AMERICAN BUSINESS CYCLES AND INNOVATION

A Senior Honors Thesis

by

MICHAEL HOOD

Submitted to the Office of Honors Programs
& Academic Scholarships
Texas A&M University
in partial fulfillment of the requirements of the

UNIVERSITY UNDERGRADUATE
RESEARCH FELLOW

April 2004

Major: Finance

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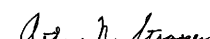
Approved as to style and content by:



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ABSTRACT

American Business Cycles

and Innovation. (April 2004)

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Economists have long studied innovation and its effects on business cycles. Economist Joseph Alois Schumpeter (1883-1950) was the first economist to thoroughly discuss these ideas in his *Theorie der wirtschaftlichen Entwicklung*, published in 1911 (English translation: *The Theory of Economic Development*, 1934). This paper focuses on three issues: defining innovation, defining and identifying business cycles, and determining which innovations caused which business cycles. The first section introduces the concepts of innovation and invention. The second section discusses the business cycles and highlights general causes of business cycles. The final section details the history of the iron, steel, aluminum, and pharmaceutical industries and incorporates the available business and economic data (output, productivity, inventories, and capital investment) required to answer the central question: which innovations caused which business cycles? The iron industry, examined over the sixteenth and seventeenth centuries, reveals that its relationship to the business cycle is likely significant but was difficult to quantify because of limited data. An examination of the steel industry from the post-Civil War period to the early twentieth century follows. The

steel industry had a significant effect on the business cycle and seemed to direct the business cycle during the growth in railroad mileage. Steel was a huge and indispensable industry for most of the 20th century so it makes a very important case to study. The aluminum industry is relevant to examine because the process for making aluminum has remained the same since the American inventor, Charles Hall, patented his method in 1889. The contribution of aluminum was significant because of the introduction of the large-scale electrical generators needed to produce aluminum. Finally, the paper focuses on the contribution of the pharmaceutical industry to the business cycle. The pharmaceutical industry is important to this study because it has already proved to be a major source of innovation and is an industry that will continue to play a significant role in the American economy. The findings reveal the contribution from this industry was most significant in the post-World War II era of research and development. The paper concludes with suggestions for improving and expanding this innovation and business cycle study.

DEDICATION

This paper is dedicated to my family, friends, professors, and advisors.

ACKNOWLEDGMENTS

I wish to acknowledge the support of my research advisor, Dr. Anthony Stranges. He was instrumental in guiding me through the research and writing of this paper and in igniting my interest in the topic of this paper. I also wish to thank the Office of Honors Programs and Academic Scholarships for coordinating the Fellows program and for providing a research stipend.

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CHAPTER I

INTRODUCTION

Joseph Alois Schumpeter

Austro-Hungarian born economist Joseph Alois Schumpeter (1883-1950) is recognized as one of the first-rank economists of the twentieth century (Shionoya, 1997). After moving to Vienna in 1893, Schumpeter attended the Theresianum, the elitist school in Vienna, until he graduated in 1904. He began his studies at the University of Vienna later that year and graduated from there in 1906 with a doctorate in law (Swedberg, 1991). At this time the University of Vienna was ranked along with Cambridge and Stockholm as a center of economic research. Schumpeter was not originally drawn to theoretical economics but was interested in legal and social history, sociology, and philosophy, especially from an economic point of view. However, he made a sharp turn and became interested in economic theory. Schumpeter says that Friedrich von Wieser (1851-1926) and von Wieser's brother-in-law, Eugen von Böhm-Bawerk (1851-1914), at the University of Vienna influenced him most (Swedberg, 1991). Von Wieser's greatest contribution to economics was the idea of opportunity costs, which are the costs of opportunities missed by a firm as a result of not spending the money on another project.

Before Schumpeter decided on academics as a career he had tried a number of other professions. He was in a private law practice beginning in 1906 in Cairo, Egypt. His first academic appointment was at the University of Czernowitz, formerly of

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This thesis follows the style and format of *The American Economic Review*.

Austria-Hungary now in Chernovtsy, Ukraine, in 1909, where he taught courses in economics and general social science (Swedberg, 1991). Schumpeter moved to the University of Graz in 1911 as full professor, the youngest full professor at this university (Swedberg, 1991). Because he "was not very happy in Graz," he used every available opportunity to venture away from the university (Swedberg, 1991). Later he was involved in politics as the finance minister for the new Austria in 1919 but was fired later that year. He then served as president of a highly respected Viennese bank until its insolvency in 1924 because of a combination of scandals and bad economic times in Austria following the war (Swedberg, 1991). Schumpeter accepted an offer to return to academia in 1925 at the University of Bonn in Germany as chair of public finance and remained there until he went to Harvard University in 1932 (Streissler, 1994).

