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Technical Education in England, Germany and France in the Nineteenth Century: A Comparison

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TECHNICAL EDUCATION IN ENGLAND, GERMANY AND FRANCE IN THE NINETEENTH CENTURY: A COMPARISON

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ABSTRACT

This paper describes the developments of technical education in England, Germany, and France during the nineteenth century, contrasting their similarities and differences. It also analyses the role of the State in the provision of technical education in those countries. The paper suggests that the high standard of scientific and technical instruction contributed significantly to a country becoming an economic power. For instance, the growing technological superiority of the Germans over the British in activities such as production of chemicals, dyes, iron and steel, has been attributed to the fact that the British persisted in using of empirical methods and incremental tinkering to accomplish improvement and adaptation, while the Germans developed an extensive system of university and polytechnic education with close ties to industry that allowed them becoming the largest industrial power in Europe by the beginning of the twentieth century.

JEL Classification: N30, N33

Key words: Technical Education, Industrial Revolution.

RESUMEN

Este documento describe el desarrollo de la educación técnica en Inglaterra, Alemania y Francia durante el siglo XIX, contrastando sus similaridades y diferencias. También analiza el papel del Estado en la provisión de educación técnica en estos países. El artículo sugiere que el alto estándar científico y técnico en la enseñanza, contribuyó significativamente para que el país se convirtiera en una potencia económica. Por ejemplo, la creciente superioridad técnica de los alemanes sobre los británicos en actividades como producción química, tinturas, hierro y acero, ha sido atribuida al hecho de que los británicos persistieron en el uso de métodos empíricos que representaban una barrera para alcanzar mejoras y adaptación, mientras que los alemanes desarrollaron un sistema de educación universitario y politécnico con fuertes lazos industriales que le permitían convertirse en la potencia industrial más grande de Europa al inicio del siglo XX.

Clasificación JEL: N30, N33

Palabras clave: Educación técnica, revolución industrial.

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INTRODUCTION

The purpose of this paper is to describe what were the developments in technical education in three different countries: England, Germany and France, during the nineteenth century. Also, we want to compare what were the similarities and differences in technical education among these countries. In addition, the paper seeks to determine what was the role of the State in the provision of technical education and if technical education was considered a public good during the nineteenth century.[1] In fact, education is essentially a private good, but the decision of most countries to provide education publicly meant it was treated as a public good.[2]

On the other hand, we want to see if the increased supply of technical education was a response to the demands of industrialization, or was a response to the demand of the public sector, or was a consequence of the competition among countries to be the major economic power.

In the next three sections, this paper studies the development of technical education in England, Germany, and France. The history of technical education in England was divided into three periods: before 1851, between 1851 and 1881, and finally between 1881-1902. This division is determined by the fact that in 1851 the Great Exhibition opened in the Crystal Palace in London where many countries participated in the exhibitions of their manufactured products.[3]

The Great Exhibition was an important determinant of the history of technical education in England, it left the messages that the level of technology in England was behind continental standards, as a consequence therefore the necessity of better technical education became mandatory. On the other hand, the history of technical education in Germany was divided into two periods: before and after the unification of the State. The political disunion of the State was an important determinant of the evolution of technical education in Germany. Finally, we divided the evolution of technical education in France in two periods: before and after the Third Republic, when new educational legislation was introduced.

1. TECHNICAL EDUCATION IN ENGLAND DURING THE NINETEENTH CENTURY

The industrial revolution produced important transformations in England during this period. That is, income per head doubled and industrial output grew at the rate of 3% per year. In addition, this period was characterized by great development in communications. In fact, 5,000 miles of railway line had been laid before 1851, and shipbuilding flourished. However, these economic improvements were not reflected in improvements in technical education. As Argles (1964) pointed out "the greatest impediment to the establishment of a system of technical

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1 Varian (1992) define a public good as: the goods that are both not excludable and nonrival. A good is excludable if people can be excluded from consuming it. On the other hand, a good is nonrival if one person's consumption does not reduce the amount available to others.

2 Varian (1992) pointed out that "Often there has been a political decision to provide the same level of educational expenditure to all citizens. This constraint requires us to treat education as if it were a public good.

3 This subdivision is taken from M. Argles (1964).

education in England in 1851 was the almost complete lack of elementary education in the country as a whole".

In public education some advances were made, at least in primary education. The beginning of the State intervention in education was through Peel's Factory Act of 1802 and Whitbread's Bill for compulsory universal education in 1807, which ensured only two years of schooling for children between seven and fourteen years. In 1816, the Select Committee on the Education of the Lower Orders recommended free parish schools for poor children.[4] On the other hand, it is interesting to note that technical education did not have the degree of government influence as observed at the elementary level. In fact, only few improvements were made: mechanic's institutions were the first institutions to provide technical education. Some of these institutions were founded in the beginning of the nineteenth century in London, Glasgow, Newcastle and Manchester. Therefore, mechanics' institutions spread in England. However, because of the lack of elementary education and little financial support, these institutes were not successful.[5] It is important to mention that technical education and technology were viewed as if they were only for lower classes. As a consequence, the upper and influential classes had little interest and made little effort to promote it.

