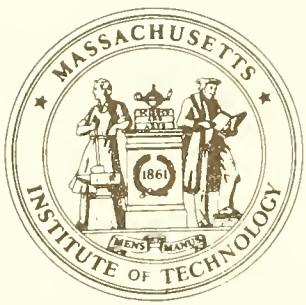

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SCIENTIFIC EDUCATION AND THE FRENCH ENTREPRENEUR

by
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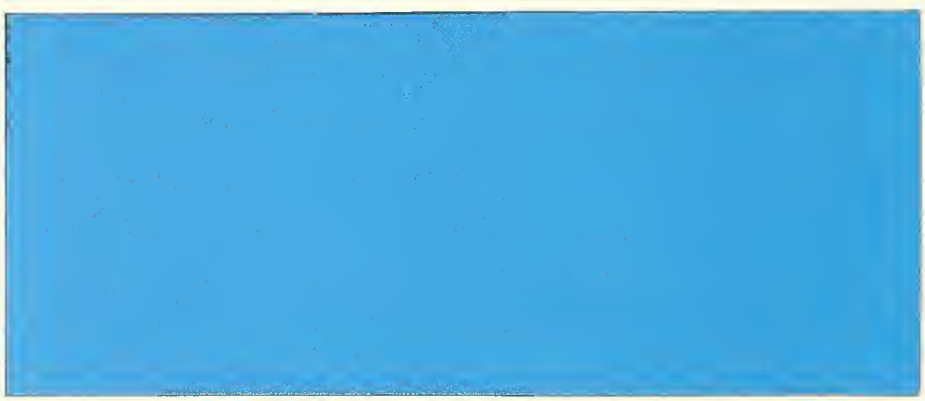

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Draft of a lecture in a series at the History Departments of Johns Hopkins and Catholic Universities, entitled "Enterprise and Entrepreneurs in 19th and 20th Century France". Corrections and comments invited.

The scheme of this lecture is to start with a description of scientific and technical education in France - a description more or less valid for the whole period since the Revolution, rather than a detailed chronological account, although some major milestones must be mentioned. There follow discussions of the role of technical education in entrepreneurship generally, and of the special characteristics which distinguish both scientific education and entrepreneurship in France. The method used is what two young economic historians somewhat sniffily call "qualitative statement and counterstatement", better in their view than "journalistic generalization" out of which it emerges, but well short of "standard economic and statistical tools" of a quantitative sort. "The social return to technical education could be estimated and comparison made (for Britain) with German and American rates of return [McCloskey and Sandberg, 107-08]. In the circumstances surrounding the quality of French scientific education its provision to one dominant monopsony employer, the state, and the family character of French firms, I doubt me of it, as the French say. For example, to estimate the return to investment in chemical education in France from comparative wages of French and German chemists - in 1913 France had 2,000 chemists and Germany 30,000 - [Palmade, 242] - requires identifying the model. If demands for chemical services were broadly identical in the two countries, and the wage rate much higher in France than in Germany, an unambiguous calculation could be made. If supply of potential

chemists were broadly the same and the French wage lower, higher demand for chemists in Germany than in France would be indicated. But if, with this difference of 15 to 1 in supply, there were both a mania for theory instead of practice in France and indifference among the French users, [Palmade, 241] both demand and supply schedules in the two countries could differ with roughly comparable wage rates, which would tell us nothing about the social return to technical education.

Even if the task of measuring exactly the contribution of technical education to growth were possible for the new breed of economic historians, however, it is not so for me, nor I suspect, would it be agreeable to you. The argument then is based on journalistic description, qualitative statement, and a few tables whose numbers will be left untortured.

II

The jewel in the diadem of scientific education in France significant for economic growth and entrepreneurial activity was and is the Ecole polytechnique. It was founded in the days after the French Revolution as part of a wave of educational reform. This surge had its origins mainly in the Enlightment, reacting against the Sorbonne and the Church, and was only to a limited degree a response to pressures from scientists [Ben-David, 1971, 90] though they quickly manned it and brought it to an eminence of

achievement which it has never lost.[1] Competition for admission was intense, with almost three times as many taking the difficult examinations, generally after a year of tutoring, as were admitted between 1794 and 1836, and six times in 1836 itself. Numbers started at an average of 130, and fluctuated between that figure and 300 [Artz, 232-33; Block, 268]. The course lasted two years, and fitted its graduates for the applied schools, to be discussed presently, except of course in times of war, and especially under Napoleon I, when classrooms were emptied to fill the ranks of company-grade officers.

A military institution, it prepared its graduates especially for the artillery school at Metz and for army engineering - a diversion from the original intention of the reformers who were interested in industrial progress. Saint- Simon, the pioneer of the movement favoring economic growth which flowered especially after 1830, in 1797 took a house across the street from the school [Artz, 242] though it is not stated whether this was the rue de Descartes on which among others, the institution fronts. He was a close friend of Monge, who with Lamblardie, was the prime mover in the school's formation. Monge and Lamblardie had the convinction that the same training was appropriate to civil as to military engineering. Before the age of the computer when the calculation of parabolas has become a trivial exercise, artillery required much mathematics. Mathematics and descriptive geometry were the backbone of the curriculum, and in less rigorous form of the

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1 Artz [151] calls the founding "in some ways the most significant advance in the whole history of higher technical education in Europe". In describing French scientific and technical institutions and accomplishments, however, this author is somewhat prone to superlatives as evidenced by pp. 136, 147, 160, 166, 170, 208, 217 (2), 230, 232, 237, 248, 266.

curricula of all French technical schools down to the primary level. Monge himself was a geometer. The 1895 list of Polytechniciens who "made their mark in science" includes 17 geometers in first place, ahead of 14 mechanical engineers, 11 physicians, 9 astronomers, 8 geologists, 7 historians and philologians, 5 chemists and in last place I regret to say - two economists, Chevalier and LePlay. [Ecole polytechnique, 517-19] Descriptive geometry was called the "Latin of the school [Artz, 235].[2]

The prestige of the Ecole polytechnique was enormous, and became, to an extent, an end in itself. "Glory"is frequently evoked by it. In 1828 Dupin complains that a decline in the quality of professors has dried up "this source of glory" [Dupin, II, 320]. The 1840 motto of the alumni Association philotechnique was "For the fatherland, for sciences, for glory," [Artz, 243], the motto now inscribed over the door of the school, for the purpose, according to Detoeuf [139] of communicating to the students an exact account of the practical role they will play. Contemporaneously, the subtitle of Callot's history of the institution reads "Ses légendes, ses traditions, sa gloire."

High prestige and limited entry are of course intimately associated, and together produce rents for those who squeeze through the portal. These rents attract more competitors for the prize, and the competition becomes limited to those who are bright, ambitious and at least moderately well-to-do.

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2 The Colleges royaux in secondary education from which one applied to the grandes écoles were called by the opposition "pas Latin" or occasionally "classes des épiciers" [Artz, 195]. In Germany technical institutes were sometimes referred to as "plumbers' academies"[Ringer, 482n].

Few graduates went into industry in the period before 1850. Civil engineering was neglected for military engineering, and within civil engineering, public dominated private works.[3]

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3 Artz records [239] that the graduates from 1795 to 1836 were not obliged to enter government service, though there was pressure to do so, and records the numbers that did as follows:

1700	artillery
917	military engineering
25	general staff
108	geographical engineers
19	state munitions manufacturing
55	naval artillery
118	naval engineers
13	naval hydrographical engineers
105	general navy
196	Corps des mines
118	Corps des ponts et chaussées.