His students would later say that he was an outstanding lecturer and delivered his provocative talks needing only the aid of a small note card. Schumpeter consistently gave his students inflated grades, and he had three categories for assigning an A grade to a student: all Jesuits got A's, all women got A's, and all the others also got A's (Swedberg, 1991). Schumpeter's was the first economist to offer a comprehensive proposal that innovation was responsible for economic development. His *Theorie der wirtschaftlichen Entwicklung,* published in German in 1911, (English translation: *The Theory of Economic Developemnt,* 1934) made him "world famous" (Shionoya, 1997). Schumpeter was twenty-eight years old at the time of publication. The purpose of the book was to identify the interaction between economic development and entrepreneurs

acting as innovators. Briefly, his theory argued that an economy in a state of equilibrium was forced into an expansion phase because of the activities of entrepreneurs as innovators bringing market-demanded inventions to market. The paper details his theory below.

The International Joseph Alois Schumpeter Society (ISS), founded in 1986 by economists Wolfgang F. Stolper (1911-2002, left his native Austria in 1933) and Horst Hanusch (1942-) with the "aim of promoting the scientific study of the problems of economic development and innovation along the lines" suggested by Schumpeter, is evidence of the influence of Schumpeter's theory and teachings (Tsuru, 1994). Most recently the ISS had 355 members from 30 countries. Modern economists rarely discuss innovation and the business cycle without mentioning Schumpeter, even if to criticize the weaknesses in his early-twentieth century work. Schumpeter himself was well aware of these criticisms, and when his original German text was translated to English and published in 1934, as *The Theory of Economic Development,* he used part of that work to answer his critics' concerns. For example, there was early criticism that his theory did not explain the periodicity of crises (Schumpeter, 1934). However, Schumpeter answered this by showing that it did. In fact, Schumpeter's "whole argument [was] aimed at this" (Schumpeter, 1934). Misplaced criticisms such as this highlight the complexity and advanced nature of Schumpeter's theory and perhaps suggest that he was far ahead of his time and other economists of his period. In fact, Yuichi Shionoya, a Schumpeter biographer and former president of the ISS (1990-

1992), writes that "misunderstanding [of the theory] began at the time the book was published [in 1911]" (1997). An overview of Schumpeter's work follows.

Rendigs Fels writes "the theory is unusually involved and peculiarly liable to misinterpretation" (1959). First, Schumpeter's model assumes that an economy is in a state of equilibrium. Second, the model also assumes that innovations come in bursts, "a bunching of innovations" (Fels, 1959). Innovation occurs because entrepreneurs have a new product to sell or a new productive capital input (Ames, 1961). Innovation acts to disturb this equilibrium as entrepreneurs invest in capital and sell products to consumers (Fels, 1959). That is, innovation disturbs this equilibrium through price creation and capital investment. The entrepreneur obtains funds by borrowing newly created money (Ames, 1961). The creation of money initiates several other activities in the economy: price changes, savings, profits, and investment. Finally, the model assumes that innovation occurs at a single instant: price creation.

Schumpeter, like Karl Marx (1818-1883), argued that capitalism would not survive. However, Schumpeter claimed that it would be destroyed because of its successes when intellectuals would attack it and government controls would undermine the efforts of entrepreneurs not, as Marx argued, by the working class whom capitalism exploited. Schumpeter, who was also regarded as an expert on historical economics, was well aware of and influenced by many economists around him. Carl Menger (1840-1921) had just ceased teaching at the University of Vienna when Schumpeter arrived, but his influence had not left. Von Wieser and von Böhm-Bawerk, who were two of Schumpeter's chief influences, were students of Menger's school of thought

(März, 1991). Menger was best known as a neoclassicist who explained that a consumer's marginal utility, or level of desire for one more unit of a good, determined market prices.

Plan and purpose of paper

This paper has its foundations in Schumpeterian theory and in the challenge that Boyan Jovanovich and Saul Lach issued in *Product Innovation and the Business Cycle* (1997): *which* innovations caused *which* business cycles? Jovanovich and Lach investigate product innovation and the business cycle and find that while the speed of product diffusion has significant effects on the level of United States GNP, it has a minor effect on shaping the business cycle (1997). As they point out in their conclusion, however, their aim in measuring technology's effect on the business cycle focused only on sales figures in the personal computer industry.

This paper incorporates other data as proposed by Jovanovich and Lach to answer the central question presented above. An answer to such a question is valuable for several reasons. First, business leaders and policy makers want to know which types of innovations are most important to an economy and how these innovations affect the economy. Business leaders want to know so that they may take advantage of profit opportunities and policy makers want to know so that a proper incentive system (patents, trademarks, etc.) is maintained to ensure entrepreneurs will innovate. Second, from an historical perspective we must be aware of past mistakes and past successes in our capitalistic economy. Last, innovation is the golden fruit of business (Grove, 2003).

The paper proceeds in this manner in the following chapters. Chapter two discusses innovation and invention. Chapter three focuses on the business cycle from an historical perspective with particular attention given to some of the early and current controversies on defining and interpreting business cycles. This chapter includes information related to particular American business cycles. In chapter four the paper examines the iron, steel, aluminum, and pharmaceutical industries. Each industry discussion includes information about the business cycles over which this industry existed. Chapter five offers the summary and concluding statements.

