# Technology Transfer and Economic Development in Latin America, 1850-1930

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# TECHNOLOGY TRANSFER AND ECONOMIC DEVELOPMENT IN LATIN AMERICA, 1850-1930

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# PREFACE

These two essays, the first on the transfer of railway building and management techniques to the Andes, and the second on the movement of agricultural, industrial, and scientific expertise to Uruguay, originated in the course of our independent research programmes and were prepared in response to a call for papers on the history of technology for the biennial conference of the Third World Economic History and Development Group at Leicester in September 1984. Both were presented at that conference, and have benefitted substantially from the comments and criticisms of experts in other areas of the Third World in the discussion there. They will appear in the volume of conference proceedings edited by Clive Dewey, The state and the market: studies in the economic and social history of the Third World (forthcoming, Riverdale Publishing Inc.). Our aim in circulating them as a working paper now is to disseminate the research more rapidly, in particular to our colleagues working in the field of Latin American economic history.

Although the essays deal with different countries in the region, and with distinct areas of technical expertise, a number of issues arise from the two. Apart from Frank Safford's justly influential work on Colombia, relatively little has been written on the acquisition of technical and managerial skills by Latin American countries in the nineteenth and early twentieth centuries. Both the theoretical literature on contemporary technological transfers to Latin America, and the historical literature on the relationship between Britain, Europe, and the United States in the era of industrialization, have little to say about the historical experience of the Third World. The latter group of writings does, however, make the significant point that imports of technology were useless without a corresponding flow of 'know-how' in the shape of people to install, maintain, and manage it; even so assimilation by the receiving country was neither an easy nor an inevitable consequence. The importance of selecting appropriate 'experts' and technology is a point made in both our essays. Moreover, both groups of literature tend to emphasise manufacturing processes. We would not wish to understate the importance of that sector in the major Latin American countries even before 1930, but, in the period of desarrollo hacia afuera between the mid-nineteenth century and the Depression, public and private institutions in Latin America recruited a large number of experts in a wide variety of activities, and probably only a minority was involved in manufacturing. The two papers here provide case studies of other sectors central to the export economy - transport, agriculture, and applied science. They raise a number of questions about the part played by governments in Latin America in stimulating change, the appropriateness of the techniques exported from Europe and North America to a very different social and physical environment, the degree of diffusion which occurred, and the steps taken to train and employ local technical and managerial elites. It is too early, given the general lack of case studies, to reach firm conclusions on such issues, but we hope that the data and the arguments presented here will help to promote debate amongst historians of Latin America on such questions.

RORY MILLER
HENRY FINCH

# TRANSFERRING TECHNIQUES : RAILWAY BUILDING AND MANAGEMENT ON THE WEST COAST OF SOUTH AMERICA. *

**Rory Miller**

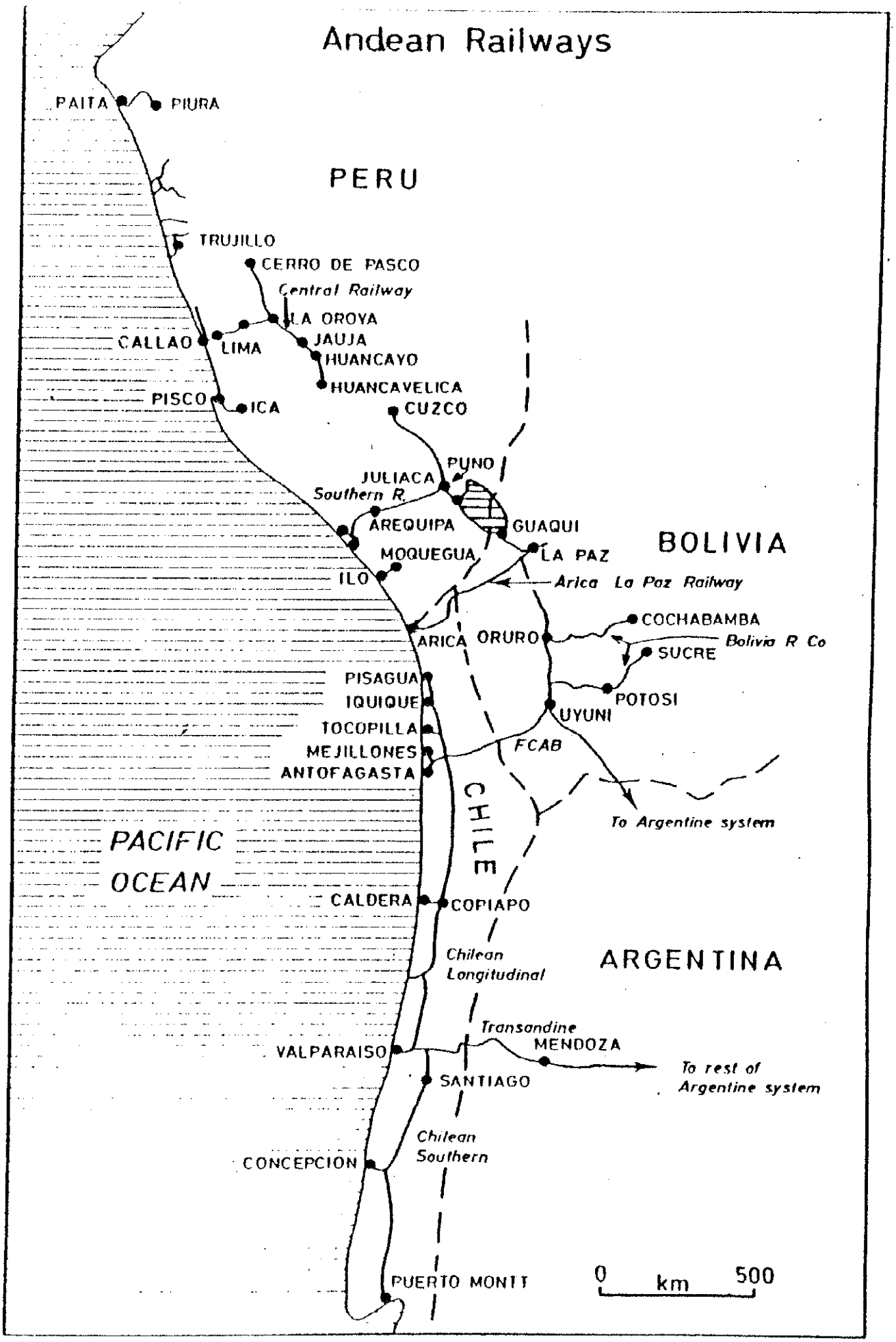
'Railroad enthusiasts,' Daniel Headrick writes of the 1840s, 'dreamed of covering the whole world with their iron rails and puffing, clattering trains.'[1] Latin American elites and governments responded. At the end of the decade railway construction began in South America, Peru and Chile disputing the claim to have possessed the first operating line in 1851. By the close of the 1850s Brazil and Argentina had also acquired short stretches of track, and from then until the coming of road transport in the 1920s a continuous, but cyclical, process of building took place.[2] For the world outside Europe and North America railways were one of the most important items of technology transferred in the nineteenth century, even in countries like Colombia where the systems were small.[3] Along with the steamship they helped to put primary-producing regions into contact with European markets, as well as providing a necessary stimulus to the internal political and commercial integration of the country concerned. For many Latin Americans in the late nineteenth century the steam locomotive symbolized modernization.[4]

Economic historians writing on Latin American railways have considered a number of different questions. The region has inevitably attracted a Fogelian attempt to measure the social savings of railways, in the form of John Coatsworth's study of Mexico, while more traditional approaches have included studies of the decisions to build railways, the financing of lines in Chile, Argentina, and Brazil, and discussions of the relationship between foreign companies and host governments.[5] Research has also tended to concentrate on individual countries rather than on comparative work, although Colin Lewis's recent article on financing railways is an important exception.[6] However, this literature, with its emphasis on the reasons for and consequences of railway construction, and the complexities of elite-government-company relations, overlooks some crucial issues, one of which is the question, how? Not how were the railways financed, or how were concessions negotiated, but rather how were they built and managed? Who did it? Where did they obtain their knowledge from, and how quickly was it absorbed by Latin Americans? Despite its limitations, in terms of its emphasis on manufacturing industry and on the North Atlantic, recent work on technological transfer has consistently emphasised the importance of the means, especially the human means,

by which advanced techniques migrated, and gone on to consider the associated problems and the implications for the receiving countries.[7] Yet very few historians of Latin America, whether of railways or imperialism, have considered these issues in any depth, a recent exception, in the case of Argentina, being Gudmund Stang, who draws our attention to the stream of 'engineers, technicians, book-keepers, clerks, and skilled (and in some cases unskilled) labour' which accompanied flows of capital and technology from Europe.[8]

It would be too much, in the space available, to consider these questions for Latin America as a whole, and the focus of this paper is confined to the countries of the central and southern Andes, Peru, Bolivia, and Chile, and thus, in part at least, it is concerned with the specialized problem of transferring the technology of building and operating mountain railways.[9] Nevertheless the early railways here, along the coast and into the Andean foothills, did not present severe or insoluble technical problems. In some parts of the Andes construction could be relatively simple and cheap. Few difficulties arose in building two of the high, transandean lines to the altiplano of Bolivia and Southern Peru, the Ferrocarril del Sur, running inland from Mollendo, where the main obstacles came in the first twenty miles, and the Ferrocarril Antofagasta (Chili) y Bolivia, which eventually ran up to La Paz.[10] The principal headaches came where railways had to gain height within a short distance and in the confines of a narrow valley: those between the ports of Tarapacá and Atacama and the nitrate pampa, the Ferrocarril Central del Perú, constructed between 1870 and 1893 up the Rímac valley from Lima, the Transandine Railway between Argentina and Chile, first planned in 1877 and not completed until 1910, and the Ferrocarril Arica-La Paz, which the Chilean government built under the terms of its peace treaty with Bolivia and finished in 1913.[11]

Techniques of building such mountain railways developed in the second half of the nineteenth century, as engineers gained experience from Europe (especially from the Alps), India, where the first line through the Ghats, finished in 1863, used zigzags or reversing stations, and the North American Rockies.[12] By the time William Wheelwright began work in Chile, the early problems of designing locomotives powerful enough to pull a reasonable payload up a steep gradient, and, more importantly, of stopping it running away on the descent, were disappearing, although discussions in the Institution of Civil Engineers suggest that there was still considerable doubt about the maximum grades and minimum curves suitable for an adhesion railway. Some new railways still continued to use the older method of a stationary engine, inclined plane, and cable, such as the Pisagua line in 1890


Andean Railways
PAITA
PIURA
PERU
TRUJILLO
CERRO DE PASCO
Central Railway
LA OROYA
CALLAO
LIMA
JAUJA
HUANCAYO
HUANCAVELICA
PISCO
ICA
CUZCO
PUNO
JULIACA
Southern R.
AREQUIPA
GUAQUI
BOLIVIA
MOQUEGUA
LA PAZ
ILO
Arica La Paz Railway
COCHABAMBA
ARICA
ORURO
Bolivia R Co
SUCRE
PISAGUA
IQUIQUE
POTOSI
UYUNI
TOCOPILLA
MEJILLONES
FCAB
ANTOFAGASTA
To Argentine system
CHILE
PACIFIC
OCEAN
CALDERA
COPIAPO
Chilean
Longitudinal
ARGENTINA
Transandine
VALPARAISO
MENDOZA
To rest of
Argentine system
SANTIAGO
Chilean
Southern
CONCEPCION
PUERTO MONTT
0
km
500

but for the most part technology had advanced beyond such a primitive stage.[13] Nevertheless, when work on the Central Railway commenced in Peru in 1870, assisted methods of gaining height like rack or Fell systems were still in their infancy, and generally considered too intricate for export to non-industrial countries. This left an adhesion railway using reversing stations as the only technological option for the engineers there.[14] By the time they came to trace the Transandine and Arica-La Paz lines, however, Abt rack systems had made it possible to construct a shorter, if steeper, railway in the mountains than the curves and grades of even a metre-gauge adhesion railway would allow, and in both cases the engineers and governments concerned took advantage of them.

## Surveying and planning the railways

The first British railway boom of 1835, F.M.L. Thompson states, found the country without the necessary supply of engineers and surveyors to plan and build the railways, and companies had to rely on a motley collection of retired army officers, mining engineers, and architects.[15] Not surprisingly Latin American countries faced the same problems. Mining engineers, with their experience of tunnelling and tramways, had, of course, led railway development in England, and both Richard Trevithick and Robert Stephenson had suggested the construction of railways in South America. However, the difficulties and primitive nature of mining immediately after independence meant that there existed little local engineering talent that could be transferred to railways. The economic and political disruption of the decades since the 1820s had halted the public works programmes of the Bourbons, so that by mid-century politicians in many South American countries could be heard bemoaning the lack of skilled personnel to carry out their plans. Alejandro Andonaegui, addressing the University of Chile in 1867, remarked that not one student had graduated in civil engineering there since 1853, partly because of the lack of employment opportunities, a point which Frank Safford has also stressed for Colombia.[16] It is doubtful that the prospects were any better in Peru and Bolivia, where the recovery of the mining industry after independence was slow.

Two sources provided the expertise to trace the first Latin American railways. A few local engineers who had received foreign training took part in the early projects. Manuel Mariano Echegaray, one of the two men who had explored the

Mollendo-Arequipa route, was a cuzqueño educated in France, and Jorge Lyon, an English-trained Chilean, participated in the early phases of the Santiago-Valparaíso Railway.[17] More usually, however, the original surveyors came from Britain, Europe, or the United States, contracted either by private concessionaires or by Latin American governments because of the shortage of local expertise. The Chilean government hired a French railway expert in 1846, while in 1852 the Peruvians brought in Ernesto Malinowski, who had attended the Ecole des Ponts et des Chaussées in Paris and became the first of a stream of Polish engineers to work for the Peruvian government.[18] In the next decade, after working on a project for the short Pisco-Ica Railway, Malinowski traced the original route for the Ferrocarril Central up the Rímac valley, and the Peruvian government also used its own engineers for the initial surveys of the Ferrocarril del Sur, where Echegaray partnered Federico Blume, a native of the Virgin Islands who, after training in Hanover, had worked in the United States and Chile before arriving in Lima in 1855.[19] Americans and Britons also came to both countries. Wheelwright had four North American engineers on the Caldera-Copiapó Railway, one of whom, Allan Campbell, went on to make the initial trace for the Santiago-Valparaíso Railway in 1850-1851. Campbell resigned two years later, when some serious errors in his planning became obvious, and William Lloyd, a protege of George Stephenson, arrived to replace him, remaining until 1865.[20] Both the Chilean and Peruvian governments took a large part in the planning of the railways, either by commissioning their own employees to make surveys, or by loaning them to private entrepreneurs. Once the railway boom got under way in Peru in 1869-1870 the government there continued to finance surveys of new lines, but, with its own engineers fully employed elsewhere, used the expertise of an American member of the Meiggs organization, John Thorndike, who had had railway experience in the United States, Canada, and Chile. In both countries it became customary to make a number of surveys before granting final approval for a route - Oppenheimer lists six choices for the final section of the Santiago-Valparaíso line and three for the Santiago-Talca line - all of which caused delays and placed strains on the limited pool of immigrant talent available.[21]

A number of developments after the first generation of railway planning meant that the renewed growth which occurred after the turn of the century could draw on a greater amount of expertise. The Peruvian administration of Manuel Pardo sent one of its Poles, Eduardo Habich, to Europe to recruit personnel for a new Escuela de Ingenieros, which opened in 1876 under his direction. His staff included two more Poles, Francisco Wakulski and Mariano Folkierski, who did a considerable amount of railway work for the government after the Pacific War, administering some state-owned railways, and then taking part in official investigatory commissions before and after the Grace Contract of 1890.[22] Both the Peruvian and Chilean governments began to organize state institutions to regulate and develop the railways, the former creating a Dirección de Obras Públicas, which published Anales collecting statistics and contracts from the 1870s, and the latter, which by this time owned and operated much of Chile's network, founding a similarly-named organization in 1888 to undertake the study and construction of railways.[23] Such bodies must have helped make civil engineering careers more attractive to local students, with the result that later railway promoters, whether private or public, could draw on a wider range of talent than in the third quarter of the nineteenth century. They might continue to contract foreign or immigrant experts for particular tasks. Another Pole, Mariano Tarnawiecki, surveyed and costed the Morococha branch for the Peruvian Corporation in 1906, and Josiah Harding, who had been involved with Chile for over thirty years, traced the Arica-La Paz route for that government in 1903, where a state engineer, Benjamin Vivanco, later revised his survey and temporarily became responsible for construction.[24] The staff of the existing railways, whether publicly or privately owned, also undertook surveys for extensions, as in the final section of the Chilean Ferrocarril del Sur or the Los Andes branch of the Ferrocarril Santiago-Valparaíso.[25] The fact that the Peruvian Corporation could accept, in its contracts to build the Huancayo and Cuzco extensions for the government in 1905, that three-quarters of the administrative and technical staff should be Peruvian nationals, indicates the depth of local resources which were by then available.[26] In contrast Bolivia, where one private line, completed in 1892, ran from the Chilean frontier to Oruro, was then only just entering its first real phase of railway construction, and, like Chile and Peru a generation before, depended entirely on foreign expertise. The Peruvian Corporation surveyed the Viacha-Oruro line in 1904, and an American, W. Lee Sisson, undertook a full survey of the principal railway schemes the following year.[27]

