Dissertations

THE ADOPTION AND DIFFUSION OF THE COMBINED HARVESTER-THRESHER: A STUDY ON ECONOMIC HISTORY

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Studies of the diffusion of agricultural technologies have become rather frequent occurrences in recent years. Notable among these efforts have been the work of Paul David and others on the diffusion of the reaper (see [1 and 2]). The reaper, however, was only one stage in a series of harvesting methods, with each successive method providing more efficient (that is, less costly) harvesting for those farmers who adopted it. The reaper itself was replaced first by the binder, a machine which both cut the stalks of grain and bound them together, and finally by the combine, a machine that not only cut the grain but also threshed it.

After combines went into commercial production in 1880, their adoption by farmers in California grew rather steadily. First used in the San Joaquin Valley, they soon found acceptance elsewhere within the state. The diffusion process continued unabated to the extent that "it was authoritatively estimated in 1900 that probably two-thirds of the wheat in California was harvested with the combine." (See [4, pp. 123-24] for a detailed discussion of the combine's early diffusion within California.) Although use of the combine became rather extensive in parts of Washington and Oregon in the first two decades of this century, it was not until 1918 that the real take-off point for the diffusion of the combine elsewhere in the United States occurred, when

> the later small prairie-type combine, equipped with an auxiliary engine and pulled by horses on a tractor, was introduced. This gave the farmers of the Great Plains a machine which with the developments that have followed in the succeeding years, has proved to be practical, efficient, and economical under most of the conditions of that region.[1] [3, p. 3]

By 1928, there were parts of some Great Plains states in which essentially all of the wheat was harvested by combine. In the mid- and late-1920s the combine began to spread into the Corn Belt states, and in the 1930s, it began to be used more in both the eastern and southern states. Even some publications which predicted its limited applicability in these regions at the same time noted changes taking place in other factors that would lead to greater use of the combine. Such changes as the development of new varieties of wheat that did not shatter as easily as the varieties grown in the Pacific and Great Plains regions and the continued development of smaller combines are but two of the factors that led to a slow but steady diffusion of the combine method in these regions.

By the early 1940s it had become apparent that it was only a matter of time before the combine became the method of choice for all farmers. In 1950, only 6 percent of the wheat grown in the United States was still harvested by means of the binder-thresher, and the diffusion of the combine was essentially complete.

The central question that my dissertation seeks to answer is why the diffusion of the combine required many decades to be completed. Two facts serve to emphasize the slowness of the diffusion process. First, it was only in the 1920s -- nearly 100 years after the first US patent for a combine was granted -- that the diffusion process really got underway at the national level. Second, the combine actually went into commercial production in 1880 -- the same year in which commercial production of the binder began -- but it was not until almost 60 years later, in 1938, that 50 percent of the nation's wheat crop was harvested by means of the combine. The dissertation shows that the factors that caused the diffusion process for the combine to proceed at a fairly slow pace were quite similar to those factors which were found by David to be the reasons for the slow diffusion of the reaper. During the early period of the diffusion process, the combine method of harvesting was a less costly method for only a small number of farmers. Over time, however, it became comparatively profitable -- a less costly method of harvesting than the competing binder-thresher method -- for a growing number of farmers and accordingly came to be adopted by an ever increasing percentage of farmers.

The key to explaining the extent of adoption thus lies in being able to explain changes in the comparative profitability of adopting the combine. The dissertation shows -- through the use of a construct known as the break-even curve -- that the two most important variables which determined the comparative profitability of adopting the combine were the acres of wheat harvested per farm and the yield per acre. As the value of either variable increased, ceteris paribus, it would become relatively more profitable to harvest wheat using the combine. The study of the adoption and diffusion of the combine technology can in large part be told through a consideration of those factors that shifted the break-even curve. The development of the smaller combine, the concomitant diffusion of the modern tractor, increasing wage rates for harvest labor -- these are but some of the factors that caused the curves to shift.

The dissertation makes use of break-even curves for the combine versus binder choice in three years: 1918, 1938, and 1950. These were years in which respectively 5 percent (at most), 50 percent, and 94 percent of the wheat harvested was harvested by means of the combine. It can be demonstrated that in the earliest year only a small percentage of the nation's farmers would have found it profitable to adopt a combine. But as the aforementioned factors caused the break-even curve to shift, more and more farmers found it profitable to adopt. By 1950, the movement of the break-even curve had made the retention of the binder-thresher technology comparatively profitable for only a small percentage of farmers.[2] Consequently, it is of little surprise that only a small percentage of wheat was still being harvested by means of the older technology.

