



# The situation in industry and the loss of interest in science education



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## Introduction

In the midst of the economic stagnation of the early 2000s, engineers and scientists are becoming scarcer in Germany. Technological research centres are bewailing the failure of large firms to recruit young scientists. Recruiting engineers is proving to be a serious problem for some 40 % of industrial enterprises (Zwick and Boockmann, 2004). Experiences in the Hamburg aircraft building area show the extent of the problem: relying on the attractiveness of these jobs, the players in this area felt that they were protected against a shortage of technical experts. Ultimately, however, they had to turn to the Swedish labour market to find the two hundred engineers they had tried in vain to recruit in Germany.

The market shortage reflects a drop in the number of young science and engineering graduates. Between 1996 and 2002, annual outflows fell from 53 000 to 36 000 in engineering and fell by as much as 50 % in conventional science disciplines such as physics and chemistry. This downturn has been caused by a major loss of interest in these subjects starting in the early 1990s. Our article analyses and interprets the reasons for this trend.

Section 1 examines the quantitative aspects of this process. To explain these changes, reference is made primarily to the cobweb cycle model. This model is examined in Section 2. A number of prior structural conditions are needed if the cobweb cycle is to emerge and continue. Two conditions are discussed in Section 3: the ability of higher

education to adapt to changes in flows and the segmentation of the labour market into occupational compartments.

## Trend, change or cycle?

Has there been a loss of interest in higher education in the sciences in Germany? Analysis of various quantitative parameters shows that the answer depends on the index used. It is possible to show an increase, a stagnation and a decline in interest in these disciplines. According to Graph 1, for instance, which shows first-year enrolments in absolute figures, enrolments in these disciplines have increased in the long term <sup>(1)</sup>. The data for other parameters tend nevertheless to show a stagnation or a downward trend; in the long term, the proportion of new enrolments in science education among the corresponding generation of upper secondary leavers has been stagnating; the proportion of all new enrolments for which enrolments in science education account has been declining <sup>(2)</sup>.

Graph 1 nevertheless shows that these processes are highly cyclical. This is also true of the other two chronological series. In the rest of this article, we will focus on the most recent cycle, starting in the 1990s.

A more detailed analysis of the statistics for this period shows major contrasts in trends in different disciplines (see Graph 2) <sup>(3)</sup>. Three types of trend can be discerned:

□ the first is typical of the traditional physical (chemistry and physics) and engineering (mechanical, electrical) specialisations <sup>(4)</sup>.

**The case of Germany is taken as an example of cyclical variation in higher education enrolment in the sciences. This article looks at the causes of this 'oscillation', focusing on the cycle of the 1990s and argues that the mechanism underpinning these fluctuations is the cobweb model. This model establishes a recursive loop between trends in enrolments in a discipline and trends in the labour market associated with this discipline. The analysis highlights two conditions that are required for the model to apply: the elasticity of higher education capacity and the segmentation of the labour market.**

<sup>(1)</sup> Enrolments for the short and long options (respectively the Fachhochschule and university) have been aggregated. This amalgamation is justified by the very synchronous trends in these enrolments. From 1993, the figures relate to re-unified Germany.

<sup>(2)</sup> As a proportion of all enrolments, new enrolments in science education fell by an average of 0.22 points per annum between 1975 and 2000. For reasons of space, these statistics are not included here. They can be obtained from the author.

