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**Article**

## Deficits in Education Endanger Germany's Innovative Capacity

Weekly Report

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# Weekly Report

## Deficits in Education Endanger Germany's Innovative Capacity

*The innovative capacity of advanced industrial countries is their most important source of prosperity and growth. DIW Berlin has investigated Germany's innovative capacity for the fourth time in an international comparative survey. The survey evaluates the ability of countries to create and transform knowledge into marketable products and services (i.e., innovations) using a system of indicators that provides an overall composite indicator of innovative capacity as well as a detailed profile of strengths and weaknesses.*

*Of the seventeen leading industrial nations investigated under the survey, Germany only ranked 8th, as it did in 2007, thus remaining in the broad middle range. Relative to its most important competitors Germany was unable to improve its position. Sweden, the US, Switzerland, Finland, and Denmark headed up the list. Germany is particularly successful in international markets for new products and services and in its ability to network key participants in the innovation process. Deficiencies in Germany's educational system and in the financing conditions for innovation and the founding of new companies remain the country's two greatest weaknesses. Prospects are dim for the considerable improvement needed in these areas.*

A country's innovative capacity – that is, the ability of people and companies to create and transform knowledge into new, marketable products and services and more efficient processes – cannot be measured directly. In this survey, a range of individual measures of innovative capacity were used to calculate an overall indicator for Germany and sixteen other highly developed competitor nations<sup>1</sup> in a series of aggregational steps (see figure 1).<sup>2</sup>

In order to be innovative, a country requires first and foremost a well-functioning national innovation system, in addition to a favorable social climate for innovation. The term national innovation system refers to the enterprises, institutions, and surrounding conditions that influence the process by which innovations arise.<sup>3</sup>

<sup>1</sup> Belgium, Denmark, Finland, France, the UK, Ireland, Italy, Japan, Canada, South Korea, the Netherlands, Austria, Sweden, Switzerland, Spain, and the US.

<sup>2</sup> cf. Werwatz, A., Belitz, H., Clemens, M., Schmidt-Ehmcke, J., Schneider, S.: Innovationsindikator Deutschland. Bericht 2008. A study conducted by the German Institute for Economic Research, commissioned by the Deutsche Telekom Foundation and the Federation of German Industries. DIW Berlin, Politikberatung kompakt No. 45, Berlin 2008; as well as the Deutsche Telekom Foundation and the Federation of German Industries: Innovationsindikator Deutschland 2008. Bonn, Berlin 2008; [www.innovationsindikator.de](http://www.innovationsindikator.de).

<sup>3</sup> Various definitions of the national innovation system are found in the literature. See Lundvall, B. A.: National Sy-

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The system ensures that highly qualified individuals (education), new knowledge (R&D), and sufficient capital (financing) come together in the process of innovation and that key players in innovation – particularly companies – are responsive to impulses from partners (networking), competitors, and market demand to produce new products, services, and organizational solutions (implementation). Each of these seven areas is underpinned by a number of separate indicators, which, taken together, provide a measure of the strength of a national innovation system. The “systemic strength” that is calculated in this fashion has a weight of 7/8 in the overall innovation indicator.

The social climate for innovation found within a country is the remaining factor in the overall assessment. For clearly, there are hidden risks in the effort to develop new technologies and products. In order to be innovative, a society must have the courage to change, trust in the actors who bring about innovation, and hold a fundamentally positive – but not necessarily uncritical – view of science and technology. For this reason, we’ve evaluated public opinion surveys on the process of change, social capital, trust, and science and technology to arrive at an assessment of a country’s social climate for innovation. This “climate indicator” has a weight of 1/8 in the overall assessment.

By drawing a distinction between seven components of a country’s national innovation system and its social climate for innovation, an innovation balance sheet can be derived, highlighting Germany’s strengths and weaknesses relative to other countries (see box).