However, after all factors are considered, neither should it be a surprise that the diffusion process required decades to be completed, for between the time of the combine's first adoption and the time when it was used to harvest almost all of the nation's wheat, there was a long period of time in which each method would have been preferred by different segments of the population of wheat farmers. Where it was profitable to adopt the combine, it was often speedily done. But for many farmers, the binder-thresher technology remained comparatively profitable until rather late in the diffusion process. The use of the older method thus seems to be indicative more of farmers who were desirous of maximizing profits rather than of farmers who were irrationally committed to traditional techniques.

NOTES

1. See [3, p. 3]. It perhaps should be mentioned that these so-called small combines were anything but small by today's standards, and it was not until after 1926 that models smaller than a 12-foot model became generally available.

2. If the possibility of hiring custom harvesting services is introduced, it can be shown that in 1950 even those farms which would have found it profitable to retain the binder-thresher technology instead of purchasing a combine would have found it even more profitable to adopt the use of custom harvesting services. That is, for all farmers, the binder-thresher method had become inferior to either a combine owned by the farmer or the use of a combine through custom services.

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THE RISE OF THE AMERICAN ELECTROCHEMICALS INDUSTRY, 1880-1910: STUDIES IN THE AMERICAN TECHNOLOGICAL ENVIRONMENT

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The rise of the American electrochemicals industry has not been treated in detail, analytically or as a narrative, either by business and economic historians or by historians of technology. It is a sector which, like chemical industries generally, is almost too diverse to be integrated around certain themes and process technologies. Yet this study attempts to do so.

Beside the fact that this industry encompasses such important firms as Union Carbide and Carbon Corporation, Hooker Chemical Company, Dow Chemical Company, Acheson Industries, and the Aluminum Company of America, and produces a large variety of needed heavy chemicals, metallic products, and other substances, why should one study its evolution? There are several reasons. It was a source of major technological innovations in equipment and chemical products. Its products were economically very important in World War I and afterward, to the present day. The rise of this industry involved developments in electric power and the Conservation Movement. It played an important role in the transition from rule-of-thumb to more scientific methods in the chemical industry and in the rise of standardization in chemical production. The industry also helped change the teaching of industrial chemistry, particularly laboratory methods, and hence aided the coming of chemical engineering as a distinct discipline in university curricula and in engineering professionalization. This industry also helped lay the foundation for corporate research in American chemical companies such as Union Carbide, even before World War I.

Further, the American electrochemicals industry, significantly borrowing expertise and ideas from other countries, nevertheless arose within a distinctive American technical climate. And the electrochemicals industry is a particularly good vantage point from which to delineate certain aspects of this environment, since electrochemicals combine electrical, chemical, metallurgical, and mechanical technologies.

This thesis is divided into three major portions: (1) background and narrative (chapters 1 through 3), (2) considerations of physical capital inputs (chapters 4 and 5), and (3) considerations of human capital inputs (chapters 6-9).

How much did the industry expand over the period under consideration here? US Census data on "Chemicals Produced by the Aid of Electricity," which typically underestimate the size of the industry at this time and which do *not* include aluminum production, indicate that total number of electrochemical establishments in this country grew from 14 in 1899 to 114 in 1919. Over this same period, value of product of these chemicals rose from just over $2 million to approximately $82.5 million (not adjusted for price changes). In 1919 New York was cited as having the greatest number of electrochemical establishments of any state with 26, that number having nearly tripled since 1899. Many of these firms were located at Niagara Falls. According to Census figures, in 1899 New York had boasted 71 percent of all electrochemical firms in the US, while in 1919 the overall industry had become much more geographically diffuse, with New York's having only 22 percent of the total number. Location of electrochemical production in various places during this time, including Niagara Falls and elsewhere, is analyzed in this study, viewing costs of transport, labor, power, and information.[1]

What helps to explain the particular viability of this industry, whose production in many cases was outstripping European counterparts before World War I? In terms of prior American chemicals performance, one might not have expected such growth in this country at this time.

