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Introduction

The objective of this paper is to explore the changing conditions affecting the way a higher education system responds (or not) to the changing needs of the economy. We use the results of more traditional historical researches (Gispen, 1989; König, 1993; Diebolt, 1997) and contemporary testimonies (e.g. Cambon, n.d., before 1914) in order to account for the evolution of the Prussian engineering education system and how it reacted both to the incentives faced by professors and to the lobbying power of employers. Our arguments are supported by a theoretical economic narrative (in the line of New Institutional History à la Greif, 1998; see also North, 1990, 1994). A future by-product of this research would be the building of game-theroretical structures accounting (and generalising) the main stylized facts derived from our "new institutional historical analysis", as we think that the observed patterns can be relevant for economic policy today (see the debate around the reform of higher education systems in Europe).

But before attempting any modelization exercise, we first turn to an explicit economic historical analysis, in the line of the *new institutional history* (NIH, see Greif, 1998, 2006 and also North & Thomas, 1973, North, 1990, 1994). This kind of analysis will enable us to pinpoint recurrent stylized facts and identify the main actors. The objective is to identify the endogenous (behaviour of actors operating within the institutional framework) and exogenous (business cycle; policy change, even it can also be the product of endogenous move by specific actors) sources of institutional change (see Acemoglu, Johnson & Robinson, 2001, 2005). It would also provide us with some guess as to how far specific institutional

arrangements might help in favouring the adaptiveness of the system as a whole: "*Institutions are subtle forms whose real functioning cannot be discerned without a deep knowledge of their context and history*." (Clark, 2007, p. 726). In fact, "*beyond the study of long run quantitative data sets, a branch of cliometrics is more and more focused on the role and evolution of institutions by aiming at combining both the desire for generality of the economists and the concern for the precise context in which economic players act that characterise both the historians and other social scientists. The middle road between pure empiricism and disincarnate theory might perhaps open the door to a better economic theory, enabling economists to understand more deeply the working of economies and societies and by the way offer better policy advice.*" (Demeulemeester & Diebolt, 2007, p. 16.).

As Kindleberger (1990) once pointed out, economic history is certainly not sufficient to ensure good economic analysis, but it is however a necessary condition. It can help in identifying which assumptions and which models are likely to best represent the reality at hand. Greif (1993, 1998, 2006) has indeed showed that very often, game theoretical models are too general and provide multiple equilibria. Only a precise economic and institutional historical analysis can help in disentangling all these elements.

In the NIH a point is common with the traditional practise of the (positivist) historian: the historical analysis had to be as "*precise*" as possible (accounting as precisely and truthfully as possible for the precise sequence of events, i.e. *wie es eigentlich gewesen ist*). However here the historical work is just a preliminary step before trying to locate some recurrent phenomena or stylized facts (or evolutions). NIH is an inductive approach aiming at providing possible elements of explanations of a circumscribed phenomenon. It is therefore a tool that can be helpful not solely for historians but also (and perhaps mainly) for social scientists or policy makers addressing contemporary equivalent issue. This is particularly true in our case, when one considers the large debate surrounding the reform of higher education systems in Europe and the contribution of higher education institutions to economic growth (see the recent neo-schumpeterian approaches about the varying optimal policies to promote growth depending on the distance to the technological frontier; see Vandenbussche, Aghion and Meghir, 2006). Changing institutions is difficult (especially in the direction desired by policy-makers). North (1990) stressed that there are forms of persistency in human institutions: their future evolution is partly conditioned by their history (i.e. path dependence, David, 2007). In a Northian perspective, institutions are the rules of the game established in order to reduce transaction costs in human interaction by reducing uncertainty and establishing some common knowledge ways of interacting. The problem is that, once established, these rules are used by the various groups in society to promote their own interests; they build by the way new organisations. By the way also existing institutions are reinforced, and they cannot be changed abruptly (institutional lock-in). The rules of the game have often been designed (ex ante) in a very static

perspective, i.e. reducing uncertainty and by the way transaction costs in the short-run. They often reflect the bargaining power of the various groups in society at a precise moment in time. They do not include any concern for dynamic efficiency. It might be, however, that certain institutional structures appear (ex post) to favour entrepreneurship and wealth-creating activities. But it might also be true that they promote rent-seeking activities (Murphy, Vishny & Shleifer, 1991). Countries could be trapped in a high-growth or a low-growth equilibrium due to their institutional framework (and the set of incentives they imply) (North, 1990, 1994). This is the reason why institutional design is so important. Historical analyses can be a good tool in order to understand the way real-world institutions evolve in a specific context.

In this paper, we concentrate on just one country (Prussia) as an illustration of the above proposed general principles. This work is an extension to previous cliometric work on education and economic growth in Germany (see especially Diebolt, 1997). We study the evolution of the Prussian technical higher education system and analyse how it is affected by (and how it reacted to) the evolution of the economy. We particularly stress the micro-foundations of institutional change as we analyse how the individual behaviour of the actors inside the institutions could shape their evolution for better or worse.

1. The foundations: the role of "*enlightened*" bureaucrats

The evolution of the Prussian higher technical education system is rather complex. As in France, it is a construction from above, by the State (*Berufkonstruktion durch den Staat*)[1] who tried to set up a system corresponding to the perceived needs of the economy (and particularly the ones of its own administration). But in Prussia, the forward-looking character of the Prussian civil-servants led to the construction of a system well in advance to the objective needs of the economy, which did not face an important industrial development before 1850 (see Appendix on the growth of the national incomes in Germany and Prussia: figures 1, 2, 3, 4). This left room (as we will show) for a movement of academization within higher educational institutions (academic drift) in order for the professors to improve their standing within a Prussian society still marked by preindustrial values (quest for status[2]). The economic crisis beginning in 1873 will anew give top priority to economic considerations and lead to a reorganization of the curriculum (increased vocationalisation and lowered entry requirements) (see the thorough analysis by Gispen, 1989).

After the defeat of Prussia (1806), a movement of economic and administrative reorganization has been set up by higher civil servants as von Stein (1757-1831), and actually put in practice since 1810 (with the chancellar Hardenberg, 1750-1822). There was a widespread belief that the economic

[1]See Koenig, 1993, p. 71; see also Lenoir, 1998, on the "*Revolution from Above*" concerning the role of the state in creating the German Research System, 1810-1910, and Pfetsch for the quantitative development of government expenditures on science in Germany, 1983, 1985).

