Innovations in the European Economy between the Wars

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edited by

François Caron, Paul Erker, Wolfram Fischer

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Preface

WOLFRAM FISCHER

At the invitation of the European Science Foundation in April 1989 twenty economic historians from fourteen European countries, Canada and the United States of America gathered in the premises of the Foundation at Strasbourg to discuss the creation of a network on the "Economic History of Europe Between the Wars". The initiative came from professor François Caron, Paris. The assembled scholars identified three topics which promised interesting new results:

1. International monetary and financial developments,
2. The source and diffusion of technical change,
3. The working of the labour market.

A Coordination Committee of nine scholars from seven European countries and the United States was elected to be chaired by François Caron; it met several times in France to work out the schemes for three workshops in different European countries and a final conference in Paris. The workshop on the first topic, organized by Charles Feinstein, Oxford, took place in May 1992 at Venice; the workshop on the third topic, organized by Rolf Ohlsson, Lund, took place in May 1992 at Lund.

The workshop on the "Sources and Diffusion of Innovation", as it finally was called, organized by Wolfram Fischer, Berlin, took place at the *Historische Kommission zu Berlin* in July 1991. Seventeen economic historians and economists from six European countries and the United States took part. Unfortunately, experts from Eastern European countries could not be recruited; the South was only respresented by one Italian, the North by one Norwegian scholar. Most participants came from the three "big" European countries France, Germany and Great Britain – and from the USA. This seems to reflect, however, the state of the arts in this field which until recently was dominated by scholars from the United States.

Two of them were asked to comment on the papers, another one, David Hounshell, to give a paper.

This book presents the results of the Berlin workshop. The papers and comments given in 1991 were re-written in the light of the discussion and those of none-English speakers were edited by Sally Horrocks, an English member of the group. An introduction by François Caron, the motor of the network and particularly of the topic on technical change, and a summary by Paul Erker, who served as one of the editors of this book, were added.

It may be mentioned that this book can also be regarded as a historical companion to the ambitious work by Horst Albach, Culture and Technical Innovation. A Cross-Cultural Analysis and Policy Recommendations (The Academy of Sciences and Technology in Berlin, Research Report 9) which was published by Walter de Gruyter early in 1994. That work is the result of an interdisciplinary research group, set up by the *Akademie der Wissenschaften zu Berlin* in 1987 which was chaired by Wolfram Fischer while its motor, *spiritus rector*, and final author was Horst Albach. At least the Berlin members of the workshop of the European Science Foundation have learnt a lot from the economists, engineers, chemists, lawyers, sociologists, psychologists, industrialists, and Japan-experts who debated that topic over several years with particular reference to the contemporary German, American, and Japanese economies. The present book adds a Western European and historcial dimension to this dicussion.

The editors thank the European Science Foundation for funding the network and the conference; they thank particularly Dr. John H. Smith, Dr.Gérald Darmon, and Ms. Margaret Kinane for their administrative assistance, and all the participants for their continuous work on the topic even several years after the workshop had taken place. They are also grateful to the publisher who has agreed to publish this book without subsidy in a time when conference-volumes are exceedingly difficult to sell.

Introduction[1]

FRANÇOIS CARON

Any history of the economic growth between the wars must take into account the achievements of technology. This period marks a decisive step in the sectoral deepening and spatial widening of the process of industrialisation. The new techniques which appeared during the last quarter of the nineteenth century, and which were to form the basis of the consumer society, achieved ever wider fields of application, not only in those countries which became industrialised early, but also in those which had but recently embarked on the path of industrial modernity. It would, however, be absurd to treat the problems of development in the 1920s and '30s in the same terms as those of the 1820s and '30s, since the techniques which served to propagate it had changed and did not have the same effects on either economic growth or economic structures.

In reality, a new model of growth was in the making, which was preparing for the achievements to come after the Second World War. The strong economic growth which took place in Europe in the 1950s and '60s was not simply the result of a process of "catching up", but was also part of a continuous effort of deepening and rationalisation, begun in the 1920s and pursued during the 1930s, in ways and conditions which varied considerably from one decade to the next. However, the transitory nature of the experience makes it all the more difficult to analyse. We shall attempt to arrive at an understanding of the complexity of these developments using three different approaches:

i) by defining the original characteristics of economic growth in the interwar period;
ii) by clarifying the nature of the structural changes which occurred, including unemployment in the analysis;

[1] Translated from French by Elizabeth Aitam.

iii) by analysing the dynamics of the technical system, which also explain the other factors, taking into account not only the role of "interdependence", but also by investigating the strategy of firms in the area of innovation.

1. Defining Growth

Placed in a long-term perspective, the performance of European economies in the interwar period appears on the whole favourable. The real problem lies in understanding why growth won over stagnation, despite the accumulation of numerous and serious obstacles. This observation results as much from an analysis of the evolution of production as of productivity.

1.1. Rates of Production

If one examines the years 1924–37, as Charles Feinstein has done for the United Kingdom, it would appear that many countries attained rates of growth in national product of more than 2% per annum, some even reaching growth of over 3%: amongst those achieving more than 3% we find countries such as Sweden, Norway, Germany and Italy, but also Hungary and Bulgaria. The United Kingdom, Belgium, Denmark, Czechoslovakia, Spain (from 1924–35) and Switzerland had growth rates of between 2 and 3%, while Austria, France (between 1924–38) and Holland did not even reach 2%, or even 1% in the case of the first two countries mentioned. These three countries suffered much from the prolongation of the depression of the 1930s; even in 1937–38 their domestic national product remained considerably smaller than it had been in 1929. These facts illustrate the harmful effect of the deflationary monetary policies of the early 1930s.