On the other hand, two schools were founded at higher technical education level: The Royal College of Chemistry (1845) and the Schools of Mines (1851). Lyon Playfair was one of the persons that had more influence on technical education. He belonged to the staff of the School of Mines, and as a member of it he had an important participation in the promotion of technical education (Argles, 1964). However, although some advances were made, higher technical education in this period was characterized by the training of engineers on the job. One way was training engineers on the job through premium pupillage and apprenticeship, this training last near three years. However, the cost for this training was assumed by the students, they have to pay high fees required for pupillage, but then they could find good positions in the job market (Guagnini, 1993).[6] On the other hand, some firms required small fees or no fees at all for training, therefore, it was an alternative way for persons that could not afford the premium, but the processes was longer, some times it last seven years; and the positions available for these students were modest in comparison to the position available to premium pupils.[7] And the other way was the training offered by firms to laborers paying them lower salaries. In fact, this generates a proliferation and cheapness of apprentice laborers. P. Robertson (1974) point out that apprentices were a cheap source of labor, they received a half of journeyman's wages. However they could become expensive for employers during depressions since they could not be laid off; also they could move on when they received better offers.

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4 See, M. Argles (1964) for a detail explanation of the role of the State in education in England.

5 See, M. Argles (1964)

6 Guagnini(1993) provide some information: "In the 1860s and 1870s, the fees required for pupillage in reputable firms varied between 100 and 300 pounds a year, to which it was necessary to add the cost of accommodation and living expenses, while formal education cost on average 120 pounds. But high premiums were not the only obstacle. Admission was so competitive..."

7 See, Guagnini (1993)

In sum, we can conclude that it seems that during this time practical skills were learned at the working place rather than at school. Therefore, technical education was almost entirely on the job training, meaning it was provided privately by the firms rather than by the State. However, almost all the costs of training had to be financed by students, either paying a premium or earning lower wages. In fact, from the theoretical point of view, Gary Becker (1975) stated that many workers increase their productivity by learning new skills and development old ones while on the job, however future productivity can be improved only at a cost, otherwise the demand for training would be infinitive. That is, without training, in equilibrium, wages are equal to the marginal product ($W_t = MP_t$), while the wages of trainees would not equal their marginal opportunity cost but would be less by the total cost of training : $W_0 = MP_0 - k$, where k represents costs for training. Therefore, workers would pay for on the job training by receiving wages below their current productivity.[8]

Some questions arise here, why did the private sector seems more interested in provide technical training than the public sector in England during that time?. Since education is an investment, the rate of return is the most important determinant of the amount invested in human capital (Becker, 1975). Therefore, we expect that private rate of return to technical education were higher than the social rate of return,[9] consequently, private sector had an incentive to invest in technical education. Unfortunately, we do not have here the exacts private and social rate of returns to technical education.[10] However, we can infer that privately firms had higher rate of returns to investment in technical education given that almost all the costs were charged to the students via lower wages or fee payments. On the other hand, the benefits for the firm were considerable high, because apprentices represented cheap labor forces. Therefore, given this higher private rate of return to technical education, it should be privately financed.

In addition, T.W. Schultz(1963), states that when the benefits of education are in the future, education is considered as an investment. Therefore in this framework training on job was an investment for both students and privately firms. Students sacrifice present earnings for possible future higher earnings, i.e. with higher training they could move on where they receive better offers; and firms giving training to their laborer reduce their wages costs and increase their output. Therefore, this way to finance training education was beneficial for both parts. However, many people were concern about this system. For example, some unions stated that apprenticeship programs were a way that led to reduce wages.[11]

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[8] See G. Becker(1975) for a discussion of the differences between general and specific job training, as well as for a discussion of the behavior of the firm that provide training.

[9] The social return to education does not necessarily coincide with the private return. The social rate of return of increasing educational expenditures is based on pre-tax salaries and costs borne by society as a whole, while the private rate of return is based in the direct cost in terms of fees and an additional opportunity cost in terms of earnings foregone(M.Weale, 1992).

[10] Further research in determining the social and private rate of return for technical education have to be done. However, we found that D. Mitch(1984) estimates the rate of return to literacy for male and female in England during 1839-1843. He found that the rate of return to literacy for males was 24.5% and for females it was 3.5%. Only for comparison purpose the Mincerian rate of return to education in England was 6.8% in 1987 (Psacharopoulos, 1993).

[11] See P. Robertson (1974).

1851-1881

In 1851 the first Great Exhibition[12] took place in the Crystal Palace in London in which several countries exhibited their manufactured products. After this event the British had the sense that they were far behind from the new advances made in continental countries. Consequently, Mr. L. Playfair, who was the director of this exhibition, began to promote technical education in England. The idea was that the apprenticeship programs have poor quality, therefore these programs have to be supplemented with technical education.[13] Therefore, 1851 marked the beginning of the promotion of this kind of education.