No number of total graduates is given, so that one cannot calculate percentages. Nonetheless, these military and government careers represented a very sizeable majority. In 1836, only 9 of 120 graduates did not enter public service.

A century and a quarter later three-fifth to two-thirds of the alumni are in public service and one third in industry, according to Callot's rough figures [288] : Of 10,000 active alumni, there are 3,400 in industry, 2,900 civil functionaires, 2,270 military personnel, plus 60 international civil servants, and 780 in nationalized industry. The proportions in private and public service may be affected by the fact that many in the Corps des mines, the Corps des ponts et chaussées and in the Génie maritime worked in industry on the basis of unlimited leaves or special missions. [Ecole polytechnique, 557]. See also Tables II to IV below.

The applied schools, Ponts et chaussées and Mines, go back to the 18th century before the Revolution, though they were reorganized during the educational reform. After two years at the Ecole polytechnique, a man - more recently also women - would go on to three years at Ecole des ponts et chaussées, or two at Ecole des mines at Paris. The latter prepared students for coal and iron mining, though the Ecole des mines at St. Etienne went in for steel and railroads as well. Ponts et chaussées was directed to means of communication but also to public works generally, including beyond 1) bridges, roads, railroads, ports and interior navigation, instruction on 2) large public works in irrigation, draining, regulation of water and factories, distribution of water; 3) mechanics, civil architecture, minerology, geology, agriculture, political economy, and administrative law. There were only 20 students a year, plus some foreigners and so-called "externes" who entered otherwise than from selection from the Ecole polytechnique [Block, 259].

The Corps des ponts et chaussées was in many respects the forerunner of the post-World War II Commissariat au plan. In 1792 it was asked by Minister Roland under the convention to prepare an economic plan to restore economic order by providing for public works, including plantations, mines and quarries, forges and factories. [Commission de Recherche, 2,9]. The famous Etoile design for the railroads, tying the country to the center at Paris came from Le Grand at Ponts et chaussées in 1830, the Louis Armand or Pierre Massé - both Polytechniciens, by the way - of his day. The Corps was a strong force for standardization and centralization, objecting with vigor to the use of English standards in building the railroad from St. Etienne to Lyons with wide curves, double tracking and a tunnel under the watershed between the Loire and the Rhône.[Dunham, 52]

Such was the prestige of the graduates of the Ecole des ponts et chaussées that they took prededence at state functions over colonels in the army. [Artz, 244].

The Ecole des mines at Paris was designed for government service, although a small stream of its graduates went into private employment, and others like Michel Chevalier, the Saint-Simonien economist, had general careers in journalism and government. The school at St. Etienne for private engineers was less selective, easier to enter, and less prestigious. That at Alais was for foremen.

There was a welter of smaller grandes écoles for a variety of purposes, military, naval, and specialized, which we will encounter in Tables II to IV, but which we need not spend time with now. The French tradition when confronted with a problem is to start a school to teach its solution. At the level of skilled instruction this results in schools of commerce, watch-making, lace-making, silk, locksmithy, those for blind and so on. It applies also to the levels of higher instruction in such fields as hydrography, electricity, geography, navel engineering and many more. But between the grandes écoles, grouped around the Ecole polytechnique as the pivot, and the primary and secondary instruction of the working population, the French have developed a variety of institutions: the Conservatoire des arts et métiers, the Ecole centrale des arts et manufactures, and the Ecoles des arts et métiers.

The Conservatoire was started during the Revolution, and provided with a museum of industrial models and an excellent library. During the Consulate, courses were undertaken, largely at a popular level. By 1810 there were 300 students regularly enrolled. [Artz, 146]. In 1873 14 professors gave 559 lessons to 135,000 individuals [Block, 259] If each student attended only one course of lessons, and each professor gave but one, the total number of students engaged would have been close to 1,000. Early in the century Chaptal organized a course in weaving. The two most illustrious graduates of the Conservatoire were Joseph-Eugene Schneider, later of the Schneider-Creusot steel company, and Joseph-Marie Jacquart who invented the loom for weaving complex designs in silk, using for the purpose a forgotten model of Vaucasson in the museum of the Conservatoire which had almost solved the problem. [Dunham, 253] The Conservatoire was especially distinguished in its work in chemistry under Frémy, whose laboratory was a showpiece, to which German students like Liebig and Kekule came. In the hey-day of French chemistry before 1850, it was France which had a practically-centered laboratory approach not Germany, but that at the Conservatoire was the only one. [Hohenberg, 68]. In 1853 the first teaching laboratory in engineering in the world was established in the museum [Artz,217].

Centrale was started privately in 1829 by a group of industrialists discontent with the numbers and qualities of engineers made available to them. In the 1850s, it was given to the city of Paris. Instruction took three years, a year longer than the Ecole polytechnique, but there were no applied schools to follow, unless one was admitted as an externe, seemingly a rare occurrence.

Like that of the Polytechnique, the first year was based on mathematics and descriptive geometry, but since the students were selected from a somewhat less qualified group of applicants, the level while severe, was not as rigorous. From 1832 to 1870 the Centrale produced about 100 engineers a year, which leads Prost to conclude that the needs were not very large [Prost 302]

This is not the way it was seen by contemporaries, however. The perennial drive to push technical education for economic growth expressed by Talleyrand in 1791 to overcome routine methods [Artz, 115] by Chevalier in 1838 to raise the quality of French goods [Dunham, 186] was extended in the Second Empire by the Saint-Simonien Louis Napoléon. One spur was the competition felt in international exhibitions. The Universal Exposition in Paris in 1862 found the French section of the international jury urging more industrial education 'to maintain the products of our industry at the level which belongs to them" - a somewhat delphic remark, and resulted in the formation of a special commission [Ministère des affaires étrangères, 1863, 27] Five years later improvement presumably had been realized. More than five hundred alumni of the Ecole impériale des arts et manufacturers, as Centrale was known in the Second Empire, had figured as exhibitors in the Universal Exposition of 1867 in Paris and 248 had won awards, among them 5 grand prizes, 65 gold medals, 8 decorated with the Legion of Honor [Ministère des affaires étrangères, 1867, 94]. But there is no benchmark with which to compare this performance either in time or between countries, and in particular there is no indication of how much these prizes reflected

French taste and workmanship, and how much cost efficiency.

The Ecole des arts et métiers originated at the eve of the Revolution when the Duke de la Rochefoucauld-Liancourt started a school for the children of his dragoons regiment. Transferred from Compiègne to Châlons-sur-Marne, its purpose was enlarged to the provision of good workmen and chiefs of workshops. Others followed at Angers and later (1843) at Aix [Prost, 303]. In 1874, these schools were each capable of handling 300 students, but had somewhat fewer [Block, 262]. Courses lasted three years and covered such subjects as foundry and locksmithy, with, of course, a strong component of descriptive geometry. Prost notes that the old alumni of Châlons and Angers got more mathematics and science than practical education, and that they were the only people able to piece out the ranks of engineers when the grandes écoles, including Centrale, proved incapable of providing the numbers necessary. [Prost, 303] Monge, Berthollet and Laplace were interested in these schools, just as the Duke of Rochefoucauld-Liancourt played an early role in the reorganization of the Conservatoire. Outside the realm dominated by the classic tradition of religion, philosophy, medicine and law, taught in the universities, scientists and educational reformers made common cause.

