ANKARA
HACI BAYRAM VELİ
ÜNİVERSİTESİ

GRADUATE SCHOOL OF EDUCATION

MANUFACTURING AND ITS TRANSFORMATION WITHIN THE GLOBAL CONTEXT: THE CASE OF USA

Sabahattin Tuğrul İMER
Advisor
Prof. Dr. Kamil Ufuk BİLGİN

DOCTORAL DISSERTATION
THE DEPARTMENT OF POLITICAL SCIENCE
AND PUBLIC ADMINISTRATION

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Director of Graduate School of Education

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18 / 02 / 2019

MANUFACTURING AND ITS TRANSFORMATION WITHIN THE GLOBAL CONTEXT: THE CASE OF USA
(Ph. D. Thesis)

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ABSTRACT

This thesis analyzes the transformation of manufacturing within a global scope and elaborates on the case through the American manufacturing industry by accentuating the impacts of manufacturing on the permanent progress of the human kind. Within that regard, the dissertation also aims to provide a perspective on the public policy of manufacturing, science and technology. The thesis examines the issue from three different related aspects. First, it describes the various transformations of the manufacturing industry since the first industrial revolution. These transformations, which converted production techniques, manufacturing systems, factory set up and business management, are the outcomes of many breakthrough innovations, which emerged due to advances in science and technology. This continuous process brought a steady increase in productivity, which may be prominently observed during the period 1870-1970 when the intensity of breakthrough innovations was relatively higher than at other times. That said, it is important to note that value added manufacturing, which arises from innovation, remains the key factor in the creation of growth, welfare and employment. The second perspective focuses on the concept of de-industrialization and re- industrialization trends in the United States. The de-industrialization concept has been laid out from 1980 until 2018 within the time frame of 1980 onward, when neo liberal policies speeded the trend of relocating many manufacturing establishments overseas. During the last ten years or so the United States Administration's policies have been changing to bring some of the manufacturing establishments back. This trend is consistent with the argument that innovation is possible when skilled human resources; universities, R&D facilities and factories are located in close proximity. As the third and final perspective, this thesis argues that despite the progressive transformation of manufacturing towards more value-added production, basic material production such as steel and aluminum still have a vital role in the American manufacturing industry today. Time based data and information from the American automotive industry supports this argument. This is important because the automotive industry is a large industrial segment that establishes a linkage between the old or mature industries such as the steel, aluminum and the new or modern industries such as ICT and electronics.

Science Code	:	111621
Key Words	:	manufacturing transformation, industrial revolution, de-industrialization, re-industrialization, manufacturing innovation, American manufacturing, breakthrough innovation, steel industry, automotive industry, public policy of manufacturing, science and technology, America, public policy
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İMALAT SANAYİNİN KÜRESEL BOYUTTAKİ DÖNÜŞÜMÜ: ABD ÖRNEĞİ

(Doktora Tezi)

Sabahattin Tuğrul İMER

ANKARA HACI BAYRAM VELİ ÜNİVERSİTESİ
LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

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ÖZET

Bu tez, imalat sanayinin küresel kapsamda ve tarihi süreçteki dönüşümünü Amerikan imalat sanayisi üzerine odaklanarak incelemektedir. Bununla birlikte insanlığın süregelen gelişiminde üretimin oynadığı rol üzerine de vurgu yapmaktadır. Aynı zamanda bu çalışma imalat sanayine, bilime ve teknolojiye yönelik kamu politikaları üzerine de bir bakış açısı vermeyi hedeflemektedir. Tez, konuyu üç farklı açıdan ele alıyor. İlk olarak, birinci sanayi devriminden bu yana imalat sanayinin geçirdiği çeşitli dönüşümleri anlatıyor. Bu kapsamda üretim tekniklerini, üretim sistemlerini, fabrika kurulumlarını ve işletme yöntemlerini değiştiren bu dönüşümler, bilim ve teknolojideki ilerlemelere bağlı olarak ortaya çıkan inovasyonlara dayalı kırılmaların sonucudur. Özellikle, inovasyon yoğunluğunun diğer zamanlara göre nispeten yüksek olduğu 1870-1970 döneminde üretkenlikte gözle görülen istikrarlı artış inovasyon ve üretkenlik arasındaki pozitif ilişkiyi desteklemektedir. Bu bağlamda, inovasyondan kaynaklanan katma değerli üretimin, büyüme, refah ve istihdam yaratılmasında kilit faktör olarak kaldığını söylemek de mümkündür. İkinci perspektifte tez ABD'deki sanayisizleşme ve yeniden sanayileşme eğilimleri kavramlarına odaklanmaktadır. Sanayisizleşme kavramı, 1980' lerden günümüze kadar olan süreçte, neo-liberal politikaların da etkisiyle birçok imalat sanayi tesisinin kapatılarak üretimin ülke dışına, özellikle Uzak Doğuya konuşlandırma eğiliminin hızlandığı bir zamanda ortaya konulmuştur. Ancak bilhassa son on yıllık süre zarfında ABD politikalarının bir kısım sanayi üretimini yeniden ülkeye geri getirmek üzerine değişmekte olduğu ve yeniden sanayileşme kavramına odaklanıldığı gözlenmektedir. Aynı zamanda bu eğilim, yetenekli insan sermayesi, üniversiteler, AR-Ge tesisleri ve fabrikaların coğrafi yakınlık ve iş birliği içerisinde bulunduğu zaman inovasyonun mümkün olabileceği argümanıyla da tutarlıdır. Üçüncü ve son bakış açısına göre ise bu tez, üretimin daha katma değerli üretime doğru ilerleyen dönüşümüne rağmen, çelik ve alüminyum gibi temel malzeme üretiminin günümüzde Amerikan imalat endüstrisinde hala hayati bir rol oynadığını öne sürmektedir. Zamana bağlı veriler ve Amerikan otomotiv endüstrisinden gelen bilgiler bu argümanı desteklemektedir. Bu bağlamda örnek vaka olarak incelenen otomotiv sektörü, çelik, alüminyum gibi geleneksel endüstrilerle elektronik ve bilişim sektörü gibi daha modern sanayi kolları arasında bir bağ kuran, geniş çeşitliliğe sahip bir konumdadır.

Bilim Kodu	:	111621
Anahtar Kelimeler	:	imalat sanayisi donusumu, otomotiv sanayi, demir çelik sanayisi, sanayi devrimi, sanayisizleşme, yeniden sanayileşme, üretimde inovasyon, bilim-sanayi- -teknoloji politikaları, Amerika, kamu politikaları
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ABBREVIATIONS

Abbreviations	**Definitions**
AAC	American Auto Council
AAPC	American Automotive Policy Council
AC	Alternating Current
AD	Anno Domini, the years passed after the birth of Jesus Christ
AHSS	Advanced High Strength Steel
AISI	American Iron and Steel Institute
ARPA	Advanced Research Project Agency
ARPANET	Advanced Research Project Agency Network
ASM	The American System of Manufacturing
BLS	United States Bureau of Labor Statistics
CAD	Computer-Aided-Design
CAM	Computer-Aided-Manufacturing
CAR	The Center for Automotive Research
CAW	Canadian Automakers Union
CEO	Chief Executive Officer
CIM	Computer Integrated Manufacturing
CNC	Computer Numerical Control
DAC	Design Automated by Computer
DARPA	Defense Advanced Project Agency
DC	Direct Current
DoD	Department of Defense
DOE	United States Department of Energy
DOL	United States Department of Labor
ENIAC	The Electronic Numerical Integrator and Computer
EPA	United States Environmental Protection Agency
EU	European Union

Abbreviations	Definitions
FCA	The Fiat Chrysler Automobiles
FE	Fuel Efficiency
FSV	Future Steel Vehicle
GDP	Gross Domestic Product
GE	General Electric
GM	General Motors
GPS	Global Positioning System
GPT	General Purpose Technology
HCI	Human-computer interaction
HSS	High Strength Steel
IBM	International Business Machine
IC	Information & Communication
ICAM	Integrated Computer Aided Manufacturing
ICT	Information & Communication Technology
IFC	International Finance Corporation
IIoT	Industrial Internet of Things
IISI	International Iron and Steel Institute
IMVP	International Motor Vehicle Program
IoT	Internet of Things
ITA	International Trade Administration
ITIF	The Information Technology & Innovation Foundation
JIT	Just- in time Delivery
LDV	Light Duty Vehicle
LED	Light Emitting Diode
MIT	Massachusetts Institute of Technology
MLP	Multi Level Perspective Approach
MPG	Miles per Gallon
MV	Motor Vehicle

Abbreviations	**Definitions**
MVA	Manufacturing Value Added
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration
NIH	The National Institute of Health
NUMMI	New United Motor Manufacturing Plant
N**REL**	National Renewable Energy Laboratory
NSF	The National Science Foundation
OEM	Original Equipment Manufacturer
PC	Personal Computer
PRONTO	Program for Numerical Tooling Operations
PV	Photovoltaic
REMI	Regional Economic Development Model
R&D	Research & Development
SMDI	Steel Market Development Institute
TFP	Total Factor Productivity
TPS	Toyota Production System
TVA	Tennessee Valley Authority
UCLA	University of California, Los Angeles
UHSS	Ultra High Strength Steel
VTO	Vehicle Technology Office
WSA	World Steel Association
WTO	World Trade Organization

INTRODUCTION

Economic growth and prosperity occur in two ways; either through naturally endowed resources such as oil, natural gas, mine deposits of various minerals and agricultural goods, of which humans have no control over, or from the refined or manufactured products which can mostly be defined as man-made wealth. In essence, there are two classical theoretical sources that constitute the basis for economic growth and prosperity. The first one is the theory laid out by some such as Adam Smith and Schumpeter who argue that such improvements in wealth creation come from innovation; others such as Ricardo argues that capital is what drives economic growth – more specifically it is the increase in factors of production which can be transformed into capital and of course capital can be natural resources.

Eventually, based on these two theoretical sources manufacturing can be described as the process of the human transformation of all resources and materials from one form to another in geometric and compositional or both ways . Thereby, with a serious of steps in the process the main output consists of goods with more discrete parts and waste products, which for some parts or products are byproducts. In other words, manufacturing comprises both the transformation of raw materials into man-made materials and that of the man-made materials into discrete parts. Most of the manufacturing processes fall into four main categories: casting or molding, forming, machining or joining to include welding, brazing and the mechanical assembly of parts which are produced out of the first three categories (Rhoades, 2005).

In the 1998 report of the U.S. National Research Council Board on Manufacturing and Engineering Design, manufacturing was defined as “the process and entities required to create, develop, support and deliver products” (National Research Council, 1998, as cited in Rhoades, 2005). The Labor Department of the United States describes manufacturing as the mechanical, physical or chemical transformation of materials, components or substances into new products. They accentuate the processing of materials and define the manufacturing tools as the power-driven machines, materials handling equipment and hand power. Thereof manufacturing is categorized as a part of the goods-producing industries super-sector group according to North American Industries Classification System (U.S. Bureau of Labor Statistics [BLS], 2018a). Literally, manufacturing is the main source of wealth as prosperity depends on how much people produce and what the quality is of what they produce. Because the humans are the end users of the goods and their life standard depends on those two parameters; the quantity and the quality of production.

Within this context, this dissertation aims to unveil supportive arguments and data which could reveal the role of manufacturing in the permenant progress of the humans in creating prosperity. The theses analysis the issue with integrity through three objectives that are closely related and linked with each other.

The first objective of this thesis is to set a correlation between manufacturing, economic growth and economic development. In this respect, the thesis analysis the causes and the impacts of the outcomes of the transformations of the manufacturing industry on economy and prosperity, through the historical perspective between 1850 and 2018, within the global context and mainly through the country case of the United States of America. It follows out that the outcomes, which have been technical, managerial as well as organizational in nature, have caused a continues gain in efficiency on the manufacturing systems which later translated into perpetual increases in productivity. It is known that there exists a positive correlation between productivity and economic growth. Nonetheless, it is also noteworthy to add that the transformations in the manufacturing industry have been triggered by the innovations, which were based on the advancements in science and technology. Also, from the standpoint of economic development, a research is conducted to reveal arguments setting a correlation between manufacturing, employment and income distribution.

United States is taken as the country case because it has achieved an exceptional economic growth since the second half of the 19’th century and through course of the 20’th century and especially, the period of fast growth in the manufacturing industry in America coincides with the time when the U.S. economy grew faster than the rest of the world during the first half of the 20’th century. United States has been the world’s largest economy since 1871 and it has reached the highest levels of economic standards in the world already at the beginning of the 20’Th Century. Also, many inventions or innovations of the 18’Th, 19’Th and 20’Th century have either happened on U.S. soil or were firstly adopted by the manufacturing industry in America. Overall, the prominent role of manufacturing in making the United States the leading economic power and the most prosperous country in the world after the turn of the 20th century, pioneering role of America in the service sector and the leading role of the U.S. in information and communication technologies (ICT) are among the main viable reasons for analyzing the case through the USA.

The second objective of this thesis is to unveil the economic impacts of the periods of de-industrialization and re-industrialization in the United States and correlate this issue with the concept of manufacturing & innovation ecosystem. The de-industrialization period started with the world oil crisis in 1973 and become more prominent after 1980, at the time of neo liberal policies, when some of the manufacturing industry has been continuously off-shored to outside of the country, mainly to Asia. The re-shoring trend became more visible after 2008 and more prominent within the past few years when the U.S. Government has been generating public polices in favor of re-shoring of some of the sectors of the manufacturing industry and encouraging manufacturing investments on the U.S. Soil. In the same context, the theory of industrial commons (Pisano and Shih, 2012) or the integrity of the manufacturing & innovation concept argues that innovation as well as progress in technology is only possible when factories, universities, R&D facilities and the skilled human power are in close collaboration and integrity with each other. Within the same context it is also claimed that this system would only function properly if all these mentioned parties are located in close geographical proximity.

The third objective of this thesis is to unveil the role of the basic material manufacturing industry and especially the role of steel as the strategic material within the historical context with its contribution to the innovation ecosystem, evolution of other industrial sectors, inventions and to the transformation of the manufacturing industry as a whole. This thesis argues that the role of steel in today’s industrial development is as critical as it has been in the 19’th and 20’th century. Because the physical and chemical properties of steel has been continuously improving in parallel with the advances in science and technology in a high pace since the invention of the process to produce bulk steel inexpensively in 1855. It shows out that still at the present day steel is the fundamental ingredient for most of the industrial sectors such as automotive, air and space, defense, energy, construction, agriculture, food and so on. Therefore, it is argued that the maintenance of a thriving steel industry is necessary for the sustainability of an industrial base which in turn is the source of economic progress and national security. To find supportive arguments and data for this thesis the case is elaborated through the American automotive industry.

The auto industry is selected firstly since it is a large industrial segment which bridges the traditional industries such as steel and aluminum and the modern industries such as ICT and electronics. Secondly, the automotive industry, since its nature of being directly customer driven, is always up to date with the latest updated technologies. Therefore the Research and Development (R&D) spending in the automotive industry is higher as compared to most of other industries. Thirdly, the automotive industry has a very extensive industrial base and therefore is intertwined with a diverse range of manufacturing sectors.

Global manufacturing starts with the global history of industrialization. Historically, the manufacturing industry has gone through a period of progressive evolution and has witnessed revolutionary transformations which were all triggered by multiple breakthrough innovations. Some good examples to those innovations are the steam engine, electricity, the electric motor, the internal combustion engine, the airplane, the semi- conductor, the transistor, the microprocessor, the computer and the Internet. The quest has been in improving the efficiency, raising the productivity and as a result generating more prosperity for people. Prosperity is obviously reached with positive economic growth. Many manufacturing technologies have been developed and applied for the sake of reaching this goal. They are mostly related to product and process development. Nonetheless, new manufacturing systems have been adopted to optimize production cost, production speed and the labor power. Though, the driving force for the permanent progress has always been improvements in science and technology. Innovations are the foremost important factors that lie behind the advancement of the manufacturing industry. Because with the application of the innovative technologies the level for powering and controlling machines has continuously increased. The improvements in the capabilities have resulted in the progressive mechanization of the manufacturing industry with the involvement of more sophisticated machinery in the production line. The technological driven transformation of the manufacturing industry has simultaneously brought new manufacturing systems to factories as well. In parallel with the technological transformations there have been transformations in manufacturing systems which include both technical and managerial aspects.

In the economic history the growth of the Western World in the period of AD 1 to AD 1820 has been noted as 0.06 % per year or 6 % in average per century (Maddison, 1999). Though within the century beginning with 1870 there was noticeable swift growth. Then, after 1970 until 2018 day the growth rate has slowed. Robert J. Gordon calls the century of 1870 and 1970 as the "Special Century" because a large number of game changing inventions such as the electrical motor, internal combustion engine, computer, microprocessor, motion pictures, etc. occurred in that time frame (Gordon, 2016:1-5). Those inventions spurred many innovations such as the sewing machine, automobile, airplane, television, washing machine, heating systems etc. which directly touched the everyday life of the people in a great way. Eventually they all affected most of the people in the world with a huge improvement in living standards which was largely reflected in the economic growth rate figures of the world economy. This revolutionary progress has changed the manufacturing system completely and had a noticeable positive effect on productivity and then on prosperity. Particularly, the great inventions made the century of 1870-1970 very special. The United States in particular became the frontier among the developed nations in shaping these changes in living developments. The undisputable industrial success in parallel to the apparently fast pace economic growth of the United Sates is remarkable following its Civil War and more so after the beginning of the 20th Century (Figure 2.1 and Figure 2.2). At the time frame beginning with 1870 the urban population of the United States was 24.9 percent of the whole which rose to 73.7 percent in 1970. As a few examples to show the change in the living standards of the American people it is helpful to observe that in 1880 none of the households in America were wired for electricity; whereas in 1940, all urban homes were wired. Also, in the same year 94% of the houses in the urban areas had clean water and sewage, more than 80% had interior flushed toilets, 73 % had gas for cooking and heating and more than 55% percent had refrigerators (Gordon, 2016:1-23). As per these examples it is important to note that conceptually prosperity is directly related to the increase in life standards for the widest range of the society as possible. Within the same scope a well-balanced income distribution is another indicator for prosperity which comes with the wealth produced by economic growth.