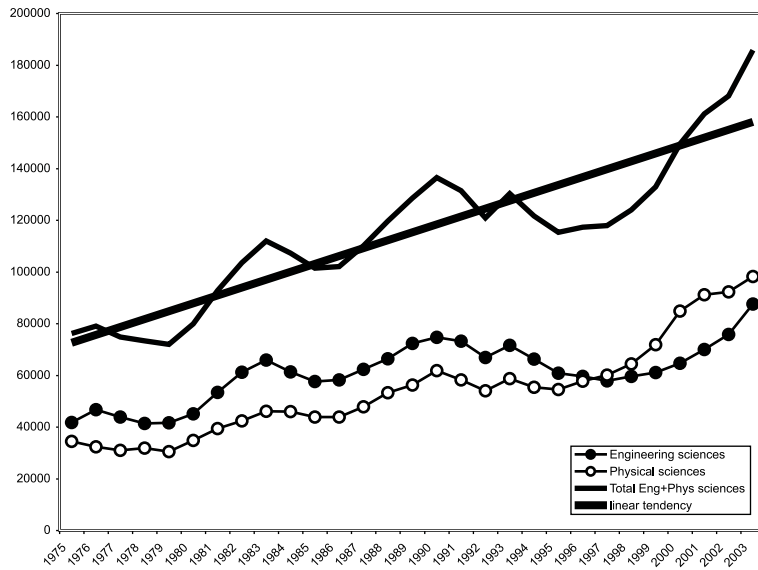
<sup>(3)</sup> Field: re-unified Germany. Fachhochschule and university enrolments have been added together.

<sup>(4)</sup> Including electronics.



**Trend in enrolments in science education**

**Graph 1**



Source: Statistisches Bundesamt

ent again. Enrolments have grown fairly stably in these subjects.

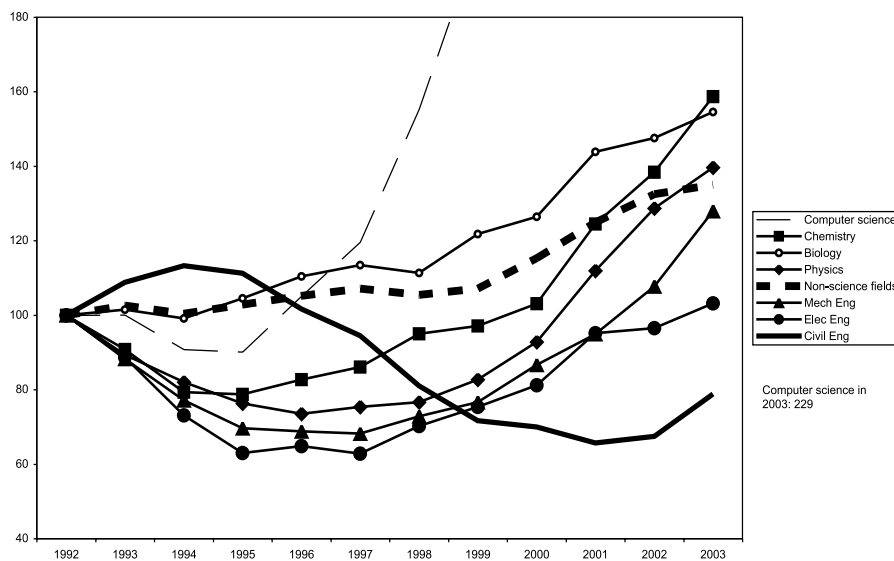
These statistical observations lead us to make two comments: first, the loss of interest in science education has to be explained in terms of cycles and not in terms of trends or changes. Second, the different trends in different specialisations are worth interpreting.

**Fluctuations in enrolments in higher science education in Germany: an approach based on cycles**

The 'cobweb model' is often used to interpret fluctuations of the first type discussed above (Bargel and Ramm 1999; Minks et al, 1998; Neugart and Tuinstra, 2003; Zwick and Boockmann, 2004). Reference is generally made in this respect to the classic works of Freeman (1975, 1976a, 1976b) on variations in enrolments in higher science education in the USA.

**Trend in enrolments by specialisation (index 1992=100)**

**Graph 2**



Sources: KMK (2003); Statistisches Bundesamt

The cobweb model establishes a recursive loop between the trend in enrolments in a discipline and the trends in the labour market associated with this discipline. The following diagram illustrates the phases and intervals making up this process.

Taking, for instance, the situation T1 of Graph 3 as an example, the process starts at that time with a massive upturn in the number of enrolments in the discipline in question. The state of the labour market explains this upturn: it is brought about by an improvement in conditions in the job market in question.