The universities of course taught science. They did little research. Up to 1830 French science was the most distinguished in the world, says Ben-David, as a result of momentum gained in the 18th century. Leading fields were mathematics, chemistry, and mechanical engineering. Scientists had little time to work, since they had to earn their living in other ways and suffered as a rule under limited facilities. Primarily they taught rather than did research, and taught deductively rather than experimentally. Instruction at

such a place as the Collège de France was superb. The freedom to reform science was gained, the will to do so declined. About 1830 French science began to rigidity. The establishment of the Ecole pratique des hautes études in 1868 served to support research, but in the absence of degree-granting powers, had difficulty in offsetting the trend. [Ben-David, 1971, chap. vi] Pasteur's institut created in response to his interest in practical problems like pebrine, phylloxera, and fermentation, was an exception. The prestige of the universities in science remained high despite authoritarian and doctrinaire organization. When choice had to be made by a student admitted both to the Ecole polytechnique and the Ecole normale supérieure to seek the aggregation and a professorial post, it was not automatic that he would choose the Ecole polytechnique.[4]

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4. The Exposé de la situation de l'empire for February 1865 [Ministère des affaires étrangères, 1865, 122] notes that in spite of all the prestige which attaches to the Ecole polytechnique, one sees candidates admitted to both competitions and in the first ranks who choose the Ecole normale. This may protest too much. The same volume notes [121] that the Ecole normale competition was brilliant with more than 300 candidates; that for 1866 notes 344 candidates for 35 places. Prost, however, observes that the non-normaliens who enter university teaching by the "back door" are generally of higher social origin than the normaliens who are looking for security, standing, vacations, etc. and never dreamed of a different career, while the non-normaliens are often those who have suffered financial reverses [Prost, 378] For a contrary view see Wylie, Bégué and Bégué [243]. They maintain that the normaliens can easily get detached from teaching and enter letters, statesmanship, and big industry.

In modern times, a well-worn route to business distinction is via the Ecoles des sciences politiques, or the Ecole de droit of a major university, preferably Paris, the Ecole normale d'administration and the Inspection des finances[Lalumière, passim] . Prior to the establishment of the ENA after World War II, the Inspection des finances was entered directly from law or following the aggregation, which came after E.N.S. Like the Corps des ponts et chaussées and the Corps des mines, the Inspection des finances was established for government services, but like them, its recruits are often seduced into private employment, temporarily or with a permanent separation.

Prior to the last few years commercial schools have existed since 1325 when two silk merchants in Paris founded the Ecole spéciale de commerce et d'industrie, to provide 'enough scientific training for students to become not engineers but to be able to direct the business end of industrial operations [Redlich, 1957, 233]. The initial staff included the economist, Adolphe Blanqui, student of Jean-Baptiste Say, who took over as director in 1830. The Paris Chamber of Commerce bought the school in 1868 when it ran into financial difficulties. In the early period the course took three years, and the number of students ran about 170 [Prost, 304].

Schools of commerce spread under the Third Republic after 1870, and especially the Ecoles des hautes études commerciales (H.E.C.). That in Paris was founded by the Paris Chamber of Commerce in 1881. Since 1955 all French universities have initiated business curricula. At the University of Paris 50 percent of the students had law degrees and 17 percent engineering degrees.

[Warner, 22]. A recent school patterned after the Harvard Graduate School of Business Administration, using the case method, has been started at Fontainebleau.

The Hautes études commerciales are "certainly less prestigious and less difficult than Polytechnique, Normale or ENA" [Wylie, Bégué and Bégué, 245n]. Wylie et al go on to explain that if one cannot get into the one of the last three, the bourgeois student is content with the world of affairs (which explains average French mentality with respect to commerce [ibid]).

Some numbers may put this catalogue of institutions into perspective, across all French higher education, over time - but only from 1913 to the present - and in national cross-section for 1913. Table I shows the rise of total numbers of students enrolled in French higher education, the gain of scientific and technical education at the expense of law and social science, largely law, and the surprising result that despite its tradition of technical education, France lagged in 1913 behind Europe in the proportion of its student body devoted to it.

This cataloguing institutions of scientific and technical education may be brought to a close by reviewing the various criticisms leveled against them, and especially against the grandes écoles:

1) instruction is too theoretical, mathematical, rigid;

2) the system is too centralized, authoritarian;

3) the schools themselves are cliquish, elitist, and turn out a product which is arrogant;

4) both the system and its output concentrate too heavily on the top ranks of instruction, administration and industry, and neglect to provide in sufficient quantities for instructors, laboratory assistants middle cadres, foreman and skilled workers.

1. As early as 1823, the British referred to the "unhappy scepticism" in France which has been justly ascribed to "mathematics", [Cotgrove, 18]. Comparison of German and French engineers in iron mining emphasizes that while both are theoretical, and unready for practical work on graduation from their advanced training, the French are far more so[Parker, passim]. French chemists have a mania for theory [Palmade, 240]. Novels and aphorisms combine to deride the dangers of dealings with engineers who understand theory but have not experienced practice. Henri Fayol, graduate of the Ecole des mines at St. Etienne who was a successful manager of the Société de Commentry-Fourchambault before going on as an efficiency engineer and prophet of something close to Taylorism, in 1900, attacked the curricula:

> "Mathematics was the subject most in need of reform. Curricula demanded an intensive study of higher mathematics. Yet in point of fact, when it came to the world of practice, almost none was used. This was Fayol's own experience. When he inquired of others, he found the same thing. Engineers at work used no higher mathematics. As managers there was even less likelihood of their so doing. The young qualified engineer, instead of being fit and alert on entering industry, was physically and mentally worn out, barely capable of undertaking the simplest tasks. If those quite useless highly theoretical studies were eliminated,

the man could start an employment sooner, and he would be better prepared for what lay ahead of him," [Brodie, 40].

2. It is hardly necessary to support the criticism that French institutions are overcentralized - a theme well developed since Louis XIV and earlier. One insight is afforded, however, by Dupin's criticism in 1828 that the time table of the Ecole polytechnique provided detail schedules of the amount of time to be spent on each subject during the day, down to minutes. He insisted that students were not identical and did not all take the same time to understand given material, asking that some students be allowed double or even triple allotments for some studies [Dupin, 321].

Authority and centralization meant domination of branches of science by established views which did not welcome new ideas from abroad in many cases, nor indulge wide-ranging curiosity in their underlings. [Guérlac, 86].

3. Tables II to IV below bear to some degree on the cliquishness of various schools; although differences in the type of education required for different industries play a role which is not allowed for. Qualitative evidence is furnished in statements of observers. Certain posts are reserved for certain schools [Deleforterie-Soubeyroux, 107]. Alumni place on-coming graduates [Prost, 300]. Companies are known by the grandes écoles with which they deal: the leading Peugeot heir is always entered for Centrale and IBM in France hires mainly there. Frenchmen today are conscious when two economists of the Ecole de droit on the Commission of the Common market, Marjolin and Barre, are replaced by two from the Ecole polytechnique, Deniau and Ortoli.

According to gossip, DeGaulle, a product of the Ecole speciale militaire at St. Cyr detested graduates of Polytechnique and would not have them in his cabinet, although the statement lacks conviction in the light of Valery Giscard d'Estaing and Bourges-Maunnory, both Polytechniciens, who were cabinet ministers, and Jacques Rueff, another alumnus, on whom he relied for monetary advice.