CHAPTER II

INNOVATION AND INVENTION

American economist Edward Ames argues that the careful student should avoid any use of the word innovation because it is a difficult term to understand (1961). This is still true some forty-plus years later. Today, as Ames wrote in 1961, innovation "has come to mean all things to all men." It is difficult today, if not impossible, to pick up any business or academic journal or newspaper and not find some discussion of innovation. While it is acceptable to use the term, users should use it properly. Innovation is not synonymous with invention. In its most fundamental form, innovation is the application of invention (Potter, 1987). This means that before we have innovation we must first have an invention. Furthermore, innovation occurs at the single instant of price creation (Ames, 1961). The term invention is "void of economic content" (Ames, 1961). Until we have innovation, hence price creation, there are no economic consequences to study or consider.

James Estey claims that invention is the discovery of some scientific novelty, while innovation is the process of "carrying these inventions into actual performance" or "exploiting them" (1950). Moreover, Estey notes that invention is probably much less fluctuating than innovation (1950). This fact follows with the reasoning that innovation requires a price and because prices are likely to fluctuate it necessarily follows that its parent, innovation, fluctuates. Innovation is subject to cycles, not invention (Estey, 1950).

Peter Meyer offers some discussion of the choice of innovation versus invention related to the concept of "collective invention" (2003). Robert C. Allen first used this phrase to describe "the free exchange of information about new techniques and plant designs among firms in an industry" (Meyer, 2003). Lucien P. Hughes, research director for technology labs at the Accenture consulting firm, predicts that the days of doing solo research and "not talking to the rest of the world" are over for now (Flaherty, 2003). Meyer indicates that a technology is truly invented only once, and "subsequent applications of it are innovations which are part of a separate process of diffusion" (2003). These definitions align with Estey's definition of the two terms. Peter Drucker, of Claremont Graduate School of Management, offers another interpretation of innovation: innovation is the specific function of entrepreneurship (2002). Further, innovation is the "means by which the entrepreneur…creates wealth-producing resources" (2002). Each of these interpretations is consistent with Ames, Estey, and Schumpeter. The entrepreneur is the central actor for innovation; the scientist or hobbyist is the central actor for invention. The entrepreneur can do nothing without first having made or having had access to a discovery or an invention. The scientist and inventor are free to act without the entrepreneur.

There has been much recent research concerning "radical innovations." While Schumpeter was indifferent towards this idea, Prussian economist A.F. Riedel, saw no need to distinguish "great innovations from small" innovations (Streissler, 1997). Riedel publish a textbook on economics in Berlin in 1838 (*Nationalòkonomie oder Volkswirthschaft*) (Streissler, 1997). Riedel argued that all innovations were just as

radical as another other. It was either an innovation or it was not. Moreover, the distinction might not be necessary because we only know if an innovation is radical after it has had time to penetrate the market. That is, if firms knew in advance whether or not an innovation would be radical, they would only pursue radical innovations because of their higher profits and forgo the other opportunities. Mokyr writes that terms like "revolution tend toe be overused and abused by historian" (2002). This might be the case with distinguishing radical innovations from innovations.

Schumpeter proposed five types of innovation depending on the source of the innovation (Schumpeter, 1934). First, new products on the market are innovations (products that are not familiar to consumers). Second, new methods of production are innovations. For example, the Bessemer steel process was a process innovation. The third type of innovation occurs when a firm enters a new market. Fourth, Schumpeter lists the exploitation of raw materials as an innovative activity. Fifth, the creation of a monopoly is an innovation because the monopoly has the power to set prices and reap all profits. Riedel however is thought to have influenced Schumpeter's thoughts on innovation. For example, Riedel addressed in great detail two types of innovation that are usually thought to be specifically from Schumpeter: the development of new markets and the exploitation of raw materials (Streissler, 1997). However, Schumpeter was the first to consider the development of a monopoly as a source of innovation (Streissler, 1997). Riedel developed his theory and consider invention to be economic activity. This was before Marx wrote about the technical side of material progress (Streissler, 1997). If Riedel had lived long enough he may have found reason to alter

his interpretation. This paper is concerned with new products and new methods of production as innovations.

The distinction between these two terms is important for several reasons. First, form an educational point of view, when the correct term is available, users should use it. For example, Drucker comments on the "confusion…[about] the definition of entrepreneurship" indicating that this confusion could lead to misidentification of a business firm's core activity, which is innovation (2002). Business managers who have different interpretations for such important business activities do not serve the company well in focusing on its core competencies if they do not view the business unit based on its fundamental activity. Last, from an economic point of view, economists are interested in the term that has implication for economics; hence, innovation because this is the instance of price creation. This is an important distinction because invention has a different connotation. For example, invention is an easier concept to understand for most people. Pfizer, Inc. recently ran a television advertisement wherein they stated that they were in the business of discovering, a much more concrete term that innovation or to say that we are innovating. Hewlett-Packard also includes the word "invent" in their advertising just below the Hewlett-Packard logo. Inventions are patented so that we may convert them into innovations. Intel Corporation chairman Andy Grove writes that "innovations with the power to transform entire industries are the Holy Grail of business strategy" (2003).

