgemeinschaft* (DFG), is the central, self-governing grant-awarding body in Germany. Its task is to provide financial support for research projects that are carried out, first and foremost, by researchers within higher education. It promotes research into all branches of the sciences and humanities at, primarily, universities and, secondarily, other publicly financed research institutes. The Foundation, furthermore, seeks to facilitate cooperation amongst researchers, to support the development of early-career researchers, and to promote links between German research centers and those abroad.

The German Research Foundation can trace its roots back to 1920 when its predecessor organization, the Emergency Association for German Science, or *Notgemeinschaft der Deutschen Wissenschaft*, was established. Refounded in 1949, this organization was, following a merger with the Research Council in 1951, renamed the German Research Foundation. Its current members include 69 institutions of higher education, 15 non-university research establishments, 7 academies, and 3 industrial associations.

Following a 2002 agreement, 58% of the funds provided by the DFG come from the Federal Government and 42% from the *Länder*. In 2006 the Foundation awarded research grants that totaled €1,588 million. Just over half of this (€817 million) was invested in coordinated programs. The Foundation awarded €568 million under its individual research grants program, and €16 million in prizes. A further €105 million was invested to support early-career researchers. Approximately 3% (€56 million) of the Foundation's budget supported research infrastructure projects. In 2006, €577 million (39%) of the Foundation's research budget for coordinated programs, the individual grants program, and schemes to support early-career researchers was used to fund projects in the life sciences; €388 million (26%) in the natural sciences; €313 million (21%) in engineering; and €211 million (14%) in the humanities and social sciences.

The Hermann von Helmholtz Association of Research Centers

In 2001, 15 research centers that focused on various aspects of biomedicine, science, and technology came together to form the Helmholtz Association. It is the largest research organization in Germany. In 2006 its budget of €2,349 million was largely met by government funds (two-thirds). The Federal Government's share of this funding was 90%; the *Länder* provided the remainder. The approximately one-third of funding for individual Helmholtz Centers that does not come directly from government sources includes support from both the public and private sectors, and the European Union (EU). In 2007 the Association employed approximately 26,500 persons, of whom 8,000 were senior researchers.

Despite focusing on different technological fields, the research centers are united by a commitment to the pursuit of long-term objectives that are of benefit to society. The Association therefore seeks to link research and technology development with measures both to prevent medical ailments and to apply innovations in various areas. In doing so, it identifies and conducts research into highly advanced areas that are of major strategic and programmatic importance to society, science, and industry. Such research often involves major capital expenditure on both equipment and facilities.

The year 2001 marked an important change in the allocation of funds within the Association. Since 2001, finances flow to the Association rather than the individual Centers, as had been the case up until then. The Association then awards funds to research programs that are carried out by the Centers, which are legally independent entities, in cooperation with one another. The change has therefore facilitated a move towards greater collaboration between the Centers. This is intended to enhance the Association's strategic importance and its research performance. The reform is hence intended to promote not only the development of researchers' capabilities, but also innovation. The collaborative research undertaken at the Centers is carried out with other national and international partners.

In order to facilitate knowledge transfer both between the various Helmholtz Association Research Centers and between the Centers and industry, the long-term mission and work priorities of the Centers, drawing on their key strengths, have been streamlined to focus on six major areas. These are energy, the environment, health, key technologies, the structure of matter, and, finally, transport and space. The decisions to fund individual projects are taken by the Federal Government and the *Länder*; their opinions are, however, based on the assessments of project proposals by international groups of experts.

The Max Planck Society for the Advancement of Science

The Max Planck Society for the Advancement of Science was founded in 1948 as an independent, not-for-profit research organization. Although founded after World War II, its roots can be traced back to before World War I, as it is the successor organization to the Kaiser Wilhelm Society, which was established in 1911. The Max Planck Society has grown from 25 research institutes in 1948 to 78 institutes and research centers in Germany in 2007. In addition, it has three overseas institutes and several branches abroad. In total, the Max Planck Society employs approximately 23,400 people. Its 2007 budget of €1,433 million was funded to a large extent (82%) by the Federal German Government and the *Länder*. The remainder was met by donations, externally funded projects, and members' contributions.

The common goal of the various Max Planck Society research institutes in the natural sciences, life sciences, and the humanities is to perform basic research in the interests of the general public. By conducting such research, these institutes seek to pursue innovative research agendas that German universities may lack the resources in terms of both finances and personnel to carry out. Moreover, the Max Planck Society seeks to perform research that is of a more inter-disciplinary nature than that often performed at German universities. This is not to suggest, however, that the activities of the research institutes of the Max Planck Society are wholly divorced from those of German universities. Indeed, in many areas, the Max Planck Society institutes complement research performed elsewhere. Moreover, some institutes make their equipment and facilities available to a wide array of researchers.

The Fraunhofer Society

Founded in 1949, the Fraunhofer Society initially undertook a largely advisory and administrative role to channel public funds to researchers who were conducting research projects that could benefit industry. In the 1970s, its role changed as it began to receive funding from the Federal Government, which matched that from industry, to perform its own research. This emphasis has continued to the present day as the Society aims to undertake applied research that is a direct benefit to private and public enterprises and that also aids society as a whole. It conducts contract research for those in the private (both manufacturing and services) and public sectors. There are 56 Fraunhofer institutes in Germany; they employ approximately 13,000 people. In addition, it has research centers in other European countries, the U.S.A., Asia, and the Middle East. Funding for the Fraunhofer Society reflects its main aim. In 2006 its revenues amounted to €1,186 million. The lion's share of this funding (€787 million, or 66%) came from public sources, which included revenues from the Federal and *Länder* governments, and the Ministry of Defense. Industry provided approximately one-third of the Society's revenues (€399 million).

The Society's remit is to fill a gap in Germany's research structure. For instance, university research (see below for the contribution of the education system to Germany's NIS) often focuses on basic science. It is funded almost entirely from public sources. By contrast, industrial research and development seeks to generate commercial opportunities from research, most of which is financed by private enterprise. Therefore, the Fraunhofer Society, which relies on both public and private funds, aims to pursue not only more application-oriented research than that conducted at universities and other research institutes in Germany, but also studies that are of a more "basic research" nature than those undertaken by commercial organizations. Its links to industry are, as a result of its objectives, stronger than those of other research institutes in Germany.