In addition, the continuing economic expansion produced by the spread of the industrialization made necessary to incorporate new and more advanced techniques to sustain the economic growth. To be competitive in the international market, innovations and development of better systems of production, as well as improvements in communications were required in order to increase productivity that lead to lower costs of production and lower cost of transaction. Therefore, the demand for better training workers began to increase, and as a result public technical education became essential in this period

Institutionally there were two important institutions in the regulation of education: The Education Department and the Department of Science and Arts. The Education Department mainly promoted primary education while the Department of Science and Arts promoted secondary and technical education. M. Argles(1964) stated that this Department was the main agency of technical education after 1851. However, most of the institutions did not have the State support, therefore they had to be endowed by a sponsor or patron, and most of the support had to be done by the public itself.

The role of the State in supporting technical education was very low. The liberal ideal of *laissez-faire* and self-reliance doctrine were very important restrictions in the development and improvement of technical education, in the sense that they limited the government intervention in this area. Therefore, the State did not have an important participation in promoting secondary and technical education[14] during this period.

Finally, although there was insufficient intervention of the State in providing technical education, this period was very important in the history of development of technical education in England. In fact, people figured out the necessity of better technical education. In particular, the Great Exhibition in 1851 left important messages: the level of technology was behind continental standards, and the necessity of better technical education became mandatory.

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[12] M. Argles (1964) stated that " Exhibitions, by their efforts both at the time and for many years afterwards, inspired this country with the feeling that without a practical instruction and a basis of scientific research the industry of this country would be doomed".

[13] See P. Robertson (1974).

[14] Cole, a secretary of the Department of Science and Arts, stated in 1858 that: "in some years' experience had shown conclusively that State interference in technical teaching did not succeed, and was therefore not necessary" (M. Argles). This thought reflected the idea of what was to be the role of the State in the Victorian England.

1881- 1902

This period was characterized by an important growth in industry:[15] New industries based on new methods of production began to appear. Some examples are electricity, shipbuilding, and combustion engines. The emerging of these new industries made necessary better technical instruction. As a result, in 1881 the Royal Commission on Technical Instruction was appointed. One of the main recommendations of this commission was that scientific and technical instruction should be greatly increased in endowed secondary schools of this country (Argles, 1964). A very important result of this commission was the creation of the National Association for the Promotion of Technical Education in 1887.

Some important efforts were also made in supporting technical education. The Technical Instruction Act of 1889 enabled local authorities to raise a penny rate in supporting of technical education. In addition, a year later, the Local Taxation Act liberated more resources for technical education.[16] Later on, in 1893 the Technical Education Board determined that a share of the "whisky money" allocated in London should be used in the provision of technical education.

TABLE 1. 'WHISKY MONEY' SPENT IN TECHNICAL EDUCATION-LONDON

Year	Whisky Money (pounds)	Amount of Whiskey Money spent in Technical education	%
1890-92	342,000	NA	NA
1893	200,000	29,000	14.5
1902-3	200.000	180,000	90.0

Source: M. Argles (1964).

According to Table 1 by 1902, 90% of "whiskey money" were used to financed technical education. This allowed an expansion of polytechnics and scholarships. Then, the number of students enrolled increased considerably: for example, from 1893 to 1900 the number of students enrolled in masonry and joinery grew from 1500 to 23000, in plumbing they growth from 7000 to 20000, and in building trades they changed from 37000 to 125000 (Argles, 1964). However, even with this increment in financial aid by the government, the public support was still low by continental standards.

HIGHER TECHNICAL EDUCATION

The spread of industrialization was one of the main causes of the expansion of British engineers. In fact, the construction of canals, railways, dock, lighthouse, and urban development, made indispensable the provision of mechanical equipment and technical knowledge (Buchanan, 1985). In addition, some industries such as iron and steel industries required more highly scientific research

[15] For example, the production in the steel industry by 1870 was 250.000 tons. By 1913 it was over 7.5 million of tons.

[16] Certain sums out of customs and excise duties were allocated to local authorities either to relieve the rates or to subsidize technical education (M. Argles).

to develop new techniques to lead to higher productivity. Another important sector that required well trained engineers was electricity; in particular power generation and telegraphy. Improvements in communication were fundamentals for the development of international markets.

By 1818 as a response of the expansion of roads and canals the Institution of Civil Engineers was founded, one of the most important technical institutes at that time. This institution also grew significantly with the expansion of the railways[17] in the 1840 and 1850 (A. Guagnini). Later on, other important institutions were also founded. However, because of the higher fees only upper classes had access to enter in these institutions.

TABLE 2. DATES OF THE OPENING OF INSTITUTIONS OFFERING ENGINEERING COURSES AND THE ESTABLISHMENT OF ENGINEERING CHAIRS IN ENGLAND

Institutions	City	Opening of Institution	Establishment of engineering chair
King's College	London	1831	1839
University College	London	1828	1841
University of Durham	Durham	1835	1838
Owens College	Manchester	1851	1868
Royal Engineering College	London	1871	1871
University of Cambridge	Cambridge	medieval	1875
Yorkshire College	Leeds	1874	1876
University College	Bristol	1876	1878
Mason College	Birmingham	1880	1882
Firth College	Sheffield	1884	1884
Finsbury College	London	1884	1884
Nottingham University College	Nottingham	1881	1885
University College	Liverpool	1881	1885
Central Institution	London	1885	1885

Source: A. Guagnini (1993), Table 1.1

Table 2 presents the dates of opening of institutions offering engineering instructions and the establishment of engineering chairs in England. Most of these institutions were located, besides London, in north and middle of England, the only university located in the south was University College in Bristol. It is important to note, especially in the beginning of the century, the lag between the date of opening of the institution and the date of establishment of a chair in engineering. This fact reflects the lower interest in technical education at that time. The establishment of some of these chairs was sponsored mainly by local manufactures. In fact, some local manufactures provided technical education in most of the provincial university colleges in the 1880s.[18]

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[17] Railways in Britain were built primarily by private enterprise, while the role of the state was secondary but certainly not absent(G.Hawke and J. Higgins,1983). Therefore, private companies involved in railways constructions demanded large number of engineers and technicians.