Elitism is perhaps carried no further than in other countries where insiders are conscious of who earns triple firsts at Oxford or Cambridge, or is graduated first at Harvard Law School. The French mention these ranks more frequently. They are impressed that President Albert LeBrun of the Third Republic entered Polytechnique in the 230th rank and was graduated first. Michel Chevalier is not referred to without repetition of the fact that he was first at Ecole des mines. It may be a matter of the relative sophistication of the two novelists, or of their interest in the characters, that the hero of Le Maître de forges was first at Polytechnique [Ohnet, 55], whereas the engineer in Porcelain de Limoges, who dies a third of the way through the book, was only second at Centrale, 'sure of his gifts and of the power of science" [Chardonne, 77]. Detoeuf mocks the practice - at the same time that his autobiographical account of his fictional hero mentions that he entered Polytechnique at an average rank, and left at one.- :

> 'It is sufficient to enter Polytechnique. As for the rank of leaving, it is useless to be uneasy, because, whatever it is, family, friends acquaintances will arrange at the end of several years, that you emerged first," [Detoeuf, 140].

The literature is replete with references to the arrogance of Polytechniciens, "those parvenus of instruction." Two will suffice. With his strong thesis and feelings Beau de Loménie is perhaps not the most impartial observer but characterizes one man in the following manner: "But Loucheur, armed with all the prestige which his title as Polytechnicien and the considerable profits acquired in war orders gave him in the eyes of men of affairs, furnished with the imperturbable assurance which was one of his most characteristic traits, gave two preemptory responses..." [Beau de Loménie, III, 153]. Kuisel speaks of Mercier, a colleague of Loucheur, and one who ultimately moved into the semi-Fascist Redressement Français more judiciously: "Conscious of the supposed intellectual and moral superiority of the graduates of Ecole polytechnique, he took great pride in belonging to a ruling caste which has a special obligation for social leadership" [Kuisel, 46]. It is deemed noteworthy that the self-made textile manufacturer, protectionist and later Minister of Finance, Pouyer-Quartier, in addition to distinguishing himself by a resistance to beer and alcohol superior to that of Bismarck with whom he negotiated over the Franco-Prussian indemnity of 1871, should, as an economic parvenu, have been sure of himself [Palmade, 178].

4. This "admirable corps of engineers which the world envies" [Vial, 129] was taught in schools and universities which lacked the middle ranks instructors, laboratory assistants etc. and emerged into an economic world with inadequate numbers of middle-managers and foremen. On the former score,

the difficulty derived from the theoretical aspect of the curriculum with its denigration of experiment and exercises. On the second, successive attempts were made to fill the gap with the Ecole des arts et métiers, specialized trade schools and the like, but the scale was never sufficient. As in underdeveloped countries today, France in the 19th century at least had too high a proportion of highly-trained theorists relative to lower ranks who would carry out their directions in production.

The position should not be distorted. In addition to the weaknesses, there was the great strength of brilliance, superb if somewhat biased training, and dedication to the goals of economic growth spread by the Saint-Simoniens. Let us now turn to see how this scientific and technical education relates to industrial enterprise.

III

In the view of some radical economists today, the function of the boss in industrial production is to exploit the workers and distort income distribution against wages and in favor of profit and rent. We take a more conventional view, and consider the functions of the entrepreneur as consisting of 1) providing inputs; 2) adopting a technology; 3) administering the production and distribution processes; and 4) selling outputs. Among the inputs are clearly capital, and in a number of instances, such as the early maîtres de forge, wooded land to furnish charcoal. (Unlike England where

ownership of land included mineral rights, such rights belonged to the state, which accounts for its preoccupation with mining embodied in the Corps des mines.) Some mercantile skill was required in buying raw materials, especially in such industries as textiles. The marketing function was entirely mercantile. Administration called for skill in human relations, including the exercise of authority and possibly could be broadened to include the speculative flair. None of these bears much relation to scientific and technical education.

In technology, the analysis will follow the familiar division of Schumpeter and deal with invention, innovation and imitation [Schumpeter, passim]. Scientific and technical education can contribute to all three, but it is not their sole source.

Entrepreneurs emerge from backgrounds which rely on these functions in different proportions. Which function deserves the emphasis will depend on the industry in question and its stage of development. Attempts have been made to characterize entrepreneurs in different schemas. "Trader, financier, speculator and industrialist" [Redlich, 1958, 96] comes close to the foregoing functional categories. A different taxomony into "business-oriented, industry-oriented, and job-oriented [ibid., 97] fits less well, though business orientation can be associated with the mercantile function and industrial orientation to some degree with technology. Cole's division into "empirical, rational and cognitive" [quoted in Redlich, 1959, 117] deals with degree of specialization, as a function of historical task-differentiation. The empirical business man could run a mercantile house, bank and textile mill simultaneously. His skills were mercantile, he

possessed capital, and he was a good administrator. The rational business man specialized in all phases of a single industry; the cognitive was a job specialist in finance, marketing, or production (again the three functions but only one of them) who could shift industries without changing the nature of his work.

There is a strong temptation to build a "staple theory of entrepreneurship"which would associate given industries with particular characteristics of their entrepreneurship, much as Harold Innis, the Canadian economic historian, related separate commodities to different types of economic stimulation in the growth process [Watkins, passim]. Broadly speaking, textiles and banking are entered by entrepreneurs from trade, the metallurgical industries from artisanal occupations, and industries of high technology from technical training or complex trades like clock-making, locksmithy or the shop of the apothecary. There may be national differences. Early English entrepreneurs are said to have been technically oriented, whereas in Germany the merchant had at least an equal weight. [Zunkel, 25]. Early entry into iron was frequently based on ownership of woodlands needed for charcoal. No generalization stands up for long. The Krupps were a merchant family. Silesian nobility went into iron and steel based on ownership of forests, but Rhenish nobility did not. Sons of professional men, especially of clergymen, are frequently successful entrepreneurs. This seems to be based less on the relation between Protestantism and business, though such was not unknown, as on the tension between limited means and cultural

aspirations, which becomes translated into material ambition, [ibid., 28-30].

In France, the "kings of iron", Schneider, Wendel, and Talabot, came respectively from petty trade via bank employment(and the Conservatoire des arts et métiers), an established aristocratic family with land and wealth, and from the Ecole polytechnique. In locomotives, Gouin was the son of a banker and Cail, an apprentice coppersmith, who teamed up with a chemist manufacturing sugar-refining machinery.

The pioneers of the automobile in France had various social (and economic) origins: small mechanic (Bouton),student (Renault), industrialist (Peugeot) and aristocrat (de Dion). [Mossé, 19]. It might be added that Citroen was a Polytechnicien and Panhard and Levassor, alumni of Centrale, and that the families of Renault, Citroen and Berliet were comfortable bourgeoisie, the Renaults in drapery (and manufacture of buttons), Citroens in diamonds, and Berliets in millinery. Most salient is that the genius of Renault lay in that he was "possessed of the demon of mechanics", while Citroen was "an astonishing commercial genius, with an extraordinary sense of publicity" [Palmade, 236].[5]

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5. Chaliot notes however, that the Citroen company reflects peculiarly French characteristics in its poor production techniques and sales performance. It was brilliant in designing cars but performed "less happily on the financial level" [Callot, 270-71]. The Michelins who took it over, started as small-scale makers of bicycle tires. I do not know whether the younger generations acquired an engineering training, or whether the "X" radial, steelbelted tires bears any relation to "X", the nickname for the Ecole polytechnique.