### Germany Again Ranked 8th

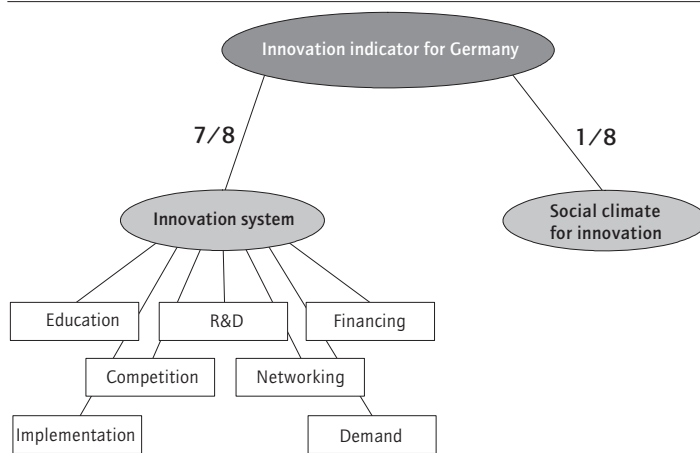
In the overall ranking of the seventeen countries in the 2008 innovation indicator, Germany occupied 8th place, thus falling in the middle range of the surveyed group. Sweden was ranked first (see figure 2). As in 2007, Sweden, the US, Switzerland, Finland, and Denmark headed up the list. In comparison to 2007, Sweden extended its lead over the US and the other countries in the leading group.

The leading group is trailed by a broad middle range, extending from 6th (Japan) to 15th place (Ireland). Spain and Italy landed at the bottom of the list, as they did in previous years, and were unable to gain ground on the broad middle range of countries.

stems of Innovation: Towards a Theory of Innovation and Interactive Learning. London 1992; and Nelson, R. R., Rosenberg, N.: Technological Innovation and National Systems. In: Nelson, R. R. (ed.): National Innovation Systems. Oxford 1993, pp. 3-21.

Figure 1

### Composition of the innovation indicator for Germany, 2008



Source: Illustration from DIW Berlin. DIW Berlin 2008.

DIW Berlin 2008

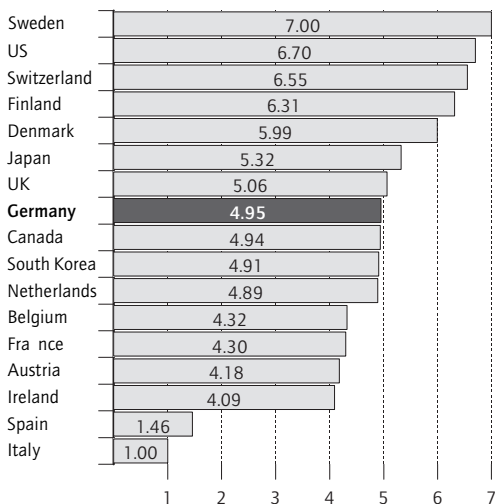
### Little Change Over 2007

While Germany’s ranking remained unchanged, the score gap separating it from the front-runner Sweden somewhat increased (see table 1). Germany’s indicators did improve slightly in numerous areas, however, as in previous years, yet this improvement was less significant than Sweden’s. Germany’s overall score thus fell slightly to 4.95, from 5.18, a reflection of Germany’s worsened position in relation to the current front-runner. Aside from Denmark all

Figure 2

### Scores and overall ranking in 2008

From Rank 1 =7 up to Rank 17 = 1



Source: Calculations by DIW Berlin.

DIW Berlin 2008

## Methods

### Data Sources for the Individual Indicators

The important sources of data for the individual indicators which were used to assess the performance of each country's national innovation system and social environment for innovation were:

National and international data on research and development, education, trade, production, and employment maintained by the OECD and Eurostat, as well as indicators calculated by the German Institute for Economic Research (DIW Berlin);

Composite indicators from other authors that assess complex factors influencing national innovative capacity with a similar, multi-step approach, such the product market regulation indicator (published by the OECD) and the information and communication infrastructure indicator (published by the WEF, in cooperation with INSEAD);

Comparative international surveys of actors in the innovation process, such as companies (Executive Opinion Survey of World Economic Forum) and people (Eurobarometer, World Values Survey).