The Leibniz Science Association

The 84 institutes of the Leibniz Science Association (formerly "Blue List Institutions", which were initiated in 1977) are funded by the Federal Government and the *Länder* as independent research centers. Their two main roles are to conduct their own inquiries and to provide supporting services, which can include advice on knowledge transfer and the use of equipment, to other researchers and research institutes. This latter function means that they play an important part in carrying out university-led research projects. They thus form a cardinal and uniquely close link between the wider research system and university-instigated research. This does not, however, mean that studies conducted within the Leibniz Science Association Centers are only carried out in collaboration with university-based research: support is also provided to researchers based elsewhere, such as those at the Max Planck Society, the Fraunhofer institutes, and, indeed, national and international companies. As the research activities of the Association's Centers lie between basic and applied research, the Association aims to form a link between the two. In order to facilitate innovation as well as cooperation between various research centers, the institutes of the Leibniz Science Association focus on:

- regional collaboration with universities in an attempt to form clusters;

- inter-disciplinary inquiries into areas that are likely to be of increasing prominence in the future (infectious diseases, learning research, environment and climate change research, marine research, and optical technologies); and
- inter-disciplinary working groups.

The focus on inter-disciplinary research reflects the broad focus of the Association's work. The five sections of the Association are:

- humanities and educational research;
- the social sciences and regional infrastructure research;
- the life sciences;
- mathematics, the natural sciences, and engineering; and
- environmental sciences.

Of the Association's total budget of €1,102 million in 2006, €756 million came, in equal measure, from the Federal and *Länder* governments. Other sources of funding include EU research grants, the private sector, and income from licences and services.

The Center for Advanced European Studies and Research (CAESAR) Foundation

The Caesar Foundation is a relatively new addition to Germany's innovation system. Established as part of the Bonn Berlin Compensation Law of 1994, which was designed to offset some of the expected job losses as a result of the decision to move the Federal capital and the majority of ministries and embassies to Berlin, the Foundation conducts basic and application-oriented research in nanotechnology, biotechnology, and neuroscience.

Uniquely amongst the major public research institutes in Germany, the Foundation does not receive an annual grant from either the Federal or *Länder* governments. Instead, it is financed from returns from its endowment fund (totaling €383 million, of which €350 million came from the Federal Government and €33 million from the state of North Rhine Westphalia) and from research conducted on behalf of industry. As a result of its funding structure, the Foundation focuses strongly on linking science and research to innovations that are likely to be commercially viable, to cooperating with the private sector, and to gaining research contracts.

Summary of output trends (R&D expenditure, patents, etc.)

Although research and development (R&D) expenditure in Germany still falls below the target of 3% of gross domestic product (GDP) as outlined by the EU's Lisbon Agenda, it still invests more than many other European countries, such as the U.K. Indeed, as Table 47.1 shows, gross domestic expenditure on R&D (GERD) as a percentage of GDP grew between 1994 and 2004 in Germany, whilst it fell in the U.K. Moreover, in 2004 just over two-thirds of GERD was financed by industry in Germany, whereas in the U.K. under half was funded by the domestic private sector. The German figure is comparable with the share of R&D supported by U.S. and Japanese industry. Between 1994 and 2004 the share of GERD that came from the government fell in Germany from 37.5% to 30.4%. As is discussed in greater detail below, the German Federal Government in association with the *Länder* has announced a number of measures that, in part at least, can be seen as attempts to redress this imbalance, particularly in research areas that may be neglected by the commercial sector (for other measures of technology output trends in Germany see BMBF, 2007).

In terms of patents, Germany has often been seen, as Japan has, as strong in medium to high-tech industries, such as automobiles, mechanical engineering, and certain electricity-related sub-sectors. Indeed, it can be argued that Germany is to a far greater extent reliant on innovation from these sectors than any other country, including Japan (Frietsch, 2007). Put another way, whilst innovation in Germany is undoubtedly strong in medium to high-tech industries, patents in cutting-edge technologies are on the whole weak.

Table 47.2 shows the relative patent advantage (RPA) for selected countries and high-tech sectors. The RPA scores are calculated by comparing the number of patents in a particular sector in a certain country with the total number of patents for all sectors of the economy for that country; this figure is then compared with the same ratio for the world as a whole. Once transformed to make the score symmetrical around zero, the RPA indicates the degree to which a country specializes in patents in the individual sectors. Positive RPA figures show that a country specializes in that sector to a greater extent than the "global average"; negative figures, that a country is less focused on that sector.

Table 47.2 reveals that Germany's innovation system remains strong in areas such as motors and engines; vehicles, vehicle engines, and parts; precision instruments; machine tools; agricultural equipment; and trains and trams. By contrast, Germany is comparatively weak in the following sectors: data-processing equipment; electro-medical equipment; biotech, pharmaceuticals, and medicines; medicaments; radio and television equipment; communications technology; office machines; and optical and photographic equipment. As many of the latter sectors are expected to be amongst the key drivers of economic growth and employment in the future, reforms within Germany's innovation system have been designed to rebalance innovation activities towards these sectors.

Table 47.1. Expenditure on R&D, total, and by funding source.