[18] Anna Guagnini (1993) provides some examples of the role of local manufactures in the promotion of technical education. For instance, Andrew Fairbairn a successful textile manufacturer provide resources for the established

TABLE 3. NUMBER OF FULL TIME DAY STUDENTS ATTENDING ENGINEERING CLASSES IN SELECTED ENGLISH COLLEGES, 1850-1910

	King's College London	annual rate of change	Owens College Manchester	annual rate of change	Yorkshire College Leeds	annual rate of change
1850	71	NA	NA		NA	
1855	58	-3.96	NA		NA	
1860	86	8.20	NA		NA	
1865	88	0.46	NA		NA	
1870	80	-1.89	34		NA	
1875	70	-2.64	48	7.14	NA	
1880	65	-1.47	26	-11.54	28	
1885	119	12.86	32	4.24	24	-3.04
1890	75	-8.82	48	8.45	43	12.37
1895	81	1.55	65	6.25	55	5.05
1900	85	0.97	67	0.61	69	4.64
1905	102	3.71	53	-4.58	NA	NA
1910	119	3.13	107	15.09	100	NA

Source: Guagnini, Anna (1993)

Table 3 shows the number of full time day students attending engineering classes. We can observe that only in the very late nineteenth century the enrollment began to increase. This fact can be explained by the existence of very high fees jointly with insufficient State support. On the other hand, in the Victorian era, engineers and technicians were viewed for lower classes, therefore, this was another important reason for the low rates of enrollment.[19] In 1860 because of the acceleration of railway building in the country, there was an important increase in the number of students enrolled in King's College in the 1860s and 1870s.

Finally, we can conclude that the State did not play an important role in promoting and supporting technical education in England. The liberal ideal and the doctrine of self-reliance were an obstacle in the development of technical education. Only in the very late nineteenth century did the State begin to release some funds for technical education, but still the government support was insufficient. In the framework of public goods, it seems that in England only elementary education can be thought of as a public good in the nineteenth century. And perhaps by the late nineteenth century with the Technical Instruction Act of 1889 and the Local Taxation Act, technical education became to be thought of as a good that has to be provided by the State. In other words, some of the apprenticeship programs provided by privately firms were not successful, therefore it was required a public policy to provided technical education. That is, when there has been a market failure in providing resources, the demand for a public policy

of a chair in Yorkshire College in Leeds, the steel manufacturer Frederick T. Mappin in Sheffield, the ship-owners and shipbuilders Alfred Holt, T.H. Isnay and Thomas Harrison, were generous in the patronage of chairs in Liverpool.

[19] With respect to this point, A. Guagnini (1993) state that " It should not be forgotten that while the supporters of the liberal ideal of education found it hard to admit technical subjects into their curricula, it was no less difficult for education to win acceptance as a requirement for entry to the engineering profession"

arises. It seems that this occurred with the technical education in England in the late nineteenth century, the State had to start to provide technical education as a public good.

2. TECHNICAL EDUCATION IN GERMANY DURING THE NINETEENTH CENTURY

Between 1821 and 1836, various technical schools and polytechnics were founded. According to Table 4 technical institutions were established mainly in regions' capitals. The fact that almost each region had established its own technical institution reflected the political disunion of the State. Each region was independent of the others in its decision of how to organize its own technical schools. In other words, as W. Konig (1993) pointed out that each region adjusted its own schools system to its own special needs.[20]

TABLE 4. DATES OF THE FOUNDATION OF GERMAN TECHNICAL SCHOOLS

1821	Berlin
1825	Karlsruhe
1827	Munich
1828	Dresden
1829	Stuttgart
1831	Hanover
1835	Braunschweig
1836	Darmstadt
1870	Aachen
1904	TH Danzig
1910	TH Breslau

Source, Konig, W. (1993)

During this period technical schools were divided in two categories: general technical training and specialized technical training. The general technical training instructed mainly merchants and civil servants. On the other hand, the specialized technical training was designed first to supply the demands of public sector and then for private industry. To fulfill the requirements of the public sector technical schools were divided in departments such as department of architecture, department of engineering, department of postal service and department of forestry. Engineers of these new departments also went first to the public sector. The public sector required engineers for the construction of railways,[21] roads, dams and canals. Therefore, engineering was a important factor in the development of each region. On the other hand, department of commerce and department of trade were oriented to the private industry. In 1840 the department of trade were divided into departments of mechanical engineering and chemical engineering (Konig, W. 1993).