According to Robert Gordon (Gordon, 2016), there were remarkable inventions and innovations after the 1970s related to electronic control, entertainment, communication and ICT but first they were less in quantity and they tended to have had an effect on a narrower scope within a more limited sphere. Further, the overall progress outside the fields of entertainment, communication and information technology was quite limited. To illustrate, by 1970 kitchen appliances were already in place, motor vehicles were already conducting transportation on the roads and air travel was already happening. Even in the medical sector, the antibiotics, radiation, the standard cancer treatment methodology called chemotherapy had already been invented and in use in the period before 1970. Finally, there has been a rising trend of inequality in the income distribution after the 1970's. Therefore, it has become more difficult to share the benefits of the innovations on equal terms among the people (Gordon, 2016:1-10)

At the present, we are talking about robotics, augmented reality, artificial intelligence, 3D Printing, additive manufacturing, the digital transformation and digital factory concept which point to the scope of data driven transformation such as the internet of things. However, these technologies are recently being applied in the manufacturing industry and their access is limited. (Muhleisen, 2018; Hernandez et al., 2016; Monahan, Taylor-Kale and Simpson, 2017) More time is needed to assess the level of their integration into the manufacturing process. Thus, the impact of these advancements on productivity, economic growth and prosperity is unknown yet.

In brief, the first industrial revolution can be marked with the mechanization of production. The breakthrough invention for that period was the steam engine. The production structure was industrial cities. The second industrial revolution covers the period between the late 19th century and the mid 20th century. Mass production, which was supported by economies of scale and the division of labor, was the main core feature of manufacturing industry for this period. The technical features were the adoption of electricity in factory-based production and the revolution in transportation that came through the invention of the internal combustion engine. The production structure evolved from industrial cities into industrial regions. The period for the second half of the 20th Century is designated as the third industrial revolution and is marked with the transformation into automation with the aid of the advancements in electronics and information technology. Work was focused on decreasing the input costs in production and in particular, labor. During the same time-period, in parallel with reduced transportation costs which brought trade liberalization, there happened to be a shift or relocation of manufacturing establishments to the developing part of the world where the labor cost was lower than in the industrialized countries. This development enhanced the development of global production networks. Especially after the 1970's the global production system shifted from traditional mass production to flexible and lean serial production. Because the flexible manufacturing system has brought many economic benefits such as enhanced machine utilization and products quality besides lower inventories, manufacturing times, labor costs and smaller factory space (Mansfield, 1993). Then the fourth industrial revolution begins with the turn of the 21'st Century and is still pending as of the present day. The main future of our times is robotization and smart manufacturing. With the penetration of electronics, IT and cyber-physical systems more value added is expected to occur in manufacturing. The digitalization of manufacturing increases the importance of the global value chain concept as the importance of unskilled labor and geography becomes less critical in terms of production costs. This trend is also supported by enhanced global distribution networks. On the other hand, the vitality of skilled labor and intellectual human capital becomes more critical than location because progress in manufacturing is being achieved today through science and technology. This trend tends to change the type and nature of the jobs in the long run (Rotman, 2013; Reenen, 1997).

From another perspective, these transformations happen as a consequence of the influence of or the human desire to use nature in the most efficient way in the journey of pursuing more happiness and thus in pursuit of least total cost, i.e. improvement in the quality of life and environment. Comfort is provided with wealth and that is created with manufacturing of the goods and services which are utilized by humans to increase their quality of life. Efficiency is important because resources are limited, while the human population is inclined to increase and as a result competition among the nations becomes a reality and thus continues.

There are some prominent factors that have been playing a vital role in the pursuit of permanent progress and in the evolution of the manufacturing industry. The first factor is the human capital. There is a blue-collar, trained workforce that executes the physical manufacturing process and the white-collar educated workforce who invent, innovate, plan, design, manage, supervise and engineer the process. This workforce is employed by the government, at the universities as well as at public/private institutions. Within that scope the universities and educational institutions are important for two reasons; first to educate the skilled workforce and secondly to perform scientific research and development work that produces outcomes which contribute to the industrial development and increased productivity. The second factor is the factories or production places. These are the places where technology is being constantly used and improved. Within that context, it is also important to accentuate the importance of university and industry collaboration. The permanent and continuous interaction is necessary for maintaining harmony and consolidation of theoretical and practical knowledge. The third factor is the role of the entrepreneur, which can come from all levels of the society. Entrepreneurs are the people who have the vision and the will to constitute and grow a viable business from scratch based on self-incentives. Throughout history, many entrepreneurs have formed unprecedented businesses and have introduced breakthrough innovations that had a direct impact on the transformation of manufacturing as the whole concept. James Watt, Thomas Edison, Henry Ford, Graham Bell, Karl Benz, Wright Brothers, Bill Gates, Steve Jobs and Elon Musk are just a few examples that can be mentioned of those who have and are those who have been significant entrepreneurs. The final factor is the role of government that set the vision, provides the political will and constitutes the required public policies which help the science, innovation and manufacturing ecosystem develop. There are also complementary factors such as the natural endowment of natural resources and economies of scale, which spur the advancement through capital accumulation and the constitution of a large and growing demand.

As a matter of fact, all the examples of the world's economic leading nations of today including USA, UK, Germany, Russia, Japan and recently South Korea and China have all gone through a similar path as they created wealth through manufacturing. Lately, China's huge improvement in economy, in particular during the past two decades, is an important example. The acceleration and enlargement in industrialization has brought about an increase in their technology and innovation capacity. There has been a transition of China's industry from imitation based to innovation based manufacturing (Yu, Pan and Stough, 2016). According to U.S. National Science Board the share of China's high technology manufacturing increased from 8% at the beginning of 2000s to 24% in 2013 and for the same time frame China's global portion of technology manufacturing rose from approximately 2 to 14.5 percent (Yu, Pan and Stough, 2016). Also regarding quantity for the similar period, China's manufacturing value added output has grown from $625 billion in 2004 to $3.59 trillion in 2017 (World Bank, 2018b). The transfer of manufacturing establishments from the west has resulted in the transformation of knowledge and technology. This movement has brought the need for skilled and educated human power (Yu, Pan and Stough, 2016). The inquiries from industry have strengthened the interaction with the universities and that in turn has resulted in quality improvement and an elevation of standards in academia. Compared with three decades ago there has been a notable increase in the quality and the number of the Chinese universities and Chinese human capital (Yu, Pan and Stough, 2016).

Within the same context it is crucial to emphasize the importance of university – industry interaction. It is worth noting that the two entities have to be intimately associated with each other. Progress in technology is not possible without an improvement in science. Vice versa, without testing technologies that have been created by the science of knowledge at the universities. Manufacturing is crucial from the perspective of research and development (R&D) as most of that work happens in the manufacturing sector. Therefore, R&D facilities and manufacturing plants generally have to be close to each other in terms of location and communication.

It is clear that technological competition and emerging technologies will play a vital role in the future of the manufacturing industry. The new transformations and improvements in the industry are expected to happen in the new sectors such as industrial robots and automation, additive manufacturing, advanced design, direct interconnections over the internet between the sensor and machines, material science, biotechnology and energy technologies. The current future of manufacturing may be viewed as evolving in technology and in methodology such as created by Elon Musk and the rising industries in solar, batteries, space and electrical car manufacturing. Though, at the same time it is difficult to comment on their possible effects on U.S. manufacturing without examining the impact of some of the new technologies such as Robotics, 3-D printing, sensors, artificial intelligence, and so on.

In the manufacturing industry, in parallel with the advances in science and technology new systems have been adopted, new production techniques have been developed, new machineries have been built and new materials introduced. Especially, in the last 40 years with the advances in the ICT sector the manufacturing industry has gradually shifted towards a more digital and computer-controlled phase where robots in part have replaced workforce in the production lines. Nonetheless, the whole manufacturing process has become more efficient and the final consumer goods have become more advanced. As a natural consequence the final outputs of the manufacturing industry in general have become more value-added and the process has become more knowledge centric. However, as this thesis implies, despite the rising trends towards more value added in sectors such as the service industry, electronic industry and the ICT sector since the beginning of the 1980’s, the old industries like the main material manufacturing industries such as steel and aluminum as well as the machine and tooling industries are still playing a critical role in creating prosperity as they were doing so in the past for a number of reasons. Regarding steel and aluminum, despite their change in the input quantity and quality over time, the automobile, aerospace, ship building, defense, construction, energy, machine, packaging and appliances industries still use them extensively. Of course, today steel, which is used in the construction of manufactured goods, is more value-added oriented than the kind of steel which was used in the 1980's. For instance, the demand for alloyed steel is greater than in the past. Also, steel production technology has improved and the steel plants have become more automated and digitally controlled with the development of better machinery and the improvement of information and communication technology.

Moreover, the improvement in the key metal industries has brought, in parallel, the developments in other advanced material manufacturing industries such as the composite materials, ceramics or plastics. They have also paved the way for other high-tech manufacturing industries such as the semiconductor or microprocessor industry since science, technology, knowledge, skill and process experience is shared and transferred between the various industrial segments. As a matter of fact, material is the foundation for all the other industrial segments given that the total of the manufactured goods is produced from a substance and hence both design and construction criteria are directly linked to the properties of the materials.

On the other hand, the machine and the tooling industry remains as the backbone of the manufacturing industry since without them manufacturing would not be possible. These industries are also important in that they are necessary to produce investment goods including other machines and materials that are required for sustainable industrialization. The advancements in technology have directly been reflected in the machines and tools which make up the manufacturing equipment at the factories. As a result, through the history of manufacturing, the capabilities and efficiencies of factories have continuously been increased. Especially the improvements in the ICT sector after the 1980's have played a critical role within that regard.

It could be argued that the low-tech, medium-high tech and the high-tech industries are closely associated with each other and they all need to work hand-to-hand within the same ecosystem. The absence of one of the other would be detrimental to the whole structure as it would slow down the pace of industrialization and innovation. The end effect would be negative on the whole economy. On the other hand, it is clear that the ICT sector as well as the service sectors are the necessary but are complementary segments to the manufacturing industry. Therefore, an optimum combination and collaboration of the all the sectors make up a successful economy. However, as a baseline, the United States will likely only be able to sustain prosperity in the long run with the maintenance of a thriving manufacturing industry.

From another perspective, the technological improvements in the robotic sector on the one hand may eliminate the need for a regular employee, while at the same time contribute to re-shoring while thus beating the cost advantage of Asia. So, this double-edged sword effect should be analyzed more in depth (Baily and Bosworth, 2014). With the improvement of technology, the U.S. based outputs may increase though the impact on employment is unclear. In all this retrospect the measurement of value-added versus employment may be a good indication in an age when technology has and is rapidly substituting for labor. As value or value-added is going up, it is doing so when labor is decreasing in number of workers. This fact then relates to changes in productivity, competitiveness and efficiency, and finally for income and its distribution in the society.

It is noteworthy to state that besides its impacts on economic growth manufacturing industry is very critical from the standpoint of creating employment. There has always been a positive correlation between the prominence of manufacturing and employment. As it has been the case in the United States, onward from 1930'Th all through the fast industrialization period through the end of 1970's, the number in manufacturing employment showed a steady increase (Figure 3.9). Then it peaked in 1979 and afterwards, in the de-industrialization period, from the early 1980's onward there is a steady decrease again. This decrease has touched the bottom after the financial crisis of 2008 and it picked back up in the following period also with the aid of the public policies, which supported re-industrialization. The job growth has been rising since 2010 when the unemployment peaked at 10 percent. Especially for the last five years there has been a steady decrease in the unemployment rate. In September 2018 it reached 3.7 percent, which is the lowest level since 1969.

It follows out that employment is the foremost important criteria for the manufacturing industry to create prosperity. Besides creating income directly to the employees in the manufacturing field it transfers prosperity to other industries such as the services, mining construction and agriculture. According to National Association of Manufacturers annual report for 2018 for one employee added to the manufacturing industry another 3.4 workers are added to the economy somewhere else (National Association of Manufacturers [NAM], 2018). A study performed by Fred Zimmerman and Dave Beal (Zimmermann and Beal, 2002:112) for 232 manufacturing counties from 1988 to 1997 supports the hypothesis of the role of manufacturing in creating employment and prosperity (Table 3.1.). Therefore, the job creation and manufacturing has always been at the core of the priority list of all the governments from another standpoint.

It should also be noted that in today's automated and technologically advanced manufacturing industry the difficulty arises in finding the skilled workforce. In parallel with the integration of the new Internet of Things (IoT) related technologies such as artificial intelligence, machine learning or the new technique in manufacturing "additive manufacturing", the profile of the manufacturing workforce is in the process of a continuous change. This reality brings the need for more focus on training and education. It follows out that, knowledge will become more crucial in the future. Also, the job definitions is within a shift from the pure manufacturing area towards a position where mix of services and manufacturing. In a broad view, trade policies, deregulation, tax cuts, investment incentives and industrial training programs are among the public policy tools that the current U.S. administration uses for the creation of more jobs.

Overall, this dissertation aims to lay out some findings which could be used in the analysis of the impact of manufacturing on prosperity, in the same respect, also, in the interpretation of the correlation between manufacturing, economic growth and economic development. The establishment and properly functioning of the manufacturing, service and the agricultural sectors with integrity is not only the matter of the natural free market equilibrium but also the main topic issue of the public policies which are generated by the government. The optimum economic model for a nation would very much depend on the domestic potential as well as the political and economic conditions of the world at that specific time. Based on many country cases, neither a purely market driven economy with zero state involvement nor an economical model which relies mostly on the state to regulate the markets have been proved out as the right recipes for success so far. Therefore the public policy tools, which the governments hold to enforce the right polies, are very critical, as they will be directly related with economic as well as national security.

As a matter of fact the manufacturing, innovation, trade, education, energy, and defense policies are very closely intertwined with each other. The sustainability and continuity of those polices are important. Because, to achieve permanent progress the industries should be linked to formal institutions of science and education as well as to the accumulated knowledge of science and arts. Since the knowledge accumulation should be regarded at least as important as the financial capital, the policies related to the training and education system plays also an important role from the standpoint of human capital. Together with the innovation and R&D capabilities they are very critical for the long-term preservation of the economic security of a nation.

In all respect, with this dissertation it is aimed to provide data, information, findings and arguments, which could contribute to the constitution of the public policies which are related with manufacturing, innovation, science and technology.

Regarding the research methodology, both empirical and non-empirical research methods have been applied fort his study. Literature survey has mainly been conducted through books, articles, research papers, reports, newspapers and conference notes; both from printed and Internet resources. This dissertation research also used archival and interpretive methods for the analysis of the statistical data.

During the research there were some limitations on the access to the complete set of data especially from the automotive industry. However, I reached out to most of the data, especially to what that sufficed to make my case. Another limitation was in the measuring of the economic impact of some of the newly emerging manufacturing technologies, such as additive manufacturing or the ICT related technologies such as augmented reality or artificial intelligence. Their impact on economic growth and development is limited at this time. Because some of those technologies are either yet at the evolutionary phase or their fully adoption to the manufacturing industry is not completed yet. This situation limits the capacity to make a firm evaluation on this issue.

CHAPTER 1

MANUFACTURING: SCOPE, IMPACT AND MEASUREMENT

The purpose of this chapter is to lay out the scope of manufacturing from different aspects. Within that regard manufacturing is firstly defined conceptually and within the historical development perspective. Finally it is further described within the philosophical and materialistic context. Then the impact that manufacturing has been creating is discussed, especially from the economic perspective. Nonetheless, in order to materialize and show this impact in numbers, certain measurement approaches are elaborated. In this context it is explained which indicators are selected and for which grounds. These indicators are used all through this dissertation in explaining the role of manufacturing in creating economic growth and development.

1.1. The Scope of Manufacturing

Everything in the history of human development started with the urge to find and provide food. This brought the "Agricultural Revolution" that was related to the transformation and cultivation of nature for the human benefit. From this came an increasing division of labor, which eventually led to the development of non-agricultural production. The purpose was to meet the needs of the people. It was a dynamic process and has been based on the concept of permanent development. Nonetheless, the first science "Astronomy" and then "Mechanical Physics" were created and assisted in the cultivation of nature even more. In fact, the idea behind all the improvements stems from the motive of the humans of imitating the nature

Later, in parallel with the migration of the people from the rural farmlands to the cities, the concepts of urbanization, commodity exchange and market have been introduced. Urbanization also brought the need to manufacture in order to provide goods and commodities for the people.

In fact, the permanent progress has brought a competition both between people and the nations. This has an upside and a downside. The upside is that, as the resources are limited and the human population is rising, competition has helped in the improvement of cultivating the nature with the best efficient way. It helped in the development of science and technology, which in turn contributed, to the development of the manufacturing structures and processes in the due course. On the other hand, it became destructive; as the people or nations who were left behind in the race of innovation technology development and efficient manufacturing, had to suffer the consequences of not living in the same standards with the people and nations who have succeeded.

According to the political scientists Thomas Hobbes and John Lock everything that humans do is for the permanent progress as to maximize the level of happiness. That is articulated by achieving better life standards. So it started with the migration to the cities and for the aim of shaping the future in the best way. An old Roman saying also indicates to the same point by stating “Salus publica suprema lex” (Welfare of the society is the supreme law of the society).