### Standardization

In order to standardize and compare the individual indicators, all data were initially applied to a uniform scale – both "hard" facts as well as "soft" opinion survey results. This was achieved through the following transformation:<sup>1</sup>

$$Y_{1bis7} = 6 \times \frac{(Y - Y_{min})}{(Y_{max} - Y_{min})} + 1$$

The formula essentially yields the deviation between Y, the original value for a country, from the country ranked at the top (Y<sub>max</sub>) and bottom (Y<sub>min</sub>). This deviation is then applied to a scale from 1 to 7.<sup>{1><0}{1>2}</sup>

The Y variables have been selected such that – based on theoretical and empirical research results – it can presumed that a higher value is "better" than a lower one (i.e., that innovative capacity rises in tandem with Y.)

**1** The transformation used here brings all of the individual indicators (and all derived provisional results) into a uniform scale while also maintaining the relative deviations displayed by the compared countries in the original scale.

**2** The deviation between the top and bottom performers was rescaled to a range of 1 to 7 because many of the individual indicators from the global manager survey conducted by the World Economic Forum already used this scale in their „raw form.“

### Weighing and Integrating the Indicators with the Primary Statistical Components

The assembled indicators are calculated as the weighted sum of the components at every stage. The relative weight of each indicator is established "empirically" (i.e., from the data) early on with the construction of the indicators using principal components analysis. With the first primary components,<sup>3</sup> this method calculates precisely the weighted sum of the individual indicators exhibited by the largest variation between the surveyed countries. The first principal component determines the weight of the individual indicators such that precisely those indicators are "awarded" a relatively high weight that exhibit a large variation between countries and which correspond well with the general direction of variation witnessed with the other indicators. The following rationale informs this approach: One should look for differences in innovative capacity when evaluating a set of advanced countries in areas where the indicators vary to the greatest extent between those countries.<sup>4</sup>

The weighting in the second to last step, in which the seven sub-indicators of "systemic strength" are drawn together, is based on the judgment of experts from the industrial and service sectors who participated in a written survey conducted by the German Institute for Economic Research in 2005 and 2006.<sup>5</sup>

The systemic indicator is weighted 7/8 when integrated with the social-climate indicator to produce the overall innovation ranking. The strong weighting on the systemic side reflects the large importance that a national innovation system has for the innovative capacity of a country. This indicator is based on the wide range of available research results on innovation systems. By contrast, at this point in time relatively little is known about the social climate for innovation – that is, the values and opinions of people and how these factors influence innovative capacity.

**3** The calculated values of the first principal components are then converted to the standard 1-7 scale for further calculations.

**4** In a few cases the weighted components of an assembled partial indicator were not calculated using principal components analysis, but nevertheless empirically determined. In these cases principal components analysis yielded a negative weighting for at least one component. If this was the case, the weightings were only calculated based on the (always positive) variance of the components.

**5** cf. Werwatz, A. et. al (2008) *ibid.*

of the countries ahead of Germany in the ranking slipped slightly relative to Sweden.

Germany's innovation profile is the product of seven system components and its innovation climate. This profile reveals a number of significant strengths and weaknesses (see figure 3).

Germany has strong advantages in the category of networking and the market implementation of innovations (taking 3rd in both of these areas). Germany also fared well in the overall ranking in the category of innovation-friendly market demand (5th place). These "systemic strengths" are undergirded by particularly good scores in two areas: 1) the market success of research-intensive industries, and 2) company networking.

Yet marked weaknesses were also in evidence, despite these strengths. Relative weakness in the areas of innovation financing (14th place) and "competition and regulation" (12th place) are two factors that account for the low number of new businesses established in Germany. The founding of new companies is particularly important for the process of innovation in high-tech sectors. In Germany, however, there is a lack of venture capital for the risky undertaking of starting a new high-tech company. Established companies thus face less pressure from new competitors. The low willingness of Germany's citizens to take on the risks associated with founding a company is an additional source of weakness – Germany, in fact, scored last in this area. Yet a weak spirit of entrepreneurialship is just one facet of Germany's relatively weak social climate for innovation, another factor in the innovation indicator. An unfavorable environment for the employment of women and the public's low trust in scientists and companies who conduct research also had a negative impact in the social-climate indicator. However, these societal hurdles to innovation stand in contrast to positive aspects, including the relatively outward-looking and tolerant attitudes of Germany's citizens as well as their optimistic assessment of the benefits and usefulness of science and technology. Yet despite these strengths, Germany ranked 10th in the overall assessment of its social climate for innovation.