In short, innovation, not invention, sets the course of the business cycle. Jeffrey R. Immelt , Chief Executive Officer of the General Electric Company (GE), says that

"unless [firms are] out there pushing the envelope and driving innovation" firms will not achieve the profit margins and growth that they need to survive (Flaherty, 2003). This profit and growth is essential to sustaining the American economy, and indeed, it is the core component of capitalism. By definition, the business cycle is an economic phenomenon and as such is affected by the economic activity present in innovations and is set in motion by entrepreneurs.

CHAPTER III

BUSINESS CYCLES

Definition of a business cycle

Schumpeter argued that business cycles began as early as the seventeenth and eighteenth centuries (Zarnowitz, 1992). He based his conclusion on his argument that capitalism goes "as far back as the element of credit creation" and that "there must have been also prosperities and depressions of the cyclical type" (Zarnowitz, 1992). The argument over business cycles is not only over whether they exist, but it also centers on answering an even more fundamental question: what is a business cycle? Most economists and authors avoid trying to offer a comprehensive definition, relying instead on the guidance provided by economists Arthur F. Burns and Wesley C. Mitchell. Mitchell first proposed his definition in 1927, and he and Burns restated it in their 1946 volume (Zarnowitz, 1992):

> Business cycles are a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic; in duration business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximating their own.

A business cycle includes a "downturn and contraction followed by an upturn and expansion" (Zarnowitz, 1992). Depression is the old term for contraction, and prosperity is the old term for expansion (Zarnowitz, 1992). Recovery is used instead of the former revival and recession is used instead of crisis (Zarnowitz, 1992). If we picture the business cycle as a wave, the crest of the wave is the peak of the business

cycle and the bottom of the wave is the trough of the cycle. Moving up towards the peak is an expansion phase, while moving down the wave towards the trough is the recession phase of any business cycle. During an expansion phase there is increased demand and capacity constraints for producers. If businesses believe that demand will continue to rise, they will invest more capital in plant and machinery in an attempt to match production and demand. At the peak there are supply constraints, and a demand for investment funds increases interest rates. Producers no longer find it profitable to make new investments in capital equipment because of the increased interest rates. The decrease in investment demand causes total output to fall. The economy enters a recession (for convenience, ignore the formal definition which requires two consecutive quarters of falling GDP) wherein businesses layoff workers and there the higher unemployment reduces consumer demand. At the trough interest rates have decreased and there is renewed demand for investment funds propelling the economy to expansion again.

The Burns and Mitchell definition has gained wide acceptance over the years for several reasons. First, the Burns and Mitchell definition allows for a broad range of cycle duration ranging from one to twelve years (Zarnowitz, 1992). It also disregards movements in economic activity that are smaller than usual (Zarnowitz, 1992). Last, the definition makes no distinction between major and minor cycles. Although economists discuss business cycles, particularly depressions, as either being large or small, this is still acceptable because they are usually comparing historical cycles and this does conflict with the business cycle definition. In short, the Burns and Mitchell

definition is widely accepted because it is relatively easy to understand, and the definition is comprehensive.

Historical business cycles

Table 1 shows historical U.S. business cycles. This table indicates that no two business cycles are the same and that expansions in the post-World War II era consistently last significantly longer than contractions. Stock lists three possible explanations for this difference (1991). First, the NBER (National Bureau of Economic Research) used different mixes of series to date prewar and postwar cycles. Cycles dated pre-World War II relied on more cycles, longer contractions, and short expansions that the pre-War dating. Although this "shifting mix of series [might have] accurately reflected the compositional changes in the United States" some evidence exits to the contrary (1991). This issue is unresolved and will require further research to resolve. Second, even if the underlying time series behavior of the United States economy did not change before and after the War, but the National Bureau of Economic Research has intentionally changed definition of a recession. To the contrary, this possibility does not support the NBER's goal of consistency and continuity in their dating methods. Lastly, Stock indicates that the NBER's intent is unchanged and the use of a broader set of economic indicators unintentionally resulted in few and shorter recessions being identified. Still, further research might help to clarify these issues.

In the period from October 1873 to March 1879, the United States experienced sixty-five months of contraction, the longest contraction period to date. The peak for this cycle occurred in October 1873 while March 1879 marked the trough. Most cycles

following this contraction period had more slightly more months of expansion than months of contractions. For example, the United States experienced thirty-six months of expansion beginning in March 1879 and lasting until March 1882. There was a period of expansion from May 1885 until March 1887 (twenty-two months) when a contraction began that lasted until April 1888 (thirteen months). These business cycles, and others that apply to this study, will be discussed in the industry discussions that follow.