[2]For a theoretical discussion of the role of this quest for status on economic performance, see Hirsch (1976), Fershtman & Weiss (1993) and Fershtman, Murphy & Weiss (1996).

backwardness of Prussia (when compared with England or France) can only be overcome by introducing economic liberalism and deregulation, as well as by improving the average level of skills in the population (Gispen, 1989, pp. 16-24). Very modern concerns as the role of human capital in permitting innovation and technological progress, and in creating a better, more forward-looking industrial class, were very much present at the beginning of the 19th century (Gispen, 1989; Lenoir, 1998). The reports of Kunth (1810), "*bear witness to the conviction that ignorance and lack of education were at the root of the problem. The reformers viewed education and freedom as two mutually reinforcing principles that would overcome Prussia's greatest handicap, the tradition-bound attitudes and backwardness of its economic classes. Stein and Kunth saw the causes of economic backwardness not merely in excessive government regulation of the economy or the lack of particular modern techniques and skills, but above all in the low level of general education of the economically active population, specifically its ignorance of the 'mathematical and physical sciences, and what is based thereon: history, especially history related to the development of culture and modern languages'. They believed that technological stagnation was ultimately the result of a more general ignorance and the lack of general education, in turn, was primarily a consequence of the vast social rift between Germany's artisanal and manufacturing classes and its 'cultivated', classically trained higher orders. Regeneration of Prussian society could take only place if that gap were bridged. That would be done by a 'revolution from above' which would introduce a program of modern, nonclassical education, centered on the natural sciences and designed for all social classes*" (Gispen, 1989, p. 18). So, the early reformers thought that economic recovery will be favored both by extending the reach of secondary education beyond a narrow elite, and by changing the curriculum towards natural sciences and modern languages.

However, two forces opposed such a movement of educational revolution from above. One was political, i.e. the fear resented by the privileged classes to loose their power in case of the emergence of a too much liberal society. The other was more narrowly financial (near-bankrupcy of the Prussian state and the need to come up with massive payments to the French conqueror). There was therefore a considerable political realignment after 1810, immediate economic modernization receiving the priority against political emancipation. The educational policy was implied, as "*the plans for a wider social and political emancipation of the industrial and commercial classes via modern, science-based general secondary education were abandoned. They were replaced by a technologically more concentrated and culturally narrower conception of separate specialized occupational training programs to achieve only the economic emancipation of select artisans*" (Gispen, 1989, p. 23). The most important part of secondary education (i.e. the general segment) was completely reorganized and became totally cut off from occupational and economic concerns.

Following Gispen (1989), the Prussian educational system tended actually to mirror the social (cultural) structure: there was a status scale based no more on noble birth but on the "perpetuation of privileged professional status groups of high social rank[3]" based on "*formale Bildung*", to be acquired through a classical secondary education and university training. The latter group was considered as superior to the former, as were the "*higher*" cultural occupations associated with the state in comparison with the "*lower*" practical occupations in the private sector. As put forward by Weiss and Fershtman (1998, p. 803), "*whatever the explanation for the existence of status rankings, the desire to attain high social status has important implications for saving, occupational choice, investment in skills and risk taking*". The "*anti-vocational*" bias within society and education was reinforced by a shift in the preferences of the elites after the defeat of France (1814-15). The tendency of 18th century enlightened absolutism to restrict the function of education to practical utility and the French cultural and scientific influences were stongly opposed. As stated hereabove the Prussian (general) secondary education was reformed in a completely anti-vocational way: prejudice against practical knowledge, emphasis on the classics, complete neglect of occupational and industrial occupation. This was the new *Gymnasium*, which spread over Prussia from 1810 to 1820 (under minister Humboldt).

"*For higher education, these educational tendencies meant the revival of the universities, especially the ascent of the philosophical faculty as a bastion of philology and Geisteswissenschaften ("cultural sciences") and the gradual development of "pure" natural science. All the emphasis in natural science was on theoretical investigation and basic research. In conformity with neo-humanist outlook, it was defined as knowledge for its own sake and as a form of moral excellence. Even if it had practical value, university-based science always rested on a foundation of classical learning. The applied sciences, in contrast, were considered morally inferior and therefore suffered neglect, or else were made over in the neo-humanist image. Disciplines such as technology or Cameralism (applied law and economics), for example, were robbed of their pragmatic technical aspects*" (Gispen, 1989, p. 24).

All this evolution was contradictory with the official policy of economic renovation. Indeed, the spread of a neo-humanist education was not particularly suitable for the needs of the economy. "*Despite the repeated complaints, Commerce Department officials were powerless to influence the course of events until 1820*" (Gispen, 1989, p. 25). The Department of Culture, held by Humboldt, set the pace of educational evolution in a way very dissimilar to the one advocated by the Department of Trade and Industry, "*mandated to revive the economy in part through a policy of utilitarian, technical education*" (Gispen, 1989, p. 25). The conflict was only partially solved in 1820, "*when the Ministry of Trade and Industry received the mission to set up, outside the orbit of "general education" its own system of specialized occupational instruction*" (Gispen, 1989, p. 25). However, as already pointed out, the new

[3] See Gispen (1989, p. 22). He speaks of *Berufsstände*.

secondary technical schools were established in such a way that they were narrowly specialized, i.e. "designed for the encouragement of private enterprise and intentionally set up in order to create narrow specialists" (Gispen, 1989, p. 25). This organization (general education based on the classics providing a moral, superior education in front of narrowly technical schools) reinforced the deep prejudices against the economically productives, and the dichotomy between a generally (classically) educated elite and the "*technicians*", considered as inferior. This preserved the preindustrial status hierarchy and solidify the recent gains of the classically educated middle class. This was something already stressed by Weiss and Fershtman in their survey on social status and economic performance: "*some view social status mainly as an instrument to restrict entry and to impose modes of behavior which help to maintain the advantage of privileged groups*" (Weiss and Fershtman, 1998, p. 803). Around 1830, there remained three types of secondary schools in Prussia: the classically-oriented *Gymnasium*, the *Realschulen* (a kind of in-between secondary schools based upon a more modern curriculum, but which will become increasingly "*classicified*" in order to allow their graduates to enter universities and the civil service), and the provincial vocational schools (the lower tier of the system, with a sole technical education).

As far as higher technical education is concerned, the Prussian State had already established it at the end of the 18th century, in a way not much dissimilar to the State-established French *Ecoles* (even if the Prussian State manifested a greater concern for the needs of the private sector). "*In 1787, the Governement had set up several Provincial Art Schools to improve the level of artisanal competence (for the private sector). In 1799, it had established the Berliner Bau-Akademie to train surveyors and its own corps of civil engineers. As a civil service school, the Bau-Akademie required a basic knowledge of Latin and French for admission*" (Gispen, 1989, p. 30). However from 1800 to 1820, the reputation of the school declined due to several combined weaknesses: teaching level too advanced for most students, lax discipline, technical incompetence (Gispen, 1989, p. 30). Beuth revived the system and tried to adapt it partially to the requirements of industrial education for the private sector. He established "*a two-tier system with a central higher institute at the top, and a string of lower-level schools in the provinces*" (Gispen, 1989, p. 30). The best students from the lower stage were allowed to the higher level, but only if they go into private industry. There were actually two tracks, one leading to the civil service and requiring a "*generally cultivating preparatory education*", and the other leading to business careers and necessitating no such "*classical*" preparatory education. The *Bau-Akademie* (renamed General Building School) required such a 'generally cultivating preparatory education' including Latin. "Students going into private industry could enter a separate institution of their own, the Industrial Institute (*Gewerbe Institut*) in Berlin[4], without having taken classics" (Gispen, 1989, p. 30). Most of these students came