In order to achieve the ultimate goal of happiness there happens to be either a conflict or collaboration between people. According to Thomas Hobbes, who is regarded as one of the founders of the liberal discourse, if any two or more men desire the same thing conflict may arise (Aubrey, 1949:317; Hobbes, 1651). Hobbes emphasizes on the permanent conflicts between people because of the equality of desires. As the resources are limited and the population is rising there will be permanent competition in the world. On the other hand, another political scientist, John Lock, who is also seen as among the founders of the liberal discourse argues that as God created the world, including ourselves, all the creatures have a purpose and that purpose is to utilize all the available resources for the survival but not to waste it. The application of science and technology means to serve for this purpose.

Hence, superiority and efficiency could only be achieved through science, innovation and technology. The application and implication of those determinants could be seen in the manufacturing industry, which serves directly to the people. Within the same line, the transformations in the manufacturing industry have happened through the breakthrough innovations, which made it possible for the industry to produce more with less cost and effort. In other words, the manufacturing industry has always geared towards more efficient production structures and technologies.

Throughout the history, all countries in the world have sought for bettering the lives of their citizens and therefore they were all in search for finding better technologies. There were wars but also collaborations between the nations at the same time. One tool of economic collaboration is trade, which helps both ends in exchanging their commodities. One will offer what the other wants to buy. However, the exchange of goods gives rise to competition since the trend has always been in offering better products or services with more competitive prices. This is only sustainable through innovation as well as improved technology, which create more value added and prosperity.

There is an obvious correlation between producing and selling more high technological products and prosperity. Today, the world’s richest nations became so by achieving more advancement in technology. There is an endless race between the nations in utilizing the nature in the best possible way. The discernable output of this can be observed in the vision of both economic and militarily superiority.

Also, it is important to take a note about equilibrium and balance in international relations between the nations, even if they interact in trade relations. As the German American economist Friedrich List (1789-1846), who developed the “National System of Innovation” has stated, “If there is a notable difference in industrial development and technology levels between the two nations, who get involved in trade relation with each other, the one with the superiority is always opt to prevail”. This fact has proven itself and has led to the self-development of many nations’ industrial and technological ecosystems such as Germany, England, United States and Soviet Union. While building their industry they heavily invested in their human capital through developing a great university system, which eventually led to the progress in science and later in technology. The South East Asia countries such as Japan, South Korea and China have followed the same footpath but with a different methodology. They rather invested in their human capital by first sending their talented scholars to the best universities in the west. After their homecoming, they converted their science knowledge into technological advancements.

It is now a very sound argument that the economic development of a country and poverty alleviation directly depends on the country’s ability to understand, interpret, select, adapt, use, transmit, diffuse, produce and commercialize scientific and technological knowledge in ways appropriate to its culture, aspirations and level of development (Watson, Crawford and Farley, 2003:1).

“When technological innovation occurs, the producers employ new, usually more efficient methods of production and very often also achieve qualitative improvements in the goods and services produced. This is an important source of economic growth” (Industry Commission [IC], 1995:59).

Manufacturing has also been designated by Marxist theory as the necessary tool for the capitalism to reproduce itself. So, the importance of manufacturing for the capital societies such as the United States is also important from another perspective.

1.2. The Power of Manufacturing in creating Economic Growth and Prosperity

Manufacturing has been the main element in both creating economic growth and development. Historically it has been contributing to economic growth by constituting value added to the country and providing employment for its people. The service industries as well as the complementary sectors such as the ICT are in convergence with the manufacturing industry as they contribute to the economy in a collective manner. Also, manufacturing is among the main critical factors in the further advancement in technology and innovation. Because all inventions in history have contributed to the rise in life standards once they reached out to the big portion of the society either directly as in the form of commodities like automobiles or indirectly when they increase the efficiency factory production such as in the case of adoption of electrical motors. Either way, without mass production this would not have been possible. From another perspective, at the phase of developing technology through the knowledge of science and technology, manufacturing facilities are required to test and prove the concept through trial and error. It is the cycle of application in the field and a continuous exchange of feed-back between the technology developers and applicators phasing through the process which result in the improvement of both theory and practice. This convergence takes product and process development to the next level.

The technology and Innovation Foundation (ITIF) accentuates the importance of manufacturing from the competition perspective of the nations through the following five principles: (1) It’s role in establishing balanced terms of trade; (2) In providing high paying jobs above the average rate; (3) Having the main role in innovation & R&D activities; (4) the manufacturing and service sectors of a country are complementary with each other and are strongly intertwined; and, (5) manufacturing is essential for the national security of a country (Ezell, 2012).

The empirical evidence reveals that the share of manufacturing in an economy changes over time. Accordingly, when the economies reach a middle-income level of wealth the manufacturing share peaks around 25 to 35 %. After that saturation point, consumption begins to shift to services and both the value-added share of manufacturing in GDP and employment begins to decrease. As in the example of the United States the employment rate went down from 25 percent in 1950 to 9 percent in 2008. In Germany employment in the manufacturing sector fell from 35 percent in 1970 to 18 percent in 2008. In the case of South Korea, the employment rate went down from 28 percent in 1989 to 17 percent in 2008 (Manyika et al., 2012:3). In case of the value-added share of manufacturing in the whole world, the value dropped from 21.47 in 1995 to 16.63 percent in 2005 (World Bank, 2018a). The findings of a recent study performed by Federal Reserve Bank economists on 24 sample countries for the time span of 2000 and 2014 on the contribution of the manufacturing, agriculture and service sectors to the GDP in terms of employment, value-added, share of exports, the share of R&D spending and productivity growth supports this trend as well (Table 1.1).

Table 1.1. Contribution of each sector to world GDP, 2000-2014 (percent)

Sector	**Share Employment**	**Share Value Added**	**Share Exports**	**Share R&D Spending**	**Productivity Growth**
Agriculture	2.34	4.61	6.90	1.24	32.91
Manufacturing	16.92	16.96	**92.01**	**64.86**	**42.32**
Service	**80.74**	**78.43**	1.09	33.90	24.77

Source: (Santacreu and Zhu, 2018)

However, according to the same data, manufacturing is the strongest sector in terms of share of exports at 92.01 percent, share of R&D spending at 64.86% and productivity growth at 42.32 percent. It is evident also from the productivity data that manufacturing is the major sector in contributing to the economic growth. Manufacturing creates benefits for the whole industry value chains by enhancing demand for raw materials, energy, construction, technology, and services from a broad spectrum of supplying industries in a country. Based on the data on EU-15 Nations and the United States between 1995 and 2005, the impact of manufacturing on economic growth is disproportional both through direct involvement and through technology spillover into the services (Figure 1.1).

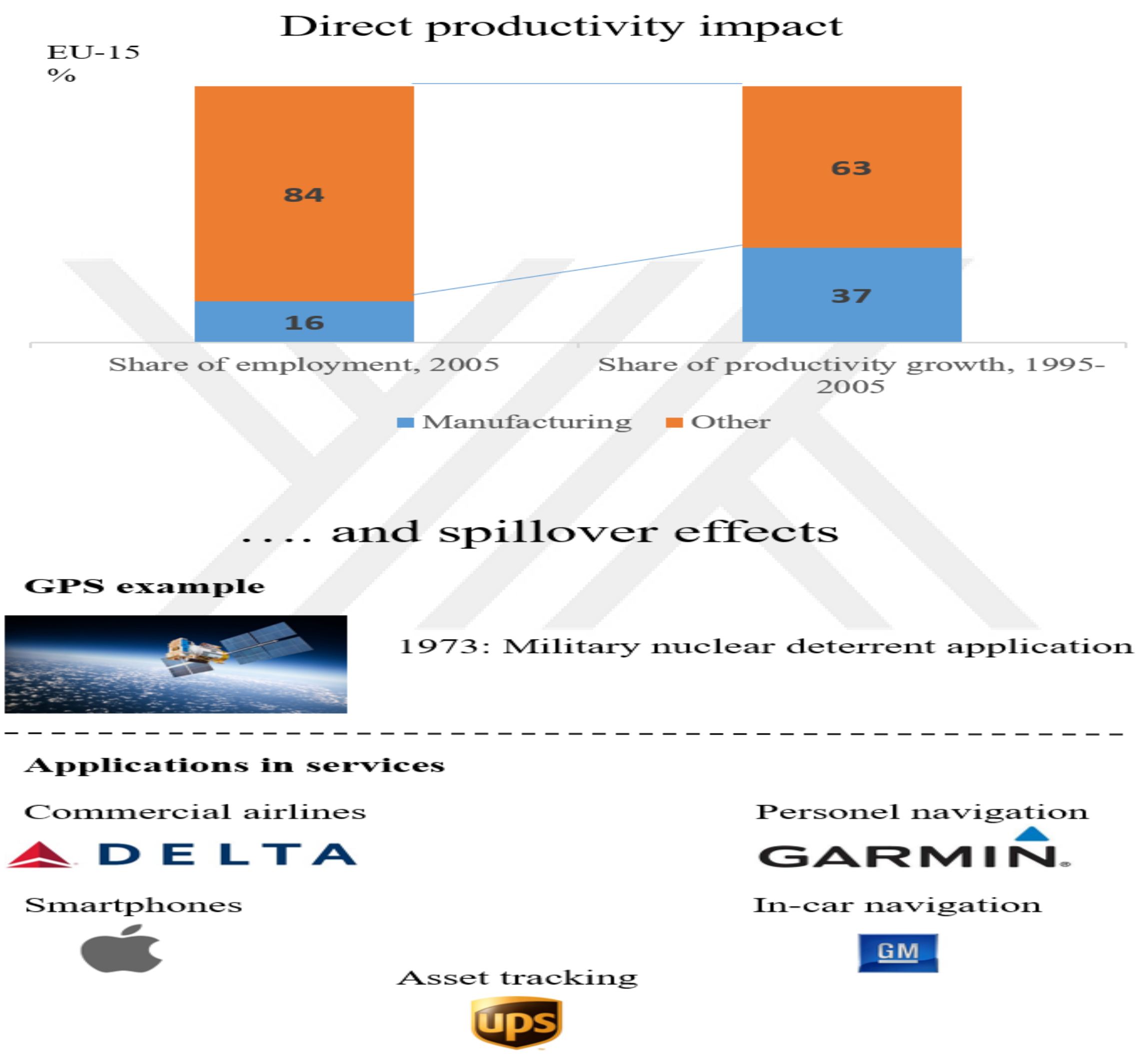

Figure 1.1. Contribution of manufacturing to economic growth

Source: McKinsey Global Institute Report (Mannyika et al, 2012: 33), IHS Global Insight; BCC Research; IDC, May 2010; EU KLEMS; OECD STAN; McKinsey Global Institute analysis

Growth in efficiency means more productivity, which is achieved with developments in science and technology. Productivity growth accelerates as industries adopt more advanced technologies and support sustained increases in the wages. Historical observations show that every developed nation went through the same path of first establishing a solid manufacturing industry and then growing it both in quantity, variety and efficiency. They increased the value added of each manufacturing segment through the adoption of science and technology. Examples of some nations who have followed this trend in the timeline are United Kingdom and Germany, and subsequently then the United States, Russia, Japan, South Korea and recently China.

Also, world trade runs mostly on manufactured products. The share of services in the world trade is very little, to date. Therefore, increasing income from export sales is only possible by producing more value-added goods on demand. It follows then that without an efficiently growing manufacturing industry achieving sustained economic growth appears to be impossible.

From the economic development point of view manufacturing is also the major contributor that is increasing living standards. The first benefit comes through the economic growth as with more people will get more income per head. Combined with a well-balanced income distribution the income level of the society increases. Also, as manufacturing has been the main source of innovation it has a direct impact on the life styles of the people by offering them better products and services such as travelling by car, train or airplane. Nonetheless, the improvement of life standards brings a need for services. Some services are directly related with the manufacturing industry such as maintenance of the machinery, airplane, and automobiles and so on whereas some services grow in parallel with the level of income such as tourism or entertainment. Beyond generating higher incomes through employment and productivity gains, advances in manufacturing help improve living standards through innovation and by keeping product prices low. Therefore, for the similar reasons, economic growth without a thriving manufacturing industry and steady economic development seems not to be possible either.

Besides, the social aspect of the manufacturing industry is outstanding. Manufacturing may be considered as the access gateway to the formal economy from the informal sector, absorbing big numbers of workers with different skills. Especially women get more employment and gain social benefits such as social security, better income and access to financial services (International Finance Corporation [IFC], 2018).

Technically, improvement in the manufacturing sector has been in the field of efficiency and that means improvement in productivity. In that sense, both the design and operation of manufacturing systems are of great economic importance. At the same time globalization is posing several challenges to the manufacturing sector in most countries from various standpoints, which are related to geography, and proximity to other manufactures and service providers. Nonetheless, as technology is developing the manufacturing industry it is also changing its shape. Recently, there has been a shift more towards a position when the manufacturing and the service industry becomes so much integrated that the boundaries between them becomes more blurred. The analysis of the recent data between 2002 and 2010 on the share of employment in job classification supports this trend. The analysis shows that the share of service type jobs in manufacturing has increased by 2.4 percent (Figure 1.2).

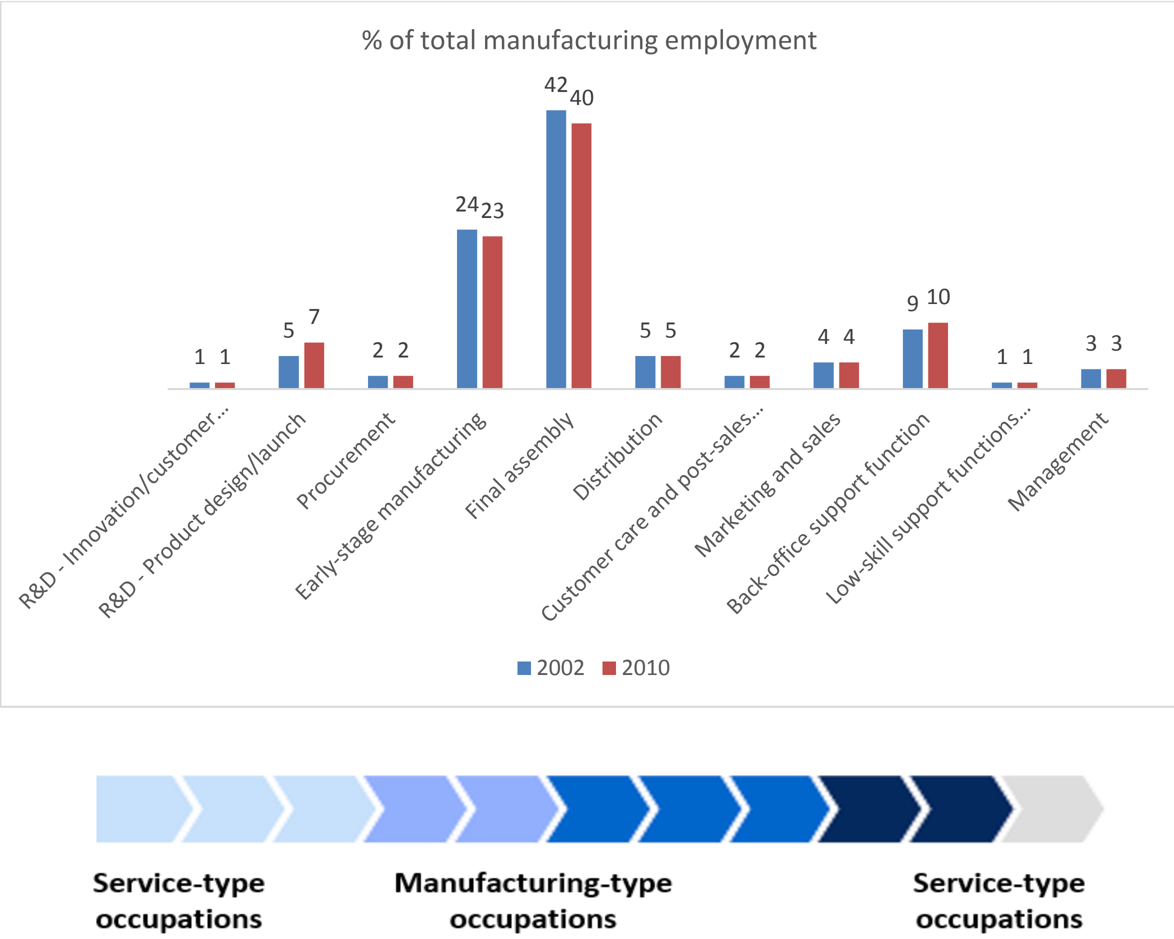

Figure 1.2. Share of job types in the American manufacturing industry, 2002-2010

Source: McKinsey Global Institute Report (Mannyika et al, 2012: 39), BLS; McKinsey Global Institute analysis

Note: Numbers do not sum to 100% because a residual "other category" is not included

Hereby it is also noteworthy to accentuate the impact of the ICT related technologies on the economy on general and the manufacturing industry on particular. Those technologies include "hardware, software, networks, and media collection, storage, processing, transmission, and presentation of information (voice, data, text, images)" (World Bank Group Strategy, 2002:3). Especially the technological advancements leading to the fast pace digitalization after the turn of the 21'st century has multiplied the impact with a faster pace. The positive effect has come with the higher speed of data transmission, faster communication and increased processing time. As a result, easier access to knowledge, people and data became possible. Also through the advances in control and processing technology the impact on the manufacturing industry has resulted with the increase in efficiency. The overall positive influence has supported the economic growth.

As a measure of the impact of digitalization on economy, according to a 2013 study of the World Economic Form, with a 10 percent raise in the digitalization level of a country there happens to be an increase of 0.75 percent in GDP per capita and 1.02 percent drop of unemployment rate which comes from the new job openings related with the ICT related sectors (Bilbao- Osorio, Dutta and Lanvin, 2013: 36).

1.3. The Measurement of the Impact of Manufacturing

In order to be able to clearly compare the impact of manufacturing in creating economic growth and development between the past and today it is essential to elaborate on the effects of the main inputs and outputs for a given time frame. The main inputs are the capital and the labor. The capital can be mainly divided as technology and materials.