In sum, during this period the local government financed the establishment of technical institutions in its own state. Local governments were interested in investing in technical education

[20] W. Konig(1993) stated that "a heterogeneous system of highly individualistic technical schools developed..."

because they need to develop their region, so higher skill workers were required in the construction of roads, railways, canals, etc. Therefore, it seems that the social rate of return was substantial to technical education, consequently technical education should be financed by local governments.

1870-1900

Until 1870, there existed different levels of technical education. In this structure students who finished their intermediate technical education had the option to start to work or to enter into higher technical school. However, in 1870 intermediate technical schools were abolished and were transformed into general secondary schools. Therefore, the State did not provide technicians at this level any more. However, a large number of industries required technicians from the intermediate level, consequently the supply of these technicians was not enough for the industry demands. To fill the gap, people in the industry began to create new private intermediate schools at the regional level. These new schools entered to compete with the general secondary schools. Private schools adjusted their programs for the demands of industry, while the State technical schools were oriented to public sectors (Konig, W. 1993). Both types of school competed to attract greater number of students. On the other hand, because of the higher interest that showed the privately sector in investing in technical education, we can infer that investments in this type of education produced higher rate of return for the privately sector.

Finally, higher technical education was also oriented to be practical. To this end, the development of laboratories was very important. These new laboratories were created first for teaching purposes. However, in the middle of the nineteenth century these laboratories began to be used also for research purposes in universities. Table 5 presents the dates of establishment of some laboratories. As we can observe the large number of establishments took place in the late nineteenth century.

New disciplines such as electrical engineering and applied chemistry became very important in the late nineteenth century. In particular, the propagation of new electrical laboratories[22] made Germany very successful in the instruction of electrical engineering. Fox and Guagnini (1994) stated that "Germany's capacity to train substantially more engineers and industrial scientists than other countries from the 1890s may very well have been crucial in allowing her to consolidate and stretch her lead in electrical technology..." Therefore, the German electrical industry was well supplied with very well training engineering.

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[21] It is important to made a distinction here: Because the disunion of the Germany, by 1830-1840, there existed 39 separated sovereign states, therefore the extent of their involvement in railway construction differed widely. For example, some governments such as Hanover, Brunswick, Baden and Wurttemberg built state-owned systems. Contrary, states such as Prussia and Saxony built railways privately (R. Fremdling).

[22] Fox R. And Guagnini, A. (1994), pointed out that in 1882, in Germany, "the Technische Hochschule of Darmstadt established the first specialized institute and chair of electrical technology in the world, with a laboratory and workshop for the instruction of the students."

TABLE 5. SELECTED LABORATORIES AND INSTITUTES AT GERMAN UNIVERSITIES AND TECHNICAL INSTITUTES, 1800-1900 BY SPECIFIC SUBJECTS

Sciences	Early period of establishment	Year	Main period of establishment	Year
Chemistry	Gottingen	1806	Giessen	1825
	Jena	1810	Leipzig	1831
	Berlin	1812	Gottingen	1836
			Marburg	1839
			Heidelberg	1855
			Karlsruhe	1851
			Berlin	1869
Physiology	Bonn	1820	Heidelberg	1860
	Freiburg	1821	Leipzig	1869
	Breslau	1824		
	Berlin	1833		
Physics	Konogsberg	1835	Heidelberg	1860
	Heidelberg	1846	Gottingen	1866
			Berlin	1878
Electro-technology	Darmstadt	1882		
	Aachen	1883		
	Hanover	1884		
Engineering	Munich	1875	Berlin	1896
Technical physics	Gottingen	1898		
Physical Chemistry	Gottingen	1896		

Sources: P. Lundgreen (1980)

PRUSSIA

It is worth mentioning the Prussian education system alone. The Prussian model of technical education was the most important exception to the German system. The Prussian model differed from the other regions in that it was oriented mainly to supply technicians for trade and industry. Therefore, Prussian technical schools had close ties with industry and trade. Most of the instruction was practical training in workshops. The Prussian model also differed the systems in other regions in that in Prussia there existed a strong separation in training for the public services from training for private industry.[23]

By 1893, the Prussian system was reformed. The Prussian state unified and reorganized almost all technical schools. Because practical training was very important numerous laboratories were opening. Most of the graduates of these technical schools entered work in private industry, especially in Prussian railways (Konig, W. 1993).

Table 6 presents the enrollment rate of males in Prussia by types of institutions during 1822-1911. We can observe from this Table that the percentage of students of male population enrolled in secondary education increased dramatically from 1822 to 1911. In fact, this proportion was

[23] See W. Konig(1993) and P. Lundgreen (1976), for details of Prussian model.

10% in 1822 and in 1911 it was 44%. It is important to note the behavior of students as percentage of total students enrolled in university. By 1822 this percentage was very high 28.51%; however it decreased, and by 1891 it was 15.85%. On the other hand, the percentage of students enrolled in technical education was almost constant. By 1822 it was 7%, and in 1911 it was 8.1%.