These data also invite two further steps of analysis: we need to compare them with the figures for the preceding and following years, and at the same time, to compare the performance of the 1920s with that of the 1930s. The British experience is particularly interesting. In the years from 1896 to 1913 this country did not experience the acceleration in growth which took place in many other European countries, and indeed it went through a serious recession between 1913 and 1924. However, between 1924 and 1937 the growth in gross domestic product (GDP) was clearly higher than it had been in the years 1873–1913 (2.2% compared to 1.8%).

It is as though the entire interwar period was a preparation for the rapid growth to come after the war (2.8% from 1951 to 1973). In countries such as France, Spain, Italy, Hungary and Scandinavia, which had experienced rapid growth in the ten or twenty years preceding the 1914 war, this tendency persisted and in some cases increased in the 1920s. In the 1930s growth was either interrupted or at least greatly reduced, as in France, or continued, as in Scandinavia and, albeit according to an entirely different system, in Italy and Germany.

In the vast majority of cases, growth in the industrial sector exceeded that in GDP and with more noticeable fluctuations; in the United Kingdom, for an average growth in GDP of 2.3%, industrial growth reached 3.2%. Within the industrial sector the differences are marked. For countries which were members of OECD in 1955, growth in industrial production (manufacturing) was 3.1%, but, on the basis of aggregate data, it ranges from a minimum of 1% in the textile industry to a maximum of 4.3% in the chemical industry. Growth was 3.9% and 3.6% in the metal products and basic metals industries respectively. In the food, beverages and tobacco industries it reached only 1.9%. Growth was smallest therefore in the sectors of consumption of non-durables and semi-durables. Durable goods were certainly gaining a position of ever greater importance in the production system. In the same way, the European car industry was undergoing remarkable expansion, and from 1926 to 1937 production in the OECD member countries grew at a rate of 7.7% per annum. It was nevertheless the semi-finished products (chemistry and basic metals) and capital goods industries which, on the whole, experienced the largest growth.

This observation suggests that technical change in the industrial sector constitutes the main explanatory factor for the dynamism of growth in an economy subject to unstable and uncertain demand. The opportunities offered by industrial technology compensated for the depressing effects of expectations founded on financial data and on demand. In addition, in the second half of the 1930s, other, external factors intervened which were linked both to the preparations for war and to voluntarist industrialisation policies.

1.2. Rates of Productivity

This hypothesis appears to be confirmed by the analysis of performance in terms of productivity. The interwar years fall within a long period of growth in labour productivity. Calculations based on production by man-

year rather than by man-hour tend, particularly in this period, to obscure the importance of this growth. The evolution in France is quite characteristic from this point of view: growth in labour productivity, calculated in man-hours, had reached 2.0% per annum between 1896 to 1913, whereas it reached 2.4% between 1924 and 1938. A comparison between the 1920s and the 1930s is also most instructive. In many countries, in fact, growth in productivity in the 1930s was slightly faster or equal to what it had been in the 1920s. Indeed, when it was slower, the gap between the two figures was always much greater for production than for productivity. In France, growth in production in all sectors fell from 2.8% to −0.5% from 1924–29 to 1929–38. Despite this fall, productivity continued to grow in the 1930s at a rate only slightly slower than that of the 1920s: 2.1% instead of 2.9% in all sectors taken together, 2.9% instead of 3.4% in industry. In France, as in most European countries, the laws introducing a reduction in working hours were passed immediately after the war and wage costs increased considerably. In addition, in the second half of the 1920s French industry lacked manpower. The result of this was an attempt at rationalisation which persisted into the 1930s, albeit in a rather different form, as we shall see, in the sense that it was above all necessary, this time, to combat the shrinking of the market and of profits caused by the Depression.

These developments were not unique to France. Charles Feinstein's conclusions about Total Factor Productivity (TFP) in the United Kingdom offer us a better perception of the specificity of the period under examination. Between 1924 and 1937 the TFP of GDP grew at a rate of 0.7% per annum as against 0.45% between 1873 and 1913. However, real industrial performance is much more impressive: here the rate passes from 0.6% to 1.9%, i. e. it triples. A comparison between the 1920s and 1930s is also informative: for a growth in GDP of 2.6% between 1924 and 1929, the TFP grew at a rate of 1.2%, whereas from 1929 to 1937 the rates were at 2% and 0.6% respectively. In addition, the TFP of the industrial sector increased more rapidly in the years 1929–37 than in the years 1924–29 (2.4% and 1.8%). The sector which realised the best performance was the textile industry with a rate of growth in TFP of 4.4%: this figure illustrates in a remarkable way the effect of the rationalisation policies imposed by the Depression.

One must conclude, with Charles Feinstein, that the factors which explain the growth in TFP are to be found on the supply side. The most important of these was, evidently, the attempt at rationalisation, which was an essential component of technical change. In the case of the United

Kingdom, there was both a catching-up effect in the area of new technology, where the UK had fallen behind Germany and the United States before, and above all during the war, and a process of autonomous technological development of domestic origin[2].

Although this analysis applies to specifically British realities, it also gives an insight into the developments in all European countries. Catching-up and deepening were both brought about by the technologies of the "second industrial revolution". As we have said, it was the perfomance in the two sectors of semi-finished and capital goods which explains the high rates of growth in production and productivity. However, they were in their turn sustained by investments from business and the public utilities. The European economy, swept along by electrification, was engaged in a dual process of renewal and development of its basic investments, and above all of equipment. The extent of the trend is demonstrated as much by data concerning rates of investment, formation and structure of capital as by those related to industrial mechanisation[3]. This trend has an impressive characteristic of a general nature, and it concerns as much the countries of Eastern Europe as Spain, Italy, the Scandinavian countries, France, Germany or the United Kingdom. The collapse which occurred in France in the 1930s is far from being a general phenomenon. In fact, in most countries activity took off again after the Depression in the second half of the 1930s.