	1994	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*
Gross domestic expenditure on R&D (GERD)—percentage of GDP											
Germany	2.2	2.2	2.2	2.2	2.3	2.4	2.5	2.5	2.5	2.5	2.5
U.K.	2.0	1.9	1.9	1.8	1.8	1.9	1.9	1.8	1.8	1.8	1.7
U.S.	2.4	2.5	2.5	2.6	2.6	2.6	:	:	:	:	:
Japan	2.8	2.9	2.8	2.9	3.0	3.0	:	:	:	:	:
Percentage of GERD financed by industry											
Germany	60.4	60.0	59.6	61.3	62.4	65.4	66.0	65.7	65.5	66.3	66.8
U.K.	50.3	48.2	47.6	49.9	47.6	48.5	48.3	45.6	43.6	42.3	44.2
U.S.	58.5	60.2	62.4	64.0	64.8	66.5	68.6	66.6	64.6	61.4	:
Japan	68.2	67.1	73.4	74.0	72.6	72.2	72.4	73.0	73.9	74.5	:
Percentage of GERD financed by government											
Germany	37.5	37.9	38.1	35.9	34.8	32.1	31.4	31.4	31.6	31.2	30.4
U.K.	32.7	32.8	31.5	30.7	30.6	29.2	30.2	28.8	28.8	31.6	32.8
U.S.	37.0	35.4	33.2	31.5	30.1	28.4	25.8	27.5	30.3	30.4	:
Japan	18.1	19.4	18.7	18.2	19.3	19.6	19.6	18.6	18.2	17.7	:
Percentage of GERD financed from abroad											
Germany	1.7	1.8	2.0	2.4	2.5	2.1	2.1	2.5	2.4	2.3	2.5
U.K.	12.3	14.5	16.3	14.6	16.9	17.3	16.0	19.8	21.6	20.4	17.2
U.S.	:	:	:	:	:	:	:	:	:	:	:
Japan	0.1	0.1	0.1	0.3	0.3	0.4	0.4	0.4	0.4	0.3	:

Source: Eurostat.
Notes: Rounding errors may prevent the relevant column totals summing to 100%.
" : " signifies that the data are not available.

In summary, the RPA scores reveal that Germany's innovation strengths do indeed often lie in those medium to high-tech industries that emerged in the 19th century. This patent specialization frequently leads to comparative advantages for Germany in the same sectors (for information on the sectors of the German economy that have a comparative advantage see Allen, 2006). It should, however, be noted that the RPA scores are aggregated at the sectoral level; this may mean that they mask strengths in sub-sectors within those sectors. For instance, within the biotech, pharmaceuticals, and medicine sector, Germany has a negative RPA score. However, it has been shown that within the biotech sector, those innovation activities—such as platform-enabling biotechnologies that are related to greater levels of organizational complexity and appropriability risks—may be facilitated by Germany's innovation system (Casper and Whitley, 2004):

Technology commercialization initiatives (national level)

In 2001 the Federal Government launched an "action scheme" that was designed to improve technology commercialization initiatives (BMBF/BMWi, 2001). After identifying deficits, the Federal Government launched "offensives" in the following four areas:

- exploitation, which focuses on transferring research results more rapidly into commercial products and services;
- spinoffs, which intends to increase the number of research-related startups;
- partnerships, which concentrates on improving incentives for collaboration between research institutes and the private sector; and
- competence, which aims to facilitate the use of research results in firms' innovation processes.

Table 47.2. Patent specialization for selected countries and high-tech (cutting-edge and medium to high-tech) sectors, for the period 2002 to 2004.

	Germany	*U.S.*	*Japan*	*EU*
Aircraft and spacecraft	8	28	−82	15
Data-processing equipment	−51	27	7	−31
Electro-medical technology	−41	35	−10	−29
Inorganic chemicals	9	−15	29	−4
Biotech, pharmaceuticals, medicines	−31	35	−34	−15
Engines and motors	41	−46	28	15
Other speciality chemicals	15	10	-3	3
Medicaments	−38	36	−45	−15
Vehicle, vehicle engines, and parts	63	−71	20	36
Organic pest control	−4	28	−47	−9
Measuring equipment	−1	4	14	−6
Warships, weapons, etc.	47	−36	−89	36
Lamps, batteries, etc.	12	−38	54	−13
Radio and television equipment	−81	−32	48	−50
Medical equipment	−45	48	−57	−25
Machines, n.e.s.[a]	43	−49	−30	28
High-value instruments	34	−23	−23	20
Machine tools	45	−41	-5	25
Communications equipment	−39	5	−11	−13
Office machines	−48	−14	75	−60
Power generation and distribution	26	−54	40	3
Climate, filtration, and air conditioning	15	7	−42	12
Dyes and pigments	24	−16	40	−3
Agricultural machinery and tractors	52	−44	−83	44
Polymers	12	1	37	−4
Optical equipment	−50	1	53	−34
Electronics	−38	7	52	−40
Optical and photographic devices	−56	−20	68	−53
Rubber manufactures	−36	−28	58	−27
Organic chemicals	−9	26	−32	−5
Trains and trams	68	−94	−60	49
Pyrotechnics	31	−3	−71	23
Photochemicals	−88	52	48	−73
Radioactive materials, nuclear reactors	12	21	−60	15
Essential oils and surfactants	6	19	−22	19

Source: Frietsch (2007, p. 21).
Note: author's translation.
[a]Not elsewhere stated.
Germany's RPA score is calculated thus:

$$\mathrm{RPA}_{kj} = 100 * \tanh \ln\left[\left(P_{kj}\Big/\sum_j P_{kj}\right)\Big/\left(\sum_k P_{kj}\Big/\sum_{kj} P_{kj}\right)\right]$$

where tanh is the hyperbolic tangent and P_{kj} represents the number of patent registrations of country k in sector j. Positive values mean that a sector has a greater weight within the relevant country than it does within the world. Negative values indicate that the country has a below-average specialization in that technological field.

As part of the "exploitation offensive", the Federal Government initiated moves to establish patent and exploitation agencies (PVAs), which would be dedicated to patenting innovations that emerge from universities and other publicly-funded research institutes in Germany. As individual universities may lack the resources and expertise to establish their own PVA, each PVA is responsible for the patenting activities of several universities within a region. A further change under the "exploitation offensive" has been to the so-called university teachers' privilege. This privilege, which granted university teachers the sole authority to decide whether or not to patent their inventions, was abolished in February 2002. Now, in general, inventions are owned by the university. If an invention is patented and if that patent generates revenues, the university researcher receives 30% of the gross income. Other measures that are designed to facilitate cooperation between researchers have been undertaken.

In order to support researchers who wish to set up their own business, the Federal Government has increased publicly-available funds for this purpose (see below). Furthermore, the Federal Government is seeking to create a more favorable environment for spinoffs and startups; for instance, by establishing associations that enable experienced entrepreneurs to mentor new ones, by creating awards for entrepreneurs, and by investing in professorial chairs in entrepreneurship at 18 higher education institutes.