Georges Dufaud, who introduced puddling of steel into France, was both Polytechnicien and an heir of a pre-Revolution established family, but he had a strong commercial sense, being interested in the firm's reputation, credit, use of intelligence in discovering new outlets, and the sense of what pleases a client [Thuillier, 24, quoted by Vial, 174].

Even in the technologically-demanding chemical industry there is contrast between Kuhlmann, who taught chemistry at the University of Lille at 21 before starting the company which bears his name, and Motte, the textile manufacturer from neighboring Roubaix, who, if the account can be accepted, was called from the army in World War I by his fellow townsman, Loucheur, to run Le Chlore Liquide, established for poison gas. Motte is reported to have said that he knew nothing of chemistry in general nor of chlorine in particular, so that he teamed up with his brother-in-law, Edmond Gillet of the Lyon firm which had started in silk, and moved into dyeing and then chemicals. Between them, Motte and Gillet formed Produits Chimiques Gillet et Fils (Progil) later absorbed by Pechiney, [Beau de Loménie, III, 67, 174].

Entrepreneurship thus stems from and is nurtured by wealth, mercantile skills, technological training and administrative ability in patterns with shifting and somewhat confused emphasis; it is nonetheless likely that the staple theory of entrepreneurship is valid. The mix in entrepreneurial capacity from these sources will vary among firms at a given time in a given industry, between industries, and over time as production processes become more complex. With its strong emphasis on technical training, therefore, one

should look for France to excell in those aspects of entrepreneurship which require it: and especially invention, innovation and imitation.

Much invention comes from scientists and engineers. Musson is right in insisting that the literature on the industrial revolution exaggerates the amateur character of British inventors as tinkerers, denigrating the contribution of the Scottish universities and the Dissenting Academies to their scientific education.[Musson, 3, 61]. French science produced many inventions and discoveries: the graduates of Ecole polytechnique alone discovered radio-activity, and initially produced artificial silk, smokeless gunpowder, reinforced concrete, the Houdry process for oil refining, the electric brake for trains, designed the brilliant Caravelle. Hydro-electric power stems from a Centralien, Bergès. From the scientists came the discovery of chlorine, the Leblanc soda process, and the contributions of Pasteur to many practical fields. There also were tinkerers, like Jacquart, of the Conservatoire, although he was trying to solve an artistic problem, and there were the artists.

Cyril Smith's theory of technological invention emphasizes the role played by the decorative arts in discovering new processes, particularly in the development of new materials and new methods of handling materials. Casting of statues uncovered new metallurgical techniques. High-temperature methods of treating materials come from ceramics. Glass-making at which the French have excelled, has many decorative aspects, including household objects of art and stained-glass windows, which in their turn provided the technique developed for molding the lead into H-shapes to hold the glass -

which later evolved into the extrusion of steel rails and I-beams [Smith, 526]. This insight has bearing on a vital economic issue: the extent to which inventions and innovations are a response to eoconomic forces. Schmookler maintains that inventors do not make discoveries by chance, but invent in response to the market. He offers powerful evidence from railroads, agriculture, petroleum refining and paper making [Schmookler, passim]. Further evidence could be cited from the 18th and 19th century that advances in instruments especially for navigation, surveying and optics, to limit the discussion to one field, were responsive to felt needs. The research that went on in the Royal Manufactory at Sèvres, however, - in glazes, enamels and paints - [Mathias, 80] - can hardly be regarded as market-induced. Science used to create an object of beauty, science for science's sake, science and technology for gloire, like science out of curiosity, and science for military purposes might all serve aristocratic rather than bourgeoise values. The market is not competitive. Within broad limits, money is no object.

Pitts has pointed to the essential ingredient of aristocratic values: prowess, the unreproductable act, whether at the work bench, on the field of battle, in the salon or the boudoir [Pitts, passim]. To the slogans he cites: "Never count your change," "never take cover", "his men adore him", can be added "Make it the way I want it and never mind the cost."

These innovations are market-induced in a sense, but the demand is inelastic with respect to price, and cost-minimization is a weak argument in the function. Nor are the inventors especially interested in making money.

This aristocratic attitude seems to have been characteristic of the Comte de Chardonnet, the Polytechnicien who invented artificial silk. Coming from the most traditional of nobility of the Vendee, he saw his invention exploited by "two groups of fortune", the Carnot Société de Viscose and the Gillet group of Lyons, [Palmade, 237, 249].Berthollet, who discovered the use of chlorine for bleaching textiles, had no interest as a scientist in the material possibilities offered [Musson, 54]. Three generations later Berthelot who opened up the field by synthesizing acetylene opposed efforts to turn organic chemistry to practical use [Weiss].

Even when an inventor hopes to gain, it is by no means assured that he will. The Jacquard loom was taken up in Britain long before its use spread back to France. Philippe de Girard's "great invention for spinning flax" was not accepted in France until it was appreciated by the British [Dunham, 293-96]. Verguin, who in 1859 discovered synthetic fuschine for dyeing cloth red, saw his team dispersed and driven to Switzerland by the impatience of Henri Germain, president of the Crédit Lyonnais, eager to make profits quickly [Bouvier, 374]. Lost Illusions by Balzac is a precautionary tale of one David Séchard who invented a process for making paper out of ubiquitous vegetable fiber instead of linen rags, only to have his invention exploited by the evil brothers Cointet, [Balzac, passim] To carry invention through to innovation requires commercial and financial sophistication, and drive. The great innovation of interchangeable parts developed in New England by Eli Whitney and the gunmakers, was anticipated in theory in the first half of the 19th century by Réamur, and actually put into practice

on a limited scale in an arsenal in Versailles before the Revolution. Persistent application of ingenuity lacked, however, and the attempt lapsed. There is something in the ironic remark: the French invent; the British do.

Imitation calls for an attribute contrary to aristocratic values, humility. There were, as we shall see, many French who were prepared to learn by visiting Britain, or to be taught by imported British workers. Some were aristocrats; many were alumni of the grandes écoles. Intellectual capacity and readiness to learn from equals characterize science; intellectual capacity and aquisitiveness in graduates of the grandes écoles who go into industry were often found with readiness to learn from peers missing.

But most graduates of the grandes écoles go into government service or into engineering, i.e. public works, which in staple-theory terms differs fundamentally from business. Instead of selling to the masses, one deals with a government or at most with bankers. Rondo Cameron's France and the Economic Development of Europe is misleading to the extent it implies that it was French bankers and businessmen who went abroad to spread the techniques of the Crédit Mobilier. The men who accompanied the bankers were engineers, building railroads, bridges, canals, tunnels, ports, stations, - not industrialists. De Lessups was not an engineer but a diplomat, though the project derived its start from the Polytechniciens under Enfantin, the French company was directed by Paulin Talabot, and many of his colleagues were also alumni [Ecole polytechnique, 52]. A number of speculators, another aristocratic and anti-bourgeois attribute, were among the French who

pioneered for profit in Russia in establishing businesses [McKay, passim]. The products of the Ecole des mines perform their engineering feats in Algiers, Spain, Russia and elsewhere outside the Hexagon. The contribution was first finance and second technological. They did not serve as entrepreneurs in the full sense involving finance, marketing, technology and administration. French genius lay in engineering, as the career of another famous bridge-builder, Eiffel, from Centrale, testifies. Folklore has it that Eiffel was discharged from Centrale without his degree of Engineer of Arts and Manufactures for some disciplinary infraction, and that when the school claimed him as its own after his fame, he resisted post facto adoption.