In France, Spain and Italy, the growth in rates of productive investment considerably increased the capital stock available per worker. But, generally, the speed of renewal of equipment greatly reduced this growth, in comparison with growth in gross rates of investment. In addition, investments, whether in renewal or in development, brought with them the "capital saving" innovation. Charles Feinstein has shown that there was a tendency towards a decrease in the capital/output ratio between the wars in the industrial sector. He writes:

"It is remarkable that a fall in the capital-output ratio between 1924 and 1937 is found in every manufacturing industry group without exception [...] It is possible to point to technical developments in this period that had, to a greater extent than most innovations have, the effect of reducing capital costs in manufacturing. The chief of these was the

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[2] See R. C. Matthews/C. H. Feinstein/J. C. Odling-Smee, British Economic Growth, 1856–1973, Oxford 1982, p. 537.

[3] See on this J. J. Carré/P. Dubois/E. Malinvaud, La croissance française, Paris 1972, p. 202, table 12.

changeover to electricity as a source of power, a development that was accompanied by an increase in the proportion of electricity purchased as opposed to generated within the firm. This had its counterpart in the high rate of growth of output and capital stock in the public utilities sector"[4].

Feinstein's analysis can, in our view, be enlarged upon. The technological bias towards capital saving modes of production has a more general significance than that of a simple transfer to the public utilities of the weight of productive investment. For it relates to the whole of the economy. In addition, whereas in the United Kingdom the upward trend in capital productivity did not continue after the World War II, this was not the case, at least until the end of the 1960s, in most industrialised countries. The British economy thus appears to have anticipated, in the interwar period, a model of growth which became typical in Europe in the 1950s and 1960s, marked by the spread of capital saving technologies[5].

2. Structural Changes and Unemployment

The growth process was accompanied by structural changes within the working population and an analysis of these changes is the prerequisite to an understanding of unemployment. We shall use the following four themes, each closely linked to the other, as our guide: agricultural under-employment, industrial structures, hidden unemployment in the non-agricultural sectors, and the mechanisms of industrial unemployment.

2.1. Agricultural Under-employment

In most continental countries at the end of the war there existed a large reserve of agricultural manpower, due to a chronic under-employment of labour capacity. In Eastern Europe, as well as in the Mediterranean, the percentage of agricultural workers remained higher than or close to 50% of the total working population and its decline was slow: even without quoting the extreme examples of Yugoslavia and Romania, these levels range from 56% in 1910 to 54% in 1930 in Hungary, and from 59% in 1921 to 52% in 1936 in Italy. Even the Nordic countries (71%, 39%, 36%

[4] Matthews/Feinstein/Odling-Smee, p. 384 f.

[5] See F. Caron, Le résistible déclin des sociétés industrielles, Paris 1985, p. 259.

and 30% respectively Finland, Sweden, Norway and Denmark in 1930) and the northern countries of Western Europe (36% in France in 1931, 29% in Germany in 1933) retained high levels of working population. Switzerland and Belgium, with levels of 21% and 17% respectively in 1930, mark the exceptions. One can therefore acknowledge that in the greater part of the European countryside there existed an "immense reserve of manpower", to use Albert Carreras' expression referring to the Spanish countryside, or, at the very least, that the possibilities of transfer from agriculture to industry were far from being exhausted by the end of the First World War. However, it is clear that this movement was not as large as the growth in industrial production might lead one to suppose. Agriculture retained an abundant workforce.

Albert Carreras has shown that Lewis' model, based on an "unlimited supply of labour", applied quite well to Spain. He observes that between 1920 and 1950, contrary to what had taken place in the previous decade, there existed an inverse relation between the productivity of industrial labour and the size of the active male agricultural population[6]. The former increased between 1920 and 1930 and fell from 1930 to 1950, the latter undergoing the reverse process.

However, Gianni Toniolo maintains that, in Italy's case, Lewis' model needs to be much more precisely defined. For one thing, according to data from several official surveys, agricultural under-employment remained significant, since it can be estimated at a third of the working agricultural population. It also had a chronic feature. It is closely linked to the model of the extended family in an agricultural environment, which permits a redistribution of income amongst its members. The labour market does not therefore function according to the simple logic of a comparison between agricultural and industrial incomes. However, the Italian case is not unique: the agricultural sector throughout Europe is characterised by hidden unemployment on a large scale, which was particularly high in Eastern Europe.

Thus the migration from agricultural to industrial activity does not depend, precisely because of chronic unemployment, solely upon the difference between agricultural and industrial wages. It fluctuates mainly according to the supply of industrial employment. At the beginning of the 1930s this migration was greatly reduced in most European countries, despite the maintenance of high industrial wages and a large fall in agricultural

[6] See J. Nadal/A. Carreras/C. Sudria, La economia española en el siglo XX, Barcelona 1991, p. 294.

incomes. Denmark, where industrial production increased at this time, is the exception. In France the movement was more intense in the 1920s, in Germany it was greater in the 1930s.

However, the migration from agriculture to industry is not, as Toniolo says, a "one-stage process". It is a reversible phenomenon which may be compared to shared forms of labour, i. e. extremely mobile and part-time. The transition from agricultural labour to industrial waged employment is the result of a long process. Toniolo shows that in the interwar period the hard core of urban workers who had broken all ties with the countryside was relatively small. Toniolo's analysis has a significance that goes beyond the Italian scene, and it invites one to examine the real nature of industrial employment and the changes it underwent[7].