[4]Established in 1821 by Beuth. It provided first rudimentary instruction to handworkers and manufacturers in mechanics and chemical-technical subjects. The school was expanded within a few years

from the system's bottom tier, namely the Provincial Trade Schools (*Provinzial Gewerbe Schulen*, established around 1820 and well-developped around 1850). There was therefore a clear distinction[5] between the education of engineers for the civil service (*Bau-Akademie*) and the private sector (*Gewerbe Institut*), the latter being less prestigious (Koenig, 1993). This higher technical education was initially very vocational, practically designed and very oriented towards the needs of the economy. Beuth was very much concerned by the practical relevance of classroom instruction. "*He attached practical workshops and a laboratory to the industrial institute to ensure the optimal usefulness of its program for industry*" (Gispen, 1989, p. 32). Beuth was not only concerned by the curriculum content or the organization of technical schools. He also set up two agencies in order to stimulate the economy by bringing together in one place representatives from industrial practice and scientific knowledge (the Technical Deputation for Industry – *Technische Deputation für Gewerbe* and the Society for the Promotion of Industry – *Verein zur Beförderung des Gewerbfleisses*) (Gispen, 1989, p. 33). However, all this institutional setting was purposedly designed in such a way that it was well in advance when compared with the actual state of the Prussian economy before 1850, lagging well behind the English, French or Belgian ones. The objective was to ensure that the take-off of the economy would not be impeded by skill shortages of any kind.[6]

2. The academic drift: the role of professors

However, all the Prussian academic system was implicitly (socially speaking) adverse to technological education, as it considered it as a second best when compared with the general classical education given by the *Gymnasium* and the new humboldtian universities. Even within higher technical education, the same dichotomy existed as the *Bau-Akademie*, educating broadly cultivated combined civil engineers and architects, who had access to civil service and were required to be acquainted with classical languages, was regarded as superior to the Industrial Institute, educating mainly mechanical engineers for the private sector, and requiring no prior knowledge of any classical language as entry requirement. Nevertheless, even the broadly cultivated engineers from the *Bau-Akademie* entering the civil service were regarded as inferior (and their actual wages reflected this prejudices) and earned less than the lawyers (Gispen, 1989, see also figure 12: one can see that enrolments in law schools were systemically higher than the ones to engineering schools before 1860, reflecting probably the difference in the economic rewards, the latter reflecting the social demands for the professions at an early stage of

to include a third class, the "*Suprema*" which treated the scientific basis of technology as a united field of study (see Lenoir, 1998, p. 22).

[5]Abolished in 1879 with the establishment of the *Berliner Technische Hochschule* (Koenig, 1993, Rurüp, 1979).

[6]We can see here the same economic philosophy as in List, 1841.

economic development). The engineers in Prussia[7] were confronted with a problem of social status and thrived to ameliorate it during most of the 19th century. Gispen (1989, p. 65) considered that they lied at the border between two worlds: the high status world of the non-productive cultural activities linked with the state and the universities (through the role of the engineers of the civil service and the professors in the technological institutions), and the low-status world of the productive sphere represented by the private sector. The engineering professional association, the *Verein Deutscher Ingenieure* (VDI) founded in may 1856, reflected this internal division of the profession. It was also unable to precisely define what an engineer was, and access was open to everybody. Deeply influenced by the dominant cultural values of the Prussian society, it was first dominated by the ethos of the professors (important in the bureaucracy, even if honorary chaimanships were accorded to managers and entrepreneurs) and tried to emulate the other professions on the same ground (while stressing no corporatist interests but the splendor of Germany through the achievements of technique[8] for its own sake[9]). However, the VDI did not defend the corporatist interests of the engineers with the same intensity as the other professional associations, and relied very much upon a liberal approach (each engineer has to prove by himself his own value on the marketplace).

This philosophy of the VDI (held until 1877) had also strong impacts on the engineering education, as far as the state of the economy did not actually impede these evolutions. The professors in engineering institutions tended to narrow the gap with the high prestige academic disciplines of the universities and with the humboldian ideals of pure research[10]. They tended towards an academic education closer to the model of the "*pure*" sciences rather than with a vocational training in applied science. Engineering was considered as a mathematical discipline with very few links with industrial practice[11]. The educators at the technical schools begin to criticize their own field for its empirical character and "*its failure to be truly scientific in approaching technology*" (Gispen, 1989, p. 35). As soon as 1829, professors at the Industrial

[7]We should note here that the *Bau-Akademie* was, after the mining academies, the most prestigious and the most demanding of all technical institutes (Gispen, 1989, p. 89).

[8]"*It will be our duty to participate in the common patriotic work, chiefly by mutual education and encouragement and, in that way, by the advancement of technology, which ranks with science and art and stands between them as a cultural-historical achievement of the human spirit in general and the German nation in particular*" (VDI Zeitschrift, 1857, pp. 14-15).

[9]Moreover, the VDI never established clear access conditions which would have helped in defining clearly what an engineer is. This will have a long lasting influence as the engineers will never succeed in obtaining the same status as the other professions.

[10]Koenig (1993) noted the persistent ambiguities of the professors of the Polytechnische Schulen, criticizing the universities for their lack of practical relevance, but adopting their values in order to gain status.

[11]A good illustration of this tendency is the professor Ferdinand Redtenbacher, mechanical engineer at the Karlsruhe Polytechnical School (Baden), best known for his effort to elevate machine building to the level of an autonomous science strictly based on mathematics and mechanics (around 1850).

Institute showed discontent with the low status of their institution and urged stricter admission standards and expansion of the natural science curriculum[12]. "*The teachers developed an ideology of practical knowledge that minimized its concrete connection with industrial reality. Instead it maximized the theoretical, purely scientific aspects as well as the general cultural significance of technical knowledge*" (Gispen, 1989, p. 38). It is interesting to note that this quest for status leading to a form of academic drift is not necessarily solely bad for the provision of skilled people to the economy. Weiss and Fershtman (1998, p. 811) noted that "*status can be socially beneficial if awarded to activities which directly enhance growth, such as investment in schooling and research.*" As Murphy, Vishny and Shleifer (1991) pointed out, the relative incentives associated with a profession are very important in explaining why some societies experience high growth rates due to their emphasis on entrepreneurial activities while others remain stagnant due to too important incentives for pursuing rent-seeking activities. In this sense, the strategy of increasing the status of Prussian engineers might have been good for growth if the increased benefit of attracting brighter people to the engineering profession more than compensate the loss in technological expertise due to the academic drift. We implicitly find such an argument in the words of Ferdinand Redtenbacher, one of the leading advocate of the "*mathematical drift*" in engineering education: "*cultivated people are right if they call the industrial class crude in its present state. But they are wrong if they believe that real cultivation is incompatible with industrial work; unfortunately, that is the prevailing attitude, which has harmed and inhibited Germany's industrial development to the highest degree. Talented and refined people will not readily enter a profession that is not respected*" (Redtenbacher, 1879, p. 57, quoted by Gispen, 1989, p. 41). However, it has also to be pointed out that such a paradigm shift might also have been "*a golden goose for the professorate, which yields it not only salary and pensions, but frequently also fringe benefits like honoraria, commissions, titles, decorations, and in general alla the advantages of a secure civil-service position*" (Schlink, 1878, quoted by Gispen, 1989, p. 37). The highest point in this academization process was surely in the sixties, when Grashof published a Manifesto (1864), which was in essence a blueprint for the reorganization of German higher technical education[13]. He strongly opposed the existing system of separate and unequal technical schools for state and society (the private sector)[14], and advocated the establishment of just one integrated *Technische Hochschule*, fully equal to the universities and providing nothing less than "*a scientific education that meets the highest possible standards*" and that suit the needs both of the public and the private sectors. These *Technische Hochschulen* (see Appendix: figures 5, 6, 7, 8) would be highly

[12]On the model of the French *Ecole centrale des arts et manufactures* in Paris, see Lundgreen, 1975.