Table 1—Business Cycle Dates

Peak	Trough	Contraction	Expansion
(Figures in parenthesis represent quarters).		Duration in months	
June 1857(II)	December 1858(IV)	18	30
October 1860(III)	June 1861(III)	8	22
April 1865(I)	December 1867(I)	32	46
June 1869(II)	December 1870(IV)	18	18
October 1873(III)	March 1879(I)	65	34
March 1882(I)	May 1885(II)	38	36
March 1887(II)	April 1888(I)	13	22
July 1890(III)	May 1891(II)	10	27
January 1893(I)	June 1894(II)	17	20
December 1895(IV)	June 1897(II)	18	18
June 1899(III)	December 1900(IV)	18	24
September 1902(IV)	August 1904(III)	23	21
May 1907(II)	June 1908(II)	13	33
January 1910(I)	January 1912(IV)	24	19
January 1913(I)	December 1914(IV)	23	12
August 1918(III)	March 1919(I)	7	44
January 1920(I)	July 1921(III)	18	10
May 1923(II)	July 1924(III)	14	22
October 1926(III)	November 1927(IV)	13	27
August 1929(III)	March 1933(I)	43	21
May 1937(II)	June 1938(II)	13	50
February 1945(I)	October 1945(IV)	8	80
November 1948(IV)	October 1949(IV)	11	37
July 1953(II)	May 1954(II)	10	45
August 1957(III)	April 1958(II)	8	39
April 1960(II)	February 1961(I)	10	24
December 1969(IV)	November 1970(IV)	11	106
November 1973(IV)	March 1975(I)	16	36
January 1980(I)	July 1980(III)	6	58
July 1981(III)	November 1982(IV)	16	12
July 1990(III)	March 1991(I)	8	92
March 2001(I)	November 2001(IV)	8	120

Source: National Bureau of Economic Research, 2003.

Theories of business cycle causes

There are several possible causes of business cycles. Economist Wesley C. Mitchell claimed that weather, overproduction, and innovation were general causes of business cycles (Mass, 1975). Economist Gottfried Haberler, who also served as president of the United States National Bureau of Economic Research in 1954, proposed a theory of overinvestment (Sherman, 1991). Haberler argued that future optimism for an industry leads investors to overinvest in capital for this industry resulting in a cyclical expansion. When interest rates rise, investment slows and a contraction begins (Sherman, 1991). Fischer Black's theory suggests that peoples' changing tastes and changes in industrial technology cause business cycles (Black, 1987). When people prefer a certain service or product, they consume that service or product. This suggests that as long as the services and products offered in an economy meet consumers' needs and desires, an economy will experience an upswing or expansion. Moreover, Black establishes that business cycle peaks occur when there is a match between the types of skills business owners want and the types of skills available in the workforce or between the type of physical capital wanted and the type of physical capital available (1987).

With this background on the general nature and description of business cycles, some general notes about specific historical cycles can be given. In the post-Civil War era, Fels notes that business was largely prosperous (1959). There was a surge of investment activity in 1865. The population was expanding, and railroad construction was increasing as the population moved westward across the United States. The

country was largely prosperous until the banking panic of 1873 with the failure of Jay Cooke & Co. (Fels, 1959). Cooke, a Civil War-financer, had also financed the Northern Pacific Railroad. By May 1873, this railroad had spent $15 million and had less than 500 miles in operation (Fels, 1959). Unable to find people to buy bonds, Cooke advanced short-term deposits in expectation that a European market would develop. In short, he was using short-term funds to finance long-term use (Fels, 1959). Later in 1873, twenty-five railroads defaulted on their bond interest payments (Fels, 1959). Schumpeter argued that during the period railroads were no longer an attractive opportunity for investors (Fels, 1959).

Schumpeter wrote that entrepreneurs cause business cycles. In fact, Schumpeter's theory states that an invention may sit on the shelf until an entrepreneur makes it into an innovation by marketing and selling the item (Karsten, 1990). As mentioned in an earlier chapter, the expansion phase of the business cycle begins when the entrepreneur decides to take the risk of selling the new product (Karsten, 1990). At the beginning of the expansion costs are low and "credit, raw materials, and labor are readily available" (Karsten, 1990). If the entrepreneur is successful, he will earn substantial profits; this entices others to enter the market (Karsten, 1990). When imitators enter the same market, several economy-wide actions take place. Investment in plant and equipment increases (Karsten, 1990). Consumer spending and household income rise as well (Karsten, 1990). The business investment is the important component here. As business investment decreases, the expansion ends. Because of the

decrease in business investment, prices decline and the costs of labor, equipment, raw materials, and interest rates will each increase (Karsten, 1990).

In summary, the definition and historical record of business cycles and business cycle theories is important for studying various innovations and their affects on specific United States business cycles. The inventions and subsequent innovations discussed below have been some of the most pervasive and important industries for economic development in the United States.