Table 7 shows the public expenditures for education in Prussia by types of institutions during 1864-1911. We can observe that in real prices total expenditures in education was increasing over time. In 1864 public expenditures for education in real per capita terms were 5.04 marks, and by 1911 they were 18.91 marks. For secondary education, per student public expenditure in real terms increased from 176 marks in 1864 to 340 marks in 1911. On the other hand, public elementary education received the greater share of the public expenditure (55% in 1911). The expenditures in both universities and technical colleges as a percentage of total expenditures for education were relatively low. In 1911, only 3.1% and 0.7% of the total expenditures in education were allocated in universities and technical colleges, respectively.

In conclusion, because of the political disunion of Germany before 1871 there existed a large number of technical schools located in the cities of the main regions, each region was autonomous in the organization of its own schools. Therefore, the role of local governments was very important in promoting and financing technical education. In addition, private industries were also engage in the creation of technical schools in towns. The diversification in the system of technical education generated great competence among schools and regions, that led to an increase in the quality of the schools.

Finally, in the beginning of the nineteenth century, technical schools were founded in order to fulfill the requirements of the public sector. One important exception was Prussia. Technical education in Prussia was oriented to private sector, this fact may be was a important determinant in the consolidation of Prussia in an economic power. On the other hand, in the second half of the nineteenth century, private industry began to promote technical education, to meet the demand of industries that need better technical educated worker in order to increase the productivity of the firm. This fact generated a significant division in technical education. Almost all the graduates of public schools entered the public sector, while the graduates of private school entered private industry.

TABLE 6. ENROLLMENT OF MALES IN PRUSSIA, 1822-1911 BY TYPES OF INSTITUIONS; VOLUNTARY FULL TIME EDUCATION

Year		All Institutions	Secondary	University	Teacher Training	Technical
1822	# of students enrolled	14,283	5,611	4,072	3,600	1,000
	students as % of male population	0.25	0.10	0.07	0.06	0.02
	students as % of total students enrolled	100.00	39.28	28.51	25.20	7.01
1828	# of students enrolled	19,835	8,310	6,125	4,200	1,200
	students as % of male population	0.31	0.13	0.10	0.07	0.02
	students as % of total students enrolled	100.00	41.90	30.88	21.17	6.05
1837	# of students enrolled	19,514	8,540	4,508	5,166	1,300
	students as % of male population	0.27	0.12	0.06	0.07	0.02
	students as % of total students enrolled	100.00	43.77	23.10	26.47	6.66
1846	# of students enrolled	21,277	10,841	4,378	4,358	1,700
	students as % of male population	0.26	0.13	0.05	0.05	0.02
	students as % of total students enrolled	100.00	50.95	20.58	20.48	7.99
1855	# of students enrolled	27,029	15,014	4,725	5,190	2,100
	students as % of male population	0.31	0.17	0.06	0.06	0.02
	students as % of total students enrolled	100.00	55.55	17.48	19.20	7.77
1864	# of students enrolled	37,419	21,534	6,050	7,220	2,615
	students as % of male population	0.39	0.22	0.06	0.07	0.03
	students as % of total students enrolled	100.00	57.55	16.17	19.29	6.99
1873	# of students enrolled	60,120	35,651	7,384	12,000	5,085
	students as % of male population	0.48	0.29	0.06	0.10	0.04
	students as % of total students enrolled	100.00	59.30	12.28	19.96	8.46
1882	# of students enrolled	82,525	47,222	12,557	19,910	2,836
	students as % of male population	0.61	0.35	0.09	0.15	0.02
	students as % of total students enrolled	100.00	57.22	15.22	24.13	3.43
1891	# of students enrolled	88,200	48,278	13,000	21,672	5,250
	students as % of male population	0.59	0.32	0.09	0.15	0.04
	students as % of total students enrolled	100.00	54.74	14.74	24.57	5.95
1901	# of students enrolled	120,491	64,180	17,500	27,138	11,673
	students as % of male population	0.70	0.37	0.10	0.16	0.07
	students as % of total students enrolled	100.00	53.27	14.52	22.52	9.69
1911	# of students enrolled	167,434	86,979	26,550	40,350	13,555
	students as % of male population	0.84	0.44	0.13	0.20	0.07
	students as % of total students enrolled	100.00	51.95	15.85	24.10	8.10

Source: Lundgreen, P. (1976)