[13]"*Except for one major change, Grashof's plan would be implemented almost to the letter in the course of the next several decades*" (Gispen, 1989, p. 78).

[14]i.e. the dichotomy between the Industrial Institute and the *Bau-Akademie* (Gispen, 1989, p. 78).

scientific and mirror the ethos of the humboldtian universities: disciplines like forestry and business education should be excluded and workshops and laboratories would be dismantled as much as possible because they were unworthy of pure science that engineering education was to become (Gispen, 1989, p. 79). Industrialists first did not criticize these evolutions as they considered themselves incompetent as far as curriculum design was concerned (see Koenig, 1993, p. 92).

Linked with this quest for status was the important debate concerning the requirement of a preparatory classical education to enter engineering schools. Influenced by the dominant culture, the engineers tended to advocate such a practice in order to gain status and come closer to the education of more traditional professions (while at the same time securing access to the civil service). This tendency (reflecting a profound identification with inherited and backward-looking notions of professionalism) was perfectly illustrated by the Grashof Manifesto of 1864, who advocated the introduction of uniform high admission standards for the *Technische Hochschule*. He proposed the elimination of the *Provincial Trade Schools as preparatory schools, and suggested that only "generally* cultivated" students should be admitted to the *Technische Hochschule* (i.e. graduates from *Gymnasium* or *Realschule I. Ordnung*). "*Only such students possessed the prerequisites for acquiring the "higher positions in life", that is, Latin, which the VDI director described as the 'most natural, almost indispensable foundation for a solid study of modern languages... by virtue of its highly developped grammar and concise sentence structure... even suited to promote the study of mathematics and the natural sciences*" (Gispen, 1989, p. 79). Therefore, the tendency towards making the engineering subject more academic was also accompanied by a desire to make it more restrictive (Koenig, 1993, p. 72).

3. The change towards vocationalism: the influence of employers

This tendency towards the traditional model of professionalism in Prussia was reverted after 1873. An economic crisis broke out that year[15] and led to radical changes in the perceptions of the private sector, so far not so interested in the design of engineering education, letting it to the professors at technical schools. An important episode in this evolution was the bad performance of German industrialists at the Philadelphia Exposition[16] (1876). Franz Reuleaux wrote a worried report on the German industrial performance (*Letters from Philadelphia*), even "a devastating critique of the quality of Germany's industrial products and design as compared with those of other countries, notably the USA" (Gispen, 1989, p. 115). He was then the director of the Berlin Industrial Institute and a well-known professor of theoretical mechanics, and also appointed commissioner-general to this industrial exhibition. He advanced three main criticisms against the German industry: its industry is too narrowly focused on short-term

[15]The Great Depression of 1873-1896. The economic crisis faced by the industry was most severe between 1881 and 1885, following Lenoir (1998, p. 25).

[16]An international industrial exhibition and centennial world fair.

objectives and looked only at producing bad and cheap products; the industrial design of German products was too inspired by "tendencious patriotic motives" which do not qualify them for international competition; and finally, "*German products were characterized by 'lack of taste in applied art and lack of progress in the purely technical*" (Reuleaux, 1877, pp. 5-6, quoted by Gispen, 1989, p. 115). Reuleaux accused the philosophy of the German business, and by the way he questioned the relevance of the current way higher technical education was organized. For Reuleaux, "*Germany's long-term economic success and international competitiveness among the industrialized nations required a fundamental change in business style*" (Gispen, 1989, p. 116). German businessmen were too much preoccupied with the short-run financial gains and with price competition, with the result that they were not very innovative. They should drop such preoccupations and instead concentrating on superior quality and technological sophistication. "*Systematic exploitation of the most advanced scientific technology would make possible specialization, mass production, and labor-saving techniques. This, in turn, would succeed in keeping prices down far better than would the murderous competition that currently prevailed and sacrified quality*" (Gispen, 1989, p. 116). This is here that Reuleaux saw a key role for the engineering profession, if correctly educated: "*Germany must turn away from the principle of merely competing on the basis of price and make a decisive transition to competition on the basis of quality or value. To produce nevertheless goods that are inexpensive and marketable, the machine, or more generally speaking the scientific technical apparatus must be employed in all those cases where physical effort can be eliminated or reduced and where mass repetition forms the foundation of production*" (Reuleaux, 1877, p. 95; quoted by Gispen, 1989, p. 116).

The movement towards a more vocational approach of engineering education was however not immediate. As pointed out by Gispen, "*the postcrash atmosphere (1873-79) did not influence the reform directly*" (Gispen, 1989, p. 86): at the beginning, concerns with social status and assimilation with the established professions remained dominant. The reforms were first of all influenced by the corps of civil engineers and architects within the Prussian state rather than by the engineering professors (in the spirit of the Grashof Manifesto: liberating the engineering education from its stigma of narrow specialisation, rising the entry standards, based on a general preparatory education at the *Gymnasium* or *Realschule I. Ordnung*, and merging the *Bau-Akademie* with the Industrial Institute into a new technical institution much closer to the universities). The former (and first of all the junior members) were very much dissatisfied by their actual situation within the civil service relative to the lawyers. They felt that they experienced "*constant discrimination in career mobility, promotion, pay, work load, and responsibility when compared with their legally trained counterparts*" (Gispen, 1989, p. 87). In order at least to keep intact their status they opposed any reform aiming at separating the functions of architect and civil engineers (Prussia's technical corps did not distinguish between them). They thought that if the lawyers

faced brighter career perspectives, this was mainly due to their "*general cultivation*", and that if engineers had not such prospects, this should be traced to the fact that they did not possess the "*generale Bildung*" as a result "*from not requiring a Gymnasium Abitur and accepting graduation from a Realschule with Latin as sufficient*" (Gispen, 1989, p. 88). If the *Baumeister* still possessed some general cultivation due to the integration of civil engineering with architecture, it would not more be the case if the two fields were separated. What they failed to recognize was the simple fact that lawyers were more demanded and rewarded due to their technical expertise and not to their alleged "*general cultivation*". The emergence of a *Rechtstaat* in the late 18th and early 19th centuries necessitated the employment of technical experts in order to maintain a legally correct government (see Hintze, 1964, pp. 102-103; Gispen, 1989, p. 88). Anyway, it is true that the corps of civil service engineers graduating from the *Bau-Akademie* faced severe problems. Their education was broad but insufficient to ensure a comprehensive mastery of both civil engineering and architecture. Moreover, the mere quality of their education declined, partly due to a chronic shortage of teachers and from imbalances in their composition (see Appendix: figure 6). The state itself suffered from the situation. Indeed, "*understaffed and underfunded, the corps was overwhelmed by the onslaught of urbanization and and building activity in the 1860s and early 1870s. Heavy involvement with trivial administrative duties and the need for utmost financial frugality had given it the reputation of a technological backwater. Problems were compounded by a tendency of corps members, especially in times of boom, to accept lucrative and interesting positions in the private sector rather than endure the hardships of a frustrating career in the Prussian civil service*" (Gispen, 1989, p. 89).