In its efforts to encourage greater collaboration between research institutes, the Federal Government has streamlined its funding to them and has acted upon recommendations to draw research centers together into broader associations (see below). It is hoped that organizational barriers that impede cooperation will be reduced as a result. In addition, the Federal Government has changed its funding regulations. Now, if a project receives Federal financial support, it must contain an exploitation plan and that plan must be implemented. As part of its "competence offensive", the Federal Government has reformed the *Meister* qualification in certain vocations and has upgraded vocational training centers so that greater use can be made of information and communication technologies.

National technology policy

Technology policy in Germany has three main strands. The first is the focus set by the government on establishing objectives for researchers in both the public and—through the use of incentives—the private sectors. The second element within technology policy concentrates on improving the research and development "infrastructure" (research institutes and equipment that requires major capital outlays). Finally, technology policy seeks to improve the skills and capabilities of scientists and researchers who either work in Germany or may be about to embark on a career in an innovation field. To be sure, in practice, the distinctions between these three elements are not wholly discrete, and, for instance, funds used to increase Germany's innovation infrastructure have implications for the development of individuals. Despite this, the categories of strategy, infrastructure, and people are useful ones to structure the following portrayal of Germany's technology policy. The latter part of this trio is covered in the education section below.

Innovation strategy

In an attempt to create the conditions in Germany that will enable researchers and organizations to gain leading positions in markets that are both technologically advanced and likely to grow in importance in the future, the Federal Government announced, in August 2006, a High-Tech Strategy for Germany. This is the first time that a national strategy has been developed that spans all ministries in Germany. Its contents have been shaped, during extensive consultation exercises, by representatives from industry and science. It is hoped by the Federal Government that the Strategy will give renewed impetus to its efforts to turn Germany into the country that provides the most conducive conditions in the world for research and innovation. By doing so, the Federal Government aims to be able to attain high rates of environmentally sustainable economic growth.

The High-Tech Strategy for Germany concentrates on altering technology policy in four main ways.

1. The High-Tech Strategy defines goals for 17 technology fields that are likely to be important in terms of both jobs and prosperity in the future. For each one of these 17 areas, a number of initiatives are planned. These initiatives focus on the promotion of research and the framework conditions within which it takes place. In addition, the aim of the Strategy is either to establish new markets for innovative products and services or to increase the economic importance of existing markets. Three of the technology fields that are deemed to be of cardinal importance in the future are health, security, and energy.
2. The Federal Government aims to harness the innovation capabilities of both science and the private sector in its High-Tech Strategy. In order to do so, cooperation and collaborative projects will be promoted to a much greater extent than has previously been the case, a research incentive will be introduced that should encourage publicly-funded institutes to gain more contracts from the private sector, and greater support will be provided to facilitate the formation of clusters in cutting-edge technologies.
3. The High-Tech Strategy aims to enhance efforts to turn research results more rapidly into innovative products, services, and processes. In order to achieve this goal, new measures have been introduced that are designed to simplify the assessment of the economic viability and value of research ideas and results. The High-Tech Strategy, furthermore, supports the efforts of the private sector to establish industry norms and standards more quickly. This, in turn, should increase the competitiveness of commercial organizations. Public

procurement will also be adapted so that the possibility of purchasing innovative products and technologies will be evaluated.

4. In pursuing its High-Tech Strategy, the Federal Government aims to improve the conditions for innovation-oriented startups and SMEs. The Strategy aims to ease the access to markets for company founders, improve the links between commercial entities and research institutes, facilitate the transfer of SMEs' own innovation-focused activities into new products, and simplify various schemes used to aid SMEs. One concrete measure that has been taken to improve the general framework conditions within which startups and SMEs operate is the reform of corporation tax. Other planned measures include the promotion of venture capital in Germany.

It is too soon to judge the effects of the High-Tech Strategy on Germany's innovation system.

Germany as a location for research and innovation

In response to heightened competitive pressures and the desire to improve Germany's innovation capabilities and hence economic performance, the Federal Government has initiated a number of programs and measures that are designed to create the framework and incentives that are needed to promote research and technological advances. The most important individual measures and programs, which form part of the Federal Government's Campaign for Innovation and Growth, that have recently been implemented include

- the Joint Initiative for Research and Innovation;
- the €6,000 million program for research and development (2006–2009);
- the Federal Government and the *Länder*'s Initiative for Excellence to promote science and research at German institutes of higher education (see section on education below).

The Joint Initiative for Research and Innovation

On June 23, 2005 the Federal Government and the *Länder* adopted the Joint Initiative for Research and Innovation. As a result of this Joint Initiative, most of the major science and research institutes mentioned above (the Hermann von Helmholtz Association, the Max Planck Society, the Fraunhofer Society, the Leibniz Science Association, and the German Research Foundation) have since 2006 received greater financial support. This increase is designed to enhance their performance, facilitate stronger and more extensive cooperation, and promote the development of early-career researchers. In addition, the Joint Initiative contains provisions that should enable new and unconventional projects to receive higher levels of funding. A yet further aim of the Joint Initiative is to enhance the formation of clusters that include researchers from both the public and private sectors. Support for women in research and science will also be increased. In order to achieve these objectives, the Federal Government and the *Länder* have decided to increase the budgets of the research institutes by at least 3% (or an additional €150 million) per year until 2010.

This additional funding, which will flow to research and innovation-focused activities in Germany, has been aided by the Lisbon Strategy of the EU. This Strategy was initiated by the European Council in 2000. One of its objectives is to increase the expenditure on research and development amongst the EU member states to 3% of GDP by 2010. In 2007 this figure was 2.5% in Germany.

The €6,000 million program for research and development

In order to stimulate innovation further, the Federal Government intends to invest an additional €6,000 million in research and development projects between 2006 and 2009. This increased funding has been earmarked to promote promising innovations that can be used to increase economic efficiency and hence economic and employment growth. In order to maximize the benefits, cooperation across Federal ministries will be emphasized. One of the reasons for enhancing the amount of public money available to research-related activities in Germany is, the Federal Government would contend, the move away from long-term research, the success and economic benefits of which may be difficult to predict, by private organizations. This has arguably led to an even greater onus on publicly-funded research for projects that have highly uncertain outcomes, but that if successful have clear benefits for society.