Regarding the comparison of the relationship between manufacturing industry and labor between early 1980's and today, while the technology has been substituting for labor in a very big way, the product and process manufacturing industries still offer jobs for the people who lack advanced education. Nevertheless, there is an obvious transition of the labor composition towards less number but more skilled workforce in the factories. Therefore, there is an expected increase in the size of the payroll per employee while the total number of workers would, at the same time, decrease.

The impact of the manufacturing industry on economic growth and development can be measured in terms of quantity and quality. Technically, economic growth through manufacturing could be created by an increase in the manufacturing value-added output volume and employment, whereas, a better economic development could be achieved with a well-balanced income distribution as well as more prosperity. Regarding the growth in general, more output with less input will be achieved by a rise in the rate of productivity.

From the quantitative perspective in this thesis the analysis is pursued through the impact of the transformation of the manufacturing industry in the United States through the changes in Gross Domestic Product (GDP), GDP growth rates, productivity rates (output per hour), total factor productivity (TFP), the share of "Manufacturing Value Added (MVA)" in the GDP and the share of employment that has been created by the manufacturing industry.

The technological and operational based advances in the manufacturing industry are expected to improve the rate of productivity. Increased productivity means lower costs and more competitiveness, which leads, in turn, to increased sales and eventually more growth. Productivity can be achieved through lower cost natural resources, greater productivity of the labor force and technology.

So, the role of productivity for creating economic growth and prosperity is quite important. Within that regard, the measure of changes in productivity over time is one good indication to measure how the manufacturing industry performed through a specific time span. Moreover, a good way to measure the progress of technology and innovation is in terms of (TFP) which tells us how fast the productivity grows in regard to growth of labor and capital inputs. This factor is also named "Solow's residual" and it is the approach, which shows the effect of innovation and technological change. It is defined in Robert Solow's work in the 1950's and refers to the residual that remains after the contributions of capital and labor to the productivity are removed from TFP. According to Solow's approach the rise in labor productivity is attributed to increase in labor quality mostly based on educational gain, increase in the amount of capital relative to the quantity of labor and the rise in the quality of capital. The leftovers are measured as the contribution of innovation and technological advancements. In essence, innovation is not only a part of the residual but may constitute some part of the capital investment as well since innovations are the source of technological change which, in turn, have an effect on the quality of the capital (Gordon, 2016:543, 568-569).

On the other hand, prosperity in a country comes with economic development, which is reflected both to the income level and the standards of living of the people. In that respect, measurement of a country's prosperity with the annual growth rates of the GDP and the labor productivity (GDP per hour) is not sufficient alone. A well-balanced income distribution is an important indicator to show how well the people in the nation are enjoining the wealth that was created through economic growth. Therefore, this thesis measures prosperity from the perspective of quality with the income distribution.

From another perspective, the improvement in living standards that came through innovation is not explicitly revealed in the figures, either. Some examples are the convenience of electric light, reduced risk of food contamination with the adoption of refrigerators, more comfortable travel through the use of cars, trains, airplanes, better quality (for example, smoother) motor roads, more comfortable homes with all the modern utilities like the network for sewage and running water, modern home appliances, better means of communication through internet and smart phones, improved medical treatments with advanced drugs and better equipped hospitals, shopping malls, more entertainment options through computerized technologies and many others. In the case of the United States, except for smart phones and Internet, many of these changes had reached urban America by 1940 and rural America by 1970. Within this context the energy consumption per head might be a good indicator for the improvement of life standards for the most part of 20th century since more energy means more access to comfort in a world where electricity has more and more become the core tool of modernity. Steel consumption per head is also another good indicator within the same context as steel became a material that is widely and diversely used in many industrial sectors for the production of various items which all are the symbols of the modern world. It is therefore also a well-accepted measure of the civilization level of a country.

As a result it can be said that manufacturing has been in existence in various forms and phases since the very early development of the human life. Because it has been about converting the nature in the best possible way in order to benefit the people. Consequently, manufacturing has always geared forward in terms of efficiency with the aid of science and technology, which has been the fuel for the ongoing transformations. Nevertheless, manufacturing has created a huge impact on human life. This impact has been both on the economy of a nation and on the society as well as on every individual living at this country. Therefore, it could be argued that there exists a correlation between manufacturing and economic growth as well as economic development. The impact of manufacturing on economic growth can be measured through the indicators of GDP, value- added output, productivity and employment variables. The contribution of manufacturing on the world economy is visible in figures. Based on the recent statistics, manufacturing has the far highest productivity growth percentage compared to services and agriculture. Also the share of manufacturing in exports is 92 percent. Although the share of value added of manufacturing to the world GDP is 17 percent (Table 1.1), many of the industries that fall into services are dependent on the manufacturing industry. Some of them would not even exist or be baseless if there was no manufacturing industry associated with them. Therefore it could be argued that the service sector is rather the necessary but the complementary while the manufacturing sector is rather the core.

On the other hand, the impact on the life standard of the society as well as the individual is a term, which is related with economic development and prosperity. Economic development is solidly based on the goal that as wide as possible spectrum of the society benefits from the economic growth. This concept is very much associated with income equality, too. Similarly, the high paid jobs offered by the manufacturing industry raises the level of life standards. Overall, prosperity depends on many other factors including but not limited to a well-balanced income distribution, good life standards designated with luxury such as electricity, water, entertainment facilities, safety, happiness and therefore is harder to measure with numerical methodologies only. It follows out that, to reach the desired life standards the necessity of a sustainable economic growth and development is an indisputable reality. Also in the historical perspective, a continuously transforming and thriving manufacturing industry has always been the main contributing factor towards reaching this goal.

CHAPTER 2

MANUFACTURING AND ITS EVOLUTION SINCE THE INDUSTRIAL REVOLUTION UNTIL 2018

The goal of this chapter is to outline the historical evolution and the transformations of the manufacturing industry through the timeline from 1850 till 2018 in association with the breakthrough innovations, which actually triggered the transformations and have led to a progress. One aim is to reveal these innovations and show the solid influence they have had mainly on the manufacturing industry and also on the life standards of the people. In the same context it is also aimed to discuss the impact that the thriving manufacturing industry has created on the economy. The interpretation and the related numerical data are displayed within the context of economic growth and development. The analysis has been conducted within three time intervals; 1850-1930 (mechanization and electrification), 1930-1980 (electronics, computers and automation), 1980–2018 (internet and digitalization) and through the case of the United States. Because another main goal of this section is to unveil the prominent role of manufacturing in making the United States the leading economic power and the most prosperous country in the world after the turn of the 20th century.

After a brief overview on the developments since the first industrial revolution this part of the thesis focuses on the evolution of the manufacturing industry since the end of the American Civil War era from the 1870’s till the present day. Because the gun manufacturing system developed and applied during the civil war, called as “American System of Manufacturing (ASM)” constituted the base for the mass manufacturing, a corner stone in the historical transformation of the manufacturing industry in the post war era. Mass manufacturing has been first officially adopted by the automotive industry and later pretty much by all other industrial segments. This period is split mainly into three divisions as the first being the period of 1850-1930, the second being the period of 1930 –1980 and the third period as the time interval between 1980 and 2018. The first period is the time frame where a great number of breakthrough innovations such as the invention of the steam turbine, electric motor, the internal combustion engine, automobile and airplane have occurred. These inventions turned into innovations, which resulted in remarkable transformations in the manufacturing industry in terms of technological advancement, factory production systems and labor skills. Their impact on productivity was enormous.

The second period is the time when the computer and digital revolution were created and evolved into core technologies of their age. During that period the manufacturing industry has been transformed by automation, especially through advancements in the fields of electronic power control and computation technology with the aid of the breakthrough inventions of the computer, transistor, semiconductors, integrated circuit and the microprocessor. This was a period when digitalization, computer-controlled automation and robotics became a part of the production process.

The third period is the evolution of the manufacturing industry through further advancements in digitalization. This interval is the Information and Communication Technology (ICT) period where the production process in factories became considerably more robotized and digitalized. This is also the period where the first Personal Computer (PC)'s were introduced and evolved with a large increase in computing and processing speed. In addition, the emergence of the World Wide Web, the web browser, the smart phones are some examples to the breakthrough innovations that had an impact on manufacturing efficiency in this respect. During this period swift data flow & processing capabilities together with the advanced hardware & software technologies elevated the level of digitalization. Lately, with the advances in digital control of machinery and the emergence of artificial intelligence robots are replacing increasing numbers of humans in the factory production. Moreover, the workforce profile has been changing as labor on demand has been transforming into more a skilled type.

All through the phases of the historical evolution of the manufacturing industry the impact on economic growth and development has evolved in parallel.

2.1. Technological Progress and Mass Production (1850- 1930)

The breakthrough innovations that impacted the transformation in manufacturing started with the industrial revolutions in the 18th and the 19th centuries when urbanization began to rise in Europe and America. Before the industrial revolution in Britain, when people mostly lived in rural areas, manufacturing occurred at homes or small shops to provide for needs self-sufficiently. Thereby small hand tools and simple machinery were used. With the industrial revolution in the late 18th and early 19th century a shift in focus has occurred towards special purpose machinery and mechanization towards scale and quantity. Larger scale production supported with mechanization triggered the quest for a more cost efficient production as the demand grew for British goods. That contributed and pushed factory, versus the home, as the site of production. For example, James Hargreave invented the “spinning jenny” which enabled one worker to produce multiple cotton threads at the same time (1764).

Then James Watt created the steam engine that gave rise to the utilization of coal power and the powering of machines (1769). This breakthrough invention is a corner stone for the transformation of manufacturing with its impact on the industrialization. It is the beginning of powering of the industry that gave rise to increase in productivity and decrease in labor costs. This outcome created a path for mechanization that eventually contributed to the development of the iron and textile industries. This revolution was one turning point in the transformation of manufacturing as it brought mechanization to industry. As a result of this transformation, hand-built and tailored goods could not compete with lower cost and efficient machine-made products (Pelz, 2016:52). At that time, the rich coal and iron ore deposits of Colonial Britain also had a big advantage from the supply side. Although Spain, Portugal, Netherlands and France were wealthier countries than Britain before the Industrial Revolution, Britain overtook them very quickly with the support of its greater manufacturing strength (Schmenner, 2001). Mechanization also later aided the transition to the mass production in Britain.

Coal and steel were the two leading factors during the phase of the industrial revolution. Coal was the source of power and steel was the key material used to make anything such as buildings, machines, tools, ships, weapons and infrastructure. In 1850, when the British Engineer Henry Bessemer found the first and highly efficient method for the mass production of steel industrialization spread out more rapidly. Steel production technology has further improved with the invention of the Siemens- Martin open-hearth process and by the 1880’s steel became the basic material for the building of ships, railroad tracks, machines and weapons. During the 19th and early 20th century, chemistry also became an important sector where important new knowledge was applied and which opened up many new product branches in manufacturing. Especially, the discovery of methodologies for producing new artificial materials in bulk and at low cost made it possible for their widespread industrial use. The discovery of the vulcanized process of rubber by American Charles Goodyear in 1839 and the invention of another American, John Wesley Hyatt, who invented the first synthetic plastic in 1869, are some examples within this context (Mokyr, 1998).

The period between 1870 and 1914, labeled as the Second Industrial Revolution brought large number of innovations such as electric motor, refrigerator, electric light, typewriter, telephone, skyscrapers, elevator, phonograph, motion pictures, washing machine, automobile, diesel engine, the airplane and spurred technological advances into the manufacturing industry. Therefore, this period is associated with the technological revolution and is marked with an expansion and evolution in the electricity, petroleum and steel industry while coal, iron, railroads and textile industry were the prominent sectors of the first industrial revolution. During that time, industrialization spread to many industries other than textile and a power shift occurred from Britain, who initiated and led the industrial revolution, to the United States and Germany (Schmenner, 2001; Landes, 1998:301). The breakthrough macro inventions in that period had a notable impact on the manufacturing technologies and later in the due course, on the prosperity of the people. The noticeable outcomes during this period are the products of the previously accumulated formal and informal scientific knowledge. According to the Scottish engineer William Rankine (1820-1872), there exist three kinds of knowledge: only practical, only scientific and thirdly, the scientific theories that can be applied to good practices (Mokyr, 2002:89; Smith and Wise, 1989:660). In other words, the methodologies used after the 1860's were traces of applied science. During this period, technology mostly evolved in a broad epistemic fashion as it was based on engineering and manufacturing practices. There was a continuous information flow and a strong collaboration between the scientific and engineering society. The evolution of the telegraph is a good example in this context.

In essence, during the 19th century and onwards, industrial improvements were supported by two key factors: electricity and the transportation. The first economic impact of electricity was observed more on the communication segment with the wide spread use of the telegraph, rather than on the application of the electric motor to the industry, which later was integrated into the manufacturing industry in the following years. Further, the invention of the electric motor by British Michael Faraday in 1821 is the second breakthrough invention after the invention of the steam engine as it also caused a remarkable transformation in the manufacturing industry in terms of powering of machines and transforming the concept of manufacturing plant design as well as machine capabilities. Many developments occurred between 1885 and 1889, which resulted in the invention of the three-phase electric power system that became the fundamental baseline for modern electrical power transmission and advanced electric motors. Bradley, Dolivo-Dobrowolsky, Ferraris, Haselwander, Tesla and Wenström are among the scientists who made major contributions to this invention. Later the three-phase synchronous motor was invented by the German Friedrich August Haselwander in 1887. Today this type of motor is used in every dynamic application such as robots and electric cars. In addition, the same year Westinghouse developed the AC motor, which became the dominant motor type after power transmission was relied on alternating current (AC) instead of direct current (DC). In the following years, in 1889, the Polish-Russian engineer Michael Dolivo-Dobrowolsky has invented the three-phase cage induction motor which today has a wide application in the manufacturing industry for the power range of 1 kW and above. The adoption of electric motors and later of the servo motors in a the manufacturing industry has changed the whole concept of the production line in the factories and in the machine industry resulting in tremendous increase in flexibility, capability, capacity, speed and productivity

The telegraph was invented by German Soemmering in 1810 and perfected by American Samuel Morse in 1836 so that the system could transmit various dots and dashes electrically. The first telegraph service was launched between Baltimore and Washington D.C. in 1844. Then, Scottish Graham Bell's invention of the telephone in 1876 was another phase in the advancement in the communication. Overall, the easy and swift flow of information over distances increased the pace of industrialization in the United States as urban migration was happening towards the west. From another aspect, the widespread use of electricity in the production sector and industry standardization depended on the efficient and less costly transmission of that utility. The American inventor Thomas Edison worked on power transmission of electricity in the form of direct- current (DC), while other American inventors, Nicola Tesla and George Westinghouse relied on more economical transmission of the electricity in the form of alternating- current (AC). Eventually, the more economic AC type of transmission prevailed and at the beginning of 1890's it became the prominent power transmission network in the United States. Also, after Thomas Edison's invention of the electric light bulb in 1879, the factories could be illuminated. As a consequence, it was possible to work longer hours and with much improved efficiency (Mokyr, 1998). This invention also gave rise to the swift development of the national power grid in the United States.

The improvements in transportation at the beginning basically were on powering by steam engine of locomotives on land and sea. Then there was a continuous quest for bringing the efficiency and the performance of the engines to a different level. The invention of the steam turbine by Laval and Parson in 1884 brought about an enormous gain in efficiency and speed. Also combined with the advances in the steel industry resulting in more quantity, better quality and lower cost production, way bigger and faster ships were built. Steel was the key essential material for industrialization owing to its attributes of strength, ductility and durability. The widespread use of steel caused railroad transportation to expand rapidly, too. In 1869 the first railroad linked the two coasts of the United States. During the same period, in 1860, in parallel with those developments, the German salesman Nicolaus August Otto started to work on development of the four-stroke gas engine which later become the basis for the first automobile engine. In 1879, the German entrepreneur Karl Benz patented the first two-stroke internal combustion engine. Later in 1885, Gottlieb Daimler and Karl Benz built the four-stroke gasoline-burning engine and the following year in 1886, Karl Benz patented the first car. In the following years with the new system of mass manufacturing, which was introduced by Henry Ford, almost a quarter million of cars were sold in the United States in 1914. Nonetheless, the first successful airplane designed by the two American engineers, the Wright brothers, realized the first successful flight in 1903 and this invention was marked as a new mode in the technological progress that happened during the Second Industrial Revolution (Mokyr, 1998). All these advancements played a very major and critical role in the economic expansion of the United States during the 20th century. The outcomes of the advances in electrification combined with the huge progress in the transportation systems gave the American manufacturing industry a competitive edge.

The two most important inventions of the late 19th century are the electric light and power and the internal combustion engine. Because their impact caused a major change of scope in manufacturing systems and the outcome is clearly reflected in productivity growth during the following period. The other impact was also on standards of living of the people. With the adoptions of the technologies related with the inventions the life style of the people changed completely. Therefore, these two inventions can be classified as General-Purpose Technology (GPT) and they are followed by a large number of sub- and related inventions. Some examples of the sub-inventions related with electricity are elevators, electrical machinery, electrical machine tools, home appliances, air conditioning, television, movie theater and so on. The examples related with the internal combustion engine are the cars, trucks and then the airplane.

In the manufacturing industry the invention of electric light increased productivity in factories through the positive effect of illumination. There were more hours to work and also the increased visibility improved working conditions. The invention of electrical power brought a remarkable improvement in factory machinery, especially after the invention of the electric motors. The advances came also to manufacturing systems such as the introduction of the assembly line, which served to enlarge mass production considerably. As a result, there was a noticeable rise in productivity (Schmenner, 2001). The other important invention was the internal combustion engine, which brought innovations to the horizontal and vertical transportation of people and goods. The invention of motor vehicles made it possible for the people to move more easily between homes and work places. In that way, human capital was utilized with maximum efficiency. Also, the raw materials needed for the production could be transported to plants and the manufactured products could be shipped to the warehouses and the market places in a very swift fashion. In the same way, with the invention of the elevators, powered by electricity, people and goods could be transported vertically as well (Gordon, 2016:17). This progress had an impact on urban population density. Again, that too had a positive impact on the utilization of the human capital.