At the end of the sixties, the graduates of the *Bau-Akademie* (regardless they stayed in governement or not) increasingly felt the need for a better professional training. A group of young architects and engineers decided to constitute a group lobbying for a reform of their employment conditions and the training at the *Bau-Akademie* (in 1866), partly through the edition of a journal, *Deutsche Bauzeitung* (Gispen, 1989, p. 91). They fought against the monopoly of lawyers within the administration, and wanted the differenciation between the training of civil engineers and of architects, their basic argument being that the future will belong to those who excelled in their profession first, and only secondarily in "*cultivation*" (we note here the awareness of the key role of human capital for individual competitiveness on the labour market). During the seventies, there was a growing awareness of the conflict between the social dimensions of professionalism (quest for status through acquisition of a general cultivation outlook) and the objective specialized dimensions (the mere mastery of the technical aspects of the profession in order to be useful in the economy), due to the ever growing prevalence of economic constraints after 1873. "The dictates of economic and technological rationality" (Gispen, 1989, p. 95) were increasingly felt in a climate of economic recession, both by politicians and business leaders. This led to a movement of reform of technical education aiming at the establishment of a modern *Technische Hochschule* in

Berlin. The energetic influence of the minister of Trade, von Achenbach, the support from the *Landtag* and the desire of the Prussian government to alleviate the massive discontent also contribute to the impetus leading to the decision to establish a *Technische Hochschule* in Berlin in 1875-6 (Gispen, 1989, p. 97). However, there were to be a long delay between the initialization of reforms and their conclusion in 1879, because of a very intense debate surrounding the admission standards (mainly the question whether or not a classical secondary education was a requirement, and whether or not graduates from the former Provincial trade Schools —the new *Oberrealschulen*[17] since 1878— could access the *Technische Hochschule*). The movement was towards acceptance of the graduates of the *Oberrealschulen*, even if the opposition to them scored a temporary victory in 1886 when the governement briefly withdrew the *Oberrealschule*'s limited accreditation privileges (see Gispen, 1989, p. 146[18]). It reinstates them permanently in 1890. Even if the VDI defended for the most part of the seventies the preparatory classical education, it changed its mind in the end, reflecting the decrease of influence of the professorial mentors of the association. Engineers tended to consider that the modern path to higher cultivation, that based on natural sciences, was equal to the one based on the classics.

The impact of the economic recession of 1873-1896 was also important in producing a shift within higher engineering education towards the practical dimensions of engineering and the manpower requirements in industry, and at the expense of a model of pure science (Gispen, 1989). Even if the *Technische Hochschule* had been established in Berlin, the teaching remained heavily biased towards an academic ideal, completely disconnected with the concerns of the private sector. It was "*unduly oriented to the public services - a situation that was not helped by the fact that certain subjects relevant to important branches of private industry, such as textiles, were not taught at the Technische Hochschule*" (Koenig, 1993, p. 71). This traditional approach was under pressure at the end of the seventies. The engineering science was increasingly considered as an applied science for which financial rationality is extremely important: "*all industrial products have their only standard of value in money. The difference between cost of production and selling price - the profit - forms the only justified and possible foundation for operating an industrial business. The most perfect production process is an economic absurdity if it sustains a financial loss*" (Schlink, 1878 quoted by Gispen, 1989, p. 125). Moreover, as pointed out by a

[17]Contrarily to the *Gymnasium* and *Realschule I. Ordnung*, these schools mainly focused on modern languages, mathematics and natural sciences. They were therefore a priori better suited for the engineering higher education in objective terms, but as they only opened access to the *Technische Hochschule*, they manifested the social inferiority of higher technical education (the only profession not requiring a classical education).

[18]"*But on 6 July 1886, Albert Maybach, the Prussian minister of public works, had issued new regulations for admission to the corps of engineers and architects. Starting in 1890, the graduates of the Oberrealschule would no longer be entitled to register for the civil-service examination in architecture or civil or mechanical engineering… The old, invidious distinction between classically educated government engineers and socially inferior engineers in private industry had been brought back*" (Gispen, 1989, p. 146). The right of admission to the engineering corps was returned to the Oberrealschule in 1892.

professor of mechanical engineering in Munich (Hermann Ludwig), "*now that social-status objectives had been reached, it was time to refocus attention on the practical training of engineers, for things had gotten so bad in the meantime that industry much preferred young graduates from technical trade schools to graduates from the Technische Hochschule... A semi-education is victorious because semi-knowledge much more often combines with practical know-how than a completed, thoroughly scientific education*"[19]. Indeed, around 1880, many firms complained about the graduates from the *Technische Hochschule* because of their lack of practical skills, their "*unbelievable difficulties*" in industry and their tendency, implanted by the schools, toward idle reflection (Gispen, 1989, p. 150; see also Koenig, 1993, p. 72). They generally accused the lack of practical training, as the shop training, customary at most polytechnical schools until the 1860s, had been abandoned during the next two decades "*because it did not accord well with efforts to upgrade these institutes to academic status*" (Gispen, 1989, p. 151). As already pointed out, the professorial dominance within the VDI passed by the end of the seventies, and from 1879 to 1884, the VDI's educational policy concentrated largely on the question of shop training for engineering students at the *Technische Hochschule*[20]. The requirement of a "*practical year*" for admission to the examination became quite widespread in *Technische Hochschule* from 1886-7 onwards. During the 1890s, a change occurred also as far as the curriculum of the *Technische Hochschule* is concerned, illustrating the influence of the industrial requirements. "*A more empirical and experimental concept of scientific research and more pragmatic teaching methods began making inroads into the excessively abstract approach...*" (Gispen, 1989, p. 153). This change occured mainly after 1895 within the new *Technische Hochschulen*, partly under the influence of the American model of engineering education (whose advantages were discovered by the Germans at the Chicago world's fair in 1893 – see Gispen, 1989, p. 152 for a thorough discussion). The movement was characterized by less emphasis on analytical mathematics (as calculus), more emphasis on diagrammatic explanations and the adoption of laboratories for research and training[21] in conjunction with a tremendous expansion of drafting instruction. For example, in Berlin, laboratory and drafting hours went from roughly 35% of the total time devoted to instruction in 1881-2 to 45% in 1886-7, 48% in 1888-9 and 1895-6, and over 70% in 1898-9" (Gispen, 1989, p. 156). There was by the way a considerable qualitative change both in engineering education and science: "*from a stepchild of the natural sciences it matured into an autonomous professional discipline with its own particular subject matter and methodology. The fundamental principles of its method were model building, scientific experimentation, and measurement*" (Koenig, 1985, pp. 33-35; Manegold,

[19]*Wochenschrift des Vereins Deutscher Ingenieure*, 1879, p. 313 and 315. Quoted in Gispen, 1989, p. 125.