The first engineers selected the route for the railway, which involved choosing among the different techniques available, and prepared estimates of the cost and time of construction. Sometimes, like Sisson in his Bolivian study, they might also have to make forecasts of the potential traffic.[28] The current state of technology and the capital available for construction almost always forced a prior decision on the choice of gauge, and all these factors placed constraints on the surveyor's freedom of manouevre.[29] Cash limitations thus gave the designers of the São Paulo railway in Brazil in the 1850s no alternative but to use an inclined plane and a 10 per cent grade, despite the inconvenience this would cause to operation.[30] Not all Andean railways were difficult. The employment of specialists like William Lloyd, A. Pagenstecher, and William Buchanan could overcome the few technical problems of the early Chilean railways, and the altiplano lines were reasonably straightforward. The real headaches came with the Ferrocarril Central del Perú, because of its long, continuous ascent within a narrow valley, the climbs on the Ferrocarril Arica-La Paz and the Transandine, the latter compounded by the dangers of snow and ice, and the descents from the altiplano into the city of La Paz, where a steep and unstable slope impeded construction.[31]

When Malinowski planned the Peruvian Central Railway in the 1860s he had no alternative to the use of zigzags or reversing stations to gain height. The idea had been employed as a temporary measure in the United States, and as a permanent feature in India, and was well-known among engineers.[32] The Arica-La Paz and Transandine routes, which were planned later, both had long histories of problems in construction and finance, which deterred both local and foreign private capital, thus placing the responsibility on government. It was imperative to reduce the initial costs of the lines, and for that reason they employed recently developed rack systems.[33] Commenting on a paper presented by the contractor who actually completed the Transandine the original promoter, Mateo Clark, claimed that the Argentine and Chilean governments fixed such a low budget for the line 'that it was impossible to think of building a long tunnel, and the engineers consequently had to seek for the shortest possible route'. Clark went on to assert that before opting for the rack he had made studies of similar systems in the Harz mountains, and also rejected the Peruvian zigzag solution because of the problems of snow. The successful contractor added that he would have estimated the cost of a broad (Argentine) gauge route at three times the actual price, and that budgetary constraints had also compelled him to use an extremely light rail.[34]

At times, when reading such discussions among civil engineers, one has the feeling that they might be divided into two groups, the elegant and the practical. In the words of one critic of the technical elite's lack of 'self-correcting or self-limiting tendencies': 'Technical problems are ... inherently interesting, frequently compelling, regardless of the intended social use or value of the problem's solution. The elegant solution of a problem is an engineer's dream just as it is the mathematician's'.[35] Whether from inexperience, or because mountain railways offered considerable scope for those seeking the elegant, many of the original surveyors found it much easier to plan feasible routes than to consider properly the time and expense of construction or the costs of operation. The exceptions were the Antofagasta Railway, built quickly, cheaply, and efficiently, and the Southern Railway in Peru, whose financial difficulties stemmed from the Peruvian government's embarrassment at the end of the guano age and the simultaneous draining of funds to the Central Railway.[36] In the case of the Central, Malinowski had originally estimated the cost at S/.27.6 million (approximately £5.5 million) for the complete line to Jauja, but it cost £4.1 million to construct just the 141 kilometres to Chicla.[37] Both the Santiago-Valparaíso and Southern railways in Chile ran over time, the former taking eleven years to construct and the latter twenty, rather than the estimates of five and five to seven respectively. The former cost twelve million pesos and the latter between ten and eleven million instead of the estimates of just over seven million and three to five million respectively.[38] Errors did not diminish with time. The Peruvian Corporation acquired a bad reputation for cost overruns on the Bajada extension into La Paz that it constructed for the Bolivian government. Some of the worst results of all, however, stemmed from Sisson's Bolivian projects. The cost of every line exceeded his original estimate, but in the case of the Oruro-Cochabamba line the actual expenditure came out at over seventeen million bolivianos against an estimate of five and a half million.[39]

Foreign surveyors might prove even worse at assessing the potential freight traffic, partly because they had neither the training nor the statistics to do so, partly because of their very foreignness, and partly out of self-interest in justifying their projects. Sisson again provides a good example, for his estimate of a gross annual return from freight of over two million pounds from the lines he planned was simply unrealistic. Even in 1926 the gross revenue of the Bolivia Railway Company lines scarcely reached £150,000.[40] The survey which James Livesey and Son, the London consulting engineers, carried out for the Peruvian bondholders in the late

1880s proved similarly optimistic, for the annual net revenues of £300,000 predicted for the Central Railway and £185,000 for the Southern Railway were achieved only in 1917-1918 (after the unforeseen expansion of copper mining) and 1925-1926 respectively.[41]

The terms under which the original planning occurred often created later difficulties. In the case of Peru, for example, the North-Western Railway became 'famous for its unnecessary windings over the low coastal hills, this condition resulting from the fact that the contractors worked on a kilometer basis and were not interested in the question of efficiency and operating costs'. On the other hand the location of the Trujillo Railway had been determined in order to save on construction costs but without thought to the traffic potential of its hinterland.[42] For the mountain railways, especially, too great a saving on the costs of construction might make the railway uneconomic, as discussions in the Institution of Civil Engineers demonstrated. In 1900 Robert Stirling, the engineer of the Tocopilla Nitrate Railway, commented that the very tight, continuous curves his predecessors had built caused heavy consumption of coal and water and excessive wear on rails and tyre-flanges.[43] Men who worked on the Central Railway like Oliver Bury, the Peruvian Corporation's managing director, and F.W. Bach, one of its engineers, extolled the operating advantages of adhesion railways; in the words of Bach, 'It was often possible to pay dividends on a larger capital outlay, where cheaper working resulted, than on lines which, although of lower first cost, were saddled eternally with high working charges.' Even the inventor of most rack systems used in the Andes, Dr Abt himself, warned of the desperation which ingenious engineers could induce in those who had to operate the railways they had designed.[44]

Contracting and construction

Very early in the history of railway construction in Britain a clear distinction developed between engineers like the Stephensons and I.K. Brunel and contractors like Thomas Brassey. Contractors needed different qualities: in the words of Asa Briggs, financial acumen, knowledge of building, an ability to handle a heterogeneous labour force, some political capacity, and most of all experience. 'A contractor could fail,' Briggs remarks, 'because he was deficient at the vital moment in only one of these skills. He could succeed only if he displayed them all.'[45] Men like Brassey gained their experience in Britain but quickly broadened

their contracting business to cover first continental Europe, then North America and India. Gradually they developed sophisticated techniques of bidding, sub-contracting, and management. In South America Brassey built the Central Argentine Railway and the Callao docks in Peru.[46] Contracting, however, proved to be extremely vulnerable to financial crises. Peto and Betts, who built the first stretch of the Buenos Aires Great Southern Railway, went bankrupt in the crash of 1866, and Brassey almost collapsed. For the most part, therefore, contractors did not found family businesses, and they have left few records behind them.[47]

The qualities Briggs lists would suggest that local entrepreneurs might find considerably greater opportunities in railway contracting than they had in engineering the lines. They might acquire the knowledge necessary to build and grade the roadbed through experience of sub-contracting. They should also have been able to handle a local labour force adequately, probably had greater expertise in local politics than a foreign contractor, and suffered only from their lesser access to cheap credit. Nevertheless, the two best-known contractors on the west coast - William Wheelwright, who built the Caldera-Copinapó Railway and began the Santiago line, before moving on to Argentina, and Henry Meiggs, who made his reputation in Chile before working in Peru - were both North American. Their fame however, should not obscure the local contribution to railway construction. In Peru the Montero brothers built the nitrate railways inland from Iquique and Pisagua, and bid, against Meiggs, for the contract for the Ferrocarril Central, but their enterprises collapsed in 1875 and almost nothing is known about either their origins or ventures.[48] Simultaneously, the Clark brothers, who, despite their name, were Chilean nationals, successfully constructed the Transandine telegraph in the early 1870s, and then moved into railway promotion and construction in their own country and in Argentina. Like the Monteros they combined the two activities, also to their cost, for they thus encountered the financial problems which forced them to transfer their enterprises to their creditors in the early 1890s.[49] A number of local contractors also undertook smaller projects. In Peru Pedro Candamo completed the Lima-Callao Railway in 1850-1851, and Modesto Basadre the Lima-Ancón line in 1867-1870. While Meiggs was building the major Peruvian railways in the early 1870s, Pedro T. Larrañaga constructed the Trujillo Railway, Federico T. Blume the Paita-Piura Railway, and Canevaro and Basadre the Pisco-Ica Railway.[50] In Argentina from the 1880s a number of minor lines were also built either by local contractors or by direct administration by government engineers.[51] The Chilean experience is not so clear. Cesareo Váldez

obtained a large portion of the contract for the Quillota-Santiago section in 1859, but the railway management rescinded this two years later and transferred the contract to Meiggs. This experience may have deterred Chilean officials from employing their own nationals, for most later contracts seem to have gone to foreigners, at least one of whom was, however, a permanent resident in Chile, until Pedro José Vivanco obtained the contract for the Palmilla branch of the Southern Railway in 1870. For a time, as already stated, a Chilean engineer also took charge of the construction of the Arica-La Paz line between 1907 and 1909, before the government awarded the contract to the British firm of Sir John Jackson.[52] What is certain, though, is that no contractor, not even Meiggs, founded a lasting fortune from the profits of railway construction on the west coast.

Whom did the contractors employ? On the large projects, almost inevitably from the early stages, the shortage of local expertise compelled them to use foreign technical staff. Oppenheimer notes that Meiggs had seven engineers in Chile in 1862, five of whom were North American, the others being German and Chilean.[53] Much the same seems to have occurred when Meiggs moved to Peru a few years later. According to Watt Stewart, many officials were foreign, but two of the seven section heads on the Ferrocarril Central were clearly either Peruvian or Chilean, indicating at least a minor role for local men. The Meiggs team also included some who had gathered a substantial amount of experience in the construction of railways in Latin America. Joseph Hill, who superintended the building of the Ferrocarril del Sur, had also worked in Chile on the Santiago line. John Thorndike, who carried out the survey for the line beyond Arequipa for the Peruvian government, had worked on railways in the United States and Canada before joining Meiggs in Chile, and later completed the Southern Railway as far as Sicuani for the Peruvian Corporation.[54] Railway building set up such a demand for technical staff, however, over a short period, that the quality of the immigrants might be very poor. John G. Meiggs complained of this in 1870, writing to John Thorndike, 'You say you are short of good Engineers please take <u>all</u> of mine!! - You may be able to do <u>something</u> with them, but I tell you beforehand God Almighty has done but little.'[55] Similarly when Livesey and Son examined the state railways at the end of the 1880s, they found that some of the work performed by Peruvian contractors on the small lines had serious deficiencies. Besides the faulty tracing of the Trujillo Railway, already mentioned, the Paita-Piura Railway of Federico Blume needed remedial work in the levelling of some of the steeper grades and the easing of some curves.[56] This information on the Chilean and Peruvian railways

survives largely because of the diligence of Robert Oppenheimer and Watt Stewart. The vulnerability of contractors has meant that we know little about the technical employees of the Monteros, Clarks, and the smaller Peruvian contractors.

The builders of the railways also found skilled labour difficult to obtain. John G. Meiggs complained of the problems of securing skilled workers, especially carpenters and masons.[57] The fact that railway construction often coincided with peaks of demand not only in the local economy, but in the developed world as well, exacerbated the problems. In Chile, certainly, it became customary to import skilled men, even to the extent that contractors were accused of employing English miners and artisans at much higher wages than their Chilean counterparts.[58] It is difficult to believe, however, that contractors would always prefer expensive foreign skilled labour over cheaper local workers, particularly in view of the probable quality of those Englishmen forced to seek work abroad. Contractors often faced obstacles too in acquiring the unskilled labour they needed. Fawcett notes that convicts graded the first Callao-Lima Railway in 1851.[59] Despite the size and poverty of the Chilean rural population in the nineteenth century, it could still prove difficult, even there, to continue work at full pace during the harvest, as Lloyd found in 1854-1855 and Meiggs in 1862-1863. As the Ferrocarril del Sur moved southwards the problems continued. In the early 1870s contractors complained of the number of peons who had followed Meiggs to Peru. They still faced shortages in 1887, when the government forced them to use soldiers rather than peons until the harvest had finished, and in 1892 when the contractor in Bío-Bío had to bribe his peons with several barrels of liquor to prevent the enganchadores recruiting them for the harvest.[60] In Peru, as is well-known, Meiggs imported Chilean peons in their thousands for work on the Southern Railway, while using large numbers of Chinese workers on the Central.[61] The problems continued into the twentieth century. The Bolivian Railway Company encountered delays in completing the Viacha-Oruro line in 1907 because of the weather and the lack of labour. The Arica-La Paz line was also retarded as Chileans did not wish to move so far north, and Bolivian peons would work on the line only because the lack of rain forced them into the labour market. In Peru, and probably also in Bolivia, established railway companies made use of local government officials to acquire unskilled labour for railway works.[62] The whole balance of the evidence, therefore, from the time of the first railway in Peru to the completion of the Arica-La Paz project, indicates that contractors found it very difficult to obtain unskilled labour at the wages they were willing to pay.

After the first generation of railway-building, changes began to occur in methods of contracting parallel to those in surveying and planning. One solution to problems with private contractors was for governments, as their experience of railways and technical resources improved, to undertake construction themselves through the direct employment of labour. The Chilean government, which had operated its own railways for a long time, appears to have been the first to follow this course. In 1887 state engineers took over the construction of a bridge on the Southern Railway after private contractors had failed to complete it, and from the mid-1890s, after further difficulties, direct supervision of railway construction by government engineers became official policy.[63] The Peruvians did not follow this course until over twenty years later, but there the state had transferred most of its railways to the British under the terms of the Grace Contract of 1890. As the Peruvian Corporation, for reasons of its own, showed little interest in extending its tracks, the government, after failures with private contractors, undertook the building of the Huancayo-Huancavelica line itself in 1918, and the following year began the extremely difficult (and never completed) Pachitea Railway.[64] By this time, of course, there was a far greater abundance of engineering skills in both countries. The Chilean railways had hired their first locally-trained engineer in 1886, and training in Peru had been institutionalized under the direction of immigrant experts since the mid-1870s.[65]

Once railway companies had become established, they could undertake their own extension work, as well as contracting for other promoters. In Argentina the Buenos Aires Great Southern began to construct its own extensions soon after the bankruptcy of Peto and Betts in the 1860s, with some success in reducing the costs of construction.[66] On the west coast the Peruvian Corporation began to build for the government in 1905, and some evidence exists to suggest that they used local sub-contractors in this work.[67] The Antofagasta Company also began the Potosí and Cochabamba routes of the Bolivia Railway Company, in which it possessed a controlling interest, in 1909, and extended the Potosí railway to Sucre for the Bolivian government in the 1920s.[68] Another Bolivian development was the employment of contractors from other South American countries. The international operations of the Clark Brothers in Argentina in the 1880s had already foreshadowed this, but in the 1920s the Bolivian government began to use Argentine firms, giving an unsuccessful contract for the Atocha-Villazón line in 1920 to the firm of Lavanes, Poli y Cía, and later employing another Argentine company, Dates and Hunt.[69]

International contracting also changed towards the end of the nineteenth century. Middlemass points out that improved engineering methods and materials, better specification of work, and standardized methods of tendering all helped to cut down risk.[70] Latin American governments could attract large international contracting firms of high reputation, of which Pearsons is probably the best example, rather than the small, financially stretched, contractors of the mid-nineteenth century. Thus, when the Chilean government awarded the contract for the Arica-La Paz Railway to the firm of Sir John Jackson, it was employing one of the largest public works companies in the world, which had built not only railways, but dams, part of the Manchester Ship Canal, and dockyards at Dover, Devonport, and Simonstown, a forerunner of the Wimpeys and Costains of today.[71] At the same time partnerships of consulting engineers, who might also oversee some railway construction, grew up in Britain. Given the large part played by British companies in Andean railways, at least after the late 1880s when the Antofagasta Railway and the Peruvian Corporation respectively bought out Chilean capitalists and the Lima government, this development was quickly transmitted to South America. The most famous, James Livesey and Son, worked for both these companies.[72] As Livesey, Son, and Henderson, they also supervised the building of the Chilean side of the Transandine Link, and by the mid-1920s dominated the engineering departments of South American railways not only in Peru and Bolivia, but also in Argentina, where they were consultants for three of the big four British lines, as well as for the Central Córdoba and Entre Ríos. An American trade envoy advised his own manufacturers that two firms, Liveseys and Fox and Mayo, 'pass judgment on practically all equipment purchased for British-owned foreign railways, particularly in South America'.[73] Another specialist consulting engineer which appeared in South America was Balfour Beatty, who in 1935 advised the Peruvian Corporation on the electrification of the Central Railway.[74] It is also worth noting that two large international engineering manufacturers attempted to enter railway financing and construction in South America, presumably in order to guarantee some work for their steel mills, but without success. When Bolivia was considering the ambitious railway projects of the early 1900s, one agent came from Schneider of Le Creusot, and when the Leguía government was drafting similarly far-reaching plans for Peru in the 1920s Armstrong Whitworth showed considerable interest before being deterred by the Board of Trade and the conditions of the concession.[75] By then the world of international contracting was very different from that when the first South American railways had been constructed.