There have also been social implications through the course of industrial revolution in parallel with the advancements in the manufacturing industry. The permanent progress has surely caused changes in the social structure and the living standards of the people. Some impacts of these changes were positive while others affected the people negatively. First of all, urbanization was increasing rapidly. People moved their residences closer to factories. The extensive family concept has begun to change as families had to shift their work places from homes to the manufacturing plants. Also, the work pace in the factories has increased remarkably as the machines took over for some part. Within the same line, the importance of artisan and craftsmen diminished, owing to mass-produced goods. This resulted in their removal from the workplace. On the other hand, the relatively cheaper factory-made goods were widely available and much more affordable for the larger part of the society. Nonetheless, the price and availability factors for those goods were determined by supply and demand conditions in the market. So, the market concept and the rules of liberal capitalist economics took their course. There was permanent progress as well as competition and the accumulation of the capital was a necessity for the sustainability of the system.

Within the same context, the living conditions for the working class contributed to the creation of class-consciousness and resulted in the emergence of socialist discourse and Marxism. In due course, the gradual substitution of machines for some of the jobs decreased the demand for labor or changed the demand on skills. This consequence brought the unemployment issue into the area of the public policy. Job creation, income distribution and household or individual income became among the foremost important policy issues to be tackled in parallel with the other outcomes of national and regional economic development (Wilensky and Lebeaux, 1958). As another negative consequence, the overall health conditions declined due to the tough and unhealthy conditions in the work places.

2.2. Transformation of the Manufacturing Systems: American System of Manufacturing, Popeism, Fordism and Mass Production

In fact, the U.S. Industrial Revolution can be said to begin with the coal power and machine production in 1820. Then, in 1850, "The American System of Manufacturing (ASM)" became another corner stone. The development of this system roots back to Eli Whitney who was the inventor of cotton gin (1794), a machine that mechanically optimized the production of cotton. When he was forwarded a contract in 1798 from the U.S. Government to produce 10,000 rifles in a short time span he was faced with finding a way to do it. Until then, the rifles had been manufactured by skilled workers. Whitney's idea was to develop special purpose machinery that would make it possible for unskilled workers to manufacture the identical gun parts, which would also be interchangeable. With the aid of mechanization and the division of labor, interchangeable parts were to be manufactured in mass. This system was further developed in the Armories during the Civil War arising from the imminent need for the massive and identical rifles. High technology precision machinery was used to achieve this task. With that system, by late 1863, the Springfield Armory became the most cost effective and biggest producer of standard U.S. Army Rifles. At the end of the war, the Springfield Armory had produced 800,000 rifles equals to 42.5% of the domestically produced shoulder arms during the war. The Armory outperformed nearly 30 domestic contractors. It was clearly an extremely high productivity increase with the combination of technological and organizational innovation (Raber, 2017).

According to Landes, the uniqueness of this American innovation was not based on a particular device only; it was rather a mode of production that introduced the standardization of product design and the concept of interchangeability for the manufactured parts. Before this new system was introduced all the weapons such as muskets, rifles and pistols were manufactured by craftsmen and no two parts were identical and interchangeable. This system was not good for the Army because it brought hardship for the repair of the weapons on the battlefield. Nonetheless, the U.S. Government generated policies that supported armories at Springfield, Massachusetts and Harpers Ferry, Virginia to make investments in gauges, fixtures, inspection devices and special purpose machinery, all which as needed to set up the mass production system that produced interchangeable parts (Pisano and Shih, 2012:46). The new concept called “the American System of Manufacturing” brought a transformation in the manufacturing process that resulted in improvement in efficiency and productivity. As an indication, during the 19th century, although the capital to labor ratio was higher in Britain, the productivity measures were higher in the United States. This fact is arguably due to the benefits of the newly introduced American System of Manufacturing (ASM) which made it possible for more swift material flow in the American factories compared to the British factories (Schmenner, 2001 and Broadberry, 1994). The same system was characterized by the historian Alfred Chandler in his Pultizer Prize winning work *the Visible Hand,* “as the drive for high speed throughput”. Improved speed of production increased productivity and reduced the costs per unit of production (Schmenner, 2001).

However, according to American business history professor Alfred Chandler (Harvard Business School and Johns Hopkins University) the fabrication and coordination of the interchangeable parts, like in the sewing machine manufacturing factory, required more detailed planning than the large batch manufacturing industries such as the oil industry. He claimed that the coordination of the workers, machines and the materials was possible through effective line and personnel management (Hoke, 1980). David Hounshell, in his book “From the American System to Mass Production, 1800–1932: The Development of Manufacturing Technology in the United States” argues that the armory experience and the practical knowledge of system manufacturing in the Springfield and Colt’s Hartford factories have later been carried over to prominent companies such as Singer, Studebaker, McCormick, Western Wheel and Ford. That constitutes the early base for the transition to mass manufacturing. However, the downside of the American System of Manufacturing was the hardship in producing with interchangeability. The degree of this problem varied between different industries (Hounshel, D. A., 1984: 23, 27

44-49, 99, 335). As in the case for the textile industry, the sewing machine invention by American Elias Howe and the following breakthrough perfection done by Isaac Meritt Singer did not lead to the creation of mass factories because in that case the manufacturing was not dependent on a centralized power source. With the Singer perfection there was a productivity increase to the users by 500% and the annual production of sewing machines rose from 2,220 in 1853 to half a million in 1870. The reason was due to the successful marketing strategy of Singer and very large demand. Eventually, the transformation to interchangeability also occurred in this sector, though the adoption was slow *(*Mokyr, 1998). It mostly appears that the source of the problem was not related with the lack of adoption of the armory experience, it was rather related with the technological insufficiency at that time in being able to make the precision machinery that would produce identical products and the sectorial differences. The difficulties arose more in the metal machining and the casting industry while the wood working process seemed to be alright. Nevertheless, the dissemination and the widespread prominence of the American System of manufacturing within the various segments of the industry triggered the emergence of many other industries. The diffusion of the accumulated knowledge in one segment of industry was transferred to the other segment which altogether contributed to the progress of the whole manufacturing ecosystem. For instance, the toolmakers who were supplying precision metal working tools to the weapon armory developed tools that were also used for the manufacturing of the textile machinery. In particular the milling machine and the turret lathe, which were developed in the armories, were also spilled over to other segments of the industry to carry out the metal working jobs such as turning, boring, drilling, milling, grinding and polishing In addition, managers, engineers and workers who gained experience and skills at the armories or sewing machine factories moved to work at other factories such as the furniture, bicycle, locomotive and automobile industries. To illustrate in 1838, the largest locomotive manufacturer, Lowell and Baldwin, was also producing textile machinery. In the same way, Pratt & Whitney Company, which was an American aerospace manufacturing company established in Connecticut in 1925, first began his work with the manufacturing gun making and sewing machinery. Then it became the producer of aircraft engines (Pisano and Shih, 2012: 46).

The other turning point in the manufacturing transformation occurred in the period between the late 19th century and the mid of the 20th century. The context was the economy of scale which was integrated with the continuous swift flow concept and the interchangeability principle of the American System of Manufacturing. The new phenomenal was mass production through assembly lines. In the early 20th century, Henry Ford introduced the “transfer line” to the manufacturing industry. With this revolutionary structuring the main input materials were processed in a fixed order to produce standardized end products in mass quantities. This was an engineered technological system which was applied to the production of the Model T cars by Henry Ford (1908). After the moving assembly line in Highland Park was set into operation in 1914, the labor time in the production of the Model T cars was reduced from 12.5 hours to 1.5 hours. This was a noticeable increase in productivity. In 1926, Ford was manufacturing 55.7% of passenger cars in the United States. (Schmenner, 2001). The cars were standard and were offered in black only. In fact, what Ford did was bringing together all the individual precision machined interchangeable steel parts of the car and putting them together in an assembly line to produce one standard intact body. From another perspective, it was a complete system that adopted the American System of Manufacturing, which was based on interchangeability, and combines it with the idea of the assembly line, which is a continuous flow production that had workers stay stationary and have the jobs move to them. With that system in place, the mass production of cars was possible. There was no need for artisan type skilled workers to perform these jobs, instead each worker at different stands repeatedly performed simple and standard duties. With simple training someone could employ unskilled workers to fulfill the job requirement (Hounshell D. A., 1984: 21, 250, 351). With the adoption of this system manufacturing time was decreased since the employer could manage the speed of the operation time and the end product was standardized. The outcome was reduction in cost, increase in productivity and gain in employment.

During that period leading up to World War I, many American, German and British manufacturing companies such as Ford Motor Company, Procter & Gamble, American Tobacco, Bayer, Siemens and Rockefeller, achieved a tremendous growth rate through the system of enhanced speed and scale as well as the integration of the system of continuous flow. Roger Schmenner, Professor of Manufacturing Management, designates this system as “Swift Even Flow and argues that this methodology is still valid today and that through history, the nations where companies in the manufacturing sectors adopted this system have industrialized much faster than the nations who did not (Schmenner, 2001).

According to a study performed by John W. Kendrick (as cited in Norcliffe, 1997) about the productivity trends in the United States the increase in the total factor productivity was 1.2 % for 1869-1878, 1.3% for 1889 -1919 and 2.1% for the period of 1919 to 1957. It is apparent that productivity growth and the transformation of the manufacturing industry through the development of the mass production system coincide within the same time periods. The innovative mass production system called Fordism has various attributes from different perspectives. From the technical standpoint it requires the use of the latest technology and the most efficient machinery which produces interchangeable parts in the most cost-effective way and speed. Regarding the production planning and factory set up it is the most optimum system integration that optimizes labor-machine interaction. The manufacturing process is viable through the assembly line that provides a continuous flow. From the managerial perspective, it brings the vertically integrated corporate management culture that applies the Taylor's Principle of Scientific Management. Within that scope, Fordism could be described as a total operation consisting of specialized departments that are locally clustered and vertically integrated (Norcliffe, 1997). Economy of scale is also the main driving force behind the whole system. It creates a continuous demand and fosters competition. The application and introduction of the first mass manufacturing system in the automobile industry by Henry Ford with the Model T cars resulted in great success. In 1910, there were 485,300 clients who purchased cars; ten years later in 1920 the number increased to around 8 million. By 1926, 93 percent of Iowa farmers had a motor vehicle (Gordon, 2016: 169*).* In 1930 23 million people or almost 90 percent of the households owned a car in the United States (Geels, 2006).

In order to sustain the system and to remain competitive in terms of the quality, quantity and price the manufacturing process has to be supported with ongoing innovations. Historically, the transformation from American System of Manufacturing to Fordism has happened gradually and within the time frame of 1870 to 1908 there have been various contributions to this system change from within the industry. In this respect, the "Pope Bicycle Manufacturing Company", which was founded by Albert Pope in the 1880's, is a good example. The company became the world's largest mass producer of bicycles at that time. Pope Manufacturing Company started out with a flexible outsourcing strategy and then gradually moved on to buying out his suppliers as well as building new factories. So, it became the biggest vertically integrated complex in the world in 1897. In 1895, when the bicycle was on top demand, the factory was producing 150,000 finished parts with a 3-shift labor force doing 500,000 operations per day. Overall, in order to remain competitive he had to achieve a high productivity level and good quality. Therefore, he adopted mechanization to the full extent to reduce labor.

The other features of the production system he developed and adopted are noteworthy, too. Because the mass production techniques used in the bicycle production and the advancements that were adopted there for modernizing the industry contributed a lot to the mass production system that was developed by Henry Ford and applied to the automobile industry. In essence, there were many similarities between those two industries. Henry Ford's first car called "Quadricycle" was made up of many bicycle parts such as pneumatic tire, hollow metal rims, axle differential, gears, shafts, wheel bearings, spring suspension, lightening, etc. The major exception was the internal combustion engine. Aside from the innovations in the products there were noticeable technological developments in the manufacturing process coming from metallurgy and mechanical sciences. Examples to the metallurgical & mechanical process developments are the cold drawn steel, electric welding, case hardening die making, annealing, stamping and pressing which were all transferred to the automobile industry in the due course. It is worthwhile also to add that the early stages of the bicycle production for the early models were mostly based on imitation and reverse engineering techniques. The first prototypes to be worked on were the British and European bicycle models. Later the Pope's company moved to the innovation stage at a very fast pace. Work was focused on improving the products, the machinery and the process. Apart from that, automation was brought to the manufacturing line at Pope's factory in Hartford. The first electrified assembly line in the U.S. was established in this factory. There were frequent and continuous innovations to lower unit costs and increase the demand in the mass market (Norcliffe, 1997).

Pope's investment in metallurgy and the precision machinery had other outcomes in terms of interchangeability. He achieved more precise specifications and closed tolerances in the production of bicycle parts by making use of the technologically modernized machinery and by inspecting the products on each step of the manufacturing line frequently. For instance, introduction of the sheet metal stamping machinery in 1890 increased the manufacturing efficiency in a remarkable way by enhancing the speed of the production. With that innovation it was possible that the parts could be directly stamped out of the steel swiftly and precisely instead of going through the time-consuming process of forging, drilling and milling in a separate sequence (Geels, 2006). Within the scope of interchangeability, he also achieved standardization. For instance, the bearings, wheels, tires or beveled gear shafts were made to fit in a large set of models. During that time a bicycle consisted of 840-1000 parts and the interchangeability phenomenon was an important cost saving factor. This conception, which is one of the features of Fordism, has also been adopted by the mass production of the cars in the automobile industry.

The transition time frame covering the period of transition from the American System of Manufacturing ending up with Henry Ford's setting up his first assembly line in 1913 is named as the pre- Fordism period and the mass production system named as Popeism could be designated as one of the major contributors to Fordism.

Literally, Fordism may be described as an innovation which harbors much of the previously developed and accumulated knowledge in the manufacturing industry. This knowledge consists of special purpose precision machinery and tools, interchangeable parts, division of labor, continuous moving assembly line on the conveyor belt, sequential set up of workstations as well as machinery and the adoption of electric motors. From the technical perspective, it is argued that one of the major factors behind the transformation of the American manufacturing industry, from specialty production to the mass production within the period of 1850-1930, is the replacement of the steam engines by electric motors in the powering of the factory machines.

This new approach for the manufacturing industry, named as "Fordism", created an impact not only on the technological system of manufacturing but also on a system of accumulation and the social structure. Hence Fordism was a technical, economical and a social model that influenced the world until the 1960's. According to Bob Jessop, there are four levels of Fordism: The first level is related with the division of labor that is associated with the capitalist labor process. It is about the pre-defined routine tasks of the semi-skilled mass worker who produces standardized goods through the moving assembly line. This level is rather a technical division process and is analyzed on micro economic scale as the feature of mass production. The second level is an accumulation regime which is based on macroeconomic concepts. It literally defines the reproduction of the system. At this level Fordism forms a virtuous circle where the mass production triggers an income rise through productivity. Then this increases mass demand which results in growth of profit by full capacity utilization to end up with further investments in mass production machinery and a further rise in productivity. However, for the continuous growth of the mass production facilities there has to be a mass market which simultaneously grows through the contributing outputs of other sectors and services. As an example, the tremendous growth of the production in the automobile industry in the United States between 1908 and 1930 is complemented by the growth in mass production of products such as steel, oil, roads, residential housing, electricity and the expansion of services such as retailing, consumer credit, banking, etc. (Jessop, 1992:42-49).

Bob Jessop designates the third level of Fordism as the “social mode of economic regulation”. Within this context the Fordist enterprise is the core entity. The wage-labor and union relationships are one subject that is examined at this level. Another topic is an analysis of the management perspective which emphasizes that the separation of ownership and control is important. The attributes of the Fordist enterprise were designated as multi divisional, decentralized and market oriented. However, the enterprise is rather managed by the central board which executes operations based on long term plans. Within this concept, Alfred Sloan, the once president and chairman of General Motors, set up a system in GM that controls work flow right from the factory production, through the dealer to the end customer. The aim was to set the relationship between the production and the demand. Within the scope of the third level the role of the commercial capital has been quite important. This system became very much a role model for other big U.S. enterprises between 1920 and 1930. Because the mass demand had to be sustained in order to enhance mass production. The commercial capital was used for that aim to organize mass retailing, mass advertising and mass loaning. The “full employment“ feature of the Keynesian Welfare State also supports mass production since the creation of mass demand would not be possible without it.

The forth level is mostly focused on individual living and consumption habits which is defined as the “American way of life”. As a matter of fact, the standardized and mass- produced items such as cars, television, washing machines, refrigerator, mass tourism are among the items that were strategically marketed and then consumed in mass quantities. After all, government policies were fostering the continuity of commodification. This level could briefly be described as the integration of the social, economic and the political life.

The mass production model based on Fordism principles and its all features based on the nation state was experienced in the United States in the 1930’s and afterwards it propagated to other parts of the industrialized world following World War II (Jessop, 1992:42-49).

2.3. Industrial Progress in the United States (1850-1930)

The period of 1850-1930, which includes the time frame designated as the second Industrial Revolution (1870-1914) according to the literature, had a direct positive impact on the real wages and the living standards. It is also the time when the power shift occurred in technological leadership and manufacturing power, from Britain to the United States. Based on Paul Bairoch studies (Bairoch, 1982), American industrial leadership in the world became absolutely apparent after the turn of the 20th century, both in terms of total shares of manufacturing output and industrial output per capita, when America passed Britain first in the former and then in the latter (Figure 2.1 and Figure 2.2). As Ray Marshall and Marc Tucker mention in their book" Thinking for a Living: Education and Wealth of Nations" (as cited in Norcliffe, 1997), the economic growth of America between the period of 1870 and 1930 was tremendous. Although in 1870 Germany and Britain were the leaders from the economic and technological standpoint, by 1926 United States was producing almost 45% of the world industrial output, 80 % of the world's automobiles and 50% of the global steel, electricity and crude oil. At the same time United States was the world's largest exporter and the largest market for the manufactured goods.