2.2. Industrial Structures

Industrial growth drew a share of the available agricultural workforce to industry, but the increase in industrial working population as a percentage of the total working population was smaller in most countries, in some cases significantly so, than the share of industrial production as a proportion of GDP. This was due to the rapid increase in industrial productivity and in spite of the reduction in working hours and the winding down of former areas of activity. In Sweden, from 1910 to 1930, the percentage of industrial product rose 11 points, and that of the industrial working population 4 points. In the UK, from 1924 to 1937, the percentage of the industrial working population as a share of total working population remained constant, at a level of 32.9%, whereas the share of the industrial sector as a percentage of total production rose from 30.9% to 34.8% in real terms.

But the stability of feeble growth in the size of industrial population in relation to total population conceals the large-scale structural changes which were taking place both within the working population and in industrial products. The former is characterised by a dual mobility: one sectoral, reflecting the changes in product structure, the other professional, which is explained by the changes in modes of production. The figures for France illustrate this very well: from 1906 to 1931 the number of

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[7] See G. Toniolo/F. Piva, Unemployment in the 1930s: The Case of Italy, in: B. Eichengreen/T. J. Hatton (eds.), Interwar Unemployment in International Perspective, London 1988, p. 221 ff.

industrial wage-earners rose by almost 1.8 million[8]. There were 5.4 million of them in 1931 and 68% of these new wage-earners were attracted towards companies employing more than 100 workers, mainly in the engineering, electrical engineering and chemical industries. The growth in industrial productivity thus results from the diffusion of production techniques, which required a certain degree of concentration, and a profound change in the nature of industrial working methods. The promoters of electrification at the end of the 19th century had hoped and predicted that the new technology would encourage a dispersal of labour. The experience of the interwar years does not bear out that expectation.

The upsurge in large factories was not peculiar to France, although one must distinguish between countries such as France and Italy, in which medium-sized factories continued to play a major role, and others like the United Kingdom and Germany, where large establishments dominated. These different structures were set up in the 19th century. The increase in manual labour within large factories is, however, not unique to North-Western Europe, and it is possible to consider the industrialisation of Eastern European countries as "dualist" in the sense that it contrasts labour-intensive establishments, typical of expanding industrial sectors, with very small artisan establishments, characteristic of the traditional sectors. It is in fact the almost total absence of medium-sized factories which sets these countries apart, with the sole exception of Czechoslovakia, which had a richer industrial past.

The development of salaried employment in industry does not necessarily imply permanent employment, in fact one might be tempted to say quite the reverse. The great Parisian car factories and the electrolysis plants in the French Alps experienced considerable turnover in their workforces. These observations concur with Gianni Toniolo's conclusions about Italy. He demonstrates that even amongst the hard core of urban workers, the percentage who had a permanent job (or wanted one!) is small: at Alfa Romeo 56% of the workforce stayed for less than a year, and at Montecatini the figure was 83%.[9]

2.3. Hidden Unemployment in the Services and in Industry

A significant part of the workforce freed from agriculture came to feed the service industries, either because of the development of certain sectors

[8] The return of Alsace-Lorraine to France accounts for 15% of this increase.

[9] See Toniolo/Piva, p. 225.

such as transport or administration, or because of the fairly widespread phenomenon of hidden unemployment in these sectors, most particularly in trade. The excess working population in the commercial sector in France was indeed one of the main themes of analysis to be found in official reports on the national economy after the Second World War. Charles Feinstein has clearly shown this to be the case in the United Kingdom. In both countries it was a response to insufficient demand and industrial unemployment. This was however not only true of France and the UK, but contributed significantly to the reduction in performance in terms of productivity of the European economy as a whole.

The mechanisms of the labour market in certain industrial sectors, as described by Gianni Toniolo in the case of Italy, reveal also the presence of hidden forms of unemployment in industry itself. In France, despite the changes we have described taking place in the 1920s, in the 1930s almost a third of the industrial workforce was still made up either of isolated workers or of "petits patrons" ("little bosses"). Their survival and even revival was favoured by the Depression.

2.4. The Significance of Unemployment

The unemployment statistics should be read in the light of these observations. Gianni Toniolo, using the population censuses, has corrected upwards the estimates of industrial unemployment rates in 1932 and 1935. He has increased them from 15.5% to 40.8% and from 11.5% to 23.2%. But he notes that these figures simply mean that workers' periods of unemployment were almost twice as long in 1932 as in 1935. Generally, according to T. J. Hatton, the duration of unemployment was shortest when turnover was highest[10]. On the other hand, when turnover was low, unemployment tended to be of longer duration. A. Newell and J. S. V. Symons have shown clearly that industrial unemployment was aggravated in the 1930s by a lack of wage flexibility[11]. This cannot be explained either by the role of the unions or by government intervention. It is rather the consequence, according to Hatton, of a new strategy on the part of firms in the management of their staff. He writes: "The interwar labour market

[10] See T. J. Hatton/B. Eichengreen, Interwar Unemployment in International Perspective: An Overview, in: Eichengreen/Hatton (eds.), p. 35 f.

[11] See A. Newell/J. S. V. Symons, The Macroeconomics of the Interwar Years: International Comparisons, in: Eichengreen/Hatton (eds.), p. 61 ff.

in Britain and the US [is] a stage of transition between a high turnover, low employment attachment regime typical of the late nineteenth century and one of lower turnover and greater job attachment of the post-war period"[12].

In the case of France and Germany this hypothesis has yet to be proved. In fact, paternalist practices, the avowed aim of which was the preservation of workers' jobs, played a significant role in these two countries in the industrial system inherited from the 19th century. The transition to a managerial system of management may have had the opposite effect on modes of labour organisation to that defined by Hatton.