### Education is the Achilles Heel

Germany's greatest weakness lies in the area of education. Here Germany was ranked 15th, after ranking 13th in 2007. Only Spain and Italy ranked worse than Germany (yet a considerable gap separated them from the middle group).

Table

### Innovation indicator scores and rankings in 2007 and 2008

	2007		2008	
	Rank	Scores	Rank	Scores
Sweden	1	7	1	7
US	2	6.92	2	6.70
Switzerland	3	6.81	3	6.55
Finland	4	6.65	4	6.31
Denmark	5	6.00	5	5.99
Japan	6	5.64	6	5.32
UK	7	5.38	7	5.06
<b>Germany</b>	<b>8</b>	<b>5.18</b>	<b>8</b>	<b>4.95</b>
Netherlands	9	5.00	11	4.89
Canada	10	4.90	9	4.94
France	11	4.56	13	4.30
Ireland	12	4.36	15	4.09
Belgium	13	4.35	12	4.32
Austria	14	4.14	14	4.18
South	15	3.87	10	4.91
Spain	16	1.38	16	1.46
Italy	17	1	17	1

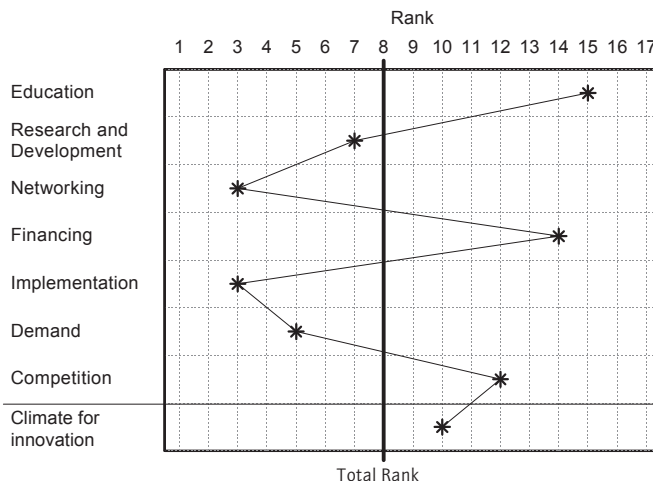
Source: calculations by DIW Berlin.

DIW Berlin 2008

Why did Germany rank so poorly? Germany's educational system is not well funded compared to other advanced nations (12th place). It ranks below-average in international university rankings and other quality comparisons such as the PISA study (11th place). Germany produces relatively few graduates with post-secondary degrees (12th place), and also fares poorly in the area of continuing education (13th place).

Figure 3

### Germany's innovation profile in 2008



Source: calculations by DIW Berlin.

DIW Berlin 2008

In short, Germany has a series of problems with its educational system. The task of creating the pre-conditions in schools, universities, and professional colleges necessary for the generation of adequate numbers of highly qualified graduates is increasingly the most important challenge faced by Germany's national innovation system. This assessment is underscored in the following section, in which national dynamics in the area of innovation are viewed from the perspective of the central goal in Germany's national innovation policy: the allocation of 3% of Germany's GDP to research and development by 2010 (the "3% goal").

### A "Baby Step" Policy

As in previous years, Germany ranked in the upper-middle range of the innovation indicator and failed to narrow the gap separating it from the leading group of countries. However, there are numerous developments underway in Germany's innovation policy. The federal government has adopted a "High-Tech Strategy" aimed at making Germany the world leader in innovation.

Increased R&D activity is of key importance in the effort to gain ground on other countries. R&D investment – one indicator in the area of research in the calculation of the innovation indicator – is currently the central focus of innovation policy. Will Germany be able to increase its R&D investment to 3% by 2010 and set a dynamic "catch-up" process into motion?