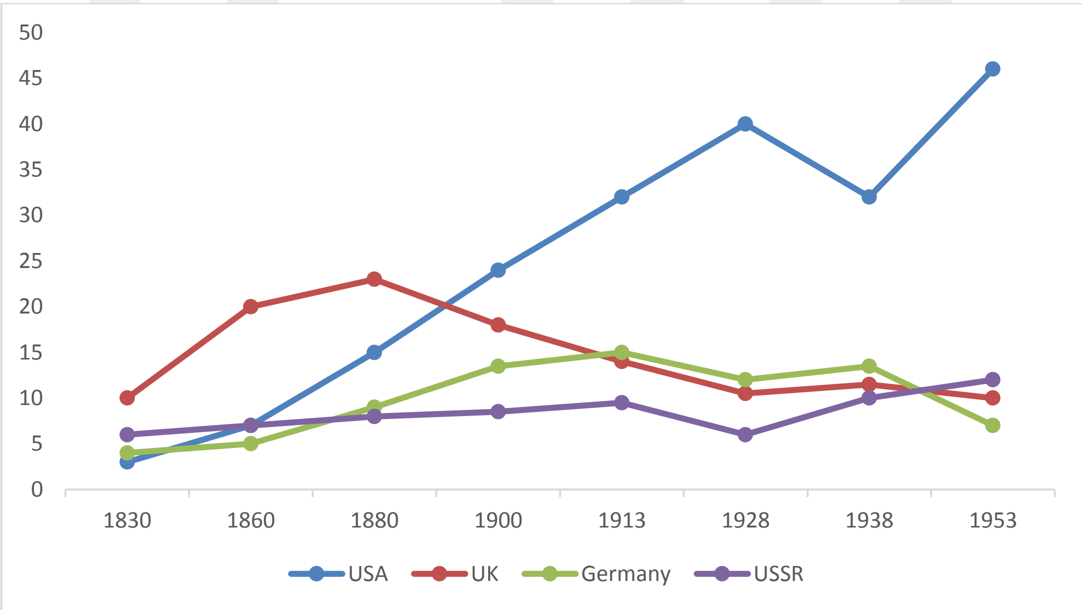

Figure 2.1. Shares of world industrial output, 1830-1953

Source: Paul Bairoch (Bairoch, 1982)

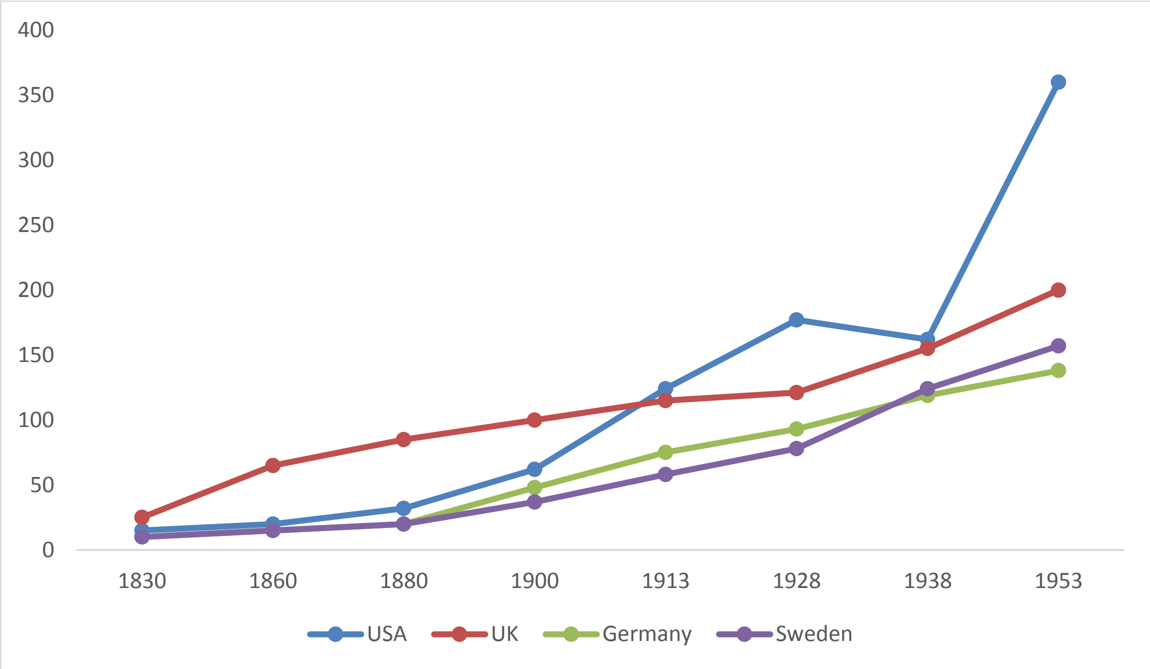

Figure 2.2. Industrial output per capita, 1830-1953

Source: Paul Bairoch (Bairoch, 1982)

Besides, there happened to be a change in the way of transformation as scientific knowledge was transferred and applied to industry. This revolution also paved the path for the forthcoming transformations in manufacturing which are mostly based on path breaking innovations and technological improvements that were happening during that time (Mokyr, 1998). It is the second, not the first industrial revolution that mostly converted the technological progress to the benefits of the people (Mokyr, 2002:79). It is also important to note that the advancements which triggered many transformations in the manufacturing industry during the time of the first and second industrial revolution is the combination of the innovations and hands to hands application of the technologies in the fields of product and process production as well as the powering of machines.

It also remains important to explore why the United States has taken the lead in the manufacturing industry during the time in the 19th century when the remarkable transformations were occurring in the manufacturing sector and what lies behind the American industrial success following that period also into the 20th century. There have been many discussion and views on the historical origins of this topic.

During the conference of "The Rise of the American System of Manufacturers, 1800-1870" held by the Smithsonian Institution in 1978, Nathan Rosenberg from Stanford University raised the point that America had the right social and economic environment at that time and also with the availability of labor and capital the mechanization of the industry happened very swiftly. The newly born technologies and systems were adopted in great number. It is also crucial to point out to the supportive role of the government in the promotion of ASM. Merritt Roe from Ohio University emphasized on the policies of the Ordinance Department between 1815 and 1854 which supported the adoption of the new technologies in a disciplined fashion that paved the way for the integration of the system of interchangeability within the light of the military tradition (Hoke, 1980).

The neoclassical economic growth theory assumes that technology to be equal for all countries and the exogenous differences in savings and education determine the income and growth rates. In other words, this theory looks at the interactions between technology and the conventional inputs. However, this explanation is insufficient for explaining the much faster growth in the United States compared with Britain through the times covering the period of the second industrial revolution extending it until the beginning of Great Depression (1870-1930). To illustrate, the income per capita in the U.S. in 1870 was 0.75% of the same value in Britain, whereas in 1929 the income per head figure for U.S. was 130% that of Britain. For the same period education per worker values increased by the factor of 2.2 in Britain and by 2.3 in the U.S. which indicate quite similar results. The saving rate difference in these two countries is not an answer either. However, it is remarkable that for the period before 1913 the net domestic investment of Britain has almost equaled its net foreign investment. In 1914, the net foreign assets of Britain were 1.5 times the GDP. Other than that, the impacts of the technological advancements, which triggered the transformation in the manufacturing industry in the United States, were not completely reflected into the formulation. In fact, the real-world occurrences are complicated and the theories or models are too simple to effectively explain fully the real cause. Regarding economic growth, in particular, it is very difficult to measure and count the extent of the real impacts of technology as opposed to the effect of the conventional inputs such as the capital. It seems to be important to try to explore how the individual factors, which make up the whole system work, interact with each other and how those mechanisms lead to an end result (Romer, 1996).

In order to make an improved understanding of the issue the new growth theory elaborates more on technology and splits it into two parts as ideas and the things. Accordingly, the economic growth is based on the exploitation of these new ideas and by making use of these ideas for the transformation of the things from low to high value added. For instance, by applying a new technology on the steel making process the standard steel is converted into a super alloyed steel which has a higher added value and has an extensive application area in the critical segments of the industry. Besides, if there is the scale of economy, as it was in the case of the United States, the rewards from the low to high value configurations will be multiplied. In 1820 the population in America was 9.6 million and in 1870 it was 40 million, which was 30% more than in U.K. The scale effect is not limited with the end consumer goods only. It is also that the well-established industries based on standardized products and interchangeability became customers and suppliers for various capital goods that helped overall growth. According to Rosenberg, technological convergence contributed to the scale effect even more. For instance, a textile mill's manufacturing tools or machinery for the textile industry expanded its business to sell the identical products to firms in other segments of the industry such as the food industry (Rosenberg, 1963). Similarly, the technological advances in the steel industry contributed to the progress in other industries and vice versa. That can be viewed as a complementary scale effect. For instance, when the breakthrough steel production technologies were applied to the Mesabi range iron ore deposits in Minnesota in the 1890's, the U.S. steel industry became the world leader in labor productivity and fuel efficiency. This in turn had a new positive impact on domestically produced steel railways which were very uncompetitive before the 1890's without the tariff protection (Allen, 1977, 1981; Wright, 1990).

In addition, the natural growing demands of the main industries contributed much to the scale effect. The impact was immense and overreaching. For example, the enormous growth of the automobile industry after 1913 triggered the emergence of various sub suppliers such as the engine part, tire, glass, plastic manufactures, etc. It also motivated the industrial entrepreneurs to come up with better ideas and technologies that optimized the cost and the quality during the production. As an example, the U.S. rubber tire manufacturers were standing behind their French counterparts in the 1890's. Though the U.S. manufacturers gained the upper hand quickly with the advantage of the productivity increase due to the mass production of the U.S. automobile industry in the first quarter of the 20th century (French, 1987; Wright, 1990). Moreover, the scale effect has also led to the emergence of brand-new industries through the utilization of the by- products as in the case of the meat-packing industry. Advancements in the refrigeration technology and the expanded railroad network made it possible for the meatpacking and its distribution to be executed from one geographical location. The rising demand for meat created a big amount of animal waste. This gave rise to the emergence of the new by products industry which used animal waste as an input. As a result, the sequence of these events contributed to the progress in the industrial chemistry (Romer, 1996). All these outcomes helped create advancements in technology and to the permanent progress of the American manufacturing industry.

The other important factor was the abundance of natural resources in America. Because the low prices of natural resources encouraged the use of machinery as opposed to labor and helped the powering of the industry with machinery. With the rise of demand for natural resources big investments were made in the extraction and processing technologies to utilize these resources in a more efficient fashion. As a result, within the period of 1870 and 1930 United States became the global leading supplier of every industrial raw material except for wood and land. Some other studies which examined the breakdown of the imports and exports of the United States for the same period, as an indicator for the manufacturing output and the source of growth, show similar results (Wright, 1990). It is remarkable that the intensity of the non-reproducible natural resources had an increasing trend between 1880 and 1920. It has been argued that the abundance of natural resources indicates an early development of production technologies in every field of the industry, including the technologies for the mining and extraction of the minerals. At the same time, the natural endowment of these resources is an undisputable advantage. Hereby, it is important to note that productivity, within the measure of GDP per man-hour, increases with the utilization of these low-cost natural resources. Because the productivity level of machines, factories and eventually of the country increase with low energy inputs. Figure 2.3 shows the U.S. mineral output as the percentage of the world output in 1913. In addition, the low-cost domestic transportation based on steel railways network and lake transport system helped to lower the production costs for the manufacturers (Wright, 1990).

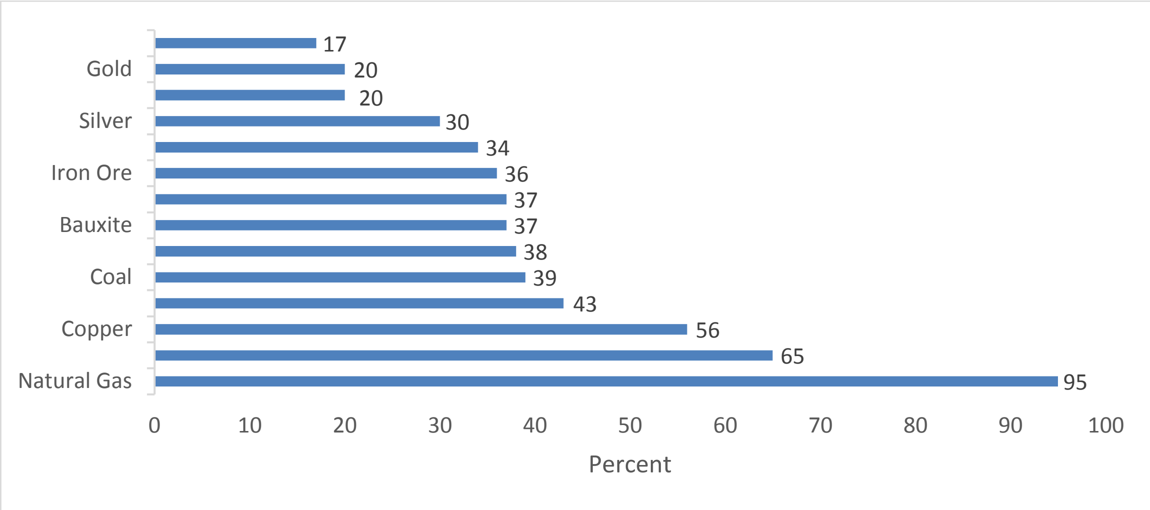

Figure 2.3. U.S. mineral output, 1913: percentage of world total

Source: George Otis Smith (Smith, 1919:288), using data from U.S. Geological Survey (1913)

For the United States, coal was a very important energy resource at the beginning if its development as a reliable source of heat and power, then later for thermal energy to generate electricity. It had a direct positive effect on the efficiency of the moving assembly lines at the mass production plants in the early decades of the 20th century. In 1913, United States was the world leader in coal production which was 39% of the world total (Wright, 1990).

At the same time low raw material costs decreased the cost of items for the manufacturing industry. Particularly the bulk production of cheap American steel at the end of the 19th century was another key element for the industrial success. Steel was the foremost important raw material for industrial products and in that regard, especially for the automobile and the machine industry. Wassily Leontief, who was an American economist known for his work on input-output analysis and how changes in one economic sector could influence other sectors, made an itemized breakdown analysis on capital and labor requirements for the final output of one million dollars-worth of motor vehicles in 1947. According to his research all the metal related items (iron, steel and non–ferrous metals) add up to almost half of the value of the car (Leontief, 1953). If export items and values may be taken as indicative factors for the domestic manufacturing industry it is notable that the U.S. manufacturing exports rose uniformly from 5.5 % in 1879 to 37.5% in 1929 (Table 2.1). Besides the rise in export values of fabricated or non-fabricated iron and steel products there is a remarkable increase in iron and steel also that comes through the automobile and machinery items. For the period of 1870 and 1940, the prominent role of the increasing supply of low cost iron and steel in the growth of the U.S. manufacturing industry is an obvious remark.

Table 2.1. Shares of United States manufacturing exports, 1879-1929 (percent)

	Iron and Steel Products (except Machinery and Vehicles)	Machinery	Automobiles and Parts	SUM (1,2,3)	Petroleum Products	SUM (1,2,3,5)
1879	2.1	3.4	-	5.5	12.1	17.6
1889	2.4	6.1	-	8.5	13.3	21.8
1899	7.6	10.7	-	18.3	9.2	27.5
1913	10.9	14.5	2.3	27.7	10.1	37.8
1923	8.8	12.4	6.4	27.6	13.1	40.7
1926	5.6	12.9	11.5	30.0	16.8	46.8
1927	5.1	13.9	13.3	32.3	14.7	47.0
1928	5.3	16.4	15.7	37.5	13.9	51.4
1929	5.4	16.4	15.7	37.5	13.9	51.4

Source: 1879-1923 (1963), Tables A-8 and A-12; 1926-1929, U.S. Department of Commerce, Foreign Commerce and Navigation of the United States for the Calendar Year 1929, Vol. 1, Tables XII and XXIV. (as cited in Gordon, 2016:)

The combined effect of cheap petroleum (which made the widespread domestic usage of automobiles possible for private and commercial clients), cheap steel (as steel comprises the important part of the vehicle bodies) and the serial mass production techniques (which reduced the manufacturing costs and increased the pace of supply) put the United States in a position to be the undisputable world leader in the automobile manufacturing industry in the 1920's. To illustrate, there were 8,000 registered motor vehicles in the United States in 1900. In comparison, in the 1930's the number of the registered motor vehicle's hit 26.8 million. This was a tremendous increase (Gordon, 2016:17). In 1929 eighty percent of the world car production was realized in the United States mainly by General Motors, Ford and Chrysler (Gordon, 2016:374-375).

It is important to note that when United States became the leader in industrial production in the 1900's the country was also the leader in the production of coal, copper, petroleum, iron ore, zinc, phosphate, molybdenum, lead, tungsten and many other minerals. It can be argued that the abundance of natural mineral resources triggered the early development of the mineral extracting and material processing industries and this outcome paved a way for early innovations and advancements in the fields of mining, metallurgy and mining engineering. Through the following years these resources were utilized by the domestic manufacturing industry and by 1955 the endowments of natural resource for the United States was no longer a noticeable advantage over the other nations of the world, particularly in terms of oil, iron ore and coal. Another reason for this change was the relatively higher pace of growth of the natural resource production in the other parts of the world and the circumstances that have led to the widespread global trade expansion which turned the natural resources from an endowment into a commodity. Besides, according to a prominent conception, at a certain point the available supply of domestic minerals was insufficient to meet the fast growing needs of the industry and United States had to import additional natural resources to fill up the gap (Wright, 1990).