Various historians have emphasized the coming of hydroelectric power at Niagara Falls and its availability to industrial customers there by 1895. Of course, Niagara hydroelectricity is important here but that cannot be the entire explanation. Indeed, as Robert Multhauf has stressed, "[T]he rise of electrochemistry as a great industry coincided almost precisely with the development of hydroelectric power," but, he emphasizes, the coming of the dynamo was critical for the early rise of this industry [3, p. 478]. This dissertation, in fact, emphasizes the *symbiosis* between electricity and electrochemistry, not only in the rise of relevant areas of science and technology , but in industrial developments as well. Indeed, the demand for Niagara power by electrochemical producers was a major element in the early success of Niagara electric power companies.[2]

Besides the coming of the dynamo and electric power, a second impetus for the rise of the electrochemicals industry in the 19th century was the search for cheap aluminum, as Multhauf has also noted [3, p. 477]. Since many electrochemicals are actually metals, much electrochemical production involves extraction and refining operations. While the personal and informational linkages and transfers among metallurgical and electrochemical firms in this country mostly remain to be explored, this study has found that there were inventors and entrepreneurs who transferred from metallurgical to electrochemical activity in the US. In fact, various Niagara firms were involved, directly or indirectly, with the search for cheap aluminum, including not only ALCOA but also Union Carbide, Acker Process Company, the Castner and Mathieson Alkali works, the Niagara branch of Norton Emery Wheel Company, Ampere Electrochemical Company, Titanium Ferroalloys Manufacturing Company, and others.

Not only did the American metallurgical sectors stimulate technological change in electrochemical production at this time but also our electrochemical (and, it should be noted, our electrical) industries owed much to the American machine shop and mechanical engineering. Particularly, it is important to note that electrochemical production has from the start emphasized equipment and processes, rather than particular products, around which this as *an* industry coheres. The primary common denominators of the many different products are the cells and furnaces in which they are made. In fact, much of the electrochemical innovation of this period owed perhaps more to mechanical ingenuity than chemical sophistication, as can be seen in Dow's earliest electrolytic cells, Castner's rocking mercury cell, and many other American, particularly electrolytic, devices.

In general, production machinery should be highlighted in the study of chemical productivity. It can be argued that design of equipment and plant, every bit as much as chemical knowledge, go into successful chemical manufacture. Yet it is a point somewhat overlooked by historians, as Paul Hohenberg also stresses [1, p. 127]. American mechanical aptitude and experience may well go far toward explaining the vitality of our electrochemical industry before 1910.

Related to this, the contrast between German and American chemical production in the early 20th century has been noted in this thesis. It is generally assumed that the US borrowed the concept of corporate chemical research and development from Germany. Yet American producers such as Frederick M. Becket of Union Carbide contributed to the evolution of research and development functions within the chemical firm, primarily through the articulation of unit operations and unit processes common to various types of chemical production.

Not only mechanical aptitude but also a certain amount of college training in chemistry and metallurgy, as well as in mechanical and electrical engineering, aided the rise of this industry. Important managers, inventors, and entrepreneurs in this sector had received university educations. sometimes at the graduate level, in these fields before 1910. In fact, courses and even degree-granting programs in industrial electrochemistry and electrometallurgy were flourishing at a number of US universities at this time. Just as the university trained key personnel for the industry, the evolution of this industry shaped university curricula in electrochemistry. Information and people transfer here constituted a two-way street.

Also, the American Electrochemical Society (AES), founded in 1902, enhanced the flow of information and interchange among scientists, inventors, entrepreneurs, and industrialists through its meetings, publications, and projects. The historian L. F. Haber has conjectured that the peculiar vitality of this industry in the early stages of its establishment in the US was due in part to the especially fruitful and easy interchange and collaboration among American businesspeople and electrochemists [1, p. 144]. Indeed, the early AES, strongly oriented to industrial concerns, may well have promoted electrochemical entrepreneurship and economic growth in the American electrochemicals industry in the prewar period.