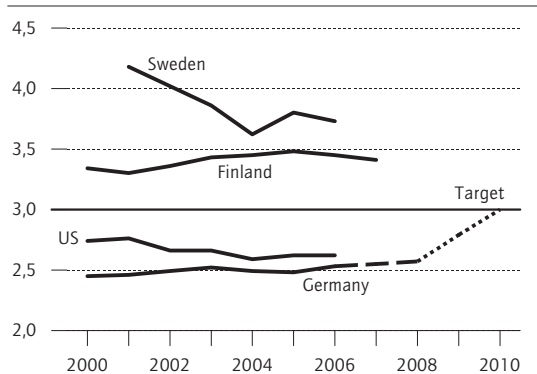
According to the latest official figures from 2006, Germany invested just over 2.5% of its GDP in research and development. As a percentage of GDP, US investment is at about the same level. In Finland and Sweden, by contrast, spending has exceeded 3% for several years (see figure 4). The long dashes indicate the likely trend in Germany in 2008 based on available investment data from the government and business sector. If this moderate growth forecast for 2008 is accurate, then a dramatic increase in expenditures will be necessary in 2009–10 for Germany to attain its 3% goal in time.

The ultimate aim is to boost research productivity in real terms, not merely the amount of money spent. To this end, a significant increase in the number of active researchers is necessary. Were the number of researchers to remain constant, an increase in R&D expenditures would primarily increase the wages of existing researchers and lead to few gains in actual research productivity. In figure 5 the long dashes extend the continuous but moderate growth witnessed between 2000 and 2006 in researchers per

Figure 4

### Actual and target research investment

R&D expenditures as a percentage of GDP



Sources: OECD; calculations by DIW Berlin. **DIW Berlin 2008**

1,000 employees active in Germany, projecting the trend to 2010. The dotted line shows the dramatic growth in the number of researchers that would be necessary in order to increase research productivity in tandem with increased expenditures. The increase shown here, however, would only bring Germany to a level already clearly surpassed by Finland, Sweden, and the US.

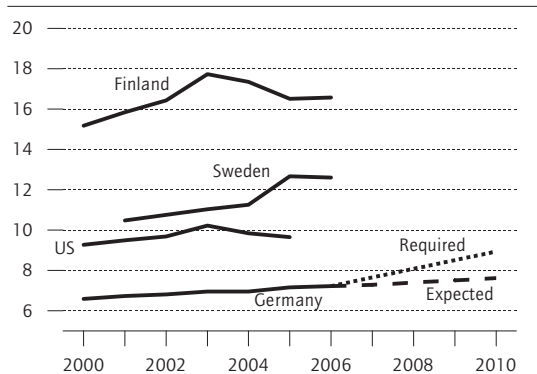
This analysis shows why the mobilization of highly qualified human resources is so important to Germany's national innovation dynamic. To achieve this goal, a number of options are available:

Institutions of higher education can produce more graduates, particularly in the fields of mathematics,

Figure 5

### Actual and required researchers

Per 1,000 employees<sup>1</sup>



<sup>1</sup> Full-time equivalent  
Sources: OECD; calculations by DIW Berlin. **DIW Berlin 2008**



engineering, and the natural sciences (the so-called "MINT" fields)

Untapped domestic researchers can be mobilized from unemployment, parental leave, non-research careers, etc.

Already educated or future researchers can be recruited from outside of Germany.

A strategy with prospects for success must make use of all of these options. Consequently, all three of these areas have been evaluated to the extent possible in the educational component of the innovation indicator.

### Germany Produces Relatively Few University Graduates, Despite Gains

Two facts are made clear by an international comparison of university-graduation trends since 2000 (measured as a percentage of population attending university at a typical age): First, Germany still lags considerably behind countries such as Sweden, Finland, the US and UK, despite positive developments since 2002. Second, it will not be possible merely through increased graduate numbers to supply the quantity of researchers needed to achieve the 3% goal (see figure 6). The required percentage of graduates, as determined in a simple model calculation, is significantly higher than the current value.<sup>4</sup> Consequently, this shifts the focus to alternative sources of highly qualified employees: women and foreign workers.