It may be deduced that, for the period of 1870 and 1930, the manufacturing output of the United States had a positive correlation with iron and steel production, automobile production and the mineral production. Within that time frame, the industrial success of the U.S. may be attributable to the combination of various factors. It is clear that the geographical advantage of abundance of natural resources has contributed to an early industrial development through law cost inputs. However, the natural resource abundance is in no way a self-sufficient factor that can be associated with the industrial strength. Nonetheless, "the American System of Manufacturing" which constituted the base for serial mass production that later came into life first with the automobile industry, brought another great advantage in the low cost production for the American manufacturing industry. Another determining factor is the application of the technology in the manufacturing industry that came in parallel with the innovative fruits of the industrial revolution. Many innovations have been made in the United States or that United States has contributed or collaborated with the inventors to keep up with the early pace of the technological advancements.

According to Frank Geels within the time frame of 1850 and 1930 the impact of technology on the transformation of the American factory production can be seen as a stepwise and progressive reconfiguration of the machine tool, building materials, material handling technologies, power generation and the power distribution technologies (Geels, 2006). This configuration can be explained with a MultiLevel Perspective Approach (MLP) which states that the system transformation occurs through the prevailing core innovations and with many peripheral technologies that are organized around them. Within this concept a dominant design gets selected from among others through various mechanisms such as competition, trial & error, learning, etc. and becomes the dominant one. Then this prevailing design lays out the basis for new industry and triggers the other components around it. For example, the gasoline car becomes the dominant design as compared to the steam and electric cars. Then gasoline engine powered cars became the core industry and the peripheral technologies such as the road building, gas station, traffic signals, etc. were all built around it. The bottom line is that the transformation from the traditional factories to mass production can be described as a gradual reconfiguration of a complex socio-technical system

In the time frame of 1850 and 1880 the availability of the skilled workers in the United States was limited compared to Europe. Therefore, the labor cost for skilled workers was pretty high. However, there was a sufficient number of semi-skilled and unskilled labor force due to the high density of immigration. This situation was an incentive for mechanization since it brought along the division of labor where tasks could be fragmented into simple pieces and that way the utilization of the unskilled work force was possible. The second effect appeared through the construction of the national rail network between 1840 and 1850. This had two impacts. The first one was the transportation of low-cost coal to the cities. That stimulated the transition from the water wheels to the steam engines. The second impact was the growth of the national market through cheap transportation. The effect was clearly on the economy of scale. Another factor contributing to the economy of scale was the tripling of the population between 1850 and 1900. As a result, in comparison, the yearly production of goods in 1865 was approximately $2 billion, whereas in 1900 this number rose to $13 billion (Geels, 2006).

The steam engines were first adopted in the textile and metalworking industries in the period of 1830- 1840 and were used in large production facilities. In the factories the power was centrally distributed through line shafts via pulley and leather belts. Despite the fact that this system was a very big step towards mechanization, there were a number of problems associated with it. Literally, the centrally powered system was running continuously, hence the individual powering of the machines was impossible. Besides, there was big power loss because of long haul transmission and through friction since there were many moving parts along the way. While the factories expanded in size the problem became more apparent. As it is mentioned in Hunter and Bryant's book "A History of Industrial Power in the United States, 1780-1930" (as cited in Geels, 2006) according to a report prepared in 1885 about 50 textile factories 25-40% power had been lost due to friction. Repair and maintenance was also difficult since the entire system was dependent on one power source and once repair was necessary, the whole system had to be stopped. Another important limitation was on the flexibility on the sequence of work operations because the machines were fixed on the line shafts. This brought inefficiency into the whole operation set up. On the contrary, for the small manufacturing shops such as the cabinet manufacturers, cloth makers, etc. the steam engines were too big in terms of the power they were generating and in terms of space they were occupying since there was also extra space required for the boiler set up (Geels, 2006).

There were attempts to overcome the power distribution problem. Decentralized steam distribution was tried through steam lines but the system wound up being inefficient. Another innovation was the power distribution through the hydraulic system. As mentioned in Hunter and Bryant's book (as cited in Geels, 2006), between 1850 and 1900, this system was firstly used in the hydraulic cranes at sea ports and later was adopted and used in moving swing bridges, gates as well as forging presses. However, under cold weather conditions efficiency was very low due to the fluid running through the system. Nevertheless, the invention and the industrial adoption of the gas engine between 1870 and 1880 was relatively more successful. Because the gas engine was more compact and allowed flexibility in the production lay out. It was also using the already existing gas infrastructure which was already in place for gas lightening. However, for the big factories the gas engines did not solve the power distribution problem either. Their efficiency was not sufficient (Geels, 2006).

The other problem in the factories was the insufficient illumination through small size windows at the factory walls. Because the wood made walls could not carry big loads due to static reasons limiting the size of the windows at the frames (Geels, 2006). With the improvement in steel manufacturing technology better quality steel replaced the main building structure which gave rise for the building of bigger and stronger factory structures. In the early 20th century steel was beginning to be used for the reinforcing of concrete. This improvement opened the door for a new transformation in the building industry. Stronger and more durable factory building could be constructed this way allowing for heavy machines and equipment to be set on the upper floors. Also, in parallel to that, the adoption of the steel reinforced concrete type building structure made the installment of bigger size windows on the factory walls possible. This advancement alleviated the illumination problem for the manufacturing industry. Henry Ford’s Highland Park Plant is among the first examples for a day light-illuminated factories. These developments brought more flexibility into the manufacturing planning and resulted in using the space in a more efficient fashion. Another technical difficulty was the labor dependency of the material handling. There was a need for a continuous flow of materials to keep the machines running. Therefore, in the processing industry the technology was concentrated on the continuous movement of the material handling together with the flow on the assembly lines and the disassembly lines.

It is noteworthy to state that there has been a positive intertwining relationship between steel, machine and the electricity generation industry. In fact, the technological advances in one of these three segments contributed development in the other industry. With the improvements in the steel industry through the use of electricity for steel making furnaces, better quality high alloy steels could be produced. The utilization of the improved quality of steel made it possible to produce machinery with higher precision. Similarly, with the better steel and improved production techniques with more accuracy higher quality electricity generation equipment could be produced.

In essence, the breakthrough innovation that came along for the manufacturing industry was associated with electricity. In 1821, Faraday introduced the first electric motor which did circular motion. Though its industrial use was not possible due to low efficiency and the heavy batteries. After Gramme Dynamo’s contribution on the improving of the efficiency in 1869 the electric motors started to be used for small power applications not exceeding 0.1 horsepower. In the period 1880 and 1900 electric motor-powered cranes were introduced which contributed to the solution of the problem with the material handling within the factories. Also, small electric motors were used in the sewing industry. Yet the motors were hand-made and power was expensive. Powering of the trams commercially in 1888 was the kick-start for the work towards development of the larger electric motors for bigger industrial applications. In the early 1890's the DC powered electric motors started to be used in the powering of the machine tools such as lathes, drill and printing presses. However, in the large factories the transition from the centrally steam engine powered system to the electric motor powered one happened gradually. Firstly, all the line shafts, pulleys and clutches of the old system remained. The large electric motor replaced the steam engine and the steam engine was switched duty to generate electricity (Geels, 2006).

Within that context, the first transition was from the direct drive to the electric line shaft drive. Later, the adoption of the electric motor for each separate shaft increased the efficiency in the manufacturing process more and brought a vast amount of flexibility in the positioning of the manufacturing equipment. In that regard the next gradual transition occurred from electric shaft drive to electric group drive where the main millwork was split into smaller machine groups which were powered by one electric motor.

Consequently, there was saving in coal consumption in the vicinity of 20-25%. In a short while, with all the advantages of electric power motors, their installed capacity drastically outpaced that of the steam engines, water turbines and the internal combustion engines. In the United States, the share of electric power in the total manufacturing power rose from 5% in 1899 to 25% in 1908 (Geels, 2006). Later, with further improvement in technology and the reduction of the electricity production costs the transition happened toward the electric unit drive where each machine was wired to be driven by its own separate electric motor (Figure 2.4).

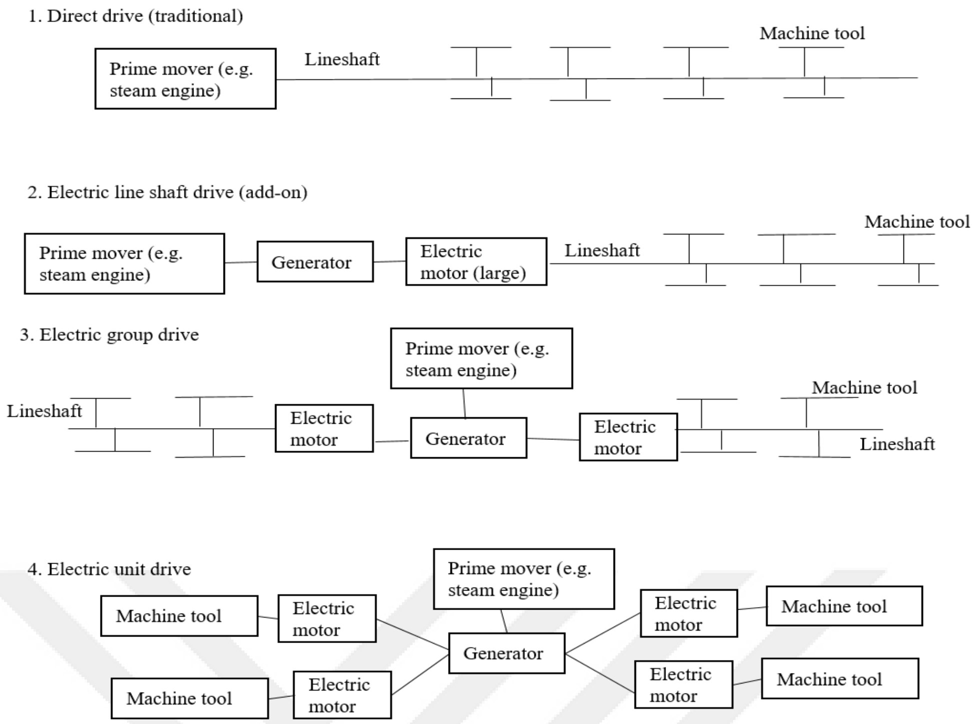

Figure 2.4. Transition in the powering of manufacturing: from direct drive to the electric line shaft drive- electric group drive and unit drive

Source: Warren D. Devine, Jr. (Devine, 1983)

Lower electricity prices were also an incentive manufacturing industry to replace the steam engines with the more advantageous electric motors. The advantages of the electric motor and unit drive was enormous: more speed, higher performance, better design flexibility, less tools, less labor, less parts, less maintenance, less floor space, less fuel consumption, better illumination, cleaner work environment, less work injuries which all resulting lower operation costs. Nevertheless, the transition happened within a certain time frame on a gradual pace and the timing of each industrial segment was different. The pioneers were the clothing, printing, tobacco and the electrical machinery industries. However, after the first decade of the 20th Century, the fast-growing automobile and chemistry industry became the strong adopters also with the influence of the mass production. The bottom line is that the transition to the electric motor-powered factories can be designated with a remarkable increase in the electricity-powered capacity from 25% of total in 1908 to 75% in 1929 (Table 2.2 and Figure 2.5). This was a huge leap to show in the history of the transformation of the manufacturing industry in the United States. It has brought along a change in the system of manufacturing and created very positive impacts on the productivity and prosperity. Similarly, the use of electric services in the American household rose from average 3 percent in 1900 to 78.7 percent in 1940 according to U.S. Census of Housing Data (Brox, 2010:164 and Gordon, 2016: 120).

Table 2.2. Percentages of aggregate electrical power of total capacity for different sectors

	1889	1899	1909	1919	1929
Food	0.1	3.0	16.1	46.9	75.7
Beverages	0.2	4.0	22.2	46.0	76.2
Tobacco	1.5	17.8	49.3	79.7	97.1
Textiles	0.2	3.4	24.3	57.6	85.2
Clothing (apparel)	7.2	28.1	60.3	85.4	92.8
Lumber	-	0.7	4.8	19.0	52.3
Furniture	0.8	2.9	19.4	51.7	82.3
Paper	0.1	0.7	11.7	34.3	69.9
Printing	8.1	39.4	80.2	93.2	98.7
Chemicals	0.2	10.0	41.0	65.0	83.0
Petroleum	-	2.6	25.8	57.0	69.3
Rubber	0.1	1.4	20.8	78.9	96.0
Leather	1.2	8.2	35.2	73.9	86.1
Stone, clay, glass	-	3.1	22.1	54.1	86.2
Primary metals	-	2.7	16.1	36.7	63.6
Fabricated metals	0.6	15.7	44.1	85.0	97.1
Non-electric machinery	0.1	9.1	51.9	75.5	93.1
Electrical machinery	8.5	49.2	87.6	96.0	90.3
Transportation equipment	0.2	7.3	43.4	86.0	92.0
Instruments and miscellaneous	1.4	7.8	41.0	72.1	93.9
All-manufacturing	0.2	4.4	22.6	51.6	77.4

Source: Richard B. Du Boff (Du Boff, 1979:97)

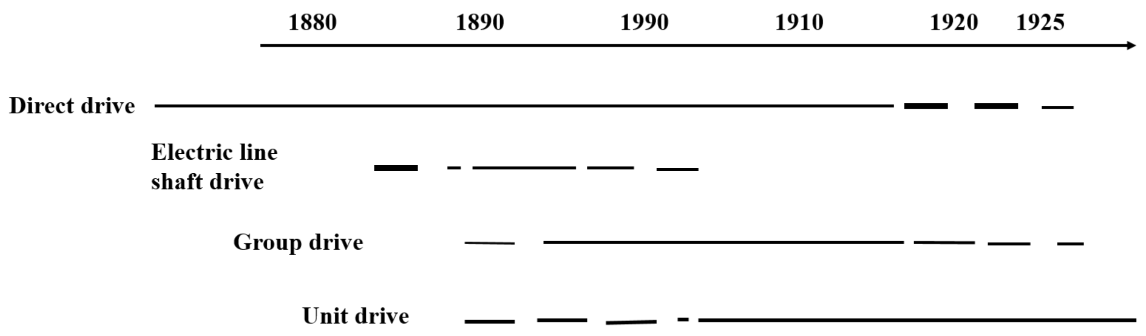

Figure 2.5. Chronology of the transition in the powering of manufacturing: from direct drive to the electric line shaft drive- electric group drive and unit drive

Source: Warren D. Devine, Jr. (Devine, 1983)

The noticeable diffusion of electric motors into the manufacturing industry may be the main technical driver that lies behind the emergence of the mass manufacturing system which was first applied in the automobile industry. The other driver is the huge market demand.

The transformation of the manufacturing industry also caused transformation in the electricity generation as steam engines were replaced by individual unit driven electrical motors. Then the electricity need for the factories were met by purchased electricity which triggered the emergence of utility companies.

Another attribute of the American manufacturing industry for the period of 1870-1930 is the high wage policy, especially for the unskilled workers of the iron and steel and the auto industry. This trend was more enhanced after the Great Depression in 1929 with the “New Deal” policies of the Roosevelt Administration which brought the concept of the “Welfare State” into the literature. This has resulted in high efficiency for the workers and a rise in the productivity (Figure 2.9).

The American Industrial Success between the period of 1870 and 1930 is the result of the effective combination of the strong intertwining factors which joined together cumulatively to create a magnified positive impact. The first factor is the geographical advantage of the United States for the abundance of the natural resources which were exploited with the utilization of technology and that also created low cost input supply for the manufacturing industry resulting in an increase in productivity. The second factor is the fast adoption of the innovations by the manufacturing industry which increased the level of mechanization resulting in an increase in productivity. One of the most critical components contributing to this factor is the wide utilization of the technologies related with electricity. The third factor is related with transportation. The most critical components here are the developments in the vehicle industry followed by the invention of the internal combustion engine and the web of railway roads that connected the locations of natural resources and the markets. The impact was the decrease in the transportation costs and the rise in the speed of delivery, leading to increased productivity and larger industrial output. The fourth factor is related to materials. The most critical material that contributed to the success for this period was steel. The fifth factor is the adoption of the mass production system increasing the amount of output and decreasing the cost of the goods. As a result, factory products became available to a larger portion of the society. This system was supported by large demand in markets triggered by growth in the size of the population, in the income per capita and in the amount of exports. The result was the remarkable increase in productivity and industrial output which were then reflected positively into the economy.

2.4. Transformation of the Manufacturing Industry in the United States (1930- 1980)

From the technical point of view, during the period of 1870 and 1930 manufacturing in the U.S. changed its face with the adoption of electric motors in the production process, advancements in the quality of materials, especially in steel, and the revolution of transportation which came along with the invention of the internal combustion engine. All these advancements in technology triggered changes in factory production systems. In terms of manufacturing transformation, this period is basically marked with the advancement in mechanization and the adoption of the mass production system.

Nonetheless, the period of 1930 and onward until the 1980’s is the time when the manufacturing was further transformed with the aid of technological developments. This interval may be designated as the time of revolutions in electronics, computing and automation. In that time frame, there were remarkable developments in the field of material science, electronics, computer hardware and software as well as power control technologies. The development of the gas turbine, the invention of the transistor, the integrated circuits (chips), microprocessor and the computer were among the important breakthrough’s which influenced the transformation in factory production. In parallel with the advances in the electronics, power and computing technologies, computers and robots were integrated into the factory production process which increased efficiency and raised productivity. From another perspective, this time interval can be viewed as the transition from mechanization to digitalization in the manufacturing industry. Nevertheless, the technical transformation in the manufacturing industry brought about change in the manufacturing systems as well. Although the Fordist mass production principles were still widely used up to the mid 1970's manufacturing had gradually evolved toward a flexible serial production system. In essence, flexible manufacturing principles were the prominent system after the 1980's which was later integrated with the "Lean Manufacturing System" in the 1990's with additional inputs.