[20]It is interesting to note that this change of emphasis took place when the industry faced the most severe phase of economic crisis (1881-85), with an ever more intense competitive pressures and actual decline in price (Lenoir, 1998, p. 25).

[21]In 1892, the Berlin materials-testing laboratory opened its doors to students.

1970, pp. 144-156). The end result of this "*vocational drift*" was particularly positive for the economy at large, as a larger number of engineers was produced, both more specialized and more practical, and quickly usable in industry (see Cambon, no date, chapter II). Gispen (1989) considered that, judging by Germany's rapid technological progress, by its surging industrialization, and by its engineering triumphs in the quarter-century before World War I, this was a real success story. However, this was not so true from the point of view of the engineers themselves (see Gispen, 1989, p. 157). The vocational drift benefitted mainly the industrialists (i.e. the demand side of engineering human capital), but not at all the engineers in terms of social status. Even if the *Technische Hochschulen* continued to face an academization process (in 1899 William II granted them the right to confer academic degrees the nominal equivalent of university degrees, even doctoral degrees - Dr. Ing. See Gispen, 1989, p. 157), their obsession for "practical usefulness, constant drafting practice and early specialization" (Gispen, 1989, p. 157) was rather a major contributor to the engineering profession crisis. This was partly due to the emergence of a nonacademic, intermediate network of engineering schools in the 1890s. This movement was partly linked with the slow transformation of many state technical secondary schools in general secondary schools (*Allgemein Bildende Schulen*) during the years 1870-80 in Prussia (see Koenig, 1993). Those graduates were nevertheless demanded by the industry. As they were no more produced by the state schools, new *Technische Mittelschulen* appeared, often under private initiative. The *Technische Hochschule* began to produce large quantities of "*narrow specialists*" at the same time that these new institutions. The result was that "*for all practical purposes, the difference between graduates of nonacademic technical schools and the Technische Hochschulen disappeared, which led to unfortunate competition*" (Hertwig, 1950, cited by Gispen, 1989, p. 157). The status of the graduates from the *Technische Hochschulen* lowered, as their technical skills were not at all different from those of their nonacademic colleagues (due to the heavy emphasis on practical training and early specialization), and "their command of the fundamentals of mathematics, mechanics, physics and chemistry" (Gispen, 1989, p. 158) were reduced in order to make room for a more vocational curriculum. However, there were the very precise intellectual tools that conferred academic engineers with "the versatility and depth that would have qualified them for the most creative tasks, and distinguished them from the more vocational engineers" (Gispen, 1989, p. 158). The acceptance of nonclassical secondary education increased the problems. The vocational drift went too far, and did not allow a clear vertical differenciation of engineers. Both in terms of wage and social status, the German engineers were confronting with bad times before World War I, as the industrialists considered them as belonging to a same pool of workers, giving no special considerations to the academically-trained. Cambon (n.d., p. 18) stressed that "*si l'on y ajoute les sujets plus nombreux encore que jettent chaque année dans l'industrie les technicums secondaires, où l'instruction est complète et nettement aussi spécialisée, on comprendra la satisfaction des industriels qui*

n'ont qu'à puiser dans le tas et le mécontentement des jeunes ingénieurs don't une telle pléthore tend à rendre difficile l'accès dans les carrières et à diminuer les émoluments." The optimal provision of engineering skills to the industry (at least in a short-run perspective) was paid by a concomitant decrease in social status. During our observation period, we note also that phases of saturation and shortage have recurred with a remarkable regularity. Figures 9, 10, 11 and 12 (see Appendix) show clearly, for the case of students in medicine and law faculties and in the *Technische Hochschulen* for example, that the cyclical development of enrollments depend on the complex interaction between the varying determinants of growth and the varying conditions of recruitment for specific careers. If the expected earnings and the professional prospects are favourable, careers will open up (especially to the lower classes), and if the prospects worsen, its recruitment basis closes a little further down again (Diebolt, 2001). The interplay of attracting effects and deterrence effects produces the extraordinary long-term pulsations of student streams. German and Prussian data (Titze et al., 1987, 1995, Diebolt, 1997) suggest that political control and regulation has effected little change in the cycle and that the cyclical reproduction is firstly determined by an independent and labour market oriented dynamic.

Some theoretical considerations as conclusion

In this paper, we have tried to analyze the evolution of the Prussian higher engineering education system. A clear decisive factor in this evolution is the evolution of the economy itself, i.e. the technological evolution and the related demand for engineering skills by the firms and the state. The supply-side (i.e. education of engineers) in Prussia has mainly been organized by the public sector (the State), although the private sector responded to any failure from the established system to address growing new (yet unsatisfied) demands. This was true for the private schools of engineering established in the German states surrounding Prussia, compensating for an insufficient development of engineering education in Prussia itself (which moreover forbade any private initiative for a long period), as it was true of the establishment of a middle-level engineering education by the private sector and local authorities in order to compensate for an insufficient qualitative and quantitative development of such institutions under public control, even if the demand for the graduates of such schools was important in the 1880s.

There were however some (classical) problems with these private initiatives, as both entry requirements and the curriculum itself were much less demanding than in comparable public institutions, as a way of attracting as many students as possible[22] (Koenig, 1993). As in France, the Prussian state seemed to have had an important role in establishing the new engineering educational system. It was both forward-looking and benevolent, as it tried to set up a system of higher technical education well in

[22]"*In reaction, during the years just before the First World War, the VDI and other organizations and committees cooperated with the most respected private schools in imposing standards and a form of state supervision for the private technical schools*" (Koenig, 1993, p. 75).

advance of the objective needs of the economy (at large, i.e. not necessarily privilegiating the human ressources needs of the public sector), in order to ensure that no bottlenecks would occur in terms of human capital provision when the economy will take off (Listian perspective, see List, 1841 and Demeulemeester and Defraigne, 2009). Even if benevolent, the institutional framework set up by the state will slowly diverge from its initial objectives, due to the actions taken by the internal actors, i.e. mainly the professors in such schools. The society at large being characterized by pre-industrial values and an anti-vocational bias, the quest for higher status meant academization of the curriculum, in order to narrow the gap with the traditional higher education institutions (Humboldtian universities). This was possible as at the beginning the demand for academically trained engineers was low (due to the low technological development of the economy at this stage), and the professors were left with much room to advance their own interests without hurting the needs of the economy. The peak of this academization process was in 1864 (Gispen, 1989). Academization meant also elitism, as entry requirements were raised drastically (also opening a market for less prestigious but nevertheless demanded private engineering schools outside Prussia). The main factor reverting the movement of academization in higher technical education was the economic recession of 1873-1896 (on the importance of this Great Depression period on the transformations of German capitalism, see Gispen, 1989, p. 113). The too much academic education of engineers was seen as partly responsible for the low performance of German products on international markets. Graduates from engineering schools were considered as too old, with no experience of industry, too narrowly obsessed with technique for its own sake without consideration for the economic (cost) and marketing (design) factors. As the international competition became more intense, employers themselves became aware of the importance of education and tried to influence its reform. Professors received less attention than employers when redesigning engineering education was considered. After 1895, the program of the engineering schools, even the most academically prestigious ones as the *Technische Hochschule*, was increasingly re-vocationalized. This phenomenon considerably narrowed the gap between middle and higher technical education, reducing vertical differenciation and creating by the way a vast labour market of undifferenciated engineers. Their market price fell as a consequence, as well as their status. However, from the economy's point of view, this evolution was desirable as it provided German industrialists with cheap and skilled manpower.