TABLE 7. PUBLIC EXPENDITURES FOR EDUCATION IN PRUSSIA, 1864-1911, BY TYPES OF INSTITUTIONS

Institutions		1864	1873	1882	1891	1901	1911
Total Expenditures	-total(in thousands of marks, current prices)	55,000	114,000	176,000	238,000	424,000	759,000
	-as % of total expenditures for educ.	100	100	100	100	100	100
	-per students (mark 1913 prices)						
Public elementary school	-total(in thousands of marks, current prices)	33,000			129,000	227,620	420,890
	-as % of total expenditures for educ.	60			54.2	53.7	55.5
	-per students (mark 1913 prices)	20.7			32	44.6	65
Public middle and girls high school	-total(in thousands of marks, current prices)				12,000	20,900	49,320
	-as % of total expenditures for educ.				5	4.9	6.5
	-per students (mark 1913 prices)				111.7	123.5	171
Secondary school boys	-total(in thousands of marks, current prices)	7,700	20,400	25,500	30,920	54,000	90,000
	-as % of total expenditures for educ.	14	17.9	14.5	13	12.7	11.9
	-per students (mark 1913 prices)	176.3	219	203.9	241.1	300.1	340
Teacher training (seminar)	-total(in thousands of marks, current prices)		2,400		4,950	8,000	14,500
	-as % of total expenditures for educ.		2.1		2.1	1.9	1.9
	-per students (mark 1913 prices)		545.7		557.4	733	788
University	-total(in thousands of marks, current prices)		6,770	7,820	13,540	17,260	23,435
	-as % of total expenditures for educ.		5.9	4.4	5.7	4.1	3.1
	-per students (mark 1913 prices)		1253.7	760.4	1272.6	1096.8	857
Technical college	-total(in thousands of marks, current prices)				1,600	2,700	5,105
	-as % of total expenditures for educ.				0.7	0.6	0.7
	-per students (mark 1913 prices)						
Mining and forestry academies	-total(in thousands of marks, current prices)				535	960	880
	-as % of total expenditures for educ.				0.2	0.2	0.1
	-per students (mark 1913 prices)						
Agricultural and veterinary colleges	-total(in thousands of marks, current prices)				620	900	1580
	-as % of total expenditures for educ.				0.3	0.2	0.2
	-per students (mark 1913 prices)						
School for engineering	-total(in thousands of marks, current prices)				230	1405	2075
	-as % of total expenditures for educ.				0.1	0.3	0.3
	-per students (mark 1913 prices)						
School for textile industry	-total(in thousands of marks, current prices)				290	775	1070
	-as % of total expenditures for educ.				0.1	0.2	0.1
	-per students (mark 1913 prices)						
Total per capita at 1913 prices (marks)	-total	5.04	6.16	7.76	9.06	13.44	18.91

Source: Lundgreen, P. (1993)

TABLE 8. FRENCH INTERMEDIATE TECHNICAL AND HIGHER PRIMARY SCHOOLS AND STUDENTS, 1895-1913

	1895		1905		1913		Annual Rate of Change 1895/1905		Annual Rate of Change 1905/1913	
	Schools	Students	Schools	Students	Schools	Students	Schools	Students	Schools	Students
Ecoles pratiques de commerce et d' industrie	25	2607	50	10342	70	14766	7.18	14.77	2.62	2.78
Ecoles nationales professionnelles	3	750	4	1327	4	1800	2.92	5.87	0.00	2.37
Ecoles d'arts et métiers	3	900	5	1500	6	1800	5.24	5.24	1.41	1.41
Ecoles primaires supérieurs	260	33000	332	45000	450	55000	2.47	3.15	2.37	1.56
Totals	291	37257	391	58169	530	73366	3.00	4.56	2.37	1.80

Source: Lundgreen, P. (1993)

3. TECHNICAL EDUCATION IN FRANCE DURING THE NINETEENTH CENTURY

After the French Revolution, the education in France was organized by the central government. In 1794 was established one of the most important technical schools: The *École Polytechnique*. This school was oriented to train the members of the State's technical service. Besides the *École Polytechnique* there existed more advanced schools: the *écoles d'application*, such as the *École des Mines, the École des Ponts et Chaussées*,[24] *the École du Génie Maritime*, and the *École de l'Artillerie et du Génie* at Metz. Each of these schools belongs to some of the Napoleon's ministries. Graduates from these schools mainly entered in public sector as civil servants.

In 1829, The *École Centrale des Arts et Manufactures* was founded by private initiative as a consequence of increasing industrial demands. The purpose of this school was to meet the demand of industry for higher technical educated people.[25] On the other hand, at a lower level there also existed two *écoles d' arts et métiers*. These schools mainly provided pre-vocational training.

R. Fox and G. Weiz (1980) point out that education during this period grew within an essentially stable structure. They also stated that there was an orderliness in the French system of scientific and technical education until late in the nineteenth century. However, this organization had many problems. There were too many institutions competing for few students and little resources.[26]

On the other hand, in some institutions tuition was high and scholarships were few, therefore this constituted a restriction on the working class to have an access to technical education.

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[24] Contrary to England, the French state interfered in the development of the railways. F. Caron (1983) stated: "the engineers at "Ponts et Chaussées", who formulated and implemented policy in the public works sector, were absolutely opposed to the idea of private ownership of railways". However, after 1838, there was a system of concessions in the construction of railways.

[25] See A. Grelon (1993) and Fox And Weisz (1980)

[26] See Fox And Weisz (1980)

1863-1914

As a consequence of modernization in production's techniques, constant changes in the economic conditions and the military and commercial rivalry between France and Germany, this period was characterized by important transformations in the educational system. One of the main priorities was the decentralization of education. To this end, academics were granted a significant degree of autonomy in the directions of the institutions. In addition, large amount of money were allocated in the construction of new building and facilities. On the other hand, research became a primary responsibility of universities academics.

These transformations were also very important in the technical area.[27] Fox and Weisz(1980) stated that " academic scientists showed an unprecedented concern with the technical applications of teaching and research". Here, decentralization became to play an important role. Local industries began to finance technical institutes to meet their demands for engineers. Therefore, industry played an important role in the promotion of high technical education. It seems again, that the spread of the industrialization produced higher private rate of return to education. In other words, in order to increase the productivity, decrease costs, and improve the quality of the production, firms had higher incentives to invest in technical education.