From time T2 there is a reversal in the trend in enrolments, leading to a sharp decline. This change is primarily explained by the fact that market conditions have become much worse. The intrinsic factor in the model is the massive influx of young graduates from the preceding period (phase T1 to T2). An external factor, such as the shock of an economic recession, may also play a part in worsening allocation. Young people at the guidance stage, alerted to the moribund state of the job market, react by losing interest in the corresponding discipline.

However, from time T3 the decline is replaced by an increase in enrolments. This new growth is due to the fact that market conditions have again improved. The improvement factor intrinsic in the model is the

These four subjects have experienced the same rhythm of heightened decline and revival of enrolments. It is largely the fluctuation in these specialisations which has provided the sciences overall with a cyclical movement;

- the trend in civil engineering is different; its enrolment cycle runs directly counter to the first cycle discussed above;
- the trend in non-science disciplines and in computer science and biology is different;



progressive shortage of young graduates; this is a result of the loss of interest among the previous generations (phase T2 to T3). Subsequently, the arrival in the market of the generation of increased enrolments bears the seeds of a renewal of the cycle.

In comparison with the enrolment curve, the graduate series is flatter and offset downwards, reflecting the fact that some of the students enrolled leave during courses. These early departures may be due to dropping out or transfers to other disciplines.

Graph 3 shows the trend in inflows and outflows for the four disciplines of the first type discussed above. The phase shift characteristic of the cobweb model is fairly clear-cut from the 1990s <sup>(\*)</sup>. According to the analysts using this model, the cycle emerged not so much because the wave of enrolments during the 1980s arrived in the labour market, but primarily because of the acute industrial recession in the early 1990s. The labour market for the four occupations considered here experienced a drop in demand, as the main industrial enterprises froze any recruitment of young engineers or researchers for a number of years and made experienced technical managers redundant for the first time. This made it very difficult for physical science and technology graduates to find jobs (Parmentier et al, 1998a, 1998b). It is this far-reaching crisis in industry-related job markets that explains the decline in enrolments in the associated disciplines.

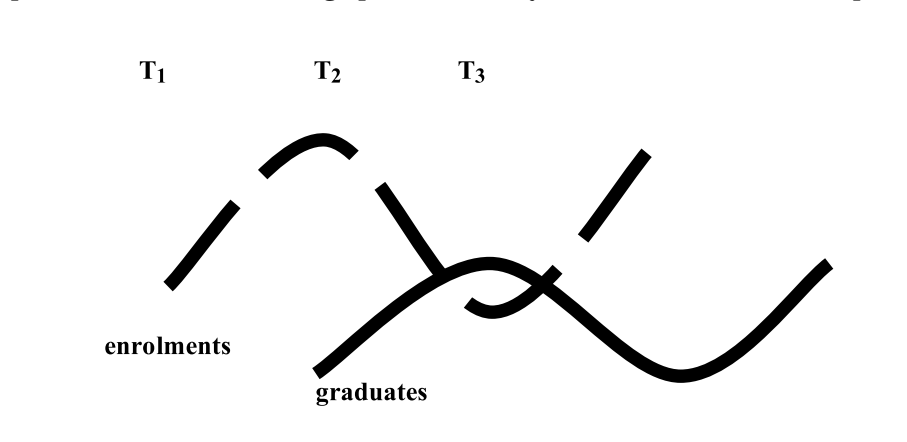
The decline in enrolments up to the second half of the 1990s is now being reflected by an extremely small number of young graduates. As a result, industrial enterprises are complaining about the shortage of engineers and scientists. In keeping with the model, new enrolments have since soared.

The picture shown by Graph 3 has been supplemented by official forecasts of the annual number of new graduates up to 2009 (KMK, 2003). According to these estimates, this number will increase sharply during this period - a result of the sustained and recent upturn in enrolments. The market situation, which is currently very advantageous for graduates in the four disciplines examined, is likely to deteriorate when the current wave of new enrolments comes on to the market.