I have been unable to find trace of any but two of the foreign students of the grandes écoles. One, Charles King, had the improbable educational experien of attending first Harrow in England and then the Ecole polytechnique. He was for some time a partner of Archibald Gracie, a merchant whose country house now serves as the mayor's residence in New York, and later became president of Columbia University. [Albion, 253]. The more interesting illustration is furnished by Alfredo Cottau, and Italian of an Alsatian family, who was able to enter the French naval school at Toulon by virtue of a great uncle in the French navy, went to the Ecole préparatoire de la Marine in Paris for two years beginning in 1855, and, after a cruise, returned to his native Naples. There he worked for a time with the English engineering firm of Guppy and Co., and studied bridge and road design locally

before returning to Paris to study engineering. The mention of bridges and roads suggests that he was an externe at Ponts et chaussées but the point is not explicit. After finishing his studies he worked with Ernest Gouin and Co, specializing in bridges and metal roofs, after which he returned to Italy, winning competitions, working briefly for the government, and finally serving as an engineer for a railroad. Cottau took an active part in public questions, writing in Il Politechnico in favor of narrow-gauge railroads to save on capital costs and coal consumption, and building viaducts, bridges and roofs of stations. Alsatian and Italian genes combined with French training, British experience and Italian conditions to produce an effective, public-spirited engineer, [deRosa, chap. ix].

It is surprising that one finds few graduates of military schools who go into industry. One should have thought that administrative capacities developed in the military - and the French army has been cited as a counter-example to the family-firm argument that Frenchmen prefer organizations small - would make a contribution to entrepreneurship. In the United States, resigned army officers are a source of top and middle-level management. Werner Siemens founded his electrical company with the artisan Halske in Berlin after fifteen years in the Prussian army as an engineer and in artillery school, "the happiest of his life". Winning contracts to provide telegraph installations to the army, he hired another artillery officer to run the administrative side of the company, an early step in the bureaucratization of the German large-scale firms [Kocka, 15, 76]. The Centennial volume of Polytechnique mentions one Jacquemart who resigned as an officer of artillery to go into the chemical industry [Ecole polytechnique, III, 560].

The semi-fictional Barenton resigned from the artillery when he married a lady whose father owned a business. The resignation of Gouin upon immediate graduation from Ecole polytechnique has been mentioned but is different as he had not served in the military forces. Table II notes only 56 outstanding business leaders in France of 15 years ago, less than 2 percent of the sample, who received higher diplomas in military schools. Military service in France - and of course for the Junker officers in Germany - catered to aristocratic rather than bourgeois or industrial values.

Technical instruction in commerce played little part in the formation of entrepreneurs in France so far as the record shows. Business leaders do not come from schools of commerce, which provided rather the middle ranks. British and German mercantile education was usually sought through a year or years abroad in the counting house of a relative or business correspondent, along lines set out in Buddenbrooks. The French were less ready to follow this practice. Graduates of the technical schools work abroad for stated periods, as we have indicated, which accounts perhaps for the surprising statement in a history of the Ecole polytechnique that Polytechniciens emigrate easily - a statement backed by the odd example of a graduate who taught at the Harvard Business School. [Callot, 303]. Nor is banking a profession acquired through learning, unless perhaps in recent years. Over most of our period it was entered through inherited wealth or through apprenticeship. Beau de Loménie's major thesis is that virtually all

positions of prominence in French politics, industry and finance were occupied by the descendents of 200 families which established themselves in positions of power in 1789 or shortly thereafter and never let go. Evidently wide of the mark in industries such as automobiles, electric equipment, and much of chemistry, it applies better to iron and steel - with exceptions for Schneider, Benoist d'Azy and Talabot - and best of all to banking. There were new entrants but apart from the Rothschilds, they did not last long. The Saint-Simonien Pereires the speculator Mirès and Bontoux, the engineer from Polytechnique and Ponts et chaussees, had moments of success, but ended up defeated. One moved into banking from commerce, industry, engineering, or even Lettres[6], or more readily one was descended from an old banking family, preferably Protestant and from Geneva.

In contemporary France scientific and technical education do train for business, as Tables II to IV from Mlle. Delefortrie-Soubeyroux illustrate. Engineering dominates, and within engineering the Ecole polytechnique leads in public enterprise, Centrale in private. It will be recalled from Callot's data in footnote 3, that while a plurality of the graduates of the Ecole polytechnique is in in industry, a large majority, divided between civil functionaries including nationalized industry and the armed forces, is not. It is likely that the proportions of Polytechniciens entering government and private industry, as opposed to the army, have been

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6. The first part of the centrennial celebration volume of the Société Générale was written by Jean Méary, a director of the bank, alumnus of the Ecole normale supérieure, aggrege in history and geography, and a member of the Inspection des finances [Méary, preface]. This must be the French equivalent of a triple first in greats.

rising from the first half of the 19th century to the middle of the 20th, but figures to fix the point are lacking. The tables show only the position in the middle 1950s, for industry - including nationalized industry, - but not government. The educational information is extracted from a wider study which includes social and regional origins, size of family and the like.

Table II is derived from biographical information in directories, mainly Who's Who in France, supplemented by surveys by Enterprise, Bottin Mondain and L'Annuaire Desfosses. Information on education is 86.5 percent complete, so that probably 700 of the 800 recorded without diplomas can be said to have had no higher education. More than a quarter of those with diplomas had more than one, including 175 Polytechniciens with other scientific diplomas, 52 with non-scientific diplomas, 123 outside of the Ecole polytechnique with more than one scientific diploma etc. [Delefortrie-Soubeyroux, 59]. What is particularly striking, apart from the dominance of engineering, is the showing of Sciences Po, equal to the Ecole de droit and more than double Letters, Science and the military schools.

Tables III and IV furnish details of the educational training of top-level management in selected nationalized and private industries, respectively. "Sans indication" is not equivalent to those without higher degrees, which is not given. The figures reflect again the dominance of engineering, the preference of certain industries for particular mixes of training and institutions, whether because of the staple theory alluded to earlier, or the alumni connections between firms and schools. The preference of nationalized industries

for graduates of the Ecole polytechnique - or vice versa - is clearly shown, and the much greater relative importance of Arts et métiers in private than in public industry. The rise of specialized engineering schools represents the culmination of a trend observed earlier. The schools of commerce are relatively unimportant in private industry and of no consequence in public.

IV

An evaluation of the success of scientific and technical education in France in promoting French entrepreneurship is overdue, but one sociological point may be made first. In France entrepreneurship typically had origins in banking, commerce or artisanry, and acquired scientific and technical capacities in later generations, whereas in Britain firms were often started by men of scientific attainments whose sons moved away from science to letters, politics, and country living. The ranks of maîtres de forge who sent sons to Ecole polytechnique or the Ecole des mines, include Wendel, Gargan, Janoyer, Reverschon, Thoyot, Dufaud and others [Vial, 179, 396]. A Japy was usually at the Ecole polytechnique, a Peugeot heir at Centrale. The son of Panhard from Centrale moved up to the Ecole polytechnique. From Alsace, the Koechlins of textiles and the Schlumbergers of textile machinery went on to Ecole polytechnique, although they did not always stay in the family line of endeavor - one Schlumberger moving into oil exploration equipment, and another later in jewelry, and

a Koechlin Polytechnicien became a leading musician. The Ecole polytechnique produced doctors, musicians, painters, novelists, lawyers, men of holy orders and diplomats, along with engineers [Callot, 298-99], probably representing those who were launched by the père de famille on a technical and scientific career for which they were not suited.