CHAPTER IV

INDUSTRIES

Iron

English colonists discovered iron ore off the cost of North Carolina in 1598, but they had no way to mine this ore. The Saugus ironworks went into operation in Massachusetts in 1645. At the beginning of the eighteenth century, iron making was underway in almost every colony from Connecticut and Rhode Island in the north to Maryland and Virginia in the south. By mid-century almost every colony in British North America "supported some measure of iron production" (Paskoff, 1989). In fact, because of this growth, English iron producers had concern about the colonists' success. Parliament passed the Iron Act in 1750 in order to stop further development of the colonial iron industry (Paskoff, 1989). Even though the Act was largely ineffective because of "administrative indifference" its introduction was indicative of the pure success enjoyed by colonial iron workers. The iron industry of 1800 resembled the iron industry of 1750 more closely than the industry in 1830. The iron industry saw its biggest development in Colonial America after the introduction of the blast furnace in 1720. The blast furnace allowed the colonists to produce such large quantities of iron that they had to begin measuring output in tons rather than pounds as early as 1720. Table 2 shows the increase in U.S. iron production. By 1800 the United States was the third largest producer of iron behind Russia and Sweden (Stranges, 2002).

The United States also experience rapid population growth between 1790 and 1860 (Valentine and Dauten, 1983). In fact, in each ten-year period between 1790 and

1860, the population grew by more than thirty percent (Valentine and Dauten, 1983). Such a rapidly expanding population provided a larger market for consumer goods and services (Valentine and Dauten, 1983). With the expanding consumer base came a need to consume more resources. Moreover, the expanding population would cause more demand for food. The average farmer in 1790 did work with wooden tools, but by the Civil War farmers in the northern states could do work with a reaper, a mower, and modern plows and cultivators (Valentine and Dauten, 1983).

Table 2—Iron Production, 1700 to 1800

Year	U.S. Production (in tons)	World Production (in tons)
1700	1,500	100,000
1750	10,000	150,000
1800	45,000	400,000

Source: Stranges, 2002.

Business cycle data is not available for the earliest periods of iron production. The period (1783-1861) following the revolutionary war was one of rapid technological development which certainly fueled economic development (Valentine and Dauten, 1983). However, before the introduction of steel, rails for railroads were made of iron. Further, the revolution in agriculture technology in the 1790s wherein farmers used iron ploys, axes, and sickles, certainly helped the iron industry. Entrepreneurs such as Joseph McClurg of Pittsburgh had the necessary capital to build new furnaces (Paskoff,

1989). Pig iron production per capita was seventeen pounds in 1810 and by 1850 per capita production was fifty-five pounds (Metal Statistics, 1954). This was in conjunction with the rapid population growth noted above.

Other close studies of innovations, such as the cotton gin from Eli Whitney, would probably provide additional conclusions regarding innovation and the business cycle for this period. The post-Civil War era and discoveries thereafter gave way to another industry: steel.

Steel

Steel is the intermediate between wrought iron and pig iron, the difference being in carbon content. In the early part of the nineteenth century steel was a small industry because very few iron masters knew how to make it (Stranges, 2002). However, technological process discoveries by William Kelly in the United States and Henry Bessemer in England eventually led to mass production of steel in the United States. Kelly invented his process in 1851, but he did not patent it until 1857 (Stranges, 2002). This was after Alexander Holley merged the two inventors' patents in 1865 (Stranges, 2002). The patent merger was necessary because Kelly had the patent on the air blast and Bessemer had the patent on the converter. Hence, each of these inventions was necessary to make mass production possible (Stranges, 2002). The process eventually became known as the Bessemer process. The expansion was rapid and significant enough that it caused the steel industry to actually support economic growth (Meyer, 2003). The railroad was certainly an innovation that took some time to "work out [its] full effects" (Estey, 1950). Steel, because it was a collective invention, advanced much

faster through the economy especially with the creation of large corporations such as U.S. Steel (Warren 2001). Table 3 shows the production of steel in the United States.

Table 3—Steel production in the United States

Year	Tons (in thousands)	Year	Tons (in thousands)
1860	13	1885	1,917
1870	77	1890	4,779
1871	82	1895	6,785
1872	160	1900	11,277
1873	223	1905	21,880
1874	242	1910	28,330
1875	437	1915	35,180
1876	597	1920	46,183
1877	638	1925	49,705
1878	820	1930	44,591
1879	1,048	1935	38,184
1880	1,397	1940	66,983

Source: United States Department of Commerce, 1975.

With respect to Meyer's discussion of the steel industry, collective invention is "a process in which improvements or experimental findings about a production process or tool are regularly shared" (2003). After Kelly and Bessemer improved the steel making process, the steel industry saw its most significant growth in the latter quarter of the 19th century (Stranges, 2002). Kelly was made aware of Bessemer's discoveries after reading a newspaper article on Bessemer (Stranges, 2002). This exchange of information, both formal and informal, was especially crucial in the development and expansion of the steel industry. Meyer cites several pieces of evidence in support of the

collective invention in this industry (2003). First, the American Institute of Mining Engineers began publishing *Transactions of the American Institute of Mining Engineers,* a mostly technical journal on iron and steel subjects (Meyer, 2003).