An interpretation based on the interaction between the job market and enrolments is

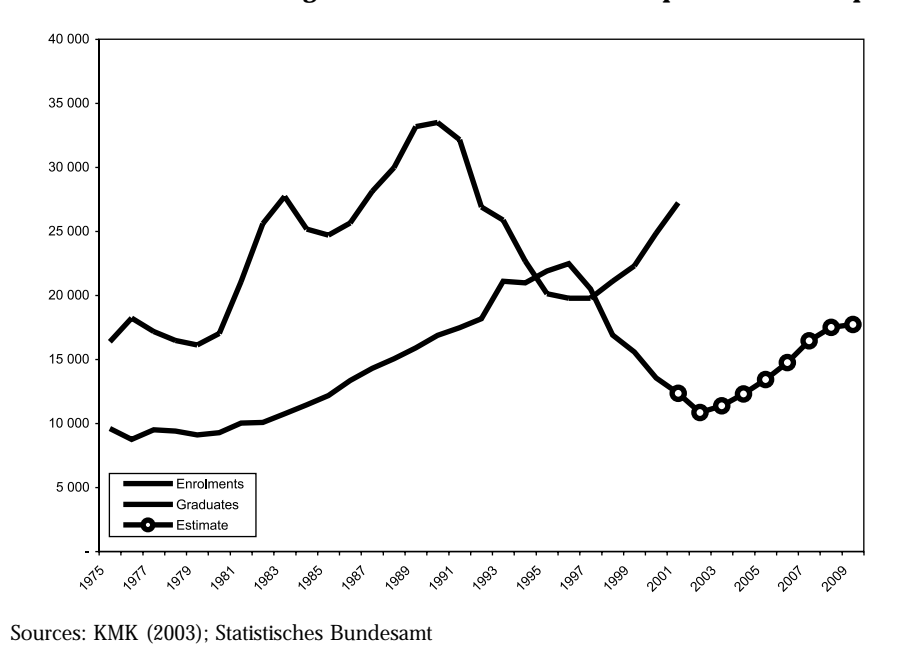
phases and intervals making up the cobweb cycle

Graph 3



Trend in enrolments and graduation in four science disciplines

Graph 4



Sources: KMK (2003); Statistisches Bundesamt

borne out by the situation in civil engineering. This discipline shows the same cycle in reverse (see Graph 2), reflecting the specific situation in the construction industry. Activity in this sector did not mirror other industries because of the rebuilding of East German infrastructure. In the late 1980s, activity in this sector increased sharply before falling back into recession from 1995. This particular rhythm has been reflected by a cobweb cycle of enrolments in civil engineering which is not in phase with the cycle for the four disciplines of the first type.

**Institutional conditions for cyclical adjustment**

A comparison of the countries of Europe shows that the labour market problems faced by physical and technological science grad-

(\*) Between 30 and 50 % of students drop out of courses in the four specialisations examined here. Analysis of motivations shows that these early departures are not primarily due to the labour market: the difficulty of the subjects taught seems to be the main reason why students drop out at an early stage (Heublein et al, 2002).



uates do not necessarily lead to a fluctuation in enrolments (International Working Group, 2003). Moreover, a comparison of the various higher education fields in Germany shows that enrolments are not correlated with the labour market in many specialisations (Briedis and Minks, 2004) <sup>(6)</sup>. These observations highlight the fact that the operation of the cobweb model depends on a number of specific conditions. Heijke (1996, p. 9) lists the three aspects conventionally put forward:

'In the first place, there must be a clearly defined sub-market for people with a particular kind of training. The second condition is that the training lasts relatively long. (...) The last important condition is that people who are choosing a course of study respond to the labour market situation at that time, rather than to the prospects as they will be when they have completed the course'.

In this section, we shall look in detail at two factors. The first is the elasticity of the education system - how well it adapts to fluctuations - a factor not included in the quotation. We are therefore introducing a new aspect which is not really dealt with in the literature. The second is the segmentation of the labour market, listed in the above quotation, which we will examine in detail for the occupations of engineer and scientist.

The condition which we have called 'elasticity of education system capacity' means that the infrastructure of a higher education discipline (departments, numbers of teachers, etc.) is maintained during slack periods and tolerates the overload during peak periods. The alternatives to elasticity are reduction by selection and, taking a market approach, the play of expansion/contraction.