The urge of the father to push his son into science and engineering in order to enable the latter to improve his business is brought out in the long speech of M. Cardonnet, father of the hero Emile, in George Sand's socialist novel, Le Peché de M. Antoine. Emile had been sent to study science because the father arrived only by instinct at solutions of problems in geometry and mechanics useful in business. When Emile moved within the exact sciences to useless astronomy, the father forced him to switch to law. He had sought to find a means to make him useful. He had a fortune, but was ignorant of law and at the mercy of perfidious counsels. Emile was to learn law, but not to be a lawyer, [Sand, I, 152-54].

The contrast, of course, is with Britain, where the sons of the founder tend to go to Oxford and Cambridge and study greats or modern greats for careers in politics, including the civil service, or the professions when they do not retire to the country or the Riviera. The classic example is perhaps that of John Marshall of Leeds, in 1848, the leading flax spinner in the world, whose two sons coped feebly with his firm, and whose grandsons ruined it, [Rimmer, passim]. In Britain, professionalism in family firms diminished; in France it increased. A hint of still a different pattern comes from Germany where a French scholar notes that it was not the successful handwerker who made it big but his son, who made the conversion from powerful merchant to big entrepreneur,

formed an Aktiengesellschaft and hired a technical man who remained in the second rank. [Aycoberry, 518]. He adds that there was no tension in the relations between second-generation merchant-become-business tycoon and his technical man. Desire for one's children to advance in the world is universal: in France it takes the form of providing them with a professional, and preferably a scientific education, which,at the same time, may continue the family concern.

The weakness of the system lay in its elitism, the arrogance of its graduates, their incapacity at personal relationships. The historical literature mentions indirectly this to a degree. "But above all there remains at the head of the enterprise a man whose real qualities count for much, the director general in whom it is necessary to have technical competence, commercial sense, aptitude for human contacts"(italics added) [Palmade, 235]. "Entrepreneurs did not go without risks in entrusting themselves to the chef d'ateliers (with his techniques). This subjection accounts for the setback to Decazeville, while perfect technical knowledge, accompanied by a policy of presence in the factory, (italics added) explains largely the successes of Wendel and Schneider", [Vial, 396] [7]

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7. Decazeville of course suffered from exhaustion of its coal fields. So, too did Commentry, which effective administration and scientific research by Fayol overcame for a time. Brodie mentions that when the Academy of Science gave Fayol the Delesse prize in 1893 it paid tribute "to his powers of observation, his skill as an experimenter, his capacity to enlist the interest of his own engineers and workers in the investigation and his ability to secure the collaboration of distinguished scientists," [Brodie, 2,3].

More direct evidence is available for the modern period. A non-American psychiatri who changed careers to industrial consultation and spent two years in France with an American consulting company, after four years work in the United States with another, has commented privately and anonymously on the "god-like" quality of the engineers emerging from the grandes écoles. Having survived a brutal competition which has eliminated all with any weakness, and on the fast track to fame and power, they tend to be proud, obsessed with excellence, insensitive, unable to relate to others, threatened by any questioning of their authority.[8] In a T-group experiment lasting two weeks and involving a large number of graduates of the Ecole polytechnique, among others, this observer found the Messieurs "X" first deeply resenting the authority of the psychologist group director, then panicking and unable to function as a group when his leadership was withdrawn. He commented that the younger business leaders who have had early outside contact with the Harvard, Chicago, or M.I.T. business schools have learned to open up, relax, and are very successful. The fundamental quality and talent are there, the drive to achieve is strong, but it is necessary to get exposed to other cultures and to overcome their weakness in personal relations.

This insight has led me to go back and contemplate those leaders of industry, many of the "X", known to have travelled abroad. In steel, the list includes Benoist d'Azy, an engineer, Bessy (Loire), Boigues, Cabrol ("X"), Dubost, Dufaud ("X"), Emile Martin ("X") who devised the Martin process, Rambourg, who worked

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8. These observations relate to Crozier's view that in French bureaucracy promotion is by objective examination, rather than evaluation of performance by immediate superiors, because of the French need to avoid interpersonal relations of tension, and especially face-to-face confrontations [Crozier, passim].

as a laborer in England and reported back on rolling and puddling, Schneider and Wendel ("X"), [Vial, 181]. Dufaud was impressed by cheapness, even at the expense of quality, on his trip to England in 1917, and later he and Boigues at Fourchambault broke with technical traditions and habits of thought to emphasize large-scale production, cheapness rather than top quality, with the factory organized and administered [Thuillier, ix, 41] In metallurgy Gouin, son of the banker, and graduate of the Ecole polytechnique at the head of his class, resigned to follow Ponts et chaussées as an externe. He then went to England to complete his technical studies, working for several months in the factory of a locomotive manufacturer before returning to Paris to order locomotives for the Paris-Orléans railroad. A traction engineer for the Paris-Saint-Germain railroad from 1839 to 1845 he opened his own locomotive and structural iron factory in 1846, [Ecole polytechnique, III, 578]. Fourteen years later his locomotive shop was directed by an Englishman named Lloyd, suggesting he had maintained his capacity to imitate technology [deRosa, 233].

Even earlier, Marc Séguin, an outsider of a Jewish family (as Gouin was an insider), but a member of the Academy of Sciences, an inventor, and a promoter of a steamboat company on the Rhône and the St.-Etienne-Lyons railroad. He or a brother had been to England, studied the Stockton-Darlington railraod. He was keenly interested in the development of the locomotive for which he invented the tubular boiler, which Stephenson promptly adopted for use in Britain [Dunham, 51]. Five Séguin brothers in all were associated in the railroad promotion with Eduard Biot, an engineer, son-in-law of Becquey, the director general at Ponts et chaussées.

While Michel Chevalier wrote more about general matters than questions of technical interest, he had travelled in the United States and written Lettres sur l'Amerique du Nord, [Dunham, 58].

A more modern example is furnished by Detoeuf, the president of Thomson-Houston started by General Electric. It is not entirely evident how much of the fictitious account of M.O.L. Barenton, Confiseur in the foreword we can transliterate into an autobiography, but it seems clear that the main lines are parallel. M. Barenton went to the Ecole polytechnique, into the artillery as a sub-lieutenant, married, resigned, entered his father-in-law's firm making corset springs - an early stage also in the industrial career of the Peugeots - tried and abandoned exports, When corsets in cities were ruined by sport, which crossed the Channel from Britain, sales were shifted to the country. World War I ruined that market among peasant women and on returning from the Army, M. Barenton went to America for a year. There he discovered ice cream. Investing the indemnity received from the damage to the corset factory, now his through inheritance, in a small ice cream factory, contrary to the advice of his friends, who claimed there was no market for it, he never looked back [Detoeuf, 18ff]. It seems clear that ice cream is a euphemism for electrical equipment and appliances, and that the small factory was a subsidiary of General Electric. While the Propos de O.-L. Barenton, Confiseur can be read as aphoristic wit, at a more fundamental level it represents a critique of French entrepreneurship and its technical education by one who has been strong affected by foreign business

methods.[9]

In the long run, and once the point about interpersonal relations has been absorbed, French scientific and technical education are doubtless going to prove right. Excessively deductive, Cartesian, geometric, mathematical, theoretical for the 19th century, the system is coming into its own in a world of scientific sophistication, equipped with computers relying on linear programming, decision and information theory, game theory and Bayesian statistical methods in making business decisions. Business schools in the United States are in some numbers reducing the inductive case method at a time when it is being introduced in France. Provided that they can acquire a little humanity, the products of French technical schools will bring to business tremendous power both in the field of technology and in administration. Financial skill is ubiquitous and has always been abundant in France. French business may lag in commercial flair, but as sophistication overtakes this in due course, she should rapidly catch up.