The €6,000 million program can be seen as one of the practical consequences of the High-Tech Strategy for Germany. That strategy seeks to prioritize research activities that are largely publicly-funded and attempts to maximize the gains from existing resources. The €6,000 million program focuses on providing additional funding in areas that promise the highest returns in terms of both economic and employment growth. Therefore, by allocating more resources to long-term, yet market-oriented research in the €6,000 million program, the Federal Government aims, partially at least, to anticipate and to be at the forefront of the markets of the future. Moreover, as a supplementary measure to the €6,000 million program, the Federal Government's entire research budget will be pooled and merged with the intention of producing greater benefits for society.

The technologies that have been prioritized under the €6,000 million program are information and communication technology, energy and security-related technology, and biotechnology and nanotechnology. The additional funds will also be used to strengthen research facilities and capabilities in Germany in the areas of medical technologies and pharmaceutical products. Such emphasis aims to build on existing strengths in these areas. For instance, Germany is the second largest exporter in the world of medical equipment; yet, it is relatively weak in terms of patents in this area. Some of the funding will be used to promote research into diagnostic and therapeutic compounds and procedures.

As the Federal Government sees the current quality and quantity of clinical trials as factors that restrict the competitiveness of Germany's pharmaceutical industry, research funding and the framework conditions for clinical research will be improved. Some of the additional funds that are being made available under the €6,000 million program will be used to conduct research into and the development of new sources of energy that are secure and economically and environmentally sound. In total, €2,000 million will be spent in this area between 2006 and 2009.

The Federal Government also plans to enhance the innovation capabilities of small and medium-sized enterprises (SMEs) as part of the €6,000 million program. In 2006, Federal funds to develop innovations and to intensify the exploitation of research findings increased by €62.5 million. Similarly, the Federal Government also launched a High-Tech Startup Promotion Fund in 2006. It is designed to encourage the establishment of new ventures that are based on cutting-edge technologies. The Fund aims to close the perceived gap in Germany for seed financing. Under the scheme, startups can receive a maximum of €1 million in equity financing. Between 2006 and 2009 the Federal Government plans to invest a total of €262 million under this scheme. Other programs that will benefit the innovation capabilities of SMEs are the Program to Promote the Innovation Capabilities of SMEs (PRO INNO II) Fund and the Cooperative Industrial Research Scheme. These programs saw increased funding, respectively, of €19 million and €6 million in 2006.

Relative strengths and weaknesses in technology

As noted above, Germany is relatively strong in medium to high-tech industries, but weak in cutting-edge technologies. Many of the policies adopted by the Federal Government are designed to address this shortcoming.

Funds flow for innovation

As noted elsewhere in this chapter, the majority of the funds for the activities of public research centers come from the Federal or *Länder* governments. However, as Table 47.1 also shows, most R&D expenditure comes from the private sector. It is worth noting here that one of the areas that has been seen as a weakness of Germany's innovation system has been the relative dearth of venture capital, which can cover seed, startup, expansion, replacement, turnaround, and bridge funding. As highlighted above, the Federal Government has announced a number of initiatives that are designed to address this shortcoming. According to the German Private Equity and Venture Capital Association, or *Bundesverband deutscher Kapitalbeteiligungsgesellshaften* (BVK), €50 million was invested as seed funding by venture capitalist investors in 2007. This represented approximately 6% of the €840 million invested by venture capitalists in that year. The majority of the funding went on expansion (c. 50%) and startups (approximately 36% or €300 million) (BVK, 2008). By comparison, according to the British Private Equity and Venture Capital Association (BVCA), £242 million was invested by venture capitalists in 2006 in the U.K. in startups; nearly £3,000 million was used to finance the expansion of companies by venture capitalists in the U.K. in 2006 (BVCA, 2007). Therefore, venture capital in Germany does not appear to be as available for the expansion of existing businesses as it does in the U.K.

In more general terms, it has often been noted that the financing of companies is shifting from a bank-based to a market-based system. This may have ramifications for the types of innovation that companies in Germany are able to carry out successfully. Put simply, it has been argued that banks are able to provide companies with "patient" capital that is focused on long-term returns. In contrast, the financial resources that are provided by markets or institutional investors mean that short-term returns are emphasized. Therefore, the provision of funding by banks may enable companies to carry out activities that they would not be able to do if they were funded largely by equities that are bought and sold by institutional investors who are focused on companies posting good financial returns in the short term. The ability of companies in Germany to adopt a more long-term approach, which can help to incease employees' firm-specific skills, has been said to be an advantage in those industries, such as vehicles and mechanical engineering, that, because they require employees with in-depth skills and knowledge about the firm's routines and products, rely on incremental rather than radical innovations (Hall and Soskice, 2001; see also Vitols, 2003).

Cultural and political drivers

The main cultural and political drivers in Germany's innovation are its education system and its vocational education training programs.

Education system

Education policies lie primarily within the responsibility domain of the *Länder*. This means that there can be substantial variation between the Federal states on, for instance, the length of time spent in different schools and the amount of emphasis on different school subjects. Therefore, the first part of this section provides a broad overview of the education system in Germany; it does not provide details on policies and practices in individual Federal states. It should also be noted that, although the Federal Government cannot direct the *Länder* to pursue certain policies, it can provide incentives to encourage them to implement certain measures.

Until the age of approximately 10, all pupils, regardless of ability, attend the same sort of school. After that age, pupils are streamed, based on intellectual ability, into one of three schools. The choice of schools at this age largely determines the type of education and training that is available to people later in life. For instance, secondary general schools, or *Hauptschulen*, prepare pupils for vocational education and training (VET) (for more on VET see below), whilst pupils at grammar schools, or *Gymnasien*, receive a more academic education and will, if they so wish and pass the relevant examinations, be able to go to university. This is not possible for pupils at a *Hauptschule*. Although pupils can move between the three types of schools, the majority of pupils do not do so (Germany's education system is portrayed in Figure 47.1).