One further observation should be made here. A sectoral and regional analysis enables one to establish a relationship, tenuous though obvious, between the levels of unemployment and an industrial taxonomy which takes account of the nature of the technologies concerned. The regional analysis made by Charles Feinstein is illuminating from this point of view. Before 1914 the highest levels of unemployment were recorded in the London area, because London acted as a magnet to workers, yet could not absorb the influx of population. Lowest rates are to be found in Scotland, Wales and in the North of England. In the interwar period, the situation was reversed: the lowest unemployment rates were achieved in London and the South-East, and the highest in Wales, Scotland and the North-East. Unemployment in the UK was thus one of the aspects of the sectoral recomposition of the economy. This judgement applies, of course, to countries other than Great Britain.

3. The Dynamics of the Technical System

We are aware of the uncertainties which weigh upon a quantitative evaluation of innovative activity: the most uncertain are those which use lists such as "major inventions, innovations and discoveries". The most often quoted of these lists is that drawn up by C. Streit in 1949, and it was the use of this source which enabled John Dunning to write that "during the interwar years, the pace of technological advance slowed down, and what progress there was strongly favoured the US economy"[13]. The five-yearly

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[12] Hatton, p. 36 f.

[13] J. H. Dunning, Changes in the level and structure of international production: the last hundred years, in: M. Casson (ed.), The Growth of International Business, London 1983, p. 109.

average of the number of inventions and innovations, according to Streit, was 38 from 1876 to 1914, and 30 from 1915 to 1939, whereas the percentage for the United States in the whole period went from 40 to 60%.

The statistics for patents deposited in the United States seem to us a more pertinent indicator. These lead one to conclude that the growth movement before the war continued into the 1920s. On the other hand, there was a significant fall in the 1930s[14]. But the number of patents of European origin awarded in the United States grew much more rapidly than the total number of patents awarded in the interwar period. In addition, the rate of increase doubled from 1920–24 to 1933–39 in relation to the previous period (1890–96 to 1920–24): 4% compared to 2.04%, and it was considerably higher in the 1920s than in the 1930s (5% compared to 3.2%)[15]. Dunning explains this increase "by the growing interest of foreign firms in the US market". Such a statement requires substantiation, since interest in the American market does not date from the interwar period.

Dunning considers that "in spite of notable inventions of the interwar period – television, radar, the jet engine, colour photography, several man-made fibres and some antibiotic drugs, for example – these were mainly years of development, adaptation and dissemination of the technological and organizational breakthroughs of the late nineteenth and early twentieth centuries". Dunning's view, which contrasts a prewar period, which discovers, with an interwar period, which develops, does apply to certain areas of technology, but not to all. In fact the new branches of technology which appeared in the 1890s and 1900s, such as electricity and organic chemistry, were indeed developed and diffused during the interwar period. By the eve of the 1914 war, these innovations had achieved a level of maturity which no longer left any doubt about their future, whereas more recent innovations, such as aviation and radio, were still in the early stages of their development. The war revealed the immense potential, which only certain, albeit the major, innovations were able to realise.

John Cantwell analyses the sectoral specialisation of patents awarded to Europeans in the following terms: "In Europe almost all the chemical fields displayed rapid growth in the interwar period, including inorganic

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[14] J. Cantwell gives the following figures: the average annual rate of increase in number of patents awarded went from 1.95% between 1890–96 and 1920–24, to 1.74% between 1920–24 and 1927–29, and -0.39% between 1927–29 and 1933–39. See the contribution of J. Cantwell in this book.

[15] Ibid.

chemicals and agricultural chemicals; and in the electrical area a fast rate of development extended to telecommunications, illumination devices and general electrical equipment [...] Related to the European strength in chemicals, there was also a fast technological development in Europe in chemical machinery and equipment, and in the materials technologies used to create non-metallic mineral products (in 1920s), and in rubber and plastic products (in 1930s)." Using the same source, he has sought to determine which were the "comparative technological advantages" of Europe, the sectors in which the share of European patents in the total number of patents in that sector was higher than the same share in the total number of patents. Europe's advantage was clearest in the chemical sector, and within this sector "the greatest European strengths centred in agricultural chemicals, bleaching and dyeing and organic compounds". In addition "the Europeans also had an advantage in the development of electrical equipment [...] Perhaps allied to this, Europe also performed well in the field of professional and scientific instruments, especially in photographic equipment". Finally, "in motor vehicles their comparative advantage was in the field of internal combustion engines and not in vehicles as such".[16]

Cantwell's conclusions concerning the orientations of the European technical system are confirmed by the evolution in the sectoral distribution of industrial products in the different countries of Europe: the rise of the electrical engineering, metallurgical and car industries, of the chemical and materials industries, and the stagnation or relative decline of the food, textile, clothing, wood and paper, and naval armaments industries.

We shall use three approaches, each complementary to the other, to describe the dynamics of the structural changes associated with the transformation of the technical system:[17]

i) The first will be based on two concepts: that of the interdependence between areas of application and technology, and that of firms' product strategy.
ii) Secondly, we shall describe the constraints of rationalisation which were imposed on European companies.
iii) Thirdly, using as yet unsubstantiated data, we shall touch on companies' research and innovation strategies.

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[16] Cantwell, p. 289 f.

[17] See F. Caron, Histoire économique et dynamique des structures, in: Année Sociologique, 41, 1992, pp. 107–28.

3.1. Interdependence and Product Strategy

The interplay of mutual dependence between the different fields of technology should be considered the main engine of technical change. It both explains the rise of the new branches and describes its downstream effects. That is to say it enables us to understand their progress within the system in place. It seems to us that this particular, and partly autonomous, dynamic of technology played a significant role in the interwar period.