Elasticity as a management method is very characteristic of German science and technology disciplines. During the slack period of the 1990s, it was very rare for physical science or engineering departments to be closed down or merged. In some places with good reputations for science education, such as the faculties at Karlsruhe and Darmstadt, enrolments fell by 70 % but they managed to survive without taking much infrastructure out of commission. The same elasticity can be seen during peak periods, in the form of overload practices. In 1991, for instance, the record year for science enrolments in engineering courses, German

federal education statistics show that 350 000 students enrolled for this discipline (all years combined) and shared the 150 000 places formally allocated to the institutions concerned (Statistisches Bundesamt, 2000).

The reasons for this elasticity depend on the trend in enrolment flows. From the point of view of infrastructure, it is obviously advantageous to try to retain the particularly large-scale technical equipment used in these fields during periods of educational recession. At the same time, the importance of this infrastructure for innovative and/or regional economic circles has been widely politically recognised. Works on industrial basins have in particular reiterated the view that the comparative advantage of many German industries lies in the traditionally very intensive relations between science and technology faculties and enterprises (OECD, 1999).

Overload is reflected by a firm tendency to cap infrastructure despite the expanding number of enrolments. Practice bears witness to a culture of free access. At the same time, it reflects the well-established political interest, shared by employers, in safeguarding a balance between vocational training and higher education. Any major higher education programme may well divert student flows and thus destabilise the status of vocational training. Access to intermediate occupations offers a particular illustration of this scenario. In Germany, vocational training is the almost exclusive nursery for these occupations. This primacy undoubtedly helps to keep vocational training attractive. A rapid and substantial expansion of higher education could well destabilise this arrangement, chiefly because of the competitive pressures that higher education graduates would exert on access to these intermediate occupations. The function of overload policy in higher education can therefore be seen as a kind of deterrent - curbing any expansion of education in order to protect the status of vocational training.

As Heijke, cited above, points out, the job market is another condition preceding a cyclical development of enrolments. A key factor in the job market is the major correspondence between the profile of graduates in a discipline (skills, career plans) and employers' preferences. According to the 'institutionalist' labour market approach (Baden et al, 1996), this mutual affinity has become root-

<sup>(6)</sup> Biology, which is growing (see Graph 2), is among the disciplines which have evidently not been affected by chronic labour market problems. As far as we know, no research offers a solid interpretation of this phenomenon. A promising avenue for exploration may well be the fact that the upturn in enrolments in biology during this period has been due exclusively to women who accounted for as much as two thirds of new enrolments in 2003.



**Proportion and number of graduates entering the service sector by scientific discipline and year of graduation**

**Table 1**

Discipline	% of graduates entering the service sector (first job)		Number of graduates entering the service sector (first job)		
	Year of graduation 1989	Year of graduation 1997	Year of graduation 1989	Year of graduation 1997	Trend 1989 - 1997
Electrical engineering	11	24	1200	2800	+ 1600
Computer science	12	55	400	3600	+ 3200
Physics	6	23	200	800	+ 600

*Field:* commercial services excluding research and training work  
*NB:* the figures are for Fachhochschule and university combined.  
*Example:* among computer science graduates in 1989, 12 % (= 400 people) found their first job in the services sector. This percentage increased to 55 % (= 3 600 people) for computer scientists graduating in 1997.  
*Source:* Briedis and Minks (2004), personal calculations

ed because it offers advantages, for both sides, in terms of certainty and of integration and adaptation. As a result, graduates very rarely experience substitution in the market segment associated with their discipline. When professionals are lacking, attracting a labour force from other disciplines or markets is an atypical move which is generally expensive, risky and therefore not very efficient. At the same time, it is very difficult for the occupation to infiltrate other job markets; in a situation of surplus, it adapts only with very great difficulty, through the exodus of surplus workers. In short, a system segmented into job markets entails inflexibility which curbs inter-sectoral mobility.