The attainment levels of pupils in German schools were often assumed to be high. The results of the OECD's Program for International Student Assessment (PISA) study in 2000 came therefore as an unwelcome surprise as German pupils fared less well than those in other developed countries. As a result of this "PISA shock",

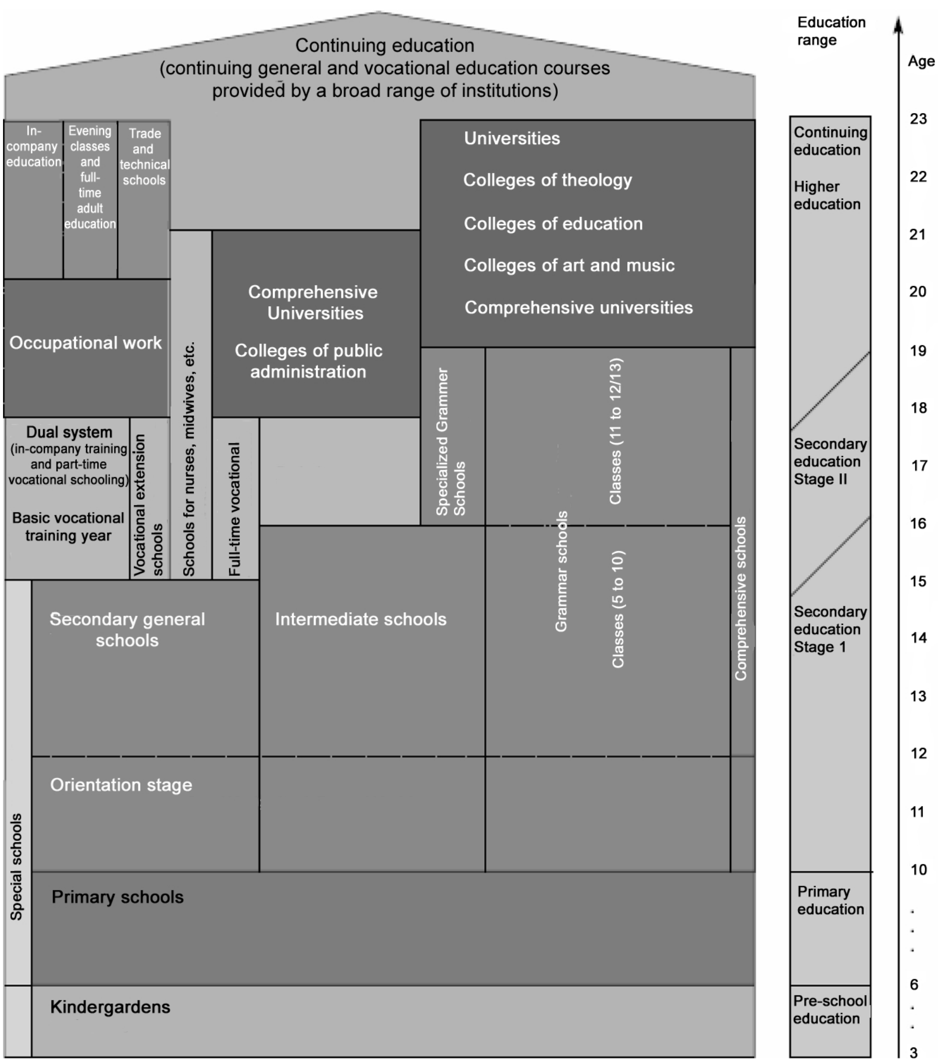

Figure 47.1. Basic structure of the education system in the Federal Republic of Germany.
Source: FMER (2004).
Notes: the above structure may dier from that in individual *Länder*. The age given for attendance at the various education institutes refers to the earliest possible (and typical) entry age.

Table 47.3. PISA mathematics and reading scores.

Mathematics score		*Reading score*			
2006		*2006*		*2000*	
Finland	548	Korea	556	Finland	546
Hong Kong-China	547	Finland	547	Ireland	527
Korea	547	Hong Kong-China	536	Hong Kong-China	525
The Netherlands	531	Canada	527	Korea	525
Japan	523	Sweden	507	Japan	522
Germany	*504*	The Netherlands	507	Sweden	516
Sweden	502	Japan	498	Norway	505
Ireland	501	United Kingdom	495	France	505
OECD average	*498*	*Germany*	*495*	*OECD average*	*498*
France	496	Denmark	494	Denmark	497
United Kingdom	495	*OECD average*	*492*	Switzerland	494
Hungary	491	France	488	Italy	487
Norway	490	Norway	484	*Germany*	*484*
Spain	480	Czech Republic	483	Hungary	480
United States	474	Hungary	482	Poland	479
Italy	462	Italy	469	Greece	474

Source: OECD (2000).

the *Länder* and Federal Government have undertaken steps to improve the performance of schools and hence the ability of pupils. For instance, in order to increase the number of all-day schools, or *Ganztagsschulen*, the Federal Government made funding available for this purpose. Before this measure was introduced, nearly all schools in Germany closed at midday. By the end of 2007, approximately 3,000 schools had benefited from this Federal program. It is hoped that the increased school day length will improve pupils' performance.

Some of the PISA scores in reading and mathematics are provided in Table 47.3 for selected countries. In terms of reading, German pupils performed less well than those in many other countries. Indeed, with an average score of 484, German pupils fell below the average for the OECD as a whole (498), and Germany was ranked in 20th position out of 38 participating OECD and non-OECD countries. It should be noted that many countries, including the U.K. and the U.S., did not receive scores on this measure as too few pupils participated to ensure statistically robust results. By 2006 the performance of pupils in Germany in terms of reading had improved. Within the PISA 2006 study, German pupils fared better than the average for the OECD. In 2006, Germany was ranked joint 15th out of 45 participating OECD and non-OECD countries. In mathematics, pupils in Germany fared better. In 2006, pupils in Germany attained an average score of 504 against an OECD average of 498. This placed Germany 17th out of 40 participating countries.

Table 47.4 shows the annual expenditure on public education institutes per pupil/student compared with *per capita* GDP. In terms of spending on all levels of education, this figure has remained relatively static in Germany, whilst it has grown in other EU member states. This may signify that Germany will need to spend more per pupil if it is to ensure that its workers have higher or comparable skill levels with those in other European countries. (The level of public expenditure on all education as a percentage of GDP fluctuated marginally around 4.6% between 1995 and 2004.) The annual public expenditure on education institutes at all levels masks significant variation within the three different sectors. Whilst Germany spends relatively less per pupil at the primary and secondary levels than the 27 current member states of the EU do, it spends more at the tertiary level. This latter figure declined markedly, however, between 1999 and 2004.