In order to understand the dynamic of interdependence from a global point of view, we shall use three concepts, which we shall support with concrete examples: these concepts are demand for invention, "spin-off effect", and technology trajectory. To illustrate the first we shall recall the history of the development of interconnected electrical networks in France, to illustrate the second that of the relationship between the aeronautical and aluminium industries, and lastly radio to illustrate the third concept.

Since before the 1914 war French electrical engineers had, in the main, considered the interconnection of electrical networks to be both possible and desirable. With the advent of war it became an issue of national importance[18]. For the implementation of such a programme the engineers were possessed of a coherent scientific doctrine and expertise which they were able, thanks to an experimental approach based on the idea of "test networks", to adopt to any particular situation which might actually arise[19]. A large measure of consensus had been achieved in this area. Confident of such certainties, the engineers were able to seize the opportunity to carry out any element of the programme as soon as it presented itself. For the very diversity of the technical methods adopted by the existing networks made an immediate global implementation impossible. One should note, however, that since 1918 agreement had been reached on the choice of 50 cycles, whereas arguments still raged about the choice of voltages.

In fact it was pressure from the consumers of electricity which determined which networks were set up first. Two consumer groups played a particularly important role: the producers of aluminium (and more generally electrochemists and electrometallurgists), and the railway companies. The electrolysis technology used in French aluminium factories, which

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[18] See Histoire de l'électricité en France. Tome premier 1881–1918, Paris 1991.

[19] See G. Ramunni, L'élaboration du réseau électrique français. Un débat technique de l'entre deux guerres, in: Un Siècle d'Electricité en France 1880–1980, Paris 1987, pp. 269–91.

was operated in the French Alps by the two great producers of this metal, AFC (or "Compagnie de Produits Chimiques et Electrochimiques, Alais, Froges et Camargue") and the Société d'Electro-Chimie, did not develop in any radical sense between the end of the 1890s and 1920. The functioning of the tanks was less than satisfactory: the intensity of current did not exceed 10,000 to 20,000 amperes, the energy produced was feeble, and working conditions were inhuman. A major technological breakthrough took place at the end of the 1920s with the adoption of two new procedures, one borrowed from electrothermal technology, the Söderberg process of Swedish origin, and the other, know as "brasquage en blocs serrés", which was perfected in French factories after a long process of testing. In the 1930s these two methods were developed concurrently in an attempt at rationalisation, which made possible the closure of several old factories and the concentration of production in new plants. Tanks using a current of 50,000 amperes were put into production in 1934 and achieved a much more satisfactory output. Thus began the process which was to culminate in the 280,000 amperes achieved in 1986 at Saint-Jean de Maurienne.

The changes which had taken place in the methods of aluminium production brought about a radical modification in the methods of electricity production. Until the 1920s electricity supply was maintained by "on-stream" factories, whose production was intermittent and irregular. In the low season the factories had to be closed, which led to an under-utilisation and rapid deterioration of the equipment. The introduction of the new tanks necessitated a vast programme of development in the Alps, which was designed to assure continuity of production. It involved the construction of a series of large dams, and the creation of interconnected electricity plants with links to the factories, which was made possible by the setting up of a high tension network and converter groups.

The only previous significant programme of electrification had been that of the railway network in the Midi before the 1914 war, in the construction of the lines across the Pyrenees. Its engineers had been inspired by the Swiss experiment and had adopted the single-phase current at 60,000 volts. 327 kilometres were electrified in 1913. In 1918 a commission was set up, which reported in 1920, and predicted the construction of 9,000 km over the three networks with hydroelectric power, the Paris-Lyon-Mediterranean, the Paris-Orléans and the Midi networks. The commission selected the direct current option at a high tension of 1,500 volts, this time using the British model, which obliged the Midi network to change the equipment of its lines.

The case of France is not unique: all the European electrical networks were conceived and built as much in response to the requirements of their large consumers as for reasons of rationalising the operation of the electrical network itself. The two motives are inseparable and this linkage illustrates the logic of interdependence. However, the construction of interconnected networks encountered three major obstacles: the diversity of the technical methods previously adopted, which added considerably to investment costs; the as yet insufficient demand to justify operations of this size; and lastly the impediment of ill-adapted legal systems. Writing about Italy, Renato Giannetti says: "It was the relative lack of demand which rendered the construction of large plants rather unappealing, given that to be economical they would have had to feed many centres of consumption", and "the expenditure required for the replacement of machinery, both in power stations and users' homes which would be necessary in the event of unification of frequencies, was considered unsustainable[20].

Hans-Joachim Braun and David Edgerton insist strongly on the importance of the links between the techniques of the aeronautics industry and other sectors of activity, and particularly on the role played by aluminium alloys in this sector[21]. We know that it was the realisation by the directors of Alcoa of the importance of this outlet which persuaded them to invest massively in research in this field. The two most remarkable European products were the Bréguet 14 perfected in 1916, and the Junkers F13, which dates from 1919–20. Both of these aircrafts were made entirely from aluminium alloys, but it was not until after 1930 that all-metal construction took over. It is a fact that the development of the aeronautics industry has exerted a profound influence on twentieth-century scientific thinking. Furthermore, the problems posed by flight control, take-off and landing represented as many challenges as those faced by the developers of the electricity networks. Born of the requirements of maritime navigation, the radio-telegraph became the necessary companion to the development of aviation.

Pascal Griset has described a double trajectory of the "wireless telegraphy" in Europe between the wars: that of the technologies applied, and that of its uses. "Radio technology", he writes, "was born within one of the dominant technical systems of the end of the 19th century: electricity. Progressively radio moved away from this technical system towards a new

[20] R. Giannetti, p. 77 f. in this book.