Invention and innovation in this industry was also aided by another kind of human capital resource -- the contributions of, specifically, women -- both in the related industrial and scientific fields and in the home. This study has focused especially on the latter, since some very significant electrochemical inventions took place in the home environment. Primarily, the efforts of Julia B. Hall, sister of Charles Martin Hall, in the early work on the electrolysis of aluminum ore have been highlighted. As an Oberlin graduate trained in chemistry, Julia served as both an assistant and advisor to Charles on the work, the patents, and financial backing. In fact, her detailed, eyewitness account helped win Charles's 1887 patent interference case. Her role in the management of information flow in entrepreneurship and technological change should be noted, as in the case of the universities and the American Electrochemical Society.

This study has served to fill in certain gaps in US industrial history, particularly the story of the rise of the electrochemical center at Niagara Falls, and has placed the electrochemical industry squarely in the vanguard of the emergence of modern, "high" technology in America. Much work remains to be done on the Niagara center, however, and on the search for cheap aluminum, on the contributions of science in its various forms to this industry's growth, on the history of chemical engineering, the rise of corporate chemical research and development in the US, and on the contributions of higher education in training managers for US chemical corporations. Also, this study indicates that the evolution of chemical standardization, of continuous processes in the chemical industry, and the history of chemical equipment need much fuller articulation. Indeed, as we probe these things, we shall surely begin to see more clearly the roots of much of America's conspicuous chemical productivity during World War I and later. Finally, there are many individuals, including female electrochemists, and firms that still need to be brought to light and their histories more fully explored.

NOTES

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1. The beginnings of the electrochemical center at the Sault Saint Marie, production on the Pacific Coast, in the Midwest (especially around Cleveland), and around New York City and New Jersey are peripherally covered, mostly in Appendix IV.

2. Both the Niagara Falls Power Company and the Niagara Falls Hydraulic and Manufacturing Company offered substantial economic incentives to electrochemical firms to locate at the Falls, as electrochemical companies held a key to the power load problems of these power companies. See chapters 2-4.

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SOUTH AFRICA'S IMPACT ON BRITAIN'S RETURN TO GOLD, 1925

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In the 1920s, despite the end of the hostilities of World War I, the international monetary structure was under siege. The basis of international monetary stability, the prewar gold standard, had been badly shaken by the war experience. The postwar goal was a return to normalized monetary relations and economic stability. Conditioned as countries were to the security of the gold standard, a return to normalcy via restoration of that standard is understandable.

In this process of restoration the British experience has been accorded much attention. This paper sheds new light on the process by analyzing the impact of South Africa's decision to return to gold on Britain's decision to do the same. The analysis relies heavily on the public and private records of Messrs. Kemmerer and Vissering, whose recommendations to South Africa prompted that country to announce the restoration of the gold standard. The hypothesis is that South Africa's action hastened Britain's decision to return to the gold standard.

In the years prior to 1925, South Africa had been undergoing significant changes. The political struggle between the Afrikaners and the Britons had persisted for generations. The power shift from the latter group to the former set the stage for the invitation to Kemmerer and Vissering.

In 1924 the opposition group, the Nationalist Party, supported mainly by the Afrikans-speaking South Africans, put together a viable coalition and, in the spring of 1924, the ruling party lost in the general election and the Nationalists took power. The Nationalist Party's long-standing call for full South African nationhood was about to become an active program. Political autonomy from England was the goal. For autonomy to become a reality, financial independence, or at least the use of financial power vis-à-vis England had first to be achieved. The plan for political independence for South Africa was grounded in the threat of or an actual financial break with London.

The war had forced South Africa to abandon the gold standard as it had most other countries. The newly elected South African government established a commission to review the matter in 1924. A similar group had been convened in 1921. Made up largely of English-speaking South African bankers and financiers, the 1921 group had recommended postponing restoration of the gold standard until July 1925. In 1924 the government turned to outside experts to advise the country, Kemmerer of Princeton University and Vissering of the Bank of the Netherlands. British advisors were conspicuous by their absence.

The commissioners met in London in November 1924 and spent time discussing the South African situation with interested British financiers, economists, and bankers, most notable among the latter group being Montagu Norman, Governor of the Bank of England. It was made abundantly clear to the commissioners while in London that the continued link between the British pound and the South African pound was essential.

After leaving London the commissioners spent about two months in South Africa. Most of the work of the body was conducted by Kemmerer as Vissering became ill and was unable either to travel or bear up under the strain of the daily interview schedule. The commission's final report was completed in January 1925. It urged that the

> wise and conservative action for South Africa to take at this time is to clinch gold parity while it is here and, to that end, to announce to the public at the earliest possible moment the intention of the Government to return definitely to the gold standard 1st July next.