Operation and management

Just as the Liverpool and Manchester Railway had killed the cabinet minister, William Huskisson, at its opening, some spectacular disasters occurred at the inauguration of South American railways, underlining the fact that railway management and operation also demanded the acquisition of specialized skills and experience. In Argentina a locomotive derailed a few days before the opening of the Oeste, injuring one of the line's directors, while on the Gran Oeste almost thirty years later President Roca's private coach became detached from the main train on its return journey and drifted unpowered for a couple of miles.[76] When the General Manager of the Antogagasta Company attended the opening of the rival Arica-La Paz Railway in 1913 he could scarcely disguise his delight:

> The inauguration as regards travelling over the Arica-La Paz line was not altogether what you might call a success inasmuch as, due to the bad state of the Locomotives, the Bolivian Committee, which left La Paz on the 11th [Sunday], took two days to make the trip and another two days on the return journey, so that they were four nights without any sleep. The Chilean delegates arrived in La Paz at half past five on the Thursday morning, having been up for two consecutive nights and were then without their luggage which did not arrive until the evening of the 15th and all the festivities that had been prepared for them were consequently postponed until the Friday.

In a masterpiece of understatement he concluded, 'the trip over the Arica/La Paz line was a fiasco.'[77]

Problems, of course, did not cease with the opening of a railway. In Argentina Ferns describes how a group of employees of the Northern Railway of Buenos Aires sold their own tickets at a one-third discount on the official fares, while Lewis comments on the state-owned Central Norte in 1892:

> The line's administration conformed to few of the normal standards of railway management. Regular accounts were not kept, although 'rough' running, day-to-day balances indicated inevitable discrepancies. Due to the dearth of revenue, the employees of the line rarely obtained a money wage but instead found themselves in receipt of promissory notes listing the number of days worked and tasks performed. These certificates circulated as money in the railway's zone.[78]

The Manager of the Antogafasta Company described how, when he first travelled on the Oruro-Viacha line of the Bolivia Railway Company whose operation he was about to take over, the previous management was 'barely able to keep their trains

running', notwithstanding the employment of 500 men. 'Derailments', he added, 'are of daily occurrence, and it is an exception for the mixed train to arrive at its destination without some vehicle derailing.'[79]

The question of management is one which historians concerned with the transfer of technology have tended to ignore, even though the mechanisms by which it might occur, the circulation of technical literature and the movement of personnel, were similar to those involved in the planning and construction of the railways. Effective management was clearly essential to the profitability of an enterprise, whether it was being operated by government or by private business, and the efficient and safe operation of railways was, by the time they reached South America, a highly specialized activity, demonstrated by the appearance of textbooks in the subject. Very few writers have, however, considered the question of railway management in South America, and it should be stressed, therefore, that the following discussion is somewhat speculative.[80]

In most South American countries railway companies were, with government, among the largest employers until the appearance of other international corporations at the beginning of the twentieth century. In Europe and North America the first railways had presented considerable problems of organization and management, not least because of the need to ensure safety. Chandler and Salsbury have also noted the unprecedented complexities of railway accounting, since cash flowed through hundreds of hands, and tasks like setting tariffs and rates of depreciation demanded considerable skill and information.[81] Different companies had found their own solutions to these questions, but by the late nineteenth century it had become customary to separate the finance and accounting departments, the engineering departments, and the traffic departments from one another, and to split a network into a number of sections. The degree of centralization might vary from the line-and-staff organization of the Pennsylvania Central to the more centralized systems of the shorter English railways. Even here, however, it was customary to separate the traffic and civil engineering departments into smaller, more manageable districts.[82]

Robert Oppenheimer has analysed the changing administrative structure of the Chilean state railways in detail. He shows how in 1862 the Superintendent of the Ferrocarril Santiago-Valparaíso, Juan N. Jara, introduced changes which were an amalgam of French, Belgian, and British practice, and divided the railway two

years later into separate departments. Even in the late 1870s, however, the three government lines still had separate administrations, which created many operating difficulties, but under the pressure of war the state adopted a reorganization, based on Belgian models, which came into effect in 1884. This put the entire system under the control of a Director-General appointed by the president, and divided the network into four departments (exploitation and transport, traffic, machinery, and accounting), and three geographical sections, each with a staff of engineers and accountants under an Inspector.[83] It thus took a generation for the state railways to develop an efficient administrative structure which could surmount the legacies of the initial period of railway construction, when the Ferrocarril Santiago-Valparaíso and Ferrocarril del Sur had been separate enterprises. The Antofagasta Company also adopted a policy of geographical sectioning before the First World War, with General Managers in both Chile and Bolivia, although largely for political reasons. As the company's operations in Bolivia expanded it had become embarrassing for the manager in Chile to have to deal with questions involving another government, laying the company open to the charge of not being fully committed to Bolivia and treating it as a second-class interest.[84] Peru differed, for there the Peruvian Corporation did not operate an interconnected network but a series of separate lines of different lengths running inland from the coast. When the company took over the railways in 1890 it adopted a decentralized structure, with a representative in Lima to deal with the government and questions of national policy, but distinct administrations (and indeed subsidiary companies) for each line, which were themselves divided into sections. This had the result of permitting the two principal lines, the Central and Southern, to retain their rather distinct identities, and allowing other managers a good deal of latitude in their relations with local clients.[85]

Nevertheless, an orthodox administrative structure, which most of these railways possessed by the end of the nineteenth century, did not guarantee efficient management. The Peruvian Corporation reorganized the Southern Railway early in 1906, appointing new heads of department for traffic, way and works, and accounts, but an independent consultant, commissioned by an American bank to report on the Corporation the following year, called the Southern Railway's administration 'depressingly faulty', continuing,

> I cannot understand how such a man as the present superintendent has been left in charge of an undertaking that requires a thoroughly competent and experienced man to run it. Not only is the manager incompetent but his staff is absolutely unsuited to the work. The engineer is a good port-work man, I believe, but he had no technical assistance in his office while I was there. The locomotive department is under an experienced engine-driver and a very good man at that work, but his office is not properly organised, as he has not been trained for such an important position. The audit office is part of the traffic department and is terribly old-fashioned. The accountant is hardworking; but he has had no proper tuition in railway work. The whole staff is inexperienced and there is no-one capable of showing how things should be done.[86]

Another influential figure, responding to complaints from the Cerro de Pasco Corporation about the Central Railway, confessed that 'the Corporation had been subjected to very bad management.'[87] Both private and state railways experienced problems of maladministration. After the centralization and reorganization of the Chilean state railways in 1884 the very efficient working that had characterized them began to disappear: the ratio of costs to gross receipts slipped from about 60 per cent before reorganization to over 100 per cent after 1907.[88] To borrow modern administrative practices developed abroad did not inevitably mean that management itself would be efficient.

In the case of the foreign-owned railways the preferential recruitment of foreign staff, if they did not have the requisite railway experience, might lead to losses and inefficiencies, besides the additional expense of paying expatriates. Behind this policy there often lay a good deal of prejudice: the Antofagasta Railway, after it found in 1909 that the station-master at Antofagasta had been embezzling funds, illogically determined that 'employees handling cash of any amount of importance should, as far as possible, be European.'[89] More often, though, the problems stemmed from inexperienced financiers not realising the specialized nature of railway management, and thus, as the report on the Southern Railway of Peru suggested, putting into posts men who did not have the skills necessary for the job. The Peruvian Corporation had made this mistake at the very beginning, when it selected for its first representative in Peru the private secretary of the Chancellor of the Exchequer.[90] Even state railways, as in Chile, showed until the 1890s a preference for foreign expertise, at least in the selection of senior technical and administrative staff, although as Oppenheimer comments, the superintendents and directors of the lines tended to come from official positions elsewhere and from wealthy and socially prominent Chilean families, bringing to their posts little experience of railway management.[91]

Again, matters seem to change in the 1890s, and a number of different patterns emerge at that point. In the case of the foreign main lines, firstly, it became customary to employ men with previous railway experience elsewhere in Latin America for senior management, and in some cases, board positions. There were obvious advantages in doing this: greater adaptability, knowledge of local conditions, and linguistic ability, especially. Thus the Peruvian Corporation appointed representatives with backgrounds elsewhere in South America or in Third World railways : Alfred Schatzmann in 1896 from the Antofagasta, following the death of an earlier appointee from El Salvador, W.E. Morkill in 1907 from the Mexican Southern Railway, and A.S. Cooper in 1920 from the Sudan. The new managing director appointed in 1912, Oliver Bury, had started work on a Brazilian railway, before becoming General Manager of the Entre Rios, Buenos Aires and Rosario, and Great Northern Railways.[92] Indeed a Latin American 'circuit' appears to have developed amongst some talented railway professionals : in the discussions in the Institution of Civil Engineers on mountain railways David Simson, by then a director of the Antofagasta, revealed that he had begun his career in South America as a junior surveyor on the Transandine, and F.W. Bach hinted at his work in Argentina and on the Guaqui-La Paz Railway before joining the Peruvian Central.[93] The foreign railways, of course, often trained their own expatriate employees from scratch at a very young age, allowing the most able plenty of chances of internal promotion.[94] This continued to limit, however, the opportunities for locally educated professionals. Even at the beginning of the 1960s expatriates still occupied 31 of the 38 most senior posts on the Peruvian Southern, and only then did a representative begin consciously to employ local professionals in the highest positions. On the less important lines of the Peruvian Corporation the monopoly of foreign managers did not apply as fully. When C. Smith visited the Pacasmayo Railway, for example, in 1907, he noted that the manager was a competent Peruvian.[95]

Elsewhere in Latin America local administrators and engineers were beginning to find greater opportunities in the 1890s. Fleming argues, in the case of the Argentine Gran Oeste, that the appointment of José Villalonga, who had earlier worked for the provincially-owned Oeste, began a turnaround in the company's fortunes, and Mattoon comments that in the 1890s Brazilians began to replace foreigners there, as the expansion of the railways offered employment to graduates of the Escola Politécnica, founded in 1874.[96] Writing in 1926, G.S. Brady asserted that although the foreign-owned lines in Argentina normally sent out executive

officers and operating chiefs from Europe, the state railways generally chose their officials from Argentine citizens, appointing Europeans or North Americans occasionally to the most senior technical positions.[97] He could have said much the same of Chile. Although the government had successively imported a Frenchman and a German as Director-General of the state railways after strengthening the powers of the post in 1907, most jobs now went to Chileans. This raised problems in itself, for political influence provided the key to many appointments and the railways became criticised for their empleomanía, but a new law in 1914 aimed to reverse this by reserving all senior posts for engineering graduates of the Universidad de Chile. Splawn comments that this resulted in 'a marked improvement in the physical condition of the roads', and Chileans occupied almost all the 1272 posts on the Ferrocarril Arica-La Paz in 1927, none of the major positions being held by a foreigner.[98] As the appointment policies of foreign and state railways diverged, then, after the 1890s, the opportunities for local managers and engineers became greatest in those countries where the state operated a larger proportion of the railways. Conversely, those countries where private foreign companies predominated, such as Peru or Argentina, or where engineering education was still in its infancy, such as Bolivia, offered fewer opportunities for the local economy and local technicians to benefit from the diffusion of management skills that the railways might bring. Where it operated only isolated lines, however, the state might still employ others to carry out the day-to-day management of its railways, whether for lack of confidence in its own expertise or because it made operating sense. Thus the Peruvian Corporation, during the 1920s, ran the Ilo-Moquegua, Lima-Lurín, and Lima-Huacho lines, and the Antofagasta Company, at one time or another, managed state railways both in Bolivia and Chile.[99]

According to Oppenheimer, in the early days of the Chilean railways a mixture of foreigners and Chileans filled middle management posts, but over the years the latter came to predominate.[100] Whereas the early station-masters were often foreigners who had worked on construction, by 1882 Chileans occupied all these positions on the Ferrocarril Santiago-Valparaíso. There all ticket agents and conductors had been Chilean from the beginning. In the case of skilled workmen he found that, although many Chileans worked as firemen and brakemen by the 1880s, the state railways were still importing drivers from England. Only then, as inflation made it difficult and expensive to hire foreigners, did the management really turn to the employment of Chilean drivers. Of the artisans, 72 of the 82

employed by the locomotive and wagon departments of the Santiago-Valparaíso Railway in 1882 were Chilean, although foreigners still dominated foremen's jobs and the smithy. It is clear, however, that after the first generation of railway work financial considerations began to overcome prejudice against local workers that had existed even in the management of the state railways. The wages of Chileans were normally 25-30 per cent less than those of contracted foreigners, and at a time of inflation and exchange depreciation the incentives to employ local skilled labour, allowing Chileans, for example, to make the same progression from cleaner to fireman to driver that was customary on British railways, were considerable. The figures for the Arica-La Paz railway quoted earlier make it clear that by the early twentieth century the Chileans had ceased to contract middle management and skilled workers from abroad.

Little parallel information has survived for Peru, although it was obviously necessary to import skilled workers at the beginning, for techniques such as driving could not be acquired locally. Again, however, the employment of nationals seems to have become the norm by the end of the century, for Peter Blanchard's discussion of the strikes of 1909 makes it clear that every group involved in the operation of trains on the Central Railway was predominantly Peruvian.[101] Brian Fawcett's account of his early days on the Central Railway in the 1920s also implies that there Peruvians made up the entirety of the skilled labour force, with the exception of a handful of long-serving foreign drivers, although he points out that the private railway of the Cerro de Pasco Corporation still continued to import American 'engineers'.[102] Whether the state or foreign companies operated the railways, there was little sense in continuing to introduce expensive foreign labour when they could pay lower wages to local recruits. In the case of the artisans this had important implications for the diffusion of skills in the economy. Oppenheimer notes that except for smiths artisans tended not to stay long with the Chilean railways.[103] Railway workshops could have a considerable local spinoff in cities like Arequipa, the centre of the Peruvian Southern Railway's operations, where, even in the early 1970s, men who had received their training in the railway workshops were said to own a good proportion of the city's talleres and ferreterías.

It similarly often took about a generation for Latin American railways to adopt innovations in management and accounting developed in Europe. The fixing of railway tariffs provides a good example. By the end of the nineteenth century in Britain this had become a complex affair. Sir George Findlay explained that 'the

rates are governed by the nature and extent of the traffic, the pressure of competition ..., but above all, the companies have regard to the commercial value of a commodity, and the rate it will bear, so as to admit of its being produced and sold in a competing market with a fair degree of profit.' By the 1880s, he continued, British railways normally divided freight into eight classes, and, in addition to the rate for the distance carried, levied fixed terminal charges to cover handling costs.[104] Discussions of the tariffs on the Peruvian Central Railway indicate that there adoption of modern practices proved extremely slow. The Grace Contract divided goods into just three classes, and the Peruvian Corporation rationalized its entire tariff structure only in 1917, when it equalized tariff categories on different sections of the line, creating ten classes of freight, and levying a terminal charge for the first time.[105] The tariff structure of the Chilean state railways, helped by the reorganization of 1884, appears to have conformed to modern practices earlier, for, whereas until then both the Santiago and the Southern lines divided freight into only three classes, by the early 1890s the state railways were using seven categories.[106]

One might also have expected the introduction of railways to Latin America to have created, in time, some demand for local equipment and machinery, if the system was of sufficient size. From the first, however, concessions tended to include guarantees of duty-free imports of essential materials. In Chile the government went even further, permitting its diplomats in Europe to act as purchasing agents for the newly formed companies in the early 1850s.[107] In Bolivia the Antofagasta Company, through a series of agreements with the government, effectively enjoyed duty-free imports from its foundation in 1889 until 1936, and even then managed to use this as a bargaining counter in wage and salary negotiations.[108] The Peruvian Corporation obtained exemption from all import duties for the 66-year term of the original Grace Contract, a concession that the Peruvian government granted to other companies under the General Railway Law of 1893.[109]

Obviously, during the initial period of construction almost all key materials had to be imported, except where the builders could use local timber resources for sleepers or bridges. However, for a time in the 1880s and 1890s, some railways did provide a stimulus for local industries or built equipment themselves. Pfeiffer thus notes that in Chile the immigrant firm of Lever, Murphy and Co. obtained an order from the state railways in 1887 for six locomotives and 30 freight cars, importing

only the wheels as finished parts from Britain. The Chilean industry, however, faded under the pressure of import competition. Long reported in 1930 that domestic production of railway equipment was negligible, although it did include a small amount of rolling stock constructed in the workshops of the state railways.[110] The purchasing policies of the principal private railway in Chile, the Ferrocarril Antofagasta (Chili) y Bolivia, did nothing to help local industry. When the company went into the market for over sixty new locomotives between 1905 and 1907, it bought all of them from suppliers in Britain or the United States. Even in the 1920s it still had its shops at Mejillones tooled only for maintenance, and, unlike the Peruvian Corporation, did not construct its own wagons and coaches.[111] The Ferrocarril del Sur in Peru had a particularly good record of constructing its own equipment from imported parts, to the extent that it had built 32 of the 46 locomotives on the 1908 roster, using foreign wheels and frames, connecting rods, and boiler plates.[112] As in Chile, however, it became easier and cheaper to import locomotives built to local specifications, although the railway workshops continued to construct other vehicles. When Long visited Peru in the mid-1920s he noted that just over half the Central Railway's locomotives were American-built, the remainder being British, but that the Guadelupe workshops built their own wagons. The Southern Railway used mainly American locomotives, but had, in the previous nine years, constructed 29 new passenger coaches and 88 freight cars.[113]

As the technology of mountain railways advanced the opportunities for local manufacture almost certainly diminished. The rack railways, for example, needed European-built locomotives to their own specifications, as well as imported rails.[114] Heavier trains demanded steel rails and the replacement of iron or wooden bridges by steel ones, all of which had to be imported. The beginnings of electrification also increased the railways' dependence on imported equipment, Westinghouse obtaining the entire contract for the reconstruction of the Chilean railways in the 1920s.[115] More recently the introduction of diesel locomotives and aluminium rolling stock on the Peruvian mountain railways has brought with it the running down of construction, as opposed to maintenance, facilities, and the growth of modern methods of railway signalling and telecommunications must have had much the same impact. It is important, finally, however, to recognise the local engineers' growing ability to adapt to the conditions of mountain railways. Two Chileans carried out the preliminary study for the electrification of the state railways.[116] The fact that for a similar task a decade later the Peruvian Corporation contracted the firm of Balfour Beatty may be suggestive of the

differences between state and foreign railways, but the Peruvian Central Railway's engineers had an impressive record of designing and operating their own locomotives, and the costliest mistakes occurred when the London office, on the advice of consulting engineers, overruled them in order to buy poor equipment from British manufacturers.[117] A reading of Brian Fawcett's autobiography and the debates in the Institution of Civil Engineers early in the twentieth century impress one with the extent to which railway employees were prepared to use their ingenuity to apply lessons learnt from elsewhere to Latin American conditions.