[21] See the contribution of H. J. Braun/D. Edgerton in this book.

one: electronics. This movement was a cause of instability for the sector, but was also the mainspring of its dynamism", and "the growing diversity of the services offered by radio technology is the other factor of dynamism and instability"[22]. But the experience of European industry, compared to that of the United States, was particularly disappointing in this area, despite the importance of its contributions to technology. National markets were too narrow, and their institutions not adapted. European companies were unable to exploit the complementary aspects of different sectors such as components, professional equipment, domestic equipment and the mass media. The dominance of the United States in the electronics sector in 1945 is not only explained by the effects of the war, but also by the disappointing performance of Europe between the wars.

These various examples illustrate the major role played by interdependence in the evolution of technical systems. They confirm the importance of supply factors in the economic growth between the wars, but they also reveal the severity of European handicaps, which were due equally to the failures and segmentation of the markets and to the negative influence of institutional systems which had not yet adapted to the demands of new technology.

There is a striking difference between the dominant specialities of European and American companies. According to figures published by Alfred D. Chandler, in 1929 24 of the top 100 German companies, rated according to their capital value, produced and distributed products destined for an end-user, whereas in the US in 1930 this figure was 60%. The UK was the only European country comparable to the United States from this point of view[23].

The product strategies of German firms, both in the electrical engineering and chemical industries, were essentially determined by advances in technology, from which they benefited in a number of areas. This was the natural consequence of a research and innovation strategy whose origins dated back to the 1880s, if not to the 1860s. Developments in chemical science created new opportunities in all areas, including the dyeing, plastics and pharmaceutical industries. They led naturally to a strategy of product diversification, which was not restricted to German businesses. This was also the case at ICI and Rhône-Poulenc. In the field of electrical engineering diversification was the result of the complementary nature of

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[22] P. Griset, p. 43 in this book.

[23] See A. D. Chandler, Scale and Scope. The Dynamics of Industrial Capitalism, Cambridge/Mass. 1990.

different kinds of equipment. Each manufacturer had to offer his customers a range of compatible materials making up a coherent system.

In electrical engineering as well as in the chemical industry success depended broadly on the capacity of a firm to adapt its products to user requirements. The conquest of a technological field by companies whose development relied on the control of scientific and technical knowledge in a particular area was not explained simply by their technical excellence; it was also the result of a constructive dialogue with their customers. Bernd Dornseifer writes about Zeiss: "At Zeiss' Microscope Division the matrix of innovation consisted of customers, in-house microscopy expertise which enabled the company to develop, diversify and test products, additional internal and external R&D capacity, and workshops. Customers continued to be a very important source of innovative ideas"[24].

Technical excellence does not necessarily imply product diversification according to the opportunities offered by a well-controlled scientific procedure. It can on the contrary be the fruit of specialisation in one specific product or category of product. A typical example of this are the Swedish multinationals which started up in the 1880s, each of which developed their own technological "niche"[25]. Among other examples of this are the leading French producers of aluminium, Péchiney, the Compagnie de Pont à Mousson, which prided itself on the manufacture of the best cast-iron piping in the world, and Michelin. In reality the vast majority of French companies between the wars only developed a single product line, and this was by no means exceptional. Most often these specialisation strategies were based on the control of one area of knowledge which may be considered to be of a technical rather than truly scientific nature.

3.2. Demand and Rationalisation

We have no accurate history of the use of the word and concept of rationalisation, which was the principal *leitmotiv* of technical literature between the wars. Indeed, as we have said, it corresponds to markedly different programmes.

An early form of rationalisation corresponded to the desire to introduce in Europe the methods of "mass production" which had been developed

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[24] B. Dornseifer, p. 213 in this book.

[25] See R. Lundström, Swedish Multinational Growth before 1930, in: P. Hertner/G. Jones (eds.), Multinationals: Theory and History, Aldershot 1986, pp. 135–56.

in the United States just before the 1914 war in response to a mass market. This technical programme, which appeared in the 1920s, did not disappear in the 1930s. It was quite different in outlook from that rationalisation which, already in the 1920s, attempted to prioritise the reduction in sharply rising wage costs, or from that which in the 1930s tried to combat the failure in demand due to a reduction in costs as a whole. This latter form of rationalisation may be applied incidentally as much to areas of organisation as to technology.

Europe was strongly influenced by America in the field of mass consumption. One recalls that the leaders of the American feminist movement came to Europe to preach the liberating virtues of the new domestic economy based on the mechanisation and rationalisation of the home environment. In the car industry, the largest manufacturers confirmed their willingness to follow the American example and some of them, principally in Great Britain and Germany, launched ranges of popular cars. In reality, neither the structure nor the development of the market was favourable to the success of this type of car.

As an explanation for the German intense specialisation in capital goods, Dornseifer puts forward "the continuing disadvantages of small domestic consumer goods markets". He adds "German enterprises did undoubtedly have access to technological resources. What limited their opportunities for innovation was the absence of a domestic consumer goods market as large and dynamically growing as the American one, and the lack of a corresponding vision, capability and structure to perform focused product development and aggressive marketing in such an environment".[26] In fact, patterns of consumption remained influenced by the level of average incomes, which were considerably lower than in the United States. In addition, the markets for a large number of products were still subject to national, regional, social and cultural barriers. In a word, they remained segmented. Finally, as mentioned above, the institutional conditions of development of certain technologies such as electricity and radio created an additional handicap. These "structural" inferiorities in Europe were aggravated between the wars by the instability of the economy. The permanent threat of a failure in final demand had a profound influence on business strategy.