As further spelled out the commission's report made it clear that this action should be taken regardless of whether Britain returned to gold.

The South African government accepted the Kemmerer-Vissering recommendations immediately upon their submission. Whether the political or financial considerations were more significant in the Government's decision is open to discussion, but South Africa's decision was to have a noteworthy impact in Britain.

Britain was in a position to serve as financial entrepôt during most of the 19th and the prewar 20th centuries because of her long-standing reputation as banker to the world and because of the stability of sterling. As the financial center Britain realized the benefits accruing to the world's banker, primarily returns on capital invested abroad. With the addition of steady returns from shipping and the associated insurance income, Britain was able to offset a dramatic debit balance in the merchandise section of her trade account.

One factor which maintained the stability of sterling and helped keep London secure as a financial center was a steady gold inflow from South Africa. This ready gold supply allowed Britain to finance her balance of trade deficit via gold outflow while at the same time building up foreign balances through returns on investment and income from freight and insurance.

London served as the entrepôt for South African gold. From London it flowed to the rest of the world. With South Africa as the major gold producer the South African-British connection became a vehicle for a smoothly functioning gold standard and for the maintenance of London as the financial center. London was able to continue this arrangement because of South Africa's reliance on imports from Britain and because of returns on capital invested in South Africa.

It was essential that London's prestige as a financial center be continued. Contemporaries felt strongly that a restoration of the gold standard at prewar parity would signify the strength of sterling and of "the City." Continuing the South African-British connection was an integral part of Britain's plan. Gold inflow from South Africa would permit Britain to finance her trade deficit as well as build up gold reserves sufficient to allow support of sterling, once gold convertibility was reestablished.

But this South African-London connection was in jeopardy. In light of Britain's financial reorientation away from traditional investments toward the Dominions this created serious problems. Sterling diplomacy needed to secure footholds on the continent and reestablish itself among the Dominions, especially in view of the financial competition occasioned by the United States. Should the link between the South African pound and sterling be broken and South African trade patterns oriented away from Britain, London's traditional source of gold inflow would be seriously threatened.

It was imperative that Britain's position as financial leader not be jeopardized by a Dominion country breaking with the fold. Such a break would not only reflect badly on London's leadership and prestige but, since South Africa was the world's leading gold producer, it would place into question Britain's ability to maintain the strength of sterling.

From the time of the Cunliffe Report in 1918, Britain intended not only to return to gold but to return to prewar parity. The question in the 1920s was not whether Britain should restore gold but when. The scenario of events leading to the announcement of Britain's decision in April 1925 has been discussed many times. What is overlooked is the South African connection and the forces which prompted Britain from an often stated slow return to gold to an abrupt decision in early 1925. As late as the winter of 1924, the Chamberlin-Bradbury Committee had taken up sessions and reported that "there was no immediate and pressing urgency for a British decision to return to gold."

The Kemmerer-Vissering recommendations for South Africa became known to the British in January 1925. On his return trip to the United States Kemmerer recrived the first hint of Norman's displeasure with the South African Commission's recommendations. The governor refused to see the professor. A letter from Kemmerer's assistant in South Africa hit on a very plausible explanation for Norman's attitude, "Norman's behavior to you in London was pretty shocking and cannot be explained away.... I think the South African Report must have jogged Norman quite a lot although that would not be admitted."

At any rate, records indicate that the process of Britain's return began to move along at a much more rapid pace in the early part of 1925. Little is known about what went on at those closed-door sessions between Churchill, the new Chancellor of the Exchequer, Norman, and the members of the Bank of England, but Norman's diary notation indicates that the final decision to announce the return to gold was made in March 1925. This paper does not assert that South Africa's decision to return to gold was the only force moving Great Britain to gold, but Kemmerer's own words sum up the role of South Africa.

> I learned from highly confidential sources that it [Britain's return to gold] was to take place this spring... and understand that the arrangements had been pretty well agreed upon by the latter part of January. South Africa's decision therefore took place just a week or two before the final decision was made in London and at a time when its influence would count most for British action favorable to a return to gold. I am inclined to think that South Africa's decision was a larger factor in London than most people believe.