### Promoting the Employment and Careers of Highly Qualified Women

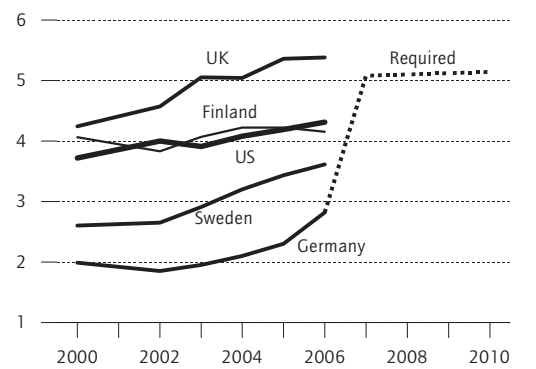
Today more than 50% of university graduates in Germany are women. Yet the percentage of women active in the academic world falls dramatically over the period from the completion of doctoral work to the achievement of full-professor status. This percentage is particularly low in engineering, mathematics and the natural sciences (the MINT fields; see figure 7). This in turn negatively impacts the number of highly qualified women who are employed in the private sector. A significantly higher number of men are active in research and knowledge intensive sectors, and therefore in the activities that produce innovation (see figure 8). By contrast, a very large percentage of highly qualified women

<sup>4</sup> The model calculation is essentially based on the three assumptions. First, only university graduates can fulfill the need for researchers. Second, the total number of additional researchers required is distributed evenly between 2007 and 2010. Third, each year a constant percentage of university graduates begin working as researchers.

Figure 6

### Actual and required number of graduates

Percentage of the population at the typical age of graduation

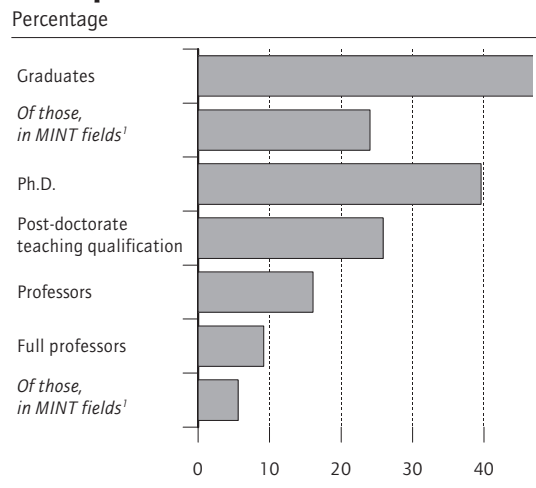


Sources: OECD; calculations by DIW Berlin. **DIW Berlin 2008**

are employed in less innovative areas of the public sector (e.g., health care, education, social affairs). In Germany and other industrial countries there is a tremendous latent potential for the mobilization of women in the innovation process. It is therefore necessary to steer more women to fields of study with relevance for the innovation process (i.e., the MINT fields) and to promote their employment in market-oriented branches of the economy that are research and knowledge intensive.

Figure 7

### Participation of women 2003



<sup>1</sup> Mathematics, engineering, or the natural sciences.

Sources: Eurostat; calculations by DIW Berlin. **DIW Berlin 2008**

### The US: A Role Model for the Integration of Highly Qualified Immigrants

When a society successfully attracts and integrates foreign talent, it taps into an important source of highly qualified employees. Talented individuals who have already attained degrees are highly sought after internationally. For this reason, a successful immigration policy should focus on attracting the best and brightest individuals at an earlier stage, while they are still studying at university. The left side of figure 9 shows the percentage of foreign students at universities in Germany and the US. Germany leads the US with its proportion of foreign students, just over 10%. Although this statistic is somewhat relativized by the lower total number of students in Germany, it shows that Germany is indeed attractive to the next generation of foreign researchers.