One other concept should be introduced here: epistemic base. The epistemic base concept posits that the technological advances witnessed during the second Industrial Revolution would not have been possible without a widening epistemic base (Mokyr, 2002). The concepts of collective invention and epistemic base certainly fueled the development of the steel industry. In fact, these two concepts are closely related. The expanding knowledge base parallels what happens during collective invention: as information is shared among an industry's participants, technology advances at a faster rate that it would without the sharing of knowledge. In a later section of this paper, this will be especially evidence in the pharmaceutical industry analysis.

During World War I United States annual production of steel exceeded the output of all German and Austro-Hungarian firms combined (Warren, 2001). This was largely a result of some United States' steel firms having combined operations in 1901 to become the United States Steel Corporation (Warren, 2001). The combination of these firms into US Steel resulted in better labor, managerial, and capital productivity (Warren, 2001). Productivity increases occurred largely because of process innovation and perfection of production (Mokyr, 2002).

With the mass production of steel came a significant increase in miles of railroads in the United States. Steel replaced the iron rails in railroads because it was

seven times stronger than the iron (Stranges, 2002). In fact, as shown in Table 4, the miles of railroad increased significantly from 1830 to 1920. Additionally, demand for steel rails propelled the steel industry through the depression beginning in 1873 (Meyers, 2003). Fels concluded that during the business cycle beginning in the third quarter of 1873 and lasting until March 1879, the U.S. experienced 65 months of contractions and only 34 months of expansion.

Table 4—Miles of railroad in the United States

Year	Miles
1830	23
1840	2,808
1850	9,021
1860	30,626
1880	93,267
1890	163,597
1900	193,346
1910	240,439
1920	252,845

Source: Potter, 1987.

If we assume that the future of steel was uncertain in 1850 collective invention acted to help innovators share their ideas. The root cause is that we were in a period of transition from iron to steel rails. When collective invention exerted its effects, we saw that this would also be consistent with Schumpeter in saying that innovation investment increased during a recession. We can integrate the modern-day theory from Meyer (2003) with Schumpeter's (1934) ideas of almost 100 years prior.

Aluminum

Danish physicist Hans Christian Oersted (1777-1851) first produced aluminum in 1825 by reacting potassium amalgam with anhydrous aluminum chloride and then distilling the mercury from the resulting aluminum amalgam leaving an impure aluminum. The aluminum industry began with Charles Hall's discovery on 23 February 1886 of a direct current electrical process for the separation of aluminum. Hall's discovery came at a most convenient time because by 1886 large direct current generators that provided several hundred amperes were available. This discovery made possible the commercial-scale aluminum production. Two months after Hall's discovery, Paul Louis Héroult, a French metallurgist, invented the same aluminum process. Héroult's discovery resulted in the development of Europe's aluminum industry beginning in Germany in 1888. Hall applied for and received a U.S. patent in 1889. The Hall-Héroult process remains the main industrial method of producing aluminum. Aluminum found wide use in telephone lines, aircraft, and zeppelins because it is strong, light weight, and has good electrical conductivity (Stranges, 2002). Table 5 shows how commercial-scale production significantly lowered the price of aluminum.

Table 5—Price of aluminum

Year	Price (per pound)
1855	$10
1886	$5
1893	$.70
1914	$.18

Source: Stranges, 2002.

Hall and Alfred Hunt, a metallurgist in Pittsburgh and a financial backer, established the Pittsburgh Reduction Company in 1888. This company became Alcoa in 1907. In 1953 Alcoa employed 56,000 people and had assets of $907.7 million. Because of the price decline and because of aluminum use throughout the economy we can conclude that it was a strong driver of economic activity over this period. Maurer writes that dollar amounts such as these help to illustrate the vastness of this early corporation (1955).

The increased production noted in table 6 below should be compared to business cycle dates. From January 1913 to December 1914 the United States experienced twenty-three months of contraction. However, from December 1914 to August 1918 (during World War I) the United States experienced forty-four months of expansion. Preceding this period of expansion and the trough of December 1914 was a substantial increase in the production tons of aluminum. This economic picture is consistent with

Schumpeter's theory in at least two ways. First, the period of capital investment necessary to meet the demands because of the War, came just before this extended period of expansion. That is, capital investment began in the recession period and continued up through expansion period fueled by the demands of War material. Second, the War opened a period of new consumer markets (the United States government) for materials made of aluminum. This area of Schumpeterian innovation should receive a closer look in another future study.

Table 6—Aluminum Production in the United States

Year	Tons	Year	Tons
1883-92	280	1920	69021
1883-1902	13,701	1921	27266
1903	3,318	1922	36816
1904	4,050	1923	64329
1905	5,405	1924	75282
1906	7,062	1925	70058
1907	8,162	1926	3693
1908	5,338	1927	81803
1909	14,540	1928	105272
1917	17,701	1929	113986
1911	19,198	1930	114518
1912	20,903	1931	88772
1913	23,639	1932	52444
1914	28,986	1933	52562
1915	45,252	1934	37088
1916	57,553	1935	59647
1917	64930	1936	112464
1918	62362	1937	146360
1919	64238	1938	143441

Source: United States Department of Commerce, 1975.