* * *

International engineering companies now operate in a world of large technical and financial consortia and 'turnkey' contracts. The task of building railways in nineteenth-century Latin America was very different. The individual foreigners who arrived in and moved about the region to construct and operate them were essential to the process, as historians of other forms of technology transfer have emphasised. Without their skills and 'know-how', for the generation after construction was complete, trains could neither run nor be maintained. Even the knowledge transmitted through the specialist press, such as the journals and proceedings of professional institutions, depended very much on the geographical circulation of experts for its cumulative effect; the use this paper has made of the publications of the Institution of Civil Engineers shows the importance of the willingness of railway experts, from South America and elsewhere, to exchange ideas in London. The movement of trained staff from one railway to another and the foundation of local bodies like the South American Centre of the Institution of Locomotive Engineers in Buenos Aires simply reinforced this process, as railway technology and operating practice, including that of the mountain lines, continued to develop.[118]

What of the effects on the recipient countries? Mira Wilkins has drawn a critical distinction between the transfer and absorption of technology, and it is worth quoting her at length:

> Only when nationals on their own (or virtually on their own) are able to produce the product does true diffusion - in contrast with the mere geographical transfer - of the technology occur ... With effective absorption there will be modification when appropriate and also improvements to fit national requirements ... Perhaps the test should

> be: if the business would fail or be seriously disrupted were foreign technicians removed, the control of technology cannot be said to be in national hands; if, by contrast, the business would remain viable and can find substitutes for the foreign technicians then it may be that despite the presence of foreign technicians in the operations, the technology has been effectively assimilated.[119]

With these ideas in mind some further conclusions may be advanced. By about 1900, in Chile and Peru at least, the introduction of European and North American railway technology had created a reservoir of local engineers and the establishments to train them (in part because even private foreign-owned railways had to be regulated by the state), a skilled workforce able to operate and maintain the lines, and workshops which could build equipment with a minimal reliance on imported parts. It was, however, neither a linear nor a generalized process across all railways, and in some respects the degree of assimilation of railway technology reached a peak in the decades around the turn of the century. Firstly, foreign ownership of many lines, and it should be remembered that both the Antofagasta Railway and the Peruvian Corporation had been 'denationalized' in 1889-1890, restricted the opportunities for local engineering and managerial talent. In the larger foreign-owned companies the penetration of local workers often tended to stop at the managerial/clerical or professional/skilled divide, although on state lines, especially in Chile, nationals proved able to perform all the tasks necessary for the functioning and continued extension of the system. It is not surprising that operating problems increased after nationalization both in Bolivia in the 1960s and in Peru a decade later, as they had in Perón's Argentina: the longstanding preference for expatriate senior staff had impeded assimilation, although there were other reasons such as political interference with management and economic weakness, preventing the purchase of spares or compelling the acquisition of cheap, inferior equipment, as well. Secondly, the slack and variable demand from local railways, coupled with changes in relative prices (including movements in tariffs and exchange rates) which favoured the metropolitan manufacturer, created greater dependence on foreign suppliers for locomotives, rails, and bridges, if not for carriages and wagons. It must be stressed that much of the more advanced manufacturing (but not the design) capability of Latin American railways and foundries had either disappeared or fallen into disuse by the 1920s. Finally, with improvements in railway technology, which involved the greater use of steel, rack systems, diesel and electric traction, lightweight rolling stock, and complex signalling and telecommunications, local expertise could not keep pace with the

increasing dependence on specialized foreign manufacturers, and state railways reflected the weaknesses of their economies in running short, at times, of the currency even to purchase spare parts. As this happened, and the competition from road transport, frequently encouraged by national governments, increased, the limitations imposed by the early choice of route, gauge, and method of operation in the planning and construction phase became ever more apparent.

## FOOTNOTES

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4. See, for example, in the case of Peru Manuel Pardo, Estudios sobre la provincia de Jauja (Lima, 1862).

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8. Gudmund Stang, 'Entrepreneurs and managers: the establishment and organization of British firms in Latin America in the nineteenth and early twentieth centuries', Historisk Tidskrift 1 (1982), 40-41.

9. As will become clear in this paper, the discussion of the Chilean case would have been impossible without Robert Oppenheimer's excellent work, to which I owe an immense debt.

10. The best survey of the engineering of Andean railways is Brian Fawcett, Railways of the Andes (London, 1963). Fawcett spent the whole of his career in the mechanical engineering department of the Ferrocarril Central del Peru.

11. George S. Brady, Railways of South America: Part I: Argentina (Washington, 1926), p.121; W. Rodney Long, Railways of South America: Part III: Chile (Washington, 1930), pp.91-94 and 144-150.

12. Headrick, Tools of empire, p.185; Thomas S. Isaacs, 'Railway incline-planes in America', Minutes of Proceedings of the Institution of Civil Engineers (hereafter MPICE) 18 (1858-59), 54-69; J.J. Beckley, 'On Indian railways, with a description of the Grand Indian Peninsula Railway', MPICE 19 (1859-1860), 594.

13. Fawcett, Railways of the Andes, p.46. Daniel Makinson Fox, 'Description of the line and works of the São Paulo Railway in the Empire of Brazil', MPICE 30 (1869-1870), 30 and 57; Santiago Marín Vicuña, Los ferrocarriles de Chile (Santiago, 1916), pp.40-42. The discussion on H.W. Tyler 'On the working of steep gradients and sharp curves on railways', MPICE 26 (1866-67), passim, continued for three meetings and filled 88 pages of minutes.

14. On the problems of maintenance in non-industrial countries see the comments of William Lloyd, who had been in charge of the construction of the Ferrocarril Santiago-Valparaíso, on Tyler's paper in MPICE 26 (1866-67), 349-350.

15. F.M.L. Thompson, Chartered surveyors: the growth of a profession (London, 1968), pp.109-110. Even in 1860 the Institution of Civil Engineers had less than 1000 members: R.A. Buchanan, 'Institutional proliferation in the British engineering profession, 1847-1914', Economic History Review 38:1 (1985), 44.

16. Horna, 'Transportation, modernization, and entrepreneurship', 36; Robert Ballen Oppenheimer, 'Chilean transportation development: the railroad and socio-economic change in the Central Valley, 1840-1885' (Ph.D. dissertation, UCLA, 1976), p.65; John J. Johnson, Pioneer telegraphy in Chile, 1852-1876 (Stanford, 1968), p.123; Frank Safford, The ideal of the practical: Colombia's struggle to form a technical elite (Austin, 1976), passim.

17. Watt Stewart, Henry Meiggs, Yankee Pizarro (Durham, NC., 1946), p.108; Oppenheimer, 'Chilean transportation development', pp.186 and 207.

18. Oppenheimer, 'Chilean transportation development', p.66; Embajada de la República Popular de Polonia, Los polacos en el Perú (Lima, 1979), pp.74-75.

19. Embajada de Polonia, Los polacos, pp.76-78; Stewart, Henry Meiggs, pp.87-88 and 103-108.

20. Oppenheimer, 'Chilean transportation development', pp.81-84 and 168-170.

21. Stewart, Henry Meiggs, pp.87-88; Oppenheimer; 'Chilean transportation development', pp.171-172 and 178.

22. Embajada de Polonia, Los polacos, pp.83-90; José María Rodríguez (ed.), Anales de la Hacienda Pública del Perú (Lima, 1912-1928), XVIII, 11a-16a, and XXI, 429a-437a.

23. The Peruvian Anales de Obras Públicas are a major quantitative source for the study of railways; Marín Vicuña, Los ferrocarriles de Chile, p.266.

24. Embajada de Polonia, Los polacos, p.131; J.J. Impett to Clive Sheppard, 17 February 1906, Caja 56.4, Peruvian Corporation archive, Lima (hereafter PC/Lima); Marín Vicuña, Los ferrocarriles de Chile, pp. 183-184.

25. Oppenheimer, 'Chilean transportation development', pp.183 and 186.

26. Peru, Ministerio de Fomento, Anales de Obras Públicas, 1905 (Lima, 1913), pp.213-214 and 227-228. The talent available in another engineering field is shown by the volumes of the Boletín del Cuerpo de Ingenieros de Minas y Aguas published in the first decades of the twentieth century.

27. El Diario (La Paz), 8 April 1904; W. Lee Sisson, Reconnaissance report upon proposed system of Bolivian railways (La Paz, 1905).

28. Sisson, Reconnaissance report, pp.119, 218 and 309.

29. Only the major Peruvian railways were built to standard (4 feet 8½ inch) gauge. The Chilean southern railways were built to 5 feet 6 inch gauge; the northern to metre gauge. The Bolivian government adopted metre gauge as the norm, although the line from Antofagasta to Uyuni, which developed out of a mineral line, was of 30 inch gauge until its conversion in 1928: Long, Railways of South America, II, 214 and 221, and III, 67 and 84; C. Cowley, 'Memorandum on the Antofagasta Company and its subsidiaries, August 1949', p.29, FCAB archive, London.

30. Fox, 'Description of the line and works', 30-32 and 57.

31. Fawcett, Railways of the Andes, provides the best summary; on the Chilean problems see Oppenheimer, 'Chilean transportation development', pp.168-172.

32. Isaac, 'Railway incline-planes', 54-69.

33. Two recent papers have stressed the importance of local private capital and government finance, as opposed to foreign private firms, in the early history of Latin American railways: Lewis, 'Financing of railway development', 51-52, and Oppenheimer, 'National capital and national development', 54-66. The Arica-La Paz line is something of a special case as Chile had agreed to build it in the 1904 peace treaty with Bolivia: reducing construction costs was thus more important than making a profit.

34. Mateo Clark, commenting on Brodie Haldane Henderson, 'The Transandine Railway', MPICE 195 (1913-14), 168-179; Henderson, replying to comments on 'The Transandine Railway', 187-190; see also the comments of Mateo Clark

and Enrique Budge (Chilean government engineer) on William Theodore Lucy, 'Notes on the working of a rack railway', MPICE 202 (1915-16), 33 and 37-39. The problem of snow could be overcome with snow-sheds as used in the Rockies and the Alps and recommended by an early surveyor of transandean routes: Robert Crawford, Across the pampas and the Andes (London, 1884), p.306. Despite its greater altitude the more northerly location of the Ferrocarril Central del Perú meant that its most difficult sections lay well below the snowline. Floods and landslides were the problem here.

35. Eugene S. Ferguson, 'Toward a discipline of the history of technology', Technology and Culture 15 (1974), 22-23. British Rail engineers have often made similar comments, if rather more bluntly, about the products of universities' civil engineering departments.

36. The metre-gauge Uyuni-Oruro extension of the FCAB was completed on schedule in 1892 at a cost of £750,000 or £2,395 per kilometre: Luis M. Peñaloza, Historia económica de Bolivia (2 vols., La Paz, 1953-1954), II, 352-353. On the financial difficulties of the Peruvian government, see Stewart, Henry Meiggs, pp.288-327, and Rory Miller, 'The making of the Grace Contract: British bondholders and the Peruvian government, 1885-1890', Journal of Latin American Studies 8:1 (1976), 75-76.

37. Stewart, Henry Meiggs, p.88; 'Reseña: transferencia de los ferrocarriles y descripción de los mismos', p.24, Caja 36.4, PC/Lima.

38. Oppenheimer, 'Chilean transportation development', p.164; Oppenheimer, 'National capital and national development', 55-60.

39. El Diario, 3 January and 28 July 1905; Sisson, Reconnaissance report, pp.191, 218 and 306; Peñaloza, Historica económica, II, 376.

40. Sisson, Reconnaissance report, p.309; Cesareo Aramayo Avila, Ferrocarriles bolivianos: pasado, presente, y futura (La Paz, 1959), p.83.

41. 'Report of the Committee of Peruvian Bondholders, 30 January 1890', p.8, and Peruvian Corporation, Annual Reports of the Board, passim, PC archive, University College, London (hereafter PC/UCL).

42 W.E. Dunn, Peru: a commercial and industrial handbook (Washington, 1925), p.64; 'Reports on the Peruvian railways and mines by Livesey and Duncan', p.13, file B1/3, and C. Smith, 'Report on the properties of the Peruvian Corporation, February 1908', p.26, file B1/9, PC/UCL.

43. Robert Stirling, 'The Tocopilla Railway', MPICE 142 (1900), 99.

44. Dr. Abt commenting on and F.W. Bach summarizing, 'Smooth-rail working on heavy gradients', MPICE 180 (1909), 116 and 130; see also the comments by Oliver Bury and F.W. Bach on Henderson, 'The Transandine Railway', 166-168, and 183-187; and Bach's comments on Lucy, 'Notes on the working', 34-36.

45. Asa Briggs, 'Foreword', to Robert Keith Middlemass, The master builders : Thomas Brassey, Sir John Aird, Lord Cowdray, and Sir John Norton-Griffiths (London, 1963), p.15.

46. Lewis, British railways, p.15; Charles Walker, Thomas Brassey: railway builder (London, 1969), pp.127-128 and 150.

47. Middlemass, The master builders, p.22.

48. Thomas F. O'Brien, The nitrate industry and Chile's crucial transition, 1870-1891 (New York, 1982), pp.34-35; Oscar Bermúdez, Historia del salitre desde sus orígenes hasta la Guerra del Pacífico (Santiago, 1963), pp.250-251; Pennano, 'Desarrollo regional', 139.

49. Virgilio Figueroa, Diccionario histórico-biográfico y bibliográfico de Chile (Santiago, 1928), II, 408-409; William James Fleming, 'Regional development and transportation in Argentina: Mendoza and the Gran Oeste Argentino railroad, 1885-1914' (Ph.D dissertation, Indiana U., 1976), pp.41-45; Marín Vicuña, Los ferrocarriles de Chile, pp.76-80; Johnson, Pioneer telegraphy, pp.99-108.

50. T.J. Hutchinson, Two years in Peru (2 vols., London, 1877), I, 229, and II, 86; Long, Railways of South America, II, 225-229.

51. Brady, Railways of South America, I, 189, and 203-206.

52. Oppenheimer, 'Chilean transportation development', pp. 172-189; Marín Vicuña, Los ferrocarriles de Chile, pp.184-185.

53. Oppenheimer, 'Chilean transportation development', p.207.

54. Stewart, Henry Meiggs, pp.87-88, 109, and 160; Peruvian Corporation, 'Contracts and documents, 1890', file C2/4, PC/UCL.

55. Quoted in Stewart, Henry Meiggs, p.111. Emphasis in text.

56. Long, Railways of South America, II, 227.

57. Stewart, Henry Meiggs, p.203.

58. Oppenheimer, 'Chilean transportation development', pp.212-213.

59. Fawcett, Railways of the Andes, pp.30-31.

60. Arnold J. Bauer, 'Chilean rural labour in the nineteenth century', American Historical Review 76: 4 (1971), 1059-1084; Oppenheimer, 'Chilean transportation development', pp.214-221; John H. Whaley, 'Transportation in Chile's Bío-Bío region, 1850-1914' (Ph.D dissertation, Indiana U., 1974), pp.76-79, 93-94, and 126.

61. Stewart, Henry Meiggs, pp.115 and 160; Hutchinson, Two years, II, 65-66.

62. El Diario, 4 June 1907; McCulloch to Morkill, 15 January 1910, file B3/7, PC/UCL. It was common practice in the Andes for government officials to impress Indian labour for public works, as it had been since precolonial times: on the practice in this period see, for example, Peter Blanchard, 'Indian unrest in the Peruvian sierra in the late nineteenth century', The Americas 38:4 (1982), 453 and 456; Florencia Mallon, The defense of community in Peru's central highlands : peasant struggle and capitalist transition, 1860-

1940 (Princeton, 1983), pp.65-66; Thomas M. Davies, Indian integration in Peru's half-century of experience, 1900-1948 (Lincoln, 1974) p.13.

63. Whaley, 'Transportation in Chile's Bío-Bío region', pp.74 and 93.

64. Long, Railways of South America, II, 246 and 270.

65. Robert Oppenheimer, 'Chile's Central Valley railroads and economic development in the nineteenth century', Proceedings of the Pacific Coast Council on Latin American Studies 6 (1977-1979), 73-86.