Table 8 shows the French intermediate technical and higher primary schools and students between 1895 and 1913. The *Écoles pratiques de commerce et d'industrie*, the *Écoles nationales professionnelles and the Écoles d'arts et métiers* were the main technical schools at that moment.[28] We can see from Table #8 that the annual changes of the number of students in the *Écoles pratiques de commerce et d' industrie* were very high (15%) between 1895 and 1905, then in the beginning of the twentieth century this dynamic fell. In fact, between 1905 and 1913 the annual rate of change fell to 3%

Finally, it is important to underline that in contrast to England, the French State played a very important role in training of engineers. A. Grelon (1993) pointed out that the "State in France has a long tradition of involvement in all aspect of education". Two Ministers were in charge directly of the education system. The Ministry of Public Instruction was in charge of primary schools and classical programs in secondary education. On the other hand, the Ministry of Industry and Commerce directed a system of technical and vocational schools.[29] However, not only did the central state have a great participation in the promotion of technical education but also the local government. In fact, many municipal governments supported the training of engineers. In addition, local private industries also promoted the formation of technical schools in order to meet the industry demand for higher educated workers.

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[27] Louis Liard dominated French higher education for a quarter of a century, coordinating the often conflicting interests that comprised the reform movements Fox And Weisz (1980).

[28] The écoles pratique was established for the creation of apprenticeship schools. The écoles nationales professionnelles were established by the Ministry of Public Instruction which training students in applied mathematics, introductory physics, chemistry, mechanics, most of their students held State scholarship. The écoles d'arts et métiers was the school that provide more higher education, these schools enjoyed full or partial government support (C. R. Day, 1980)

[29] See C. R. Day (1980)

In addition, if we compare France with Germany we find some similarities, especially at the low and intermediate technical education level.[30] In both Germany and France institutions played an important role in organization and development of technical education. In both countries we found that the system of technical education was based on many specialized institutes. Also, in both countries there was a clear distinction among institutes that provide technical education oriented to the public sector, and technical institutions that provide students to meet the industry demands. Although the organization was very similar, both countries differ in the fact that in Germany, because the disunion of the State, education was promoted and supported by local capital from both local governments and local private industries, while in France education was promoted mainly by the central government.

However, it seems that the main differences in both countries were based on their higher technical education. In Germany, the faculty of philosophy and science made research mandatory since 1830, while it was only late in the nineteenth century that research became more popular in the French faculties. Therefore, research in France was lower than in Germany.[31] In addition, the Germany led France in the number of engineers produced at the highest level of educational system in 1890s. Fox, R. and Guagnini, A. (1980) state that in 1896, there were more students in the Technische Hochschules in Prussia alone than in all the technical *grandes écoles* and *écoles d' arts et métiers* throughout France.[32] In addition, by late nineteenth century, German allocated more amounts of resources in academic and teaching facilities than France.[33] Therefore, at least, in higher technical education Germany was first, rather than France.

4. CONCLUSIONS

It seems that technical education in the nineteenth century was strictly treated as a public good only in France. In fact, since the French Revolution, the central government has been participating in promoting and supporting technical institutions. In other words, the French State has been interested in training engineers and technicians not only for public service but also for private industry. Contrary, during the Victorian era in England, the liberal ideal of *laissez-faire* restricted the inference of the government in technical education, therefore the public itself had to financed it. In the middle was Germany, we can see that technical education was treated as a public good by the local government. That is, because of the disunion of Germany, local government played a key role in promoting and supporting technical institutions. In fact, each region had its own technical school. But not only the local government interfered in technical school but also local private industries were interested in the fomentation of technical education in order to meet the industry demands for technicians.

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[30] P. Lundgreen (1980) made a quantitative comparison of the technical education between France and Germany. He found that the number of professor for science and technology at the universities and specialized schools are similar for both countries. However, in students enrollment for science and technology Prussia leads through out the period.

[31] Fox, R. and A. Guagnini (1994) pointed out that research was scarcely in France, or at least , it was less well endowed than Germany.

[32] The statements made by Fox, R and A. Guagnini(1994) are based on the results presented by P. Lundgreen(1980).

[33] See Fox, R. and A. Guagnini (1994)

On the other hand, we can see that in the three countries it seems that the expansion of technical education was the response to the demand for both public services and private industry. In the case of Germany and France there was a clear distinction of which schools have to promote technical education oriented to industry, and which schools have to be oriented to public sector. The modernization and development of the countries required more engineers and technicians in order to work for public sector. They were required mainly for the construction of railways, canals, dams, roads, urban developments, etc. In addition, engineers were required to improve communications, especially in telegraphy. On the other hand, engineers and technicians were required by industry. New modern methods of production required highly training workers that were educated in technical schools.

Finally, it seems that Germany was the leader in promoting higher technical education focused on the formation and training of engineers, based on a well extensive system of secondary education, and on the construction and expansion of research facilities such as laboratories which allowed a higher level of technical absorption and innovations to be obtained.

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