There are some puzzles: why for example Machine Bull was unable to make the breakthrough from punch card to electronic computation on its own. Others failed, as well, such as General Electric and R.C.A. There may be mistake

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9. The emphasis is primarily on theory, but occasionally a note on human relations appears. Thus the French industrialist has mediocre collaborators. That does not displease him. He detests eminent collaborators, [Detoeuf,69]. Among international comparisons:

> "The Englishman is a practitioner, who has no theories;"
> "The German is a theorist who applies his theories;"
> "The Frenchman is a theorist who does not apply them."
> "That is called with us having good sense" [Detoeuf, 69]

Cf. the remark of one Captain Hore, a British naval attache in Paris, "The English have no system of naval education and the French have too much,"[Artz,265]

in the trade-off between technological sophistication and practicality, as American engineers claim to be the case in S.E.C.A.M. Important dangers lie in wait: trying too much too fast, forcing science for science's sake, for gloire, so as to win seats at international scientific conferences, or a bigger share of Nobel prizes, instead of harnessing effort to the tasks at hand [Gilpin, passim]. Nonetheless, French scientific and technical education are coming into their own. The staple theory of entrepreneurship suggests that the technological component has grown with time. I have not seen the Hudson Institute study which predicts that France will grow faster than all the countries in Europe and North America and faster than most of those in the rest of the world. If it relies on French technical capacity - and if the French overcome their weakness in human relation, - it is a forecast from which it is difficult to dissent.

Table I

Student Enrollment in Higher Education by Faculties or Subjects
France, Selected Years, 1913 to 1958, Selected Other
Countries, 1913

France	all numbers	Medicine	Law Social Sciences	Arts Science	Technical	Other
1913	38,000	21.7%	44.1%	16.8%	17.5%	
1924	48,000	23.1%	35.1%	19.0%	22.6%	
1930	66,000	24.5%	29.5%	25.5%	20.5%	
1932	78,000	32.3%	22.6%	18.7%	19.4%	
1951	142,000	20.1%	27.8%	26.2%	19.9%	
1958	226,000	18.2%	16.5%	27.7%	35.1%	

Other Countries 1913

Belgium	8,000	17.1 %	13.4 %		12.0 %	26.8 %	31.0 %	
Germany	65,000	20.3 %	14.5 %	- 21.2%		13.9 %	24.1 %	
Netherlands	5,000	35.1 %	18.5 %		6.8 %	10.0 %	29.8 %	
US	206,000	14.7 %	11.2 %	1.9 %	28.1 %	14.3 %	8.0 %	15.4 %
Britain 1925-26	40,800	21.3 %			50.9 %	18.0 %	10.0 %	

Source: Joseph Ben-David, Fundamental Research and the Universities, Some Comments on International Differences, Paris Organization of Economic Cooperation and Development, 1968, pp. 40-41

Table II

Distribution of a Sample of French Business Leaders taken from Who's Who in France, etc. (1953-1956) by Higher Diplomas*

	Number	Percentage of Leaders with Higher Diplomas	Percentage of Total Leaders in Sample
Ecole Polytechnique	456	21.4	15.5
Other engineering schools	640	30.1	21.7
Higher professional schools	86	4.1	2.9
Military schools	56	2.6	1.9
Science faculties	81	3.8	2.7
Letters	81	3.8	2.7
Law	188	8.8	6.4
Ecole des Sciences Politiques	190	8.9	6.4
Various studies (preparing for the liberal professions: medicine, architecture, etc.)	23	1.2	0.8
Not indicated	76	3.6	2.6
Total with diplomas	2,126	100	72.1
Total sample	2,947		100

* In the case of those with two or more diplomas (670 in all), only one has been entered.

Source: Nicole Delefortrie-Soubeyroux, Les dirigeants de l'industrie française, Paris, Colin, 1961, p. 58

	One oil company	Ten Metallurgical Companies	(One electro-metallurgical company)	(Two associated Metallurgical companies)	An automobile company in the Paris region	Three electrical companies	Three food companies	25 textile companies	An enterprise engaged in public international service assisting navigation	One large department store	Total
Ecole Polytechnique		30	(12)	(16)	4	4		3	6		47
Ecole Centrale		34	(7)	(20)	4	13	4	6	2	5	68
Ecole des Arts et Métiers		68	(1)	(56)	28	19	4	2			121
Ecole des Mines		28	(4)	(21)	3						31
Ecole Supérieure d'Electricité						7					7
Instituts électro-technique		9	(7)			12					21
Ecole d'ingénieurs spécialisés	2	14	(3)	(10)	4	8		1	1		30
Ecoles diverses d'ingénieurs	1	14	(1)	(12)	8	12	7	5			47
Sciences	3	20	(10)	(10)	2	2	3	2	1	1	34
Lettres									2		2
Droit	4	11	(2)	(6)	3	5	1	2	9	5	40
Sciences Politiques	2	6	(2)	(3)	2	4			7	3	24
Ecoles Commerciales	3	11	(1)	(14)	2	4	5	6	2	10	32
Ecoles Textiles								14			14
Ecole militaire		2		(2)	1	1	4		2		10
Universités étrangères	4								9		13
Divers		4		(4)		1				4	9
Sans indication		68			5			6		2	31
Total	19	319	(50)	(170)	66	95	28	47	41	39	617

Source: Nicole Delefortrie-Soubeyroux, Les Dirigeants de l'industrie française, Paris, Colin, 1961, pp. 121, 205, 209, 211, 221, 229, 241, 253, 259, 263.

	Régie Renault	Construction aéronautique	Charbon de France and three Coal basins	Gaz de France and Electricité de France	Compagnie Nationale du Rhône	S.N.C.F.	Air France	Compagnie Générale Transatlantique	
Ecole Polytechnique	3	5	23	87	4	111	2	3	239
Ecole Centrale	8	2	2	97		29	2		140
Ecole des Arts et Métiers	71	7		34		1	5	2	120
Ecole des Mines			71						71
Ecole Supérieure d'Electricité				36		3			39
Ecole des Ponts et Chaussées						1			1
Ecole Supérieure d'Aéronautique		4					14		18
Ecole de Pilotes							2		2
Ecole d'ingénieurs spécialisés	6		6	98		2		4	116
Ecoles diverses d'ingénieurs	15	10	4	22			2	4	57
Sciences	8	3	3	3		2		1	20
Lettres		}		{		3	2	1 }	
Droit	6	3 }	9	9		1	7	9 }	50
Sciences Politiques	3	1	6	1			4	3	18
Ecoles Commerciales	6	2	7			1	8	7	30
Ecoles militaire	3	1					5	1	10
Divers		1		1				1	3
Sans indication			1	15		5	1		22
Total	129	39	132	403	4	159	52	36	956

Source: Nicole Delefortrie-Soubeyroux, Les dirigeants de l'industrie française, Paris, Colin, 1961, p. 123

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