A first example of Germany's segmented structure is to be found in the ability of young graduates from three 'neighbouring' disciplines to get round the problems of gaining a foothold in the industrial sector by shifting into the booming commercial services sector. The three disciplines considered here are computer science, electrical engineering and physics (?). All three have a strong information technology component. These technologies are spreading, as we know, through all sectors, including services.

The following table shows that the services sector has been moderately infiltrated by electrical engineering and physics graduates but has been massively infiltrated by computer science graduates.

This contrast is due to the relationship between training and the specific market. Computer science prepares for ubiquitous jobs; the ubiquity of outlets is also a feature of law and economics. The fact that 'transverse' disciplines such as computer science do not follow a cobweb model (see Graph 2) is explained by the wide range of outlets that they offer for their graduates. The other two

specialisations are much more subject to segmented market restrictions. Physics trains 'generalists' who are channelled towards and of interest to industrial or public research but are fairly remote from the needs of small service enterprises; these prefer specialists who can be put to work straightaway (Fuchs, 2004). Electrical engineering is linked, in terms of training and attitudes, to jobs which call for the joint mobilisation of the two competences of 'IT' and 'electrical/electronic equipment' (ZAV, 2002). This type of job is fairly rare in the services sector.

A second example of market segmentation is provided by careers in engineering. There is a popular expression in Germany according to which this group has 'funnel careers' (Schornsteinkarrieren). This revealing expression relates to the promotional streams within and between enterprises which are both well marked out vertically and very narrow horizontally. Comparative international research into engineers has shown that this kind of career predominates in Germany (Faust 2002; Lawrence, 1992) - and that a double qualification is persisting, which is very different from the case in France and the United Kingdom. In practice, engineers do not swap their technical responsibilities for managerial responsibilities during their careers, as may be the case in France and the United Kingdom. In Germany, organisational systems require them to develop both competences. A result - whether intentional or not - of this arrangement is that it is almost impossible for technical managers to become pure managers eligible for and interested by a wider range of operational and economic sectors.

The two institutional conditions examined here, the elasticity of the education system's capacity and the segmentation of the job market, combine to cause any adjustment

(?) Industry is traditionally a main outlet for these three disciplines. Among electrical engineering graduates in 1989, 75 % found their first job in an industrial sector. This percentage was 66 % for computer scientists and 30 % for physicists graduating in the same year (Briedis and Minks, 2004).





to be transferred: the characteristics of the job market curb inter-sectoral mobility, thus transferring the supply/demand adjustment pressure to enrolments in the corresponding higher education courses. Without quotas, this transfer is reflected by cycles in enrolments. These cycles bring about subsequent mismatches generating or continuing the cobweb process.

### Conclusion

The loss of interest in higher education in the sciences is, in Germany, part and parcel of a cyclical process of enrolments in the disciplines in question. The process is not compatible with the image of a medium- or long-term trend or with the image of a recent change. It is much more in line with the cobweb model in which there is a cyclical alternation of interest and loss of interest in this area of education.

The cobweb system is based on a recursive loop; the labour market imbalance directly causes changes in enrolments which, in turn, lead to new imbalances. A number of conditions are needed for these imbalances to occur. Without being exhaustive, these include the ability of the education system

to modulate its reception capacity, the length of training and the segmentation of the labour market into occupational sectors.

The model implies that it is these labour market processes, rather than demographic or cultural changes or changes in the education system, which determine the rhythm of enrolments in these subjects. This hypothesis is consistent with the judgment of a number of contemporary observers. According to Lewin (1999), Wolter (1999) and Zwick and Renn (2000), the social institutions are gradually losing the ability to ensure that people prepare for specific career plans. Among other things this is due to the increasing proportion of secondary school leavers who play a waiting game or are undecided about their choice of pathway and education. The rift brought about by this 'under-socialisation' is helping practices based on calculations of immediate commercial value to gain ground. According to Lutz (2001), the proportion of young people whose behaviour mirrors the neoclassical models of human capital investment is set to increase sharply. The cyclical alternation of interest and loss of interest in the sciences is therefore a spectacular manifestation of the advance of a utilitarian attitude towards choices of education.

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### Key words

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