66. H.S. Ferns, Britain and Argentina in the nineteenth century (Oxford, 1960), pp.351-352.

67. Anales de Obras Públicas, 1905, pp.213-214 and 227-228; Sheppard to Shearman, 4 December 1906, Caja 46.3, PC/Lima.

68. Stallibrass to Bolden, 29 September 1909, Robinson to Bolden, 3 November and 17 November 1911, General Manager's letters, FCAB archive; Long, Railways of South America, II, 13.

69. Long, Railways of South America, II, 7.

70. Middlemass, The master builders, pp. 171-173.

71. Who was who, 1916-1928, p.546.

72. 'Reports on the Peruvian railways and mines', file B1/3, PC/UCL; Board minutes, 12 January and 7 September 1893, Minute Book 1, FCAB archive. Nathan Rosenberg is somewhat critical of the peculiarly British institution of the consulting engineer, noting that they were often obsessed with technical perfection in the purely engineering sense and imposed their own tastes and idiosyncrasies on product design at the expense of commercial criteria: 'Economic development and the transfer of technology', 560-562. The example of the Central Railway's locomotive purchases, quoted below, bears him out.

73. On their role in the Transandine, see Henderson, 'The Transandine Railway', and Lucy, 'Notes on the working', passim; on their role in Argentina, see Brady, Railways of South America, I, 37, 61, 82, 126, 138; the quotation is from Long, Railways of South America, III, 22.

74. Cecil to Hixson, 10 September 1935, Caja 19.8, PC/Lima.

75. El Diario, 16 and 17 June 1904; Foreign Office to Grant Duff, 23 March 1922, A1995, FO371/7242; Edgcumbe to Grant Duff, 27 April 1922, A2798, FO371/7242; Ashurst, Morris, Crisp and Co. to Eyre Crowe, 7 December 1922, A7395, FO371/7242.

76. Lewis, British railways, p.6; Fleming, 'Regional development and transportation', p.142.

77. Robinson to Bolden, 30 May 1913, General Manager's letters, FCAB archive.

78. Ferns, Britain and Argentina, p.355; Lewis, British railways, p.137.

79. Robinson to Bolden, 12 February 1909, General Manager's letters, FCAB archive.

80. The classic English example of a textbook was Sir George Findlay, The working and management of an English railway. I consulted the sixth edition, published in London in 1899. Just as I was completing this paper I obtained a copy of Gudmund Stang, 'Aspectos de la política de personal de las empresas británicas en América Latina, 1880-1930', in Asociación de Historiadores Latinoamericanistas Europeos, Capitales, empresarios y obreros europeos en América Latina (Stockholm, 1983), pp.501-550, who uses a lot of evidence from Argentine railways to consider the question of the management policies of British firms.

81. Alfred D. Chandler and Stephen Salsbury, 'The railroads: innovators in modern business administration', in Alfred D. Chandler et al., The changing economic order : readings in American business and economic history (New York, 1968), pp.231-234.

82. Chandler and Salsbury, 'The railroads', pp.239-254; Findlay, The working and management of an English railway, pp.59-63 and 111. I should stress that I am using English terminology, which differs from U.S. practice.

83. Oppenheimer, 'Chilean transportation development', pp.229-253.

84. Cowley, 'memorandum', p.35, FLAB archive.

85. 'Report of the Committee of Peruvian Bondholders, 30 January 1890', p.7, PC/UCL.

86. El Diario, 17 March 1906; quotations from Smith, 'Report on the properties', p.47, PC/UCL, my emphasis. For a fuller discussion of the Peruvian Corporation management, see Rory Miller, 'The Grace Contract, the Peruvian Corporation, and Peruvian history', Ibero-Amerikanisches Archiv 9:3/4 (1983), 335-338.

87. Grace to Eyre, 20 May 1907, file B1/6, PC/UCL.

88. Marín Vicuña, Los ferrocarriles de Chile, pp. 275-282. It has been credibly suggested to me by Manuel Fernández that tariffs were kept low on government railways as an indirect subsidy to landowners, but, as the discussion below notes, critics were complaining by the turn of the century that posts on Chilean railways were being awarded to the influential rather than the qualified.

89. Board minute, 20 July 1909, Minute Book 4, FCAB archive. Stang, 'Aspectos de la política de personal', pp.525-531, tends to subordinate the explanation of prejudice to one which rationalizes the employment of Europeans in terms of the need to maintain control over staff over long distances. Unfortunately it is difficult to find an explicit statement to this effect in railway archives. My reading of Peruvian Corporation and Antofagasta Railway archives, as well as interviews with expatriate railway employees in the 1970s, would incline me not to underestimate simple prejudice on the part of conservative management, especially amongst those based in London.

90. The Times, 26 March 1891. The Financial News, 7 December 1896, commented scathingly: 'To manage the vast interests of the Corporation in Peru, which required not only administrative ability of a high order, but knowledge of railways and diplomatic tact into the bargain, a gentleman from the Treasury was sent out. That Mr. Dawkins was not a conspicuous success is no more disparagement to his undoubted capability in his own line than would be the failure of a railway engineer if pitchforked into the position of Chancellor of the Exchequer.'

91. Oppenheimer, 'Chilean transportation development', pp.255-259.

92. Peruvian Corporation, Annual Report of the Board, 1896, p.11, and Annual Report of the Board, 1907, p.12, and Report of Proceedings at the Annual General Meeting, 19 December 1912, and Report of Proceedings at the Annual General Meeting, 19 December 1912, p.1, PC/UCL.

93. Discussion on Henderson, 'The Transandine Railway', 164-166, and 184-185. Note that in the case of textile factories in the East and Latin America J.S. Fforde recounts stories of 'a nomadic race of British spinning or weaving masters, with long overseas experiences, who go from mill to mill on short-term contracts' : An international trade in managerial skills (Oxford, 1957), p.31. Stang, 'Aspectos de la política de personal', p.547, fn.82, provides some additional examples of Central Argentine Railway employees who had also worked in Chile, Uruguay, and Cuba, as well as in African and Asian countries.

94. For an example, see the autobiographical sections of Fawcett, Railways of the Andes, passim.

95. Interview with Michael Lubbock, former representative of the Peruvian Corporation, 7 July 1971; Smith, 'Report on the properties', p.23, PC/UCL.

96. Fleming, 'Regional development and transportation', pp.142-152; Mattoon, 'Railroads, coffee, and the growth of big business', 289-290.

97. Brady, Railways of South America, I, 23.

98. Marín Vicuña, Los ferrocarriles de Chile, pp.130, 280-282, and 323; Walter W.M. Splawn, Government ownership and operation of railroads (New York, 1928), p.158; Long, Railways of South America, III, 94.

99. Dunn, Peru, p.65; Long, III, 140.

100. This paragraph is based on Oppenheimer, 'Chilean transportation development', pp.261-266, 276-280, and 'Chile's Central Valley railroads', 79. Note, however, that on the large British-owned lines in Argentina British engine-drivers were still being imported in the early twentieth century and Argentines were only just replacing British foremen and superintendents at the time of nationalization in 1948: D.S. Purdom, British steam on the pampas: the locomotives of the Buenos Aires Great Southern Railway (London, 1977), pp.29-33. Gudmund Stang notes that just before the First World War on British railways in Argentina one had to go down to the level of stationmaster before finding the English administrators in a minority. Argentina does seem to be an extreme case of the preferential employment of expatriates, where the financial considerations obvious in Chile were largely ignored: Stang, 'Aspectos de la política de personal', p.522.

101. Peter Blanchard, The origins of the Peruvian labour movement, 1883-1919 (Pittsburgh, 1982), pp.66-69.

102. Fawcett, Railways of the Andes, pp.185-188.

103. Oppenheimer, 'Chilean transportation development', pp.279-280.

104. Findlay, The working and management, pp.263-270.

105. Rory Miller, 'Railways and economic development in central Peru, 1890-1930', in Rory Miller et al. (eds.), Social and economic change in modern Peru (Liverpool, 1976), pp.41-44. Smith's report in 1908 drew attention to the Peruvian Corporation's backwardness, when he called for 'a thorough reorganization of the tariffs': 'Report on the properties', p.34, PC/UCL.

106. Oppenheimer, 'Chilean transportation development', p.302; Whaley, 'Transportation in Chile's Bío-Bío region', p.99.

107. Oppenheimer, 'Chilean transportation development', pp.155-156.

108. Cowley, 'Memorandum', p.34, FCAB archive.

109. Circular of the Committee of Peruvian Bondholders, 29 November 1889, PC/UCL, reprints the Grace Contract; Long, Railways of South America, II, 193.

110. Jack B. Pfeiffer, 'Notes on the heavy equipment industry in Chile, 1880-1910', Hispanic American Historical Review 32:1 (1952), 139-144; Long, Railways of South America, III, 22-23.

111. See the orders in Minute Book 3, FCAB archive; Fawcett, Railways of the Andes, pp.119-126.

112. Fawcett, Railways of the Andes, p.157.

113. Long, Railways of South America, II, 215-224; Purdom, British steam on the pampas, p.76, notes that it became customary in Argentina for locomotives to be built to local designs but shipped fully-erected.

114. Lucy, 'Notes on the working', 4-5.

115. Long, Railways of South America, III, 71-72; see also Mattoon, 'Railroads, coffee, and the growth of big business', 293, for an indication of the role of GEC in Brazil.

116. Long, Railways of South America, III, 71-72.

117. 'Report by Oliver Bury, 1913', file B1/13, PC/UCL; Fawcett, Railways of the Andes, pp.55-58; Long, Railways of South America, II, 203-204.

118. Purdom, British steam on the pampas, pp.2-3.

119. Wilkins, 'Role of private business', pp.170-171.

# TECHNOLOGY POLICY AND THE STATE IN URUGUAY, 1900-35 *

**Henry Finch**

During the period in which import-substituting industrialization (ISI) was the dominant growth model in Latin America, much attention came to be focussed on the implications of an industrial structure in which the production of capital goods was largely absent. In particular, it was apparent that trade and exchange regimes which penalized or prohibited the import of consumer goods while facilitating the entry of machinery and equipment, in the interests of a more rapid rate of industrial growth, entailed the adoption of production technologies which had been developed in the context of relative factor and input prices which did not correspond to those prevailing in Latin America. At later stages of the ISI process when the participation of transnational capital was more pronounced, it became evident that the international commercialization of their technologies entailed heavy financial costs for Third World countries in terms of patents, licenses and royalties. The extent to which Latin American countries have as a result become passive recipients of foreign technologies, with their scientific communities oriented more to the international research agenda than to national needs in applied science and technology, has suggested to some writers that there is a specific form or phase of dependency characterised by technological dependency.[1]

If it is true that Uruguay has avoided some of the more obvious aspects of technological dependency, this mainly reflects the fact that the domestic market is very small and has grown slowly over the last thirty years, thus greatly reducing its attraction to foreign capital.[2] It certainly does not indicate that Uruguay has been successful in establishing a national technological capacity. At the beginning of the 1950s, in the rapid growth phase of industrialization, the Chamber of Industry and the Faculty of Engineering of the University of the Republic jointly recognised the desirability of closer contact between existing technical research facilities and private sector industry. As a result of this, and of the creation in 1952 of a government commission, the Armour Research Foundation of the Illinois Institute of Technology in 1954 presented an assessment of the country's technological competence and requirements in industry, and urged the establishment of a technical assistance centre.[3] The initiative came to nothing, in part at least because of inadequate support from the Chamber of Industry itself.[4] Even in the 1970s, when the Uruguayan Laboratory of Technological Analysis (LATU) was

providing quality control assistance to new export industries, the country's attempts to generate and make available appropriate technologies were disorganized and inadequate.

To some extent, the burden of technological backwardness in manufacturing industry has been disguised by the crisis of ISI in the mid-1950s and the succeeding period of stagnation. The very long-run stagnation in output and yields in the rural sector is also widely attributed to technological deficiencies. This is particularly true of the livestock sector, the source of almost all of Uruguay's export earnings, where the failure to use land intensively limits cattle and sheep production to what can be sustained on the low and irregular nutritional yields of natural pasture. The problem has been recognised, and has changed remarkably little, since the early years of this century. The explanation of it, however, has been attributed to the lack of, or unprofitability of, land intensification technology, as well as structural or financial burdens preventing the adoption of new techniques.[5]

Even in terms of what has been achieved elsewhere in Latin America since the Second World War, Uruguay's institutional and financial support for research and development activity has been deficient,[6] in spite of the country's relatively high level of per capita income and high average level of educational attainment. This paper does not propose to offer an explanation of general or specific technological weakness, but instead makes the point that in the early years of this century the government of Uruguay was actively concerned to establish a technological capacity. This effort merits analysis of the sectors in which expertise was to be established, the manner of its incorporation, the extent to which it was successful, and its long-term significance. The experience also indicates the peculiarity of the Uruguayan state in this period. Before examining what occurred, however, it is necessary to outline briefly the context.

## The Batllista State 1900-19

While many aspects of the batllista state remain unclear or controversial, the legislative achievement of the period marks it out as one of remarkable vision and innovation. Particularly during the second presidency of José Batlle y Ordóñez (1911-1915), but in a more general sense from the middle of the first decade of this century until the beginning of the 1930s, Uruguay witnessed an expansion of state activity in economic and social affairs which was unparalleled elsewhere in Latin

America and in advance of practice in much of Europe. The ideology of batllismo was humanitarian in its social dimension and dirigiste in economic policy. The radicalism of batllista social policy is reflected in the extent of labour and social welfare legislation, as well as in Batlle's support of the working class movement.[7]

The objectives and techniques of economic policy in this period help to locate and define the nature of the batllista state itself. The economic structure of Uruguay at the turn of the century was dominated by the production of cattle and sheep and the export of livestock products, a trade which was about to be transformed by the arrival of the frigorífico and the development of the British market for frozen and chilled beef. Nonetheless, although the growth process was export-led, the rural sector did not provide the dynamic attraction to immigrants that the wheat economy provided in Argentina. During the modernization of the livestock economy in the final decades of the nineteenth century there was in fact a net reduction in the labour requirements of the sector, while the numbers engaged in arable agriculture remained small. If Uruguay were to attract immigrants, therefore, it was necessary to secure an expansion of the arable sector or to promote the urban economy.

Although a high level of urbanization has been a pronounced feature of the country in this century, and is frequently regarded as characteristic of batllista Uruguay, probably at least one-quarter of the total population lived in Montevideo throughout the nineteenth century. The port had substantial natural advantages which enabled it to handle a significant entrepot trade, and although this was diminishing towards the end of the century Montevideo remained an important commercial and financial centre. In addition, the growth of incomes and early protectionist legislation encouraged the establishment of a limited number of factory-based manufacturing activities in the 1890s and the early years of this century. Still more important as an expression of the dominance of Montevideo was the expansion of the railway network and the modernization and extension of the urban infrastructure.

The context in which Batlle's economic policies were constructed was thus one of export growth based wholly on a livestock sector in which latifundia predominated, which appeared to offer no prospect of expanding employment and which indeed was regarded as an obstacle to the development of the rural economy. The urban sector was already remarkably large, and was diversifying. Moreover, Batlle's

Colorado party could traditionally count on the urban electorate for the major part of its support. The central thrust of Batlle's economic policy may therefore be fairly regarded as urban. More systematic protectionism was pursued, in particular a law permitting the free import of raw materials, in 1912. The development of the frigorífico industry was regarded as urgent. There were extensions to the state sector to include electricity supply, insurance, port services, and state banks. In spite of (indeed, largely consistent with) hostility to the British-owned public utility companies, Batlle's attitude to domestic private capital was generally supportive.

Nonetheless, the reform of rural Uruguay remained an issue of major concern. The 'reformism' of the early twentieth century may have been the work of Batlle and his followers, but it is clear that the problem of the primitive livestock sector as an obstacle to rural progress was perceived much more generally.[8] Although the interval between Batlle's two administrations - the presidency of Claudio Williman - was in several respects a reversion to conservatism, the urgency of rural reform remained common ground to all leaders of the Colorado party. The social instability of the interior had been a major element in the uprising of Saravia in 1904, threatening to carry into the twentieth century the traditional antagonisms and insurrections of the nineteenth.[9] Such a prospect was intolerable to the ruling Colorado party.

The problem was not only the concentration of power in the hands of the latifundistas, possessors of huge tracts of land, which offended the moral basis on which batllista reformism was constructed. It was also that the large estancias were associated with primitive livestock production which prevented an intensification of land use. In the absence of unclaimed public lands or an open frontier, the conversion of natural pasture to crop land provided the only source of land with which to attract agricultural colonists, or to reduce the level of rents to existing arable farmers, or to settle the nomadic rural poor. Contemporaries believed that perhaps one-third of the total land area of the country was fit for ploughing.[10] The obstacle lay in the notorious reluctance of landowners to rent out land for arable use, and their rejection of 'reforms' imposed by a government in which the interests of landowners had little representation. What was at stake for the livestock producers was their claim to be the only 'productive' sector, and therefore to be the only authentic voice on issues affecting rural affairs. For the Colorados, failure to modify the traditional livestock system would perpetuate

social instability and frustrate the attempt to secure a political settlement and their own hegemony. Batlle could not contemplate a direct confrontation with the landowning class over the principle of private property rights in land. Instead, the policies attempted included modest land taxes, partly inspired by the theories of Henry George, state promotion of colonization schemes, the recovery of state lands in private possession, and even a proposal (by Williman) to impose sanctions on landowners who failed to cultivate a proportion of their lands. But not the least of the state initiatives of this period was an attempt to promote the agricultural development of the country, and its exploitation of raw materials, through the incorporation of new techniques and practice employed abroad.