Higher education

In common with other aspects of Germany's innovation system, the origins of the university system can be traced back to the 19th century. There is insufficient space to cover the many changes that have taken place within this system since them. Therefore, this section will concentrate on the major characteristics of the system as well as the important changes that have occurred within the last 5 years. Whilst there have been significant changes of late to the German higher education system, one of the enduring characteristics of it has demonstrated comparatively high numbers of graduates in engineering, manufacturing, and construction. As Table 47.5 shows, as a share of all

Table 47.4. Annual expenditure on public education institutes per pupil/student compared with GDP *per capita*.[a]

	1999	*2000*	*2001*	*2002*	*2003*	*2004*
For all levels of education						
EU (27 countries)	23.2[b]	23.3[b]	24.3[b]	24.2[b]	24.6[b]	26.1[b]
Germany	22.3	21.7	21.6	22.2	22.6	22.3
Primary level of education (ISCED 1)						
EU (27 countries)	16.7	17.1	18.1	18.6	19.2	20.8[b]
Germany	16.3	15.7	16.2	16.6	16.7	16.4
Secondary level of education (ISCED 2–4)						
EU (27 countries)	24.7	24.8	25.7	25.1	25.1	26.4[b]
Germany	19.9	19.3	19.1	19.2	19.2	19.0
Tertiary level of education (ISCED 5–6)						
EU (27 countries)	37	36.6	38	37.2	38.4	39.5[b]
Germany	43.1	41.9	41	41	42.4	40.9

Source: Eurostat.
Notes: [a]Based on full-time equivalents. [b]Eurostat estimate.
The ISCED levels relate to the International Standard Classification of Education (ISCED). Level 1 covers primary education; levels 2 to 4 comprise lower secondary, upper secondary, and post-secondary non-tertiary education; and levels 5 and 6 encompass tertiary education.

Table 47.5. Graduates (ISCED 5–6) by discipline—as a percentage of all disciplines.

	1999		*2005*	
	EU	*Germany*	*EU*	*Germany*
Education and training	10.9[a]	8.7	9.9	7.5
Humanities and art	12.3[a]	10.0	11.4	10.5
Social science, business, and law	32.6[a]	20.7	36.2	24.3
Science, mathematics, and computing	10.2[a]	9.5	10.0	10.9
Engineering, manufacturing, and construction	14.5[a]	17.9	12.7	16.3
Agriculture and veterinary	2.0[a]	2.4	1.6	2.3
Health and welfare	14.1[a]	26.9	14.2	24.2
Services	3.4[a]	3.9	3.9	3.9
Unknown	2.6[a]	0.3	0.5	0.4
Total graduates (ISCED 5–6)—absolute numbers	12,511,189[a]	2,087,044	16,342,307[a]	2,268,741

Source: Eurostat.
Notes: "EU" relates to all current 27 members; rounding and estimation errors may prevent the relevant columns summing to 100%.
[a]Eurostat estimate.

graduates those in engineering, manufacturing, and construction and those in health and welfare comprised a far higher percentage in Germany than they did in the 27 current member states of the EU in 1999 and 2005.

The freedom of research and teaching, which is anchored in Germany's constitution (*Grundgesetz*), has meant that universities, in general, and university professors, in particular, are relatively more autonomous than their counterparts in many other developed countries. Whilst the freedom that university professors have enjoyed may in some respects have enhanced innovation, as it has meant that their choice of research areas has been less directed by a governing body, it can also be seen as hindering flexibility within the innovation system. This lower degree of flexibility may, in turn, hamstring efforts to pursue new research possibilities. In short, research within German universities has tended to be conducted as discrete projects that are controlled by one or a couple of professors who also have administrative responsibilities. This, in turn, may hamper competition within departments, which are led administratively and intellectually by a professor, and lead to lower levels of innovative outcomes. By contrast, where administrative authority is separated from intellectual authority, the power of departmental heads to direct research may be diminished. This may result in a diversity of research goals and approaches (Whitley, 2007). The Initiative for Excellence (see below) may have increased the competition between universities for increased funding, but it may not lead to an increase in the plurality of research projects that are conducted.

In addition to the selection of "elite universities" (see the section on the "Initiative for Excellence" below), one of the main changes in the higher education sector that has recently been implemented is the 2004 reform of the Framework Act for Higher Education. This reform has for the first time given universities in Germany the opportunity to award bachelor's and master's degrees. This reform means that the broad contours of the German higher education system will resemble those in the U.S. and U.K. The Federal Government hopes that this restructuring will boost the numbers of those on business studies and technology-related degree programs. A further change has been the introduction of a new salary structure for those who are appointed as professors for the first time. Such appointees receive a lower basic salary than those who were already professors before the reform. However, the former, unlike the latter, can supplement their basic salary by performance-related payments that are based on research and teaching. It is hoped that this reform will help professors intensify their research activities, which, in theory, will spur innovation. It is too early to judge the effects of these reforms.

Initiative for Excellence

Marking a significant shift in Germany's higher education policy, the Federal Government in cooperation with the *Länder* announced an Initiative for Excellence that, it is hoped, will enable selected universities to increase their expertise and international renown in research areas in which they are already strong. Before the Initiative, all universities were regarded as equal by the Federal Government. This, in turn, reflected a desire that emerged in the 1960s amongst the populace to eschew the idea of elitism within the higher education sector. The Initiative therefore represents an important caesura in policy, as it intends to facilitate the emergence of "elite universities" that are able to conduct more extensive and more advanced research than those not selected. The Initiative can be seen as a response, first, to increased competition in the areas of research and innovation from both developed and developing countries; second, to calls to address the problem of chronic underfunding within tertiary education, and, finally, to concerns about Germany's reputation abroad as a research location.