However, as illustrated by the right half of figure 9, the relatively high percentage of foreign students in Germany does not ultimately translate into a larger percentage of highly qualified resident foreign immigrants. Germany lags behind the US in the number of highly qualified immigrants per capita. The figure shows that the US, which has always considered itself a country of immigrants, enjoys a considerable lead over Germany, which has only moved hesitantly in this direction.<sup>5</sup>

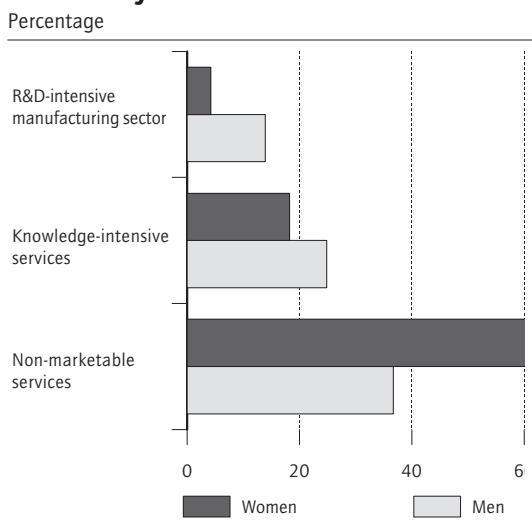
### Summary of 2008's Findings

In recent years a greater focus has been placed in Germany on innovation policy, and not just on a rhetorical level. Real efforts have been made and change has been witnessed thanks to important initiatives such as the federal government's High-Tech Strategy, the High-Tech Gründerfonds (a capital fund for high-tech ventures), the German Universities Excellence Initiative, and the Research Bonus (a government grant program). As these initiatives are new, and there is a natural delay before new programs can take effect and be measured, they have not yet impacted Germany's position and profile in the innovation indicator. Germany continues to lag behind the world's most innovative countries, both in the overall assessment, and in most individual areas. While Germany ranked close to the top in a few indicators (networking, implementation), its performance was average in most areas, and lagged considerably in others (education, competition and regulation, financing).

<sup>5</sup> In the US this is achieved partially through successful integration, i.e., many foreign graduates (particularly Ph.D. graduates) remain in the US after completing their studies. See Finn, M. G.: Stay Rates of Foreign Doctorate Recipients from U.S. Universities. Oak Ridge Institute for Science and Education, 2005, orise.orau.gov/sep/files/stayrate05.pdf.

Figure 8

### Hours worked by highly qualified women and men by sector

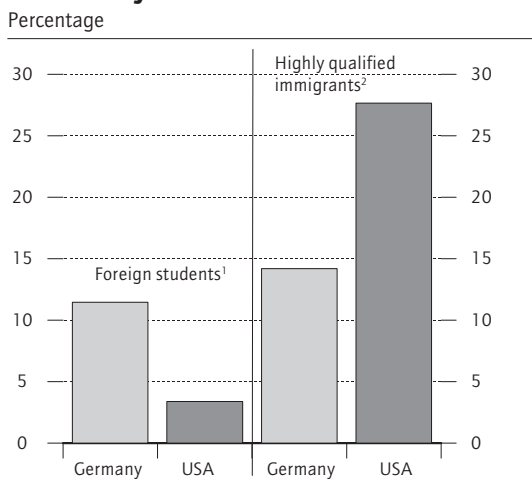


Sources: EUKLEMS; calculations by DIW Berlin. **DIW Berlin 2008**

Germany's strengths lie in its established innovation landscape. German companies are particularly successful in the manufacture of technology-intensive, innovative products, and they benefit from their strong market position, the country's excellent physical infrastructure, and from their ties with the research community, an area especially well rated by company managers. The greatest weaknesses in Germany's national innovation system are evident at

Figure 9

### Foreign university graduates and students in Germany and the US



<sup>1</sup> 2004.

<sup>2</sup> 2005.

OECD; calculations by DIW Berlin. **DIW Berlin 2008**



its foundation: in the supply of highly qualified personnel. This is first and foremost a result of deficiencies in the educational system – a system of intermediate quality, which, compared to other countries, produces too few post-secondary graduates. If the problems in this area are not addressed, the shortage of highly educated employees will become a serious stumbling block for innovative, research-based companies at the very latest with the retirement of the baby-boom generation from 2015 onward. Yet this weakness extends beyond the “classic” educational system and into other areas. To date Germany has had less success than other countries in integrating highly qualified women and well-educated immigrants into its national innovation system – in this regard preconceived social judgments more prevalent in Germany than in other highly innovative countries have certainly played a role.

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