It seems that in the long run, the primacy of the technology and the economy is quite clear, even if in the short run some deviation occured from an optimal responsiveness to economic needs (consideration of social status were much more important). At the difference of France, there were no need of creation of new institutions to respond to the needs of the private sector[23]; it seems that the Prussian state was more

[23]If it was true for engineering education, this was not so true for advancing the German scientific research. Lenoir (1998) indeed pointed out that "*the progress of science at the turn of the century*

benevolent and more concerned by the human resources needs of the economy at large (and not solely the public sector). This situation may paradoxically be linked with the lower status of engineers in the Prussia (even within the public sector, where the lawyers were much more rewarded, both in monetary terms and in prestige) than in France (where engineers enjoyed a very high status in the public sector and in French society generally). The French system appeared more stable maybe because established engineers had few reason to change the system. The Prussian system was less stable because engineers had less weight in the public sector, and were at the same time dissatisfied, leading them to constantly desire changing the engineering educational system. Moreover, as the engineering profession was by itself very divided between professors, civil servants, engineers in the private sector and managers, the latter system was subject to multiple possible sources of change, depending on the bargaining power of each of these groups (itself influenced by the objective economic and technological conditions, and the organization of the profession itself, see the role of the VDI in influencing the curriculum design).

The history of the Prussian higher engineering education system shows that when economic conditions become dominant, i.e. when simultaneously the economy itself becomes sufficiently developped and technologically sophisticated and special circumstances —economic crises— render the economic constraints binding, employers demands become more prevalent and the engineering higher education system responded by adapting to the new demands (also thanks to the increased weight of employers rather than professors in the professional organizations as the VDI, the latter having an influence on the curriculum design). External pressure on the system appeared necessary, but the German system allowed such pressure to feed back in the educational system itself, thanks to the weight given to employers through their increased role in the VDI. On the other hand, when economic conditions are less binding, either because the economy is not sufficiently developped to suffer from a lack of competent highly trained engineers (as was the case in Prussia before 1850), or because the economy is booming, social considerations of quest for status become more dominant features. It seems that this is the internal force which drives the history of higher education systems when let alone (this is the Gispen's thesis in his seminal book of 1989). There is a movement of academization coupled with one of increasing entry requirements, in order to fill the gap with more traditional forms of higher education. This movement is

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depended on more than simply providing good scientists with time for research by reducing their teaching" (even if it was nevertheless a necessary requirement). Generating scientific scientific research and the production of new knowledge also increasingly required "stimulating interconnections between otherwise autonomous disciplines" (Lenoir, 1998, p. 25), but this was difficult to implement within universities due to their "*rigid hierarchies and social divisions*" (Lenoir, 1998, p. 25). Therefore, "*the solution to these structural problems depended on establishing an Archimedean point outside the universities. The impetus for change and the specific solutions to the problems of establishing the necessary institutional conditions for advanced research came about as a result of acute awareness of the increasing importance of academic science for industry and the centrality of industry to the German Imperial State*" (Lenoir, 1998, p. 25).

good in terms of the social status of the profession (its begins to appear like the traditional professions of law and medicine, and it benefits from the scarcity of its graduates) but possibly bad for the economy as the technological graduates are scarce, expensive and not immediately operational in industry. As long as the industry does not need such graduates in great numbers or that their academic education does not jeopardize the competitiveness of its productions, the system is stable. However, as soon as the technological developments require engineers in large numbers and that increased competition make cost considerations vital (as well as marketing considerations), the industry cannot remain indifferent to a situation very unsatisfactorily for her. If channels exist that can translate industrialists disappointment in changes in the curriculum, they will happen. The design of such channels, allowing a feedback from the economy to the education system, appears to be a key-element in the provision of an adaptive higher education system.

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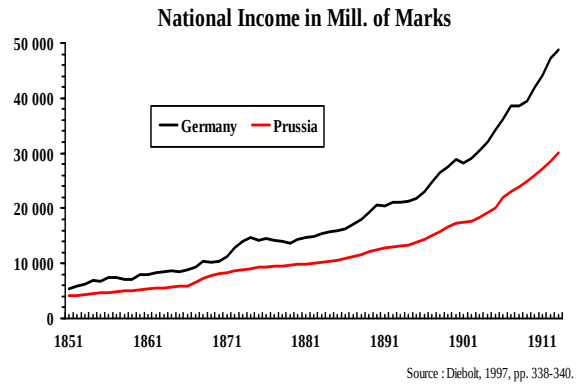
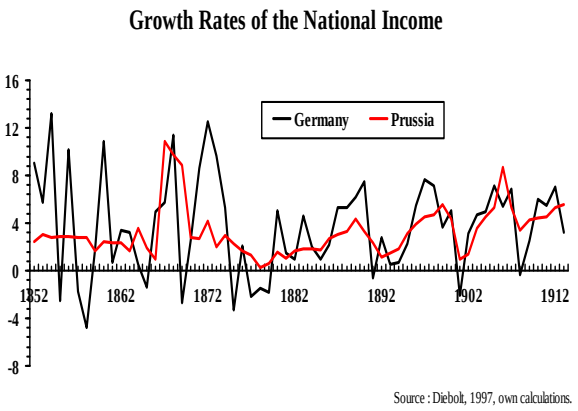
Appendix



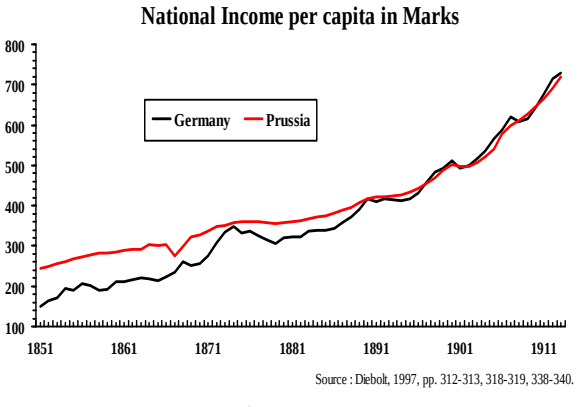
Source : Diebolt, 1997, pp. 338-340.

Figure 1



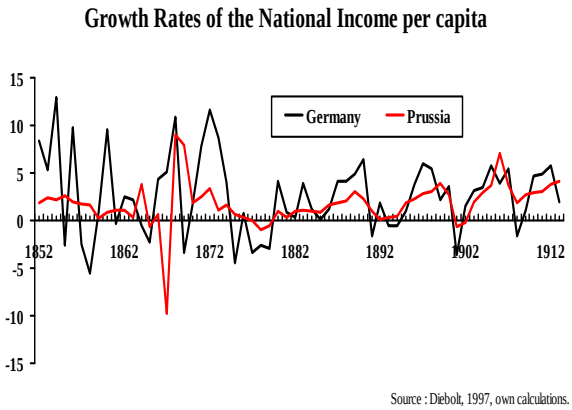
Source : Diebolt, 1997, own calculations.