## The Establishment of Agricultural Research

### (a) The Faculty of Agronomy and Veterinary Science 1906-1911

An important feature of the import of technology into Uruguay in the period before the First World War is the extent to which it resulted from a positive decision taken by the state to transform existing practice, rather than a transaction between elements of the capitalist class in Uruguay and the more advanced nations. In this sense it is appropriate to speak of a technology policy; or more exactly, of a development policy in which the incorporation of new technology played a central role. The mode of incorporation followed the same general pattern in the various sectors of the economy; foreign experts were recruited in Europe or North America to set up state-financed institutions, to research local problems, and to train a nucleus of national experts.

The attempt to improve the technical level of agriculture originated at the beginning of the century, and was particularly the work of José Serrato, Minister of Development ( Fomento) in Batlle's first administration, and of Eduardo Acevedo, Rector of the University of Montevideo during 1904-1907 and Minister of Industries in 1911-1913. In 1903, Serrato announced the award of three scholarships for study at the School of Veterinary Science at the University of La Plata in Argentina,[11] and the same year set in motion the process which led to the creation in 1906 of the Faculty of Agronomy and Veterinary Science in the University of Montevideo. This diversification of the university's teaching and research functions (which also included the creation of a Faculty of Commerce), following the introduction of engineering in the Faculty of Mathematics at the end of the 1880s, represented a

major innovation. Acevedo, as rector, made clear the rationale of the new Faculty in 1907: it would contribute to the formation of technically proficient personnel who would modernize and transform a sector hitherto characterized by traditional practice and by a level of prosperity or poverty based on chance rather than scientific principle. Moreover, the sons of rural producers need no longer qualify as lawyers, physicians or actuaries in their search for improvement - thus cutting themselves off from the rural sector - but would be able to study in the new Faculty for their own and the nation's betterment.[12]

At this early stage the bias towards the preferential development of arable or mixed forms of farming was much less well-defined than it became later. Nonetheless, the attempt to secure a closer association between the world of learning and the world of commerce was already offensive enough to the conservative classes. The naive belief of Batlle and his followers that ignorance and prejudice would retreat in the face of reason and educational opportunity ran up against the powerful opposition of those who feared the interference of the state in their own affairs. The reaction came soon after the inauguration of Williman (himself rector of the university before Acevedo) as president in 1907. As part of a general reconstruction of the university, increasing centralized control and practical and professional teaching at the expense of 'pure', the new government abolished the recently created Faculties, reducing their status to Schools of Agronomy and Veterinary Science in 1908.[13] In vain was it argued by Acevedo's successor as rector that their function was

> to create their own literature, adapted to the needs and characteristics of the country, and with it the scientific environment necessary for livestock production and agriculture, our two great industries, to emerge from the crude empirical stage into the solid and real progress which can only be based on science.[14]

The new government declared belief in the training of good foremen or farm administrators, carried out under the supervision of representatives of the rural sector rather than by the state. Otherwise a new class of doctors of agronomy would merely serve to swell the 'intellectual proletariat'.[15] Although this last point proved to be a fairly accurate assessment of the level of demand in the rural sector for qualified agronomists, the reduced status of the Faculty did not in practice make much difference to what was taught and researched. By 1908 substantial progress had been made in establishing the new institution.

When Serrato determined in 1903 to promote agricultural education, he hoped to recruit an agronomist in France to direct the undertaking. The search for a suitable candidate was subsequently widened to other European countries and North America, in conjunction with Acevedo. In 1906, after extensive negotiation over the terms of the contract, Alejandro Backhaus accepted appointment as Director of Agronomy, charged with the task of organizing teaching and research in the new Faculty, and of advising the state on agricultural affairs. Backhaus was from the University of Königsberg, having previously taught at Göttingen, and was also employed as an adviser by the government of Prussia. He was not only a relatively senior appointment in terms of research, teaching and advisory experience, but also proved to be a dynamic administrator with an eye for detail and an intolerance of shortcomings. The demands he placed on the state administration, the university and locally-recruited workers, as well as his intemperate and racist views, brought 'the new Bismarck'[16] into frequent conflicts. But speed was essential if the original design was not to be frustrated by the Williman government, and in that Backhaus was substantially successful.

The new institution had three main functions: to train agronomists, to undertake scientific research, and to stimulate agricultural advance in the country by analyses, tests and reports. Alongside its building in the suburb of Sayago was a model farm which permitted field experiments, and allowed some training of technicians and overseers. But Backhaus entirely agreed with Acevedo as to the greater importance of educating agronomists rather than low-level staff. He had not removed himself from Germany merely to give practical lessons to farm hands: besides, 'to create a good army it is first necessary to train competent officers'.[17]

Backhaus also agreed with the batllistas in their diagnosis of the problems of the rural sector:

> The latifundia are what is characteristic of Uruguay's rural economy ... [They] diminish the productive potential of the country and ensure wealth for a few privileged people and poverty for the rest ... Three-quarters of the land is controlled by the large landowners who devote it to extensive livestock production using primitive pasture. Such a system prevents colonization and the proper distribution of wealth and welfare.[18]

The solution could not be a complete change in the system of land use, but rather a closer association of arable with livestock production, each estancia devoting ten

per cent of its land to crop production - preferably cereals for a few years, then artificial pasture. The problems of the arable sector were thought to be the appropriate methods of cultivation, plant selection and disease control, and the need to secure a suitable labour supply, if possible from the 'cold countries'.[19]

If Backhaus obliged the batllistas in supporting their rural policy, he in turn was given a completely free hand in making appointments in the Agronomy Section of the new Faculty. Of the eight original chairs, five were filled by German nationals, one Belgian, one French, and only that of Physics and Meteorology was held by a Uruguayan.[20] The explanation Backhaus gave of this preponderance of foreign appointments was that the few agronomists available in the country were ineligible because of the full-time nature of the posts, but this was probably no more than a rare exercise of tact.[21] Backhaus was attracted by the possibility of assembling his own team of teachers and researchers to establish his own institute, rather than of incorporating available elements in the country. Indeed quite junior appointments were also made in Germany, where all the machinery and equipment, as well as breeding stock, was acquired, financed by credits from the Bank of Hamburg.[22] Such links with Germany were unprecedented in the university, and helped to make Backhaus, with his sense of mission and driving discipline, a remarkable and not universally welcome phenomenon.

The early years of the Veterinary Section of the Faculty were in many respects a contrast to those of Agronomy. The same search was undertaken through Uruguay's diplomatic representatives abroad for a director, but the urgency felt in the university to begin teaching led to the initiation of courses in 1905 in an annexe of the Faculty of Medicine. The appointment of Daniel Salmon as director brought to Uruguay in 1907 a North American who was 'undoubtedly born to display his evident ability in the calm surroundings of the laboratory'.[23] Salmon had received his doctorate at Cornell thirty years earlier, and had directed the Animal Industry section of the Department of Agriculture in Washington since 1884. He arrived with plans and programmes for the new institute, but did not possess the drive (or find the financial resources) to secure their implementation. Salmon reached Montevideo after Backhaus, by which time the Agronomy building was already under construction. Nor were there funds to recruit experienced academics abroad: all three of the students sent to La Plata in 1903 were appointed to teach in the new Veterinary Section. When Batlle returned to office in 1911 (the same year that Salmon returned to the United States), progress had been very

disappointing: 'the teaching is deficient and the research almost nil'.[24] It was decided to increase expenditure on facilities and attract another eminent veterinary scientist from outside the country as the new director. This time the choice fell on J. Basset, deputy director of the School of Veterinary Science at Alfort, France.

(b) Acevedo's Reforms 1911-1913

The first two years of Batlle's second administration, between inauguration and the financial crisis of 1913, saw the full range of measures intended to introduce modern techniques and knowledge to the rural sector. With Eduardo Acevedo now installed as Minister of Industries there was continuity with the earlier period, but the instruments to achieve the technification of agriculture now changed somewhat. At the Institute of Agronomy, only three of Backhaus' original collaborators still remained by the end of 1911, though the replacements for the others continued to be found in Europe.[25] But it was now the government's view (and that of Backhaus) that the work of the Institute needed to become known more widely. In addition, ministerial agencies governing rural affairs were regarded as in need of reform, since the Divisions of Livestock and of Agriculture of the Ministry of Industries embodied precisely the distinction that batllista policy was intended to eliminate, and there was also 'a formidable tendency for tasks requiring daily and close contact with landowners and farmers to become urban and sedentary'.[26]

The new structure involved the creation of a National Inspectorate of Livestock and Agriculture in place of the old Divisions. This service was to be decentralized and conducted through travelling inspectors (inspectores volantes). It was supplemented by an Animal Health Police, to reduce animal losses from disease and to protect the health of the human population, and a Commission for the Defence of Agriculture which worked to minimize the damage caused by agricultural pests and plagues, especially of locusts. The formal teaching of agronomy was to continue in the Institute, but more attention was to be paid to practical instruction and the training of overseers through the intended creation of six Agricultural Stations (Estaciones Agronómicas) in the interior, and a new school (in addition to the model farm at Sayago) for farm overseers at Toledo.

The new programme thus contained some major initiatives. Perhaps the most startling was the decision to send the first six young agronomy graduates as a

formal commission of agronomists to twelve countries in Europe, North America and Australasia for twelve months during 1911-1912. Their remit was to study the organization and practice of animal husbandry and arable agriculture and derived industries, and to find out under what conditions the country could expect to attract as immigrant colonists or contracted personnel the technical staff and skilled overseers who would be needed. The 1300-page report[27] which they published on their return contains a profusion of proposals and suggestions for Uruguayan agriculture. Their seriousness of purpose is evident, but revealingly, there is a suggestion that the new profession of agronomist was largely dependent on state patronage:

> The Government, in sending us abroad, has united us in a moral commitment to work in the administrative organization of agriculture. when we twelve national agronomists completed our course, some were without a well-defined outlook - a consequence of some defects in our Institute - others went abroad, and there was no opportunity to apply together the knowledge we had acquired together.[28]

The opportunity to work together - perhaps to work at all - as agronomists came from the decision in 1912 to employ the returning students as travelling inspectors. The title was a misnomer, since their essential role was to assess the state and needs of rural production, and to operate a primitive agricultural extension service. This was evidently of enormous importance if small producers were to benefit in any way from the technification of agriculture. Carlos Saralegui was allocated the Departments of Canelones and San José, a diversified agricultural region of small producers. Here the practical problems became evident: 'All the time I tried to show in practical terms the usefulness of the science of agronomy. Being on my own with no help at all means that even the very best intentions fail'. No-one came to his office for consultations, but on farms or in casual meetings he encountered a strong response. When he gave lectures, 'the audience was composed of people for whom I had to omit all technical terms and use the simplest, even childish, words and phrases'.[29] The visits to Cambridge, Rothamsted and many other research centres and model farms must have seemed very distant. Saralegui and his collegues organised practical classes, ploughing competitions and demonstrations of all kinds; but lacking adequate resources, or a class of producers equipped financially and educationally to benefit from their expertise, it is doubtful whether the inspectorate had any appreciable impact.

The other important innovation of the pre-war years was the establishment in November 1911 of three Estaciones Agronómicas, in the Departments of Cerro Largo, Salto and Paysandú. The primary intention was to bring the scientific advances being achieved in the Institute of Agronomy closer to producers: as model establishments they would be a show-piece of what could be achieved (and would be in part self-financing), and would offer training in farm skills without separating the students from the rural environment. By 1913 financial assistance was available for 100 students to attend courses. The director of the new scheme was Backhaus, who had apparently resigned from the Institute in 1910.[30] In spite of his belief in the importance of scientific enquiry, Backhaus had travelled extensively in the interior to discover at first hand the nature of the agricultural problem in the country, and had argued publicly that there should be a model farm in every Department.[31] The original design (when six stations were intended) was for the Paysandú station to operate on Danish lines, breeding pigs, dairy cattle and sheep, employing special modes of soil cultivation, and a cooperative basis of farm management. The Salto station would be concerned with the production and conservation of fruit on the Californian model, contracting technical staff and workers in the United States. Little of this seems to have developed in practice. Backhaus once more looked to Germany for the directors of the individual stations, but his abrasive style no longer produced results with the Uruguayans. By the end of 1912 both Backhaus and the station directors had resigned, and all were replaced by Uruguayans.

Indeed, Uruguay's honeymoon with foreign agricultural experts was (with some outstanding exceptions) apparently ending. Backhaus' eventual successor at the Institute of Agronomy was Professor H. Raquet of the Higher Agricultural Institute at Gembloux, Belgium, appointed at the beginning of 1912. Raquet gave a more practical orientation to the teaching of agronomy, perhaps 'to give it in the opinion of the rural population the prestige which it has until now unfortunately been unable to acquire'.[32] Nonetheless in April 1914 Raquet was replaced by a Uruguayan, Enrique Etcheverry, and the course was further rationalized 'to eliminate abstract material and excessive specialization'.[33] Nor were affairs much happier in Veterinary Science. Basset, appointed as director for three years in October 1912, had his contract terminated in 1914 following 'incidents', and there was rueful reflection on the perils of importing expertise in teaching:

> the greatest error committed in this respect was in having tried to apply here exactly the same methods, programmes of study etc as in similar European institutions, without having taken into account the enormous differences of context.[34]

As we have seen, the batllistas sought the improvement of agricultural techniques not merely to raise average levels of productivity, but rather to effect a gradual reform in the rural economy by diversification and new methods of production. To achieve these more specific ends two further research stations were established in 1911, and a further input of expertise from abroad was obtained. The stations were La Estanzuela, in the Department of Colonia, and the Nursery and National Seed Station of Toledo. A specific technique which it was hoped might prove viable in Uruguay was that of Dry Farming, involving crop production in areas of low or irregular precipitation without irrigation works. Accordingly, while the first commission of agronomists visited Utah to see the experience at first hand, two North Americans developed a programme of experiments at Toledo and La Estanzuela during 1911-1912. Two other initiatives in this period concerned poultry-farming and dairying, at Sayago and La Estanzuela respectively.' Model establishments were again constructed under the direction of three North Americans, but their involvement had ended by 1915.

In spite of the potential importance of such schemes, the central purpose envisaged for the two research stations was to assist in making available to producers better quality seed and young plants. The government was concerned at the low germination rates of much seed, and began to sell imported seed at cost price through its Seed Commission.[35] At the stations, Toledo was initially to specialize in raising young trees, to meet the demand which Acevedo's requirement that landowners should plant a minimum of five trees per hectare was expected to create. In its first year 800,000 young trees were produced, and three times as many in 1913; but like so many initiatives at this time the tree-planting programme fell victim to the financial crisis of 1913-1914.[36] The problems of low rates of seed germination and of selection of plant strains appropriate to Uruguayan conditions were to be investigated at La Estanzuela, though little seems to have been achieved at first. Meanwhile, Baekhaus offered a contract to Alberto Boerger, then working in the Faculty of Agronomy at the University of Bonn, to undertake research in plant genetics.

When Boerger arrived in 1912, Backhaus (as Inspector of the Estaciones Agronómicas) intended that he should work at the proposed station at Durazno, which was never in fact established. Boerger, contracted for three years and anxious not to lose a crop year, began work at Toledo, and then in 1913 moved to Cerro Largo. Clearly impressed by the quality of his work, the government designated him Director of La Estanzuela in March 1914.[37] Under Boerger, the institute developed as a major research centre of international renown. In 1917 it was visited by the Director General of Agriculture and Agricultural Defence of Argentina, who described it as 'the best organized institute of its kind in South America, to be envied by many first rank European institutions'.[38] By 1941 it listed 332 publications, of which 77 were published outside Uruguay, including 29 in Germany and 6 in Great Britain.[39]

Boerger's principal interest was in improved plant selection: 'to find them by experimental observation or biological selection is perhaps the most important task of contemporary agricultural research in the River Plate countries'.[40] At least for the first fifteen years, most of the experimental work concerned the application of theoretical plant genetics to the country's main crops. Comparative tests of over forty strains of wheat revealed the clear superiority of native over imported types. The same general conclusion was reached for oats and maize, whereas the adaptability of barley gave an advantage to Chilean and German strains. Field trials necessarily involved Boerger's team in the study of related matters: sowing seasons and methods, rotations, and the use of fertilizers, as well as problems relating to forage crops and alfalfa. The value of the programme was limited, however, by recognition of the great variability of soil types within Uruguay but reluctance, in part perhaps because of a lack of resources, to commission a programme of soil analysis. That decision had an obvious bearing on the attitude of La Estanzuela to the use of fertilizers in the 1920s (see below). Boerger insisted however that agricultural progress in Uruguay had been achieved largely by the provision of good seed. 'In such a markedly livestock-producing country in which a short while ago there was still an antipathy towards arable production on the part of some landowners, we may still regard as "miraculous" the decisive effect of "good seed" on the economic structure of the country.'[41]

Searching for Raw Materials

An important element of the reformist economic policy of the Colorado party before the First World War was evidently the diversification of the economy, not

merely to resolve the rural question and to buttress the economy of Montevideo, but also to enhance the potential of the economic structure of the economy as a whole. The batllistas did not initiate protectionism - and indeed the incidence of import tariffs showed no increase between 1903 and 1914 - but there was continuous support for industrial initiatives in this period.[42] Yet the policy statements of the time had little to say about commercial vulnerability as such. Import substitution was pursued very much as an end in itself, to increase the level of self-sufficiency by displacing items from the import bill.