Pharmaceutical

The pharmaceutical industry began in Germany in the late nineteenth century as scientists began to discover the chemical structure of numerous organic compounds. The pharmaceutical industry underwent significant expansion after the discovery of the structure of DNA (deoxyribonucleic acids) by James Watson and Francis Crick in 1953. With this discovery, the molecular biology revolution began (Pisano, 2002). Before this time this industry practiced "random screening" (Pisano, 2002). Random screening is a process wherein researchers try several drugs until they find one that works. It is akin to pulling test tubes off the shelf and using whatever will work (Pisano, 2002). After World War II and the mass production of penicillin, we saw the beginning of formal research and development programs (Pisano, 2002). Table 7 shows the increase in health expenditures as a percent of United States GNP. Table 8 shows the research expenditures for United States pharmaceutical firms. This is the dollar amount from private research spending, hence, entrepreneurs acting as innovators along with scientists as discoverers of new drugs. Notice the 53% increase between 1955 and 1960 (the period following Watson and Crick's 1953 discovery). Expenditures increased by another 50% between 1965 and 1970. The increase health care the spending share of GNP is most revealing when examining the business cycles over this period. From February 1961 until December 1969, the United States experienced 106 months of expansion. This period coincides with the increase in the percent GNP that health expenditures contributed to United States GNP. While it is difficult to draw empirical conclusions, it is certainly apparent that the increase in research dollars and in GNP

share contributed to the business cycle expansion as pharmaceutical firms increased their research and development and brought new drugs to market. As Agrawal writes, the United States is responsible for over 40% of new drug introductions in the world (1999). This is also evidence of the significant growth of this industry in United States despite this industry having had its roots in Germany.

Table 7—Health Expenditures as a percent of United States GNP

Year	Percent of GNP
1950	4.5
1955	4.4
1960	5.3
1965	5.9
1970	7.3

Source: United States Department of Commerce, 1975.

Table 8—Private Research Health Expenditures

Year	$ Amount (in mil)
1950	38
1955	60
1960	125
1965	166
1970	194

Source: United States Department of Commerce, 1975.

If Meyer's (2003) hypothesis is correct (when a technology's future is uncertain, collective invention does a better job at advancing the technology), imagine what would

happen if the pharmaceutical industry was motivated by collective invention rather than in securing patents. Nevertheless, pharmaceutical products have enjoyed a long history of strong patent protection (Pisano, 2002). This is not surprising since innovation is the lifeblood of this industry (Sorescu, 2003).

The United States dominates the world in terms of research dollars expended on biotechnology (Pisano, 2002). That are some institutional factors that explain this: the United States government has provided "massive support to basic biomedical research" (Pisano, 2002). Moreover, many start-up firms originate from people leaving academia after discovery some biotechnology using federal funds for the research. Nathan Myhrvold, a former top Microsoft Corporation top scientist, predicts that of the top twenty pharmaceutical firms today, most will be replaced by small start-up firms and only one or two would be familiar names in the near future (Flaherty, 2003).

Andy Grove, chairman of Intel Corporation, writes that the health care industry could be the next industry to undergo significant change for several reasons (2003). First, this industry represents 15% of the GDP of the United States. Second, the customers are ready for action and want better results as they become more informed about health care issues. Third, Grove notes that with an aging population, the monetary strain on the health care system is expected to significantly increase but with no plan in place to cover these rising costs. Lastly, Grove argues that there are a number of technologies with enough combined power to synthesize large amounts of data resulting in better and more efficient drug production.

CHAPTER V

SUMMARY AND CONCLUSIONS

This paper has presented an overview and analysis of innovation and the business cycle. Joseph Schumpeter wrote prolifically about this relationship. It is his research that forms the foundation for any study of the business cycle and innovation. Modern-day researchers still cite his work and rely on it for guidance in researching and evaluating today's economic issues. Innovation and business cycles are among the most debated and discussed issues in economics and business. Each of these issues is important for a comprehensive understanding of the American economy or any other capitalistic economy.

This paper presented some of the historical and current issues that permeate current business discussions. The necessity to invent and innovate is the root of capitalism, and the United States, through its policy making, has been able to give scientists, engineers, general inventors, and entrepreneurs some essential incentives for inventing and innovating (patents, trademarks, etc.).

As time passes and we have more historical data to synthesize, researchers should be able to discover some provocative issues that will help policy makers and business leaders. Further research should focus on the amount of imports and exports related to the industries above. Future research could also look at the international impact of some of these industries in the post-World War II era. This would be particularly useful for the steel and pharmaceutical industries. Another study might examine some of these innovations in conjunctions with others over the same time

period. This paper examined two of Schumpeter's five types of innovation. It would be useful if further research could investigate come of the other types of innovation as proposed by Schumpeter. For example, it might be useful to look at the firms that penetrate new markets as a type of innovation and investigate the effects thereof.

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