Figure 2



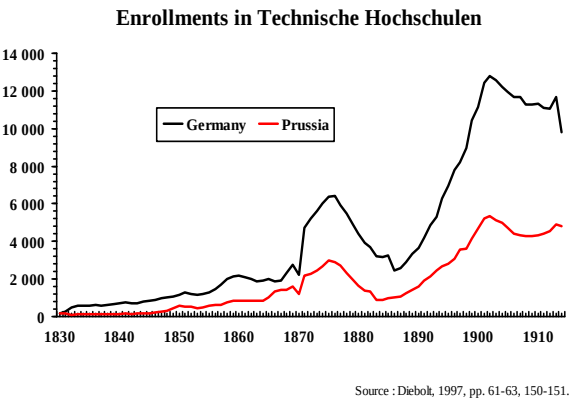
Source : Diebolt, 1997, pp. 312-313, 318-319, 338-340.

Figure 3



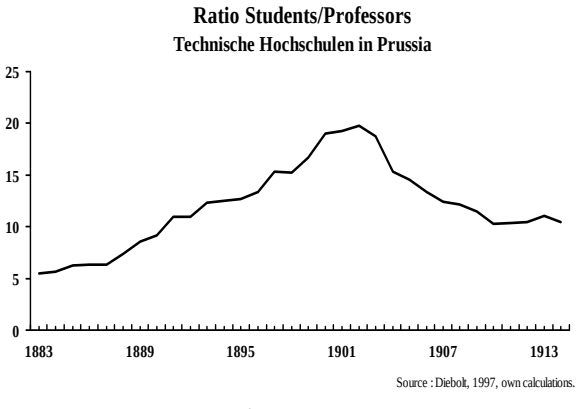
Source : Diebolt, 1997, own calculations.

Figure 4



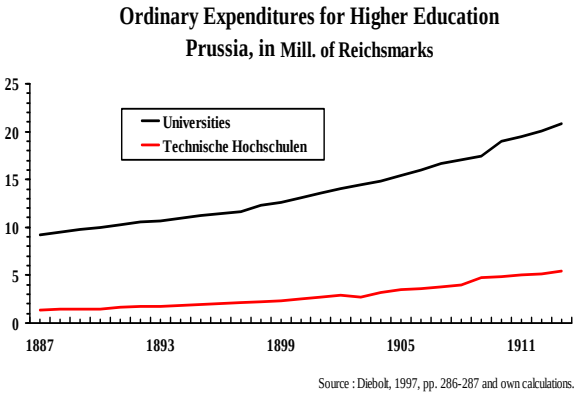
Source : Diebolt, 1997, pp. 61-63, 150-151.

Figure 5



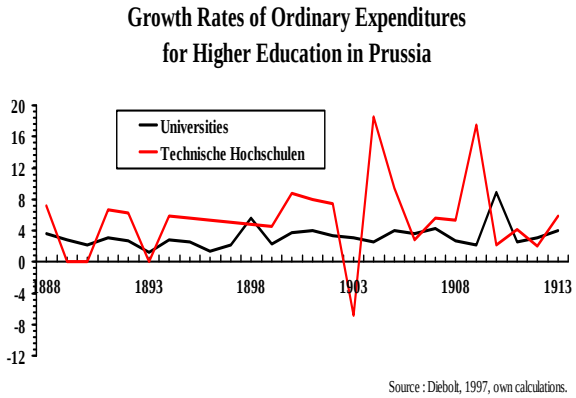
Source : Diebolt, 1997, own calculations.

Figure 6



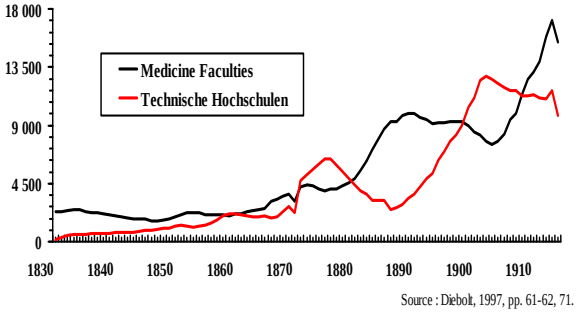
Source : Diebolt, 1997, pp. 286-287 and own calculations.

Figure 7



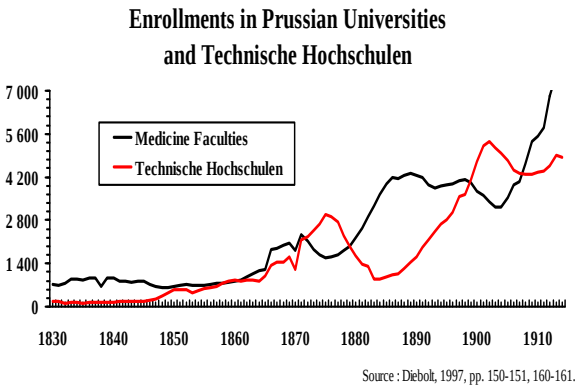
Source : Diebolt, 1997, own calculations.

Figure 8



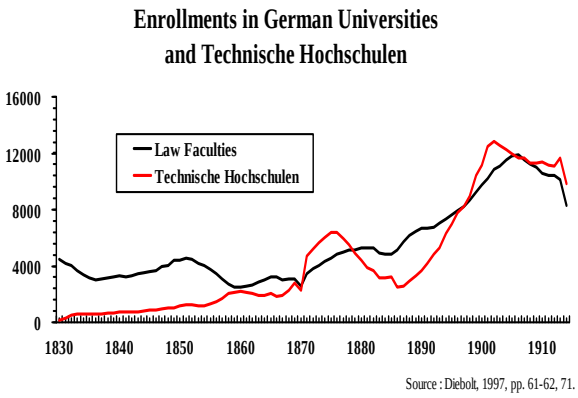
Source : Diebolt, 1997, pp. 61-62, 71.

Figure 9



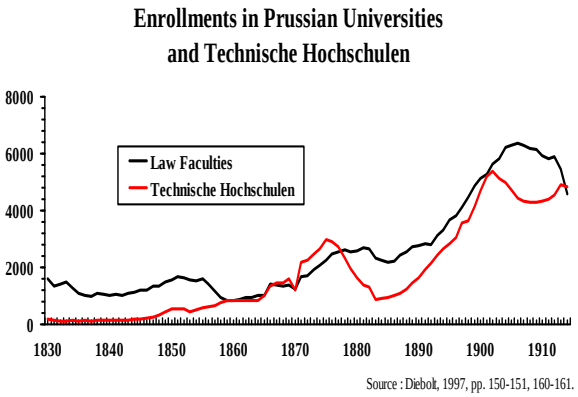
Source : Diebolt, 1997, pp. 150-151, 160-161.

Figure 10



Source : Diebolt, 1997, pp. 61-62, 71.

Figure 11



Source : Diebolt, 1997, pp. 150-151, 160-161.

Figure 12

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