Consistent with this approach was the view held strongly by Acevedo that Uruguay was potentially rich in raw materials (in addition to those of rural sector origin), and that the resources of the state were required to make them commercially available. During 1911-1912, therefore, three new institutions were created, each to be directed by experts contracted abroad, whose task was to investigate the nature and commercial viability of under-exploited natural resources.

Uruguay's coastal waters of the South Atlantic and the River Plate, as well as inland rivers, are rich in fish stocks. At the beginning of the century there was little systematic information about these stocks, and there was almost no commercial utilization either for domestic consumption or for export. In 1909, Andrés Bouyat, a French national who had taken up the chair of Zoology in the Faculty of Agronomy the previous year, was commissioned by the government to report on the potential for a fishing industry. The report was enthusiastic.[43] As a result, the Instituto de Pesca was created with modest resources under the direction of Nelson A. Wisner to promote the possibility of a commercial fishery. The task was initially perceived by Wisner as that of conservation, through the study of the natural history of the fish stocks, and by recommending appropriate restrictions on their utilization.[44] More ambitious plans for fish breeding, installation of cold storage facilities, and for increased production by the Instituto as well as by private capital, were abandoned in the aftermath of the crisis on the eve of the First World War. Neither the Instituto nor the very limited private sector involvement recovered subsequently,[45] and the initiative was a comprehensive failure. Not until the 1970s did fishing become an economic activity of significance.

The two other new organizations, the Instituto de Geología y Perforaciones (IGP) and the Instituto de Química Industrial, were created together in 1912 with

functions which were to some extent complementary, and which perfectly exemplify the role of the state in enhancing the profitability of private capital. The intention was that they would systematically explore the mineral resources of the country, and by the chemical analysis of these (and other) materials encourage private capital in the direct exploitation of them and in manufacturing industry in general. In particular it was hoped that the geological survey might reveal workable deposits of oil or coal.

The IGP recruited five scientists and engineers abroad, including its director Mauricio Lamme.[46] There were high expectations of its work. The message from Batlle and Acevedo proposing its creation stated bluntly that

> the country has several substantial sources of wealth which only require the intervention of the State to begin functioning properly. The mining industry is one such. Only the public authority can undertake the costly studies necessary for their exploitation. In their absence the treasures in our soil remain unexploited and even unknown ... It is therefore necessary to begin the geological study of the national territory.[47]

The belief in Uruguay's mineral wealth had recently been reinforced by a favourable report by the geologist Carlos Guillemain, commissioned by the German government.[48] The achievements of IGP, however, did little to justify this optimism (or indeed to disperse it). It began by analysing known deposits, for example manganese in Rivera and Colonia, marble in Maldonado, and granite in Minas. Although small quantities of gold were still mined up to the First World War, IGP saw more commercial possibility in increased exploitation of base minerals (such as sand, gypsum, talc) than in the continued pursuit of precious metals.[49]

The principal tasks were to chart the geology of the country, and to discover a domestic fuel supply that would reduce Uruguay's complete dependence on imported supplies which accounted for 10 per cent of the import bill in 1908-1910.[50] Guillemain's report had given encouragement to the view that coal deposits could be expected near the Brazilian border, and in 1915 Lamme announced that exploration work for coal (and oil) was about to begin. The resulting report in 1918 of the new director of IGP, Llambias de Olivar (whose private company had received a state subsidy in 1909 to aid its search for coal), indicated the probable location of low-grade deposits, but there were no further developments. Nor did the work of preparing a detailed geological survey begin,

'because of a lack of personnel and resources. There is not a single geological institute in the world which has so few staff as ours'[51] - a deficiency which was never made good. When the Libro del Centenario was published in 1925, the lack of a complete study of the geological characteristics of the country was still blamed for the failure of a mining industry to have developed, along with deficiencies in the transport system. Indeed the author of the section on geological formations made scant reference to the work of IGP, basing himself instead on the publications of Carl Walther, appointed by Backhaus to the chair of Geology in the Agronomy Institute in 1908.[52]

The fate of IGP proved to be in direct contrast to that of its twin, the Instituto de Química Industrial (IQI). Acevedo, whose conception it was, planned four functions for it: to study and improve the organization of industries in the country, discovering uses for waste products; to encourage the development of new industries, through the analysis (in conjunction with IGP) of domestic raw materials; to be available to existing industry as consultants in the analysis of inputs or output; and to propagate technical advances through publications and lectures.[53] In his first annual report, the director doubled the number of potential functions, but only two represented new initiatives: the first was to offer instruction to a limited number of students; the second, of great significance, was that IQI should begin production of a limited range of chemicals both for research purposes and to earn revenue so that it might eventually be self-financing.[54] Neither had by then commenced.

The new institute did not begin well. It was intended to have (like IGP) six technically-qualified personnel from abroad, but only three were in fact appointed, for limited terms of three years. J.E. Zanetti, born in Cuba, was named Director. Latham Clarke, also from Harvard, was effectively his deputy. Carlos Duzaine Hansen, a graduate of the University of Copenhagen, was an assistant. Within six months Zanetti had returned to the United States where he remained, apparently for personal reasons. Hansen also resigned in 1913. By May 1914 IQI was occupying its third (and still provisional) premises. Equipment ordered from the United States, Germany and Holland was delayed in arriving. The circumstances were not propitious, yet the career of Latham Clarke (like that of Boerger) was to be a vindication of the policy of recruiting abroad. Clarke received his doctorate at Harvard in 1905, at the age of 24, and he apparently continued to work there apart from a period in 1909-1910 in Berlin and Dresden.[55] He was named Director

of IQI in mid-1913, and held the post until 1926, apart from a period spent in the United States in 1916-1917 in protest at the policies of Viera's government. Subsequently he was a member of the directorate of the Administración de Combustibles, Alcohol y Portland (ANCAP), and died in Uruguay in 1962.

The early work of IQI was inevitably modest, in keeping with its resources. Perhaps the most important analysis undertaken was of numerous samples of peat, which were found to contain so much mineral material as to be of little commercial value. Samples of sand were analysed, but were found to be low in silica and high in iron, and therefore unsuitable for the manufacture of glass. Boiler feed water was analysed with a view to recommending methods of preventing corrosion and scale. A range of paints was analysed in order to discourage adulteration. Experiments were conducted on samples of oil shale from the Department of Cerro Largo, but they proved inconclusive. A variety of other investigations was carried out on domestic and imported materials (for example limestone and coal). During 1914, 569 samples in all were submitted to IQI for analysis and 220 reports were prepared.

As early as 1914 Clarke expressed himself extremely anxious to begin production of sulphuric acid, which was then imported at a price he considered excessive.

> This acid is the key to industries which involve chemical processes; it figures directly or indirectly in the manufacture of almost all commercial products ... The industrial prosperity of a nation is gauged by the volume of sulphuric acid it uses ... It is my opinion that we should manufacture it in this country, and moreover that we should sell it at a low price, to stimulate and ease its use ... Such a factory is especially important if we are going to utilize some of the raw materials of the country which at the moment have no use.[56]

This was undoubtedly a main objective for Clarke, but in the context of pre-war financial crisis and war-time shortages it had to be suspended. Indeed it is remarkable that IQI survived the crisis as well as it did, a fact which Acevedo attributes to the courses of study it had instituted and the right of students to complete them.[57] But by 1915 Clarke had another argument with which to sustain IQI's position: 'No politically independent country is so in reality without its economic independence. It must try to manufacture with its own raw materials all the products required by its industry'.[58] So the Factory Section of IQI began production in 1915, in tiny quantities and doubtless at very high cost, of a number

of chemical products unobtainable during the First World War. They included ether for anaesthetics, sodium sulphate, pure alcohol, collodion, and many others. Production was a technical and commercial success, the revenue allowing IQI to increase the volume and range of its output. Clarke's disagreement with government policy in 1916-1917 was concerned with its interference in IQI's teaching activities, not with its production programme, which evidently greatly enhanced IQI's, or Clarke's, prestige in the opinion of the government.[59]

At the end of the war the production of many of these chemicals ceased, but the importance of IQI as an industrial producer effectively dates from 1918 when its first sulphuric acid factory was authorized. Two years later production of superphosphates was proposed, and its approval in 1921 also required an increase in sulphuric acid capacity. About forty chemicals were produced in commercial quantities during the 1920s, including nitric acid, various sulphates and sulphides, and hydrochloric acid.[60] Clearly sulphuric acid was basic to the development of this chemical industry. Sales of the acid itself increased from less than 10 metric tons in 1919 to 98 tons and 208 tons in the two succeeding years.[61] Thereafter the rate of growth was slow: in 1921 it was lamented that 'consumption of sulphuric acid in the country is insufficient to sustain activity in the factory throughout the year', keeping production costs as high as £4 per ton.[62] Nonetheless in 1930 capacity was further increased and production expanded rapidly in the 1930s, exceeding 1000 tons in 1938. During the 1920s, however, it is evident that expectations of increasing demand for sulphuric acid were primarily based on its use as an input in the production of superphosphates, but that market was to prove much more difficult than anticipated (see below).

During the 1920s IQI remained active in the search for a national fuel supply, but attention was diverted away from domestic deposits of coal and shale, whose yield was disappointing, to the potentialities of alcohol derived from domestically-produced maize. There were two reasons for this interest. The first was the long-standing attempt by the state to organize a monopoly of the supply of alcohol in place of the private monopoly of the distilleries of the French industrialist Julio Meillet. In 1912 Batlle's first attempt to expropriate the distilleries was defeated, tariff protection was removed, and Meillet proceeded to dominate the import trade. When Batlle renewed his bid to acquire the distilleries in 1921, Latham Clarke acted as a consultant to the government in the matter. Indeed, had the state been successful in securing a monopoly, in the proposed law of 1923, the

administration of it would have been vested in a new Fábrica Nacional de Productos Químicos, effectively a re-designated IQI.

The second reason for the importance of alcohol was the close attention paid to French experiments in the use of mixtures of alcohol and petrol as fuel in internal combustion engines. This was particularly the research interest of Angel Goslino, appointed as Hansen's replacement in 1914 and Clarke's successor as Director. Goslino had published in 1917 some preliminary conclusions on the potential of alcohol as a fuel, but the Toulouse trials in May 1923 (which Goslino attended) evidently stimulated renewed interest, as four months later trials were held in Montevideo using alcohol and petrol mixed in equal proportions in twelve unmodified vehicles. Though the results were apparently satisfactory, and further research reports appeared later in the 1920s, no further progress was made. Goslino's attention turned to the possibility of developing a gas-fuelled vehicle, and after attending further tests in France in 1927 Goslino acquired a lorry for trials in 1928.[63] However, with the creation of ANCAP in 1931 the state assumed exclusive rights of importing and refining crude oil, and Goslino was appointed general manager.

The Fertilizer Question

A feature of the technological backwardness of the rural sector in contemporary Uruguay is that the problems - whether of the limitations of natural pasture, or the incidence of plant or animal disease, or of variations and deficiencies in the composition of the soil - have been defined as such since the early years of this century. Indeed, systematic research on a wide range of questions had begun by 1914. The economic difficulties of recent decades may have served to conceal the level of expertise reached earlier. Thus it was asserted in the 1960s that

> despite the obvious importance of fertilizers in raising agricultural production, Uruguay continues to employ only very small amounts ... Agronomic research with fertilizers is relatively new in Uruguay, and trials are not yet of long enough duration to provide reliable data from which to develop recommendations for farmer use.[64]

Though the first of these propositions is true (if simplistic), the second is decidedly misleading; research on fertilizer use had begun over fifty years before. But remarkably, this research produced a confrontation between two of the most

successful institutions of the pre-war period, Boerger's La Estanzuela and Latham Clarke's IQI.

Although the last quarter of the nineteenth century produced a number of publications in Uruguay on fertilizers, no serious work was done until the arrival of the German agronomists in 1906-1907. Two in particular, Dammann and Schroeder, published papers on fertilizer use,[65] and their findings were supplemented by those of the geologist in the Faculty, Walther. But the most notable contribution to be made on the value of fertilizers to Uruguayan farmers came from Boerger and his associates at La Estanzuela. The technique he adopted (much influenced by the example of E.J. Russell at Rothamsted) was to establish permanent experimental fields in which over an open-ended number of crop-years the increased yields derived from applications of NPK (nitrogen, phosphorus and potassium) and combinations of two of the three were assessed against yields on unfertilized land. The crops so tested were wheat, maize, chick-peas, potatoes, linseed and barley. The technique was thus not based on making good deficiencies of nutrients in the soil based on chemical soil analysis. Boerger placed very little faith in that approach, although he was well aware from the work of other agronomists that the soil types of Uruguay are characterised by great heterogeneity, but that in terms of plant nutrients there is a generalised deficiency of phosphorus ($P_2O_5$).[66] Emphasis was placed instead on the actual yields to be obtained in field conditions. The tests began in 1915, as soon as Boerger arrived at La Estanzuela, and by 1939 data had accumulated from four complete cycles of a six-year crop rotation.

The definitive statements of Boerger's results came in his two major books, published in 1928 and 1943.[67] In fact Boerger found little reason to alter his conclusions in the intervening period. In terms of yields, the application of phosphates in soluble form gave better results for all six crops compared with the unfertilized land. Potassium had a negligible effect on yields. Nitrogenous fertilizer appeared to be of greater utility in 1943 than it had fifteen years earlier.[68] But this apparent testimony to the value of phosphates came heavily qualified. First, the average increased yields over twenty-four years for Uruguay's two main crops, wheat and maize, were only 19 percent and 16 percent respectively following applications of NPK. Second, as a determinant of yields, climatic variation was of far greater significance than fertilizer. Third, without accompanying changes in cultivation techniques, especially weed control, the use of fertilizers by the generality of producers might give very poor results. Fourth,

Boerger emphasised that fertilizer use was an economic rather than a technic question: it depended not on the level of nutrients in the soil, but on the increas yield that fertilizers would make possible, the market value of that increas output, the financial cost to the producer of the fertilizer, and the risk that b weather would convert the potential gain into an actual loss.[69]

Parallel research by other agronomists tended to confirm Boerger's conclusions. 1931 Jorge Spangenberg published results derived from his work in the Faculty Agronomy at Sayago, which seemingly proved that for wheat (the most extensive grown crop), the selection of 'pedigree' seed was the most important factor raisi yields in the 1920s. Soil analysis, he argued, should be more concerned with t physical structure of the soil, and the levels of humus and acidity/alkalinity (pH than with the presence or absence of plant nutrients which by themselves had litt value as indicators of productive capacity.[70] Even more damaging to the case f fertilizer use was the report by Gustavo Fischer, Boerger's collaborator at l Estanzuela since 1918, on the results of experimental pasture fertilization.

> Although from a scientific point of view the changes in the production and composition of the vegetation are attractive, the same cannot be said from an economic standpoint. The irregularity of the results, and the doubtful value of clovers with short periods of growth in place of grasses, do not encourage the improvement of our pastures through fertilizers while we are unable to ensure a satisfactory rate of return through sowing good, well-adapted pastures, and above all pulses. The procedure is onerous, and the producer who prefers to rent an additional pasture rather than undertake risky operations with fertilizers is quite right ... While the income is so small, the private sector looks at accumulated fertility as a mineral deposit, and engages in an extractive industry.[71]

Many of these results were still unknown, of course, when IQI sought governmen funding to begin production of superphosphates in 1920, using deposits of burnt bones at the old meat salting plants (saladeros) as raw material. But the early results at La Estanzuela - which were known - did not encourage any generalized use of superphosphates, in spite of the deficiency of phosphorus in the soil. The point was made during the parliamentary debate on the project that although the chemists would manufacture the fertilizer, it was not they who were conducting the agricultural trials.[72] Thus did the two outstanding technological initiatives of the batllistas come into conflict. IQI needed an expanding market fo superphosphates to take up some of its excess sulphuric acid capacity and provid

revenue for the expansion of IQI's largely self-financed activities. Boerger refused to make any general recommendation to farmers that they should use the material. In 1922 a special commission of the Ministry of Industries was set up to examine the issue, with Boerger as a member, but its work was inconclusive. To stimulate demand, IQI distributed samples and leaflets recommending its product. In 1926 credits for fertilizer purchase became available, and between 1928 and 1930 IQI organised a free service of soil analysis which completed over 330 tests.[73] Consumption of superphosphates was slow to increase until 1928, and did not exceed 1000 tons until 1931. By then a further clash with the agronomists had occurred, at an international congress held in Montevideo in 1930, at which Spangenberg delivered his criticism of the 'plant nutrients' approach, while IQI reported the phosphorus and calcium deficiencies revealed in their soil surveys. Once more the debate failed to find common ground, except in the need for more research.[74]

Nonetheless a partial rapprochement was achieved in the 1930s. Fischer, of La Estanzuela, became a member of the directorate of IQI, and from 1934 collaborative experiments were carried out in addition to the permanent trials at La Estanzuela. The general conclusion reached was that use of superphosphates was justifiable for high-value crops provided that weeds were controlled.[75] Boerger seems to have remained sceptical.[76]

While the fertilizer question remained a major preoccupation for IQI, the 1930s also saw a more fruitful relationship develop between the Institute and the rural sector over a range of problems, especially concerning production and use of chemicals for control of plant and animal disease. In 1932 production of copper sulphate began for use in the control of peronospera, an epidemic of which damaged vineyards two years later. IQI's journal which began to appear in 1935 was wholly devoted to agricultural questions. Paradoxically, IQI appears to have lost contact with manufacturing industry in its capacity as consultant in the post-Depression period.