Within the framework, €1,900 million will be made available to the selected universities between 2007 and 2011. The Federal Government will contribute 75% of this sum; the remainder will come from the *Länder*. In order to select the universities that will receive the additional funding, an exercise to evaluate current research activities as well as the ability to develop the talents of early-career researchers was conducted. That exercise was led by the German Research Association and the Science Council. In October 2006 the first three "elite universities" were announced. They are Munich's Ludwig-Maximilian University, Munich's Technical University (TU), and the University of Karlsruhe. These three universities will receive approximately €120 million in additional funds between 2007 and 2011. In a second round of the Initiative, Berlin's Free University, RWTH Aachen University, and universities in Freiburg, Göttingen, Heidelberg, and Constance were, in October 2007, recognized as further "elite universities". Each of these six universities will receive approximately €100 million in additional funding between 2007 and 2011.

In a further measure to support important research projects and to increase the number of university students, the Federal Government and the *Länder* concluded, in 2007, the Higher Education Pact 2020. It will channel increased funds to selected projects that have gained funding from the German Research Foundation. In 2008, €242 million was available under this scheme. By 2010, €1,270 million will have been invested.

Vocational education and training

Within the area of vocational education and training (VET), the Federal Ministry of Education and Research (BMBF) together with the Federal Institute for Vocational Education and Training play in conjunction with employer and employee representatives key roles in establishing the broad parameters within which employers, training providers, and employees operate. The provision of VET is underpinned by the principle of dual training.

Within Germany, the Federal Ministry of Education and Research (BMBF) is responsible for general policy issues that relate to vocational education and training (VET). As part of its remit, it is legally accountable for the supervision and funding of the Federal Institute for Vocational Education and Training (BIBB). In addition, its tasks include the implementation of measures that are designed to improve the quality of VET. The BMBF does not, however, have the power to recognize individual occupations that require formal training; that responsibility lies with the individual ministries that oversee the relevant occupational area. In practice, this means that the majority of occupations that require formal training are recognized by the Federal Ministry of Economics and Technology. In the mid-2000s, there were 343 recognized training occupations that covered all sectors of the economy. The origins of the current occupation-focused and industry-focused VET system in Germany can be traced back to the 19th century when large companies in industrial sectors established their own training programs. The input of employers in designing training programs has remained a key feature of the system and has ensured the continuing relevance of the skills provided by it.

Founded in 1970, the Federal Institute for Vocational Education and Training (BIBB) is a national and international center of excellence for research not only into initial and continuing VET, but also into the development of VET. Its research, development, and advisory work focus on identifying the future demands that VET is likely to face and the ways in which training can meet those demands. Moreover, it seeks to develop practical solutions for initial and continuing VET. The activities of the BIBB have ramifications for those organizations involved in the development of VET. These include Federal ministries, *Länder* ministries, and peak-level employers' associations and unions. In addition, guidance and recommendations made by the BIBB are directed towards influencing the activities of universities, colleges of further education, and vocational training schools. The BIBB also seeks to shape the training activities within firms, as its activities have implications for those people within organizations who have an influence over training, such as personnel managers and works councillors. In many of its activities and recommendations, however, the BIBB consults with and is influenced by employers' associations and unions.

Dual training

The principle of dual training underpins many VET measures. This means that two partners share the responsibility for providing VET to trainees. In the first instance, a company concludes a training contract with an apprentice. This contract includes details of the training measures that the apprentice will undertake. Much of this learning is performed within the company. The apprentice usually spends 3 or 4 days a week at the firm. For the remainder of the working week, apprentices attend vocational training schools, the other partner in the dual-training program. The material studied there is of both a theoretical and practical nature; it is designed to support the primarily practice-oriented knowledge acquired within the company. The dual-training system therefore promotes the provision of firm-specific and industry-specific skills.

The continuing relevance of the skills acquired within the dual-training system to companies is maintained by the important contribution of employers' representatives and unions in the design of and influence over changes to VET schemes. The actions of the Federal Government, the *Länder*, employers' associations, and unions are governed by the provisions of the Vocational Training Act, which was amended most recently in 2005. The Chambers of Industry and Commerce, which cover companies within a particular sector, perform advisory and monitoring functions for individual training contracts. They also verify that companies and instructors involved in VET have the necessary skills to do so.

In terms of the NIS, VET schemes in Germany provide firms and industries with the workers with the skills that can help to maintain competitive advantages (Culpepper and Finegold, 1999; Hall and Soskice, 2001; Thelen, 2004; Whitley, 1999, 2007). The role of state agencies, employers' associations, and unions in organizing and controlling the vocational skills system leads to the development of highly valued, standardized skills for a large section of the workforce. This therefore enables workers to make a contribution to the innovation capabilities of companies. This is likely to be especially true in situations in which lengthy job tenures, which are in part encouraged by Germany's system of industry-wide collective wage agreements, promote firm-specific skills in addition to the industry-specific skills already acquired (Whitley, 2007). The structure of VET in Germany is thought to be an important source of competitive and hence comparative advantage in certain sectors, such as vehicles and mechanical engineering, as workers' skills are well suited to the innovation patterns in those industries.

Most school leavers (approximately 60%) embark upon a dual-training course. Others attend full-time vocational schools, for which the *Länder* are solely responsible. Such schools provide training in the health and laboratory sectors. Attendance at these schools does not preclude training placements within companies. The companies that provide the training contracts contribute the largest share to the financing of the dual-training system. In 2007, companies are thought to have spent nearly €15,000 million on dual training. The *Länder* spend close to €3,000 million on part-time vocational schools.

Conclusion

Germany's innovation system should be seen as a relatively coherent set of policies and practices that support the emergence of certain organizational capabilities. Those capabilities are particularly important in the medium to high-tech industries. It is, however, the case that the

Federal German Government is aware that economic growth and employment are overly reliant on those sectors. For that reason the government has undertaken several steps to promote innovation and growth in other economic sectors. Indeed, by creating "elite universities" the Federal Government has shown that it is willing to break long-held taboos. The interlocking nature of the innovation system means, however, that other aspects of the framework that remain unchanged are likely to continue to exert an influence over the types of capabilities that firms are able to create. This is not to suggest though that the reforms are likely to be futile. It does, instead, indicate that competences in German organization may be suited to certain forms of innovation activities than others. These competences are likely to be prerequisites in many sectors and sub-sectors of the economy, including those that are based on cutting-edge technologies.

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