One of the paradoxes of the interwar period was the determination on the part of engineers and entrepreneurs in all European countries, despite these handicaps, to introduce methods of mass production, be they For-

[26] Dornseifer, p. 206 in this book.

dist or Taylorist. An example of this was the Ba'ta company in Czechoslovakia which managed to cut the manufacturing costs of its shoes to such an extent that the traditional European shoe industry was directly threatened. However, in the majority of cases the transposition of American methods was only partial and necessitated adaptations which greatly modified their original conception. In the case of the car industry it was possible to speak of a "British system of mass production", which was more respectful of a worker's control of his labour than the American system, but which was already leaning towards automation"[27]. In France, Citroën and Renault were the only manufacturers to apply the Ford programme in any thorough way, when they launched their assembly lines in 1933 and 1935. Michelin and the Paris-Orléans railway company, on the other hand, were the only ones to apply an out-and-out Taylorist model of planning, the former in its machine shops and the latter in its repair shops.

That is not to say that French industry did not make considerable efforts at rationalisation, but it was applied differently according to the needs of each sector. The Depression, far from slowing down this process, actually accelerated it. More or less complete forms of assembly line working spread into the mines, the food and beverages industry and into the railway workshops. The actual technological bases for this type of Fordist rationalisation are threefold: they rely on the electrification of the driving force, on the adoption of machine tools, specialised or universal depending on the case, most of which were imported from the United States or made under American licence, and they depend on the development of continuous production. However, the most common forms of rationalisation were closer to the Taylor than to the Ford model. They were extraordinarily diverse and mainly involved the adoption of more rigorous forms of organisation of work. Factories specialised within groups and within large firms. The lay-out of factories improved, and this cleaning-up programme was facilitated by the closure of many older factories during the 1930s. Timing and piece-work, but also budgetary control, quality control and scheduling made considerable advances. All these measures, the aim of which was the control of cost prices, involved not only economies of labour but also of capital. This phenomenon was not peculiar to France, for the attempt at "industrial rationalisation" dominates the 1930s throughout Europe, and it explains the increase in productivity analysed above.

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[27] W. Lewchuk, American Technology and the British Vehicle Industry, Cambridge 1987.

The rationalization of labour in the factories constitutes but one aspect of a much more general reform of company structures, based on the diffusion of a functional model of organisation. This process began in the 1920s as a result of the trend towards concentration which occurred in many sectors, and intensified in the 1930s. An analysis of this vast movement of reorganisation is outside the scope of this paper. On the other hand, it is appropriate to examine the place held by R&D in these structural reforms.

3.3. Competitive Research

Since the 18th century, and particularly in France, research had been identified as a natural and necessary function of an industrial company, closely linked to the production process. But it was within German and American companies after 1870 that research developed as an independent activity, thanks to the creation of laboratories whose research was becoming more and more scientific in nature. In Germany before 1914, these laboratories had become quite large and were awarded sizeable budgets, which enabled them to carry out wide-ranging research programmes. British and French companies, on the other hand, while not ignoring the necessity for developing a coherent research strategy, did not adopt such radical measures.

Nevertheless the stake in research policies was vital, most particularly for companies which had embarked upon the path of new technology, and their importance was further confirmed in the period between the wars. The following excerpt, written in 1936, which is taken from the ICI Dyestuffs Group, is an illustration of this: "Our main problem is the highly competitive character of research work in organic chemicals. The IG believe so whole-heartedly in this field that their research effort is preponderating in this field. This is indicated by the patents taken out by the IG, almost three-quarters of which are in fields in which the Dyestuffs Group is interested" [...] "Painful evidence of IG's strength was furnished by the frequent experience of finding that when we (Dyestuffs Group) do succeed in opening up a new line of work, the IG are already there, setting up the inevitable patent barrier"[28].

"Competitive research" policies thus defined have the aim of developing a company's range of activities, and of developing and defining its

[28] W. J. Reader, Imperial Chemical Industries, A History, 2 volumes, Oxford 1975. See Vol. 2, p. 34.

patents. In the electrical industry, as in the chemical industry, many agreements were concluded in the interwar period based on the exchange of patents. One of the most important was the agreement signed by ICI and Du Pont in 1929, in which IG Farben refused to participate. These agreements underline the strategic importance of integrated research to firms' survival and development. The figures for foreign patents taken out in the United States confirms their effectiveness: in 1913, 34% were of German origin, 23% British and 8% French. After the war Germany rapidly re-established her position and during the 1920s confirmed her supremacy in the crucial sectors of organic chemistry and electrical equipment. In 1937 German patents represented 38%, British patents 22,7% and French patents 9% of foreign patents registered. Compared with the other two countries, a much larger share of the German patents came from large companies, which was a natural result of their research effort. It is clear that Germany owed her pre-eminent position to this policy of research.

Little is still known about the research strategies pursued by companies. Two further, complementary steps are needed to perform this analysis. We need to attempt to measure the extent of the research performed and to assess the functioning and efficiency of the system.

3.4. Extent of the Research Effort

In an article published in 1984, David C. Mowery compared certain quantitative data measuring the research effort in American and British companies[29]. He concluded that in terms of jobs the intensity of research was four to five times less in the UK, and in terms of expenditure it was three time less. He explained the inferiority of the British research effort in two ways: a less marked trend towards concentration, and an incomplete rationalisation of company structures. Since the large British companies had not been able either to accomplish their "managerial revolution" or to adopt a system of divisional organisation, they had not developed autonomous and powerful research departments.

Mowery's assessment needs considerable qualification. First of all, one of the specific traits of British research was the important role played by cooperative research. This achieved some spectacular results. Let us

[29] See D. C. Mowery, Firm Structure, Government Policy and the Organisation of Industrial Research: Great Britain and the United States, 1900–1950, in: Business History Review 58, 1984, pp. 504–31.