## Conclusions

Although very little material is available on which a comparative assessment could be based, it seems likely that the Uruguayan experience of technology incorporation in the decade before 1914 was unusual.[77] The mode of incorporation

was distinctive, relying essentially on encouraging European or North American experts to work in Uruguay on short-term contracts. The number who did so was not small: about 55 such individuals may be identified in the institutions discussed in this paper, a significant element in a society of about one million inhabitants. It was intended that they should apply their learning to the study of Uruguayan conditions, particularly to neglected natural resources, and communicate their skills to those Uruguayans who would take over when contracts ended. The financial burden of this did not go uncontested in the legislature, but the batllistas were determined to secure well-qualified personnel.[78] The nationality of the experts showed a clear preponderance of Germans, to be explained in part by Backhaus' appointment, rather than as a result of government policy. There was no British representation at all, which to a limited extent may have reflected the antipathy of the Foreign Office for Batlle, but had much more to do with the clear lead of the United States and continental European countries in technical studies in institutions of higher education.

A feature of the introduced technology was how little contribution it made to the problems of the livestock sector. Some studies were made of natural pasture, and of the cultivation of fodder crops, but they were little more than incidental to the task of modernizing the arable sector. That objective was central to Batlle's plan to reduce the overwhelming weight of extensive livestock production in the rural economy. The resources of the state were thus deployed to diversify the rural sector, and to strengthen the urban economy, by supporting small producers who occupied subordinate positions in the structure of dominant class interests. Modernization of the livestock sector was expected to occur indirectly through the incorporation of colonists and the devotion of more land to arable production.

In view of the 'extensive production practices and low levels of technology'[79] which still characterize agriculture, the continuing absence of a viable technology for profitable improved pasture exploitation, and the inability to discover new mineral resources, it is easy to describe the initiatives of 1906-1912 as a failure. Undoubtedly expectations were exaggerated and projects were under-financed, especially after funding was cut in 1913-1914. There was naivety in assessments of what small-scale projects might achieve, as in underestimates of the resistance of the large-scale cattle producers to incursions in their province. Not until 1964 did the number of entrants to the Faculties of Agronomy and Veterinary Science each exceed 100, still representing together only 10 percent of admissions to the

university.[80] On the other hand, and largely through the inspiration of two individuals, significant centres of research and technical expertise were established in agronomy and (to a lesser extent) industrial chemistry, which were of long-term value. To explain the inadequacy of these advances in subsequent periods exceeds the bounds of this paper, but four elements might be singled out: the growth of research and development expenditures in the industrialized countries and the international commercialization of the resulting technology; the acquiescence of the producing class in Uruguay in its technological incapacity; the under-representation of the landowning class in the Uruguayan state; and the decline of the batllista inspiration in Batlle's political heirs.

## FOOTNOTES

* The author gratefully acknowledges the financial support of the Nuffield Foundation for the research on which this paper is based.

1. The literature on technology transfer and technological dependence is extensive. See for example Nathan Rosenberg, 'Economic Development and the Transfer of Technology: Some Historical Perspectives', Technology and Culture, 11 (1970); A.O. Herrera (ed), América Latina: Ciencia y Tecnología en el Desarrollo de la Sociedad (Santiago de Chile, 1970); the proceedings of a conference on the application and adaptation of foreign technology in Latin America in Nueva Sociedad, 8/9 (September-December 1973); and Dilmus D. James, 'Bibliography on Science and Technology Policy in Latin America', Latin American Research Review, 12:3 (1977), 71-101. Studies of the development of science and technology in Latin American countries include Nancy Stepan, Beginnings of Brazilian Science: Oswaldo Cruz, Medical Research and Policy 1890-1920 (New York, 1976), and Frank Safford, The Ideal of the Practical: Colombia's Struggle to Form a Technical Elite (Austin, Texas and London, 1976). The international transfer of agrarian technology is the subject of Yujiro Hayami and Vernon W. Ruttan, Agricultural Development: An International Perspective (Baltimore and London, 1971), part IV, and R. Evenson, 'International Diffusion of Agrarian Technology', Journal of Economic History, 34 (March 1974), 51-73.

2. M.H.J. Finch, A Political Economy of Uruguay since 1870 (London and New York, 1981), p. 185.

3. Comisión Especial para Fomento de Laboratorios Tecnológicos e Investigaciones Industriales, Antecedentes Relacionados con la Creación en el Uruguay de un Centro de Asistencia Técnica para la Industria (Montevideo, 1956); Finch, Political Economy, p. 185.

4. Danilo Astori, Los Industriales y la Tecnología: Un Análisis de las Actitudes de los Empresarios Uruguayos (Centro Interdisciplinario de Estudios sobre el Desarrollo Uruguayo, Montevideo, 1980), p. 52.

5. See Danilo Astori, La Evolución Tecnológica de la Ganadería Uruguaya 1930-1977 (Montevideo, 1979); Finch, Political Economy, pp. 110-122.

6. Centro de Investigaciones Económicas - Centro de Informaciones y Estudios del Uruguay, El Problema Tecnológico en el Uruguay Actual: Estudio de Casos (Montevideo, 1981), p. 10. The level of funding of research and development activity at the beginning of the 1980s is estimated at 0.2% of GDP; of this amount 67% is provided by the public sector, and 16% is externally financed: UNESCO, Informes Nacionales y Subregionales de Política Científica y Tecnológica en América Latina (Paris, 1983), p. 239.

7. For a discussion of batllismo and further bibliography, see Finch, Political Economy, chs. 1, 2 and 7.

8. José Pedro Barrán and Benjamín Nahum, Batlle, Los Estancieros y el Imperio Británico. Vol. II: Un Diálogo Difícil 1903-1910 (Montevideo, 1981), 75-136.

9. Barrán and Nahum, Batlle, los estancieros, II, 52.

10. Barrán and Nahum, Batlle, los estancieros, II, 87. That figure is in line with a more recent estimate of 31% to 39%, though the proportion capable of bearing an annual crop is only 18% to 23%: Plan Nacional de Desarrollo Económico y Social - Ministerio de Ganadería y Agricultura, CIDE - Sector Agropecuario, Los Suelos del Uruguay, Su Uso y Manejo (Montevideo, 1967), p. 74.

11. Juan Oddone and Blanca Paris, La Universidad Uruguaya Desde el Militarismo a la Crisis (1885-1958) (4 vols., Montevideo, 1971), II, 580-581.

12. Eduardo Acevedo, Anales Históricos del Uruguay (6 vols., Montevideo, 1934), V, 371-372.

13. Oddone and Paris, Universidad, III, 98. In 1909 the Schools were re-designated National Institutes. Not until 1933 did they regain their status as Faculties of the university.

14. Report to Commission of Chamber of Representatives, quoted in Oddone and Paris, Universidad, I, 87.

15. Communication of the Executive to the General Assembly, 14 May 1907, Diario de Sesiones de la Honorable Cámara de Representantes (DSHCR), 192 (1907-8), p. 866.

16. La Tribuna Popular (Montevideo), 11 October 1907, cited in Oddone and Paris, Universidad, II, 570. Oddone and Paris cite much additional material, especially from the archives of the university, on the appointment of Backhaus.

17. Revista de la Seccion Agronomía de la Universidad de Montevideo (RSAUM), 2 (December 1907), 228.

18. Alejandro Backhaus and José Virginio Díaz, 'Experiencias y Principios de la Colonización Aplicados a la República Oriental del Uruguay', RSAUM, I (July 1907), 95.

19. Backhaus and Virginio Díaz, 'Experiencias y principios', 111, 122-123, 139. Arriving in a country with a large immigrant population preponderantly of Italians, Backhaus expressed his feelings frankly: 'Neapolitans have a pronounced characteristic. They prefer to be independent, taking jobs which are unproductive to the State: flower-sellers, lottery-ticket vendors, greengrocers, itinerant peddlers etc. For these reasons we believe that the immigration of Italians is not what Uruguay most needs or is suited for, besides which Italians have the highest proportion of anarchists, revolutionaries and dissolute individuals who are dangerous for the true progress of the State' (p. 122). Italians from the north were however partially exempted from this indictment.

20. Backhaus and Virginio Díaz, 'Experiencias y principios', 212.

21. RSAUM, 2 (December 1907), 229-230.

22. Oddone and Paris, Universidad, II, 564-567.

23. Angel Bianchi Frizera, 'Escuela de Veterinaria de Montevideo: Bosquejo Histórico', Anales de la Facultad de Veterinaria, 4:2 (October 1943), 345.

24. Communication of the Executive to the Chamber of Representatives, DSHCR, 214 (1911), p. 484.

25. Their experience might, however, be more extensive. Teólogo Kessissoglou was appointed to the chair of Agriculture in February 1912, having previously taught at the Agricultural Institute of Kweilin in Kwang-si Province, China, during 1909-1911. His extensive report of the production of rice and proposal that it should begin in Uruguay (Revista del Ministerio de Industrias, 1:5 [October 1913]) had little effect until the 1930s.

26. Memoria del Ministerio de Industrias (MMI), 1911, p. 5.

27. Ministerio de Industrias, Notas Sobre la Organización Agronómica de Doce Paises en Relación a las Condiciones del Uruguay (2 vols. Montevideo, 1913-1914).

28. Ministerio de Industrias, Notas sobre la Organización Agronómica, II, 584. The other six agronomists were the following year's graduates, with whom the first commission met up in the US on their way home. At least four commissions of young agronomists made study visits abroad, but no other was as extensive as the first.

29. MMI, 1913, pp. 296-300.

30. Oddone and Paris, Universidad, II, 572.

31. MMI, 1911, p. 347. Backhaus also shared with Batlle an anxiety that Uruguay should be setting an example to other nations: 'The fundamental ideas [of the Estaciones Agronómicas] differ from the principles and experience of similar institutions in other countries ... but it is very likely that, as with the Escuela Superior de Agronomía, where new principles are used which were subsequently praised by many countries and scientific authorities, so the Estaciones Agronómicas of Uruguay may establish a new departure of national and world importance'.

32. MMI, 1913, p. 434.

33. MMI, 1914, p. 986.

34. MMI, 1914, p. 978.

35. Acevedo, Anales, V, 577; José Pedro Barrán and Benjamín Nahum, Batlle, Los Estancieros y el Imperio Británico. Vol IV: Las Primeras Reformas 1911-1913 (Montevideo, 1983), 133.

36. Acevedo, Anales, V, 577.

37. This account of Boerger's arrival is from Alberto Boerger, Observaciones Sobre Agricultura (Montevideo, 1928), 9-13, and differs from Acevedo's version (Anales, V, 576).

38. Boerger, Observaciones, 38-39. In 1919 it was renamed the Instituto Fitotécnico y Semillero Nacional 'La Estanzuela'; and in 1961, after Boerger's death, it became the Centro de Investigaciones Agrícolas 'Alberto Boerger'.

39. Alberto Boerger, Investigaciones Agronómicas (3 vols., Montevideo, 1943).

40. Boerger, Observaciones, p. 5.

41. Boerger, Observaciones, p. 567.

42. Finch, Political Economy, p. 168.

43. The conclusions of the report are quoted in Avelino C. Breña, El Problema Pesquero en Uruguay (Montevideo, 1946), p. 105.

44. MMI, 1912, p. 309; Acevedo, Anales, V, 587.

45. El Libro del Centenario del Uruguay 1825-1925 (Montevideo, 1925), p. 226; Breña, Problema Pesquero.

46. It is not known by what means they were recruited. The majority were apparently from the US, though the Mining Engineer, Rolf Marstrander, was Norwegian.

47. DSHCR, 215 (1912), p. 57.

48. The six-month study was undertaken in 1907, and the report apparently published in Zeitschrift für Praktische de Geologie (Berlin, September 1910): Libro del Centenario, pp. 234, 241.

49. MMI, 1913, p. 567.

50. The proportion increased to one-quarter in the late 1920s, and to one-third in the early 1930s: Finch, Political Economy, Table 6.3.

51. Lamme, quoted in Acevedo, Anales, VI, 60. Acevedo claimed that in addition to the pre-war financial crisis, IGP suffered from budget cuts imposed by Viera's government (1915-1919), 'which condemned the technical contracted staff not to move out of Montevideo and the equipment to remain in the sheds indefinitely' (V, 585).

52. Especially 'Las Líneas Fundamentales de la Estructura Geológica de la República', Revista del Instituto Nacional de Agronomía (1919).

53. MMI, 1912, pp. 10-11.

54. Memoria del Instituto de Química Industrial, 1 July 1913 - 30 June 1914, p. 4.

55. See the excellent account by Jorge Grunwaldt Ramasso, Historia de la Química en el Uruguay 1830-1930 (Montevideo, Instituto Histórico y Geográfico del Uruguay, 1966), p. 144.

56. Latham Clarke, in MMI, 1914, pp. 1056-1057.

57. Anales, V, 586. In fact, however, formal teaching at IQI did not begin until 1915.

58. Latham Clarke, quoted in, 'El Instituto de Química Industrial', Anales de la Asociación de Farmacía y Química del Uruguay, 33: 11 (1930), 253.

59. See, for example, the exchange between Deputies Andreoli and Secco Illa, in which it was not disputed that IQI had been very successful; but it was suggested by Secco Illa, opposed to public enterprise, that it was largely due to the high quality of leadership at IQI, which might not continue: DSHCR, 289 (1921), p. 490.

60. It should be noted that the majority of IQI's products did not receive tariff protection.

61. Anuario Estadístico.

62. R. Gatti and F. Engel, Las Fábricas del Instituto de Química Industrial (Montevideo, 1927), pp. 108-109.

63. Grunwaldt, Química, pp. 155-157; Cámara de Representantes, Monopolio del Alcohol (Montevideo, 1923), esp. pp. 79-96, 133-139; L. Clarke, F. Engel and R. Gatti, Investigaciones Sobre las Naftas Empleadas en el Uruguay (Montevideo, 1926); Luis Batlle Berres, El Batllismo y el Problema de los Combustibles (Montevideo, 1931).

64. Russell H. Brannon, The Agricultural Development of Uruguay (New York, 1967), pp. 114, 117.

65. For example, Hans Dammann and Juan Schroeder, 'Ensayos de Cultivo, 1. Ensayo Permanente de Abonos', RSAUM, 4, (1908): and 'Ensayos de Cultivo con Diferentes Abonos Fosfatados', Revista del Instituto de Agronomía de Montevideo, 5 (1909).

66. Boerger, Observaciones, pp. 16-22 and ch. 6.

67. Observaciones and Investigaciones, respectively.

68. Boerger, Investigaciones, I, 491-492.

69. Ibid., I, 533-537.

70. Jorge Spangenberg, 'Contribución al Estudio del Problema de los Abonos en el Uruguay', Revista de la Facultad de Agronomía, 5 (July 1931), 131-202.

71. Gustavo Fischer, 'Experiencias Recientes de Abonado en el Uruguay', Archivo Fitotécnico del Uruguay, 3:1 (1937), 26-47, quoted in Boerger, Investigaciones, I, 499-500. Fischer's analysis of the problem of pasture improvement remains substantially valid for contemporary Uruguay.

72. DSHCR, 289 (1921), p. 485.

73. Grunwaldt, Química pp. 158-9; S. Elorza, 'Hay Que Abonar Nuestros Suelos Con Superfosfato de Calcio', Instituto de Química Industrial, 1:1 (April-May 1935), 24-38.

74. Spangenberg, 'Contribución'; Silvio Molteda and Sixto Puga, 'Contribución al Estudio Físico y Químico de los Suelos Uruguayos'. The debate is reported in Segundo Congreso Sudamericano de Química, Montevideo, 16-21 Diciembre de 1930: Actas y Trabajos, I, 94-98.

75. Gustavo J. Fischer, 'El Empleo de Abonos Fosfatados', Revista del Instituto de Química Industrial, 12 (May-June 1938).

76. Investigaciones, I, 498-499.

77. Research on rural technology in Argentina had similar preoccupations to the Uruguayan experience but (in spite of the earlier establishment of Faculties at the University of La Plata) may have lagged behind. 'Before the 1956 creation of the Instituto Nacional de Tecnología Agropecuaria, public research and extension services were grossly inadequate. Five research stations were created in 1912 ... Research on wheat was conducted from 1912 on; late in the 1920s aspects of corn and linseed cultivation were also studied. Research was concentrated almost entirely on seed improvement ... Public and private research on livestock production was practically nil, in spite of the influence and wealth of cattle ranchers': Carlos F. Díaz Alejandro, Essays on the Economic History of the Argentine Republic (New Haven and London, 1970), p. 190. In Colombia, on the other hand, the practices of contracting foreign specialists and of sending students abroad had been much employed by the 1880s, by which time university studies in agronomy had begun, though they were not properly established until after 1916: Safford, Ideal of the Practical, esp. chs 6 and 8.

78. See, for example, DSHCR, 214 (1911), pp. 493-494.

79. Brannon, Agricultural Development, 106.

80. Marcha (Montevideo), 19 March 1965. Sixty percent of students were admitted to study law, notarial studies and medicine.