It is important to note that the period of 1930 through 1970 is when the greatest rise in productivity occurred in the United States. With the New Deal policies taking effect after the Great Depression in 1929, the pre-1928 upward trend in real wages, productivity experienced a large upward. Labor unions in the manufacturing industry became more involved starting with the primary industries such as the automobile steel, and other durable goods that spilled over into other segments. The National Labor Relations Act of 1935 which determined the rules of union formation and the New Deal's Fair Labor Standard Act of 1938, which set out the mandatory forty-hour week with the overtime working hours system, was passed. As a consequence, working hours decreased whereas real wages increased (Gordon, 2016: 542-543).

The two World Wars, especially World War II were responsible for the rapid transformation of scientific knowledge into technologies. During the war years, the collective work of the government, corporations and R&D teams speeded the innovation process. Nevertheless, in the period after World War II, the American industrial success changed its shape shifting s more resource based driven prosperity to a well-educated human capital labor force, science based technology with a strong research and development oriented prosperity.

There are various factors that contributed to the economic growth during the period of 1930-1970. The expansion of government capital is one important development which evolved out of the New Deal policies. In the 1930's and 1940's the U.S. Government provided funding for investments in infrastructure projects such as the Golden Gate Bridge, the Bay Bridge, Tennessee Valley Authority (TVA) Dam Project, Hoover Dam Project and to factories for the production of military goods especially during the war (1942-1945). Besides supply, capital and labor constraints during the war forced all private companies to innovate their product and process technologies. Especially during the war period the government assumed the role as the investor for factory and equipment while the private sector became the operator (Gordon, 2016:538, 552).

In the post war period, in order to support the Research and Development activities, the government founded and established national research institutes. The National Institute of Health (NIH), which had been in operation since 1887, and the National Science Foundation were supporting basic research. Other agencies such as Department of Defense (DoD), Atomic Energy Commission and Defense Advanced Project Agency (DARPA) had been using funding to develop technologies related to the applied sciences. During the post war period corporate R&D expanded considerably and industrial R&D expenditures increased to very high levels. To illustrate, in 1969 the total expenditures on R&D in the United States was more than the double value of that of the U.K., Germany, France and Japan combined.

In the manufacturing industry the electrification of the factory tools and equipment continued after the 1930's. With the support of economies of scale and the use of technology the per unit cost of electricity production declined. Technically, higher efficiency was achieved when tightly sealed boilers were produced which could withstand higher temperatures and pressures. This improvement is an example of "incremental tinkering" which refers to improvements in existing technologies.

The period starting in 1930, with the discovery of the Texas Oil field, the largest and the most productive oil field at that time, is also the beginning of the rise of the petroleum and other related industries such as the chemical industry. The vast supply of petroleum, being the main input for the plastics, synthetic rubber and some of the coating industry, speeded up the adoption of these materials in the manufacturing sector leading to incredible savings in capital costs and an increase in productivity.

Plastics have been used in many industrial segments, especially in the automobile industry when parts of the vehicles were produced from these materials leading to weight reduction and greater fuel efficiency. Within the same context, coatings increased the rack life of the motor vehicles, which were mostly made of steel. The life span of railroad ties increased the same way with the application of coatings which protected steel form corrosion and abrasion effects.

Alongside the advances in motor technology, improvements in the synthetic rubber industry generated a production capability for larger and more durable tires. The positive impact was on road transportation and on agricultural industry where trucks and tractors were used (Gordon, 2016: 561).

Within the same period, the advancements in the steel industry led to the production of more durable steel products. Steel was the most widely used material in industrial production. It was mainly utilized in the construction, energy, transportation, packaging and appliances industries. Even today an average of 50 percent of the weight of cars and 75 percent of the weight of home appliances is steel. World steel consumption has shown a steady increase since the turn of the 20th century until 2018. Within this context, stainless steel which was created in the form of chrome-nickel based alloy steel that is corrosion resistant, was a remarkable advancement for the manufacturing industry. Stainless steel was invented by the British metallurgist Harry Brearley in Sheffield, UK in 1913, when during the First World War he was trying to solve the erosion problem of the gun barrel's internal surface. Later, the first stainless steel passenger train car was produced in the United States in 1930. The train, named as the Budd-Michelin train was manufactured with the collaboration of the American Budd Manufacturing Company which delivered the high strength structural steel design and the French Michelin Company which delivered metal-flanged rubber tires. In principle, structural steel was replaced with high strength stainless steel which made possible the design of more durable, fuel efficient and lighter weight vehicles. The anti-rust properties of stainless steel increased the durability under all kind of weather conditions. Later, the first stainless steel airplane was built by the Budd Manufacturing Company in Philadelphia, USA in 1932 (Cobb, 2010:134-136).

The computer revolution is another benchmark in the evolution of manufacturing industry since it laid the ground for the transformation to digitally and automatically controlled production systems. This transformation which is still continuing had an enormous impact on productivity as it changed the scope and size of the labor contribution in factory production. To make an analogy, while the invention of the steam engine, electric motor and the industrial combustion engine may be regarded as muscular revolutions the invention of the computer could be thought of as an intellectual revolution.

The first programmable general-purpose digital computer named ENIAC (the Electronic Numerical Integrator and Computer), which was completed in 1946 at the University of Pennsylvania by the War Department Scientists, was one example for a breakthrough innovation of the war period. It could compute mathematical problems 1,000 times faster than ever before, could add 5,000 numbers in second but weighed 60,000 pounds, occupying a space of 16,200 cubic feet and consumed 175 kilowatts of power. The computer was based on vacuum tube technology and contained 17,468 vacuum tubes. There were many other spillover technologies which were developed during the war period that had a technical impact on advancements in the manufacturing process.

The invention of transistors by William Shockley, John Bardeen and Walter Brattain in Bell Laboratories in 1947 was a breakthrough event in modern electronics. Transistors replaced the vacuum tube-based technology in the computers. This progress opened the gateway to the development of smaller, faster and more reliable computers in the due course.

The introduction of the first commercial silicon transistors by the American company Texas Instruments in 1954 was another cornerstone in the development of computers. Prior to that transistors were made of germanium which did not work properly at elevated temperatures. Texas Instruments, by then a startup company, was the first to mass-produce silicon-based transistors. Then the first integrated circuit (chip), was developed in 1959 by Jack Kilby by Texas Instruments, enhanced the processing power and constituted the groundwork for the forthcoming computer revolution. The power of the processor, i.e. processing speed and capacity, depends on the number of the circuits that can be placed on silicon chips. Therefore, more circuits per unit space means more power. The other turning point for the computer revolution was in 1971 when the American company “Intel” created the first commercially available microprocessor, “the Intel 4004”, which later became the core determining component for increased computer power. It was a proof that geometrically scaling of semiconductor devices could be produced. Further advancements in technology produced increased progressing speed whereas the size of the electronic components steadily decreased. As an illustration, the equivalent logic of a large scale integrated circuit placed on chips with one inch square size chips in 1976 can be compared to a room full of vacuum tubes in 1956. In fact, the principle of storing data through binary representation remained the same, though the digital nature of the computer has transformed from flip-flop, electromechanical relay and gas tube to semiconductors (Davis, 1977).

With the effect of both the advancement in technology and price decreases of the electronic components the number of circuits which could be placed on the silicon chip increased exponentially between 1958 and 1980. Especially, in the 1970's improvement in technology was achieved with the support of advancements in electronics, optics, crystallography, plasma physics, material science, metallurgy, surface physics and chemistry. Miniaturization and superconductivity became the foremost important criteria in computer design as all these developments resulted in the steady increase of logic, memory and storage capacity of the computer. In essence, the progress in the computer hardware industry was faster than in software until the early 1980's. In the early days of computers, in the 1950's, the hardware to software cost ratio was over two to one. On the contrary, by the beginning of 1980, the same ratio had reversed to one to five resulting in a recognizable increase in the programming costs (Figure 2.6). The term software was invented in 1947 which was almost as old as the first digital computer and was used to designate all programs and programing languages that required to operate a computer, to perform a given task and to let people communicate with computers. By 1980 most of computer users were already working with computer languages known as COBOL, FORTRAN, BASIC, ALGOL, PL/I and APT. Until the 1980's much effort was put on software development and quality control techniques both of which evolved from mathematics as well as logic. The software part of the computer system has been highly labor intensive (Davis, 1977).

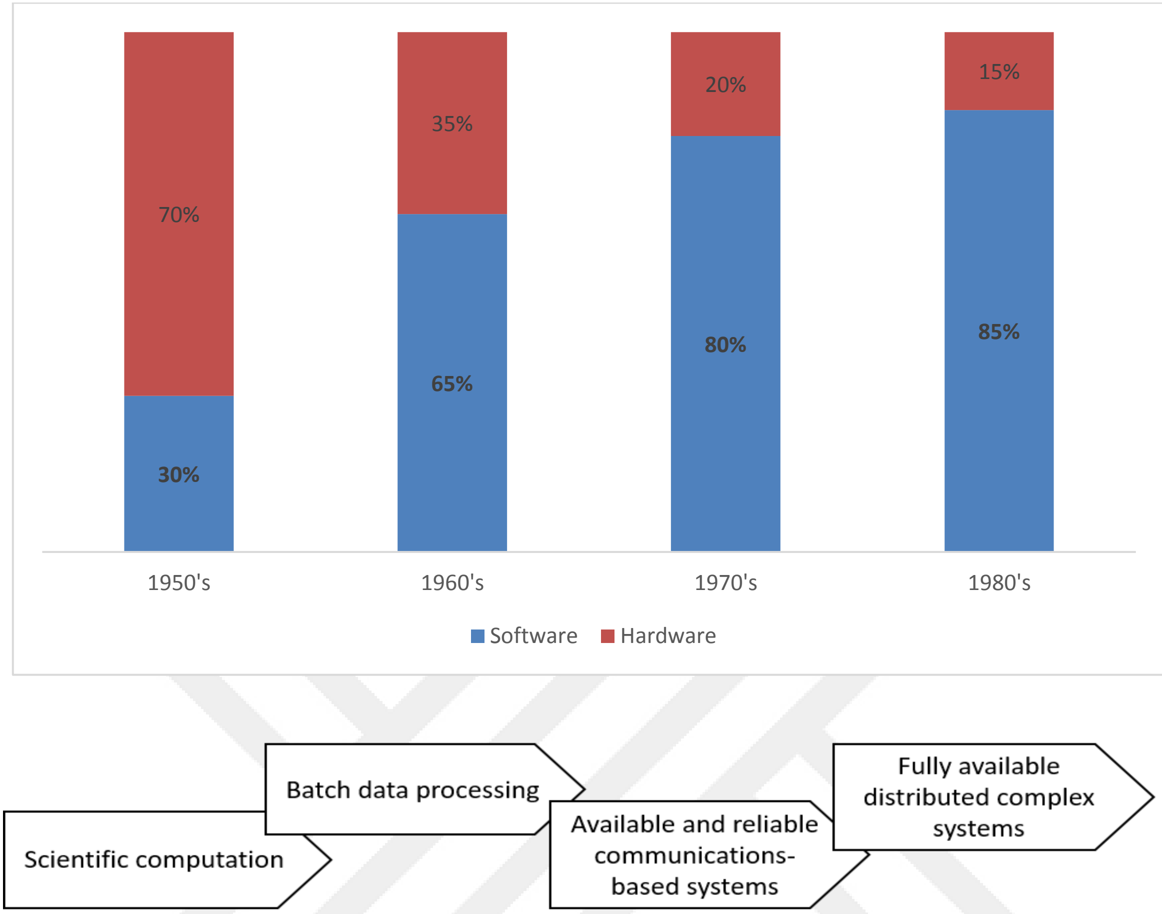

Figure 2.6. Trends in computer hardware and programming costs

Source: Lewis M. Branscomb (Branscomb, 1982)

In general, regarding the hardware, microelectronics has been the core area of innovation in the improvement of the computer power. The effort of diminishing the size of all the components, especially the brain of the computer, the microprocessor, has led to the introduction of cheaper, faster and more reliable computers. The technological advancements up to the 1980's made it possible to embed around ½ million logic circuits on a single silicon wafer which was capable of storing 288,000 bits of information. Between 1950 and 1980 the dollar per instruction executed per second value has been decreasing at a yearly rate of 25 percent for the small computers and 15 percent for large- general-purpose computers (Figure 2.6). To illustrate, in 1960 the first electronic business computer was shipped to General Electric in Louisville Kentucky in the U.S. Thereafter, computer power in America has increased at a rate of approximately 40 percent per annum. In the 1950's there were 1,000 computers in the United States, all of which were conventional devices mostly devoted to execute governmental jobs. In the 1960's the number went up to 30,000.

Though the size of the machines was still big and they were conventional as well. In the mid 1970's, however, with the advancements in science and technology, out of the 220,000 computers in the nation 40 percent were big or medium sized while the other 60 percent were minicomputers which were smaller sized general-purpose computers most of which had a selling price of less than $20,000 at that time. In the beginning of 1980's there were ½ million general-purpose computers in the United States. As another example for the automobile industry, in 1981 6½ million cars in America were equipped with microprocessor. General Motors had the capacity of building 25,000 microprocessors a day (Branscomb, 1982).

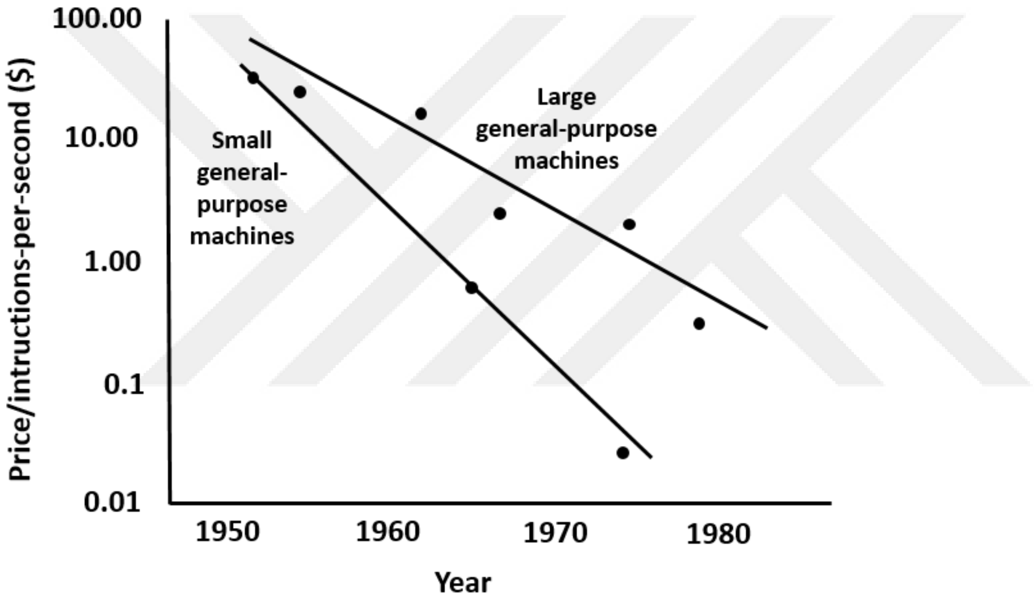

Figure 2.7. Trends in computer prices and performance
Source: Lewis M. Branscomb (Branscomb, 1982)

Literally, the Information and Communication Technology (ICT) revolution started with the adoption of computer in the daily life of businesses in the 1960's with the processing of tedious operations such as the bank statements, telephone bills, insurance policies, etc. In the same way, in the manufacturing industry, the process monitoring and control, which had been done by analog devices before, were progressively converted into being executed by digital based systems such as computers and microprocessors. As a matter of fact, the computers changed the way information was being obtained, processed and distributed; from the analog form to the digital form. Regarding the communication technology, the digital revolution also increased the capacity of the data transfer from one location to another while increasing the speed enormously. With the installment of glass fiber transmission lines data could be transmitted digitally with rates of about 10*9 bits per second. Also, by means of satellites the transmission power of information has increased which is another reflection of the digitalization in the communication technology (Abelson, 1982). In general, digital processing and transmission had two advantages over analog-based processing. First, the error rate was minimal and secondly a large chunk of information could be converted to digital data which was to be stored and transmitted into other systems if desired.

The use of computers from 1946 through 1980 may be organized under three main categories. The first one is in scientific calculations and the second is data processing or information handling. The third one is more related with the industry as it is the control of continuous process and the special purpose machinery as well as tools. This field of application has been in the steel, automotive, chemical industry as well as in power plants. The computer control application provided much efficiency in mass production systems and to the industries requiring continuous and repeating task performance and process control. Nonetheless, this adoption needed self-regularity as well as enhanced self-controlling capabilities both of which are related with hardware and software development. At that time, in particular, software development was limited in these areas (Davis, 1977) as compared with the period following the 1980's.

With increasing adoption of general-purpose conventional computers, the manufacturing industry played a piloting role. In 1976 factory production at thirty one percent had the highest share of ownership of general-purpose conventional computers of all business segments in the United States (Table 2.3).

Table 2.3. Ownership (by percentage) of general-purpose conventional computers within the United States in 1977

Ownership by industrial classification	**Percent of computers**
Manufacturing industry	31.0
Electric machinery – 3.5%	
Nonelectric machinery – 4.5%	
Other process manufacturing – 9.7%	
Other manufacturing – 11%	
Transportation equipment – 2.3%	
Miscellaneous business	13.3
Advertising, employment, equipment, rental, engineering services, other professional services	
Banking, credit, insurance, real estate and other financial institutions	
Trade (wholesale and retail)	13.1
Educational institutions (schools, universities, libraries)	5.7
State and local government	5.7
Federal government	3.4
Transportation carriers	2.9
Medical and health services	2.7
Printing and Publishing	2.4
Communications	1.9
Utilities (electric, gas and sanitary services)	1.6
Other professional services	1.9
Petrochemical industry	1.0

Source: Ruth M. Davis (Davis, 1977)

Until this time software development has been steered by studies in the field of human-computer interaction (HCI) conducted at universities and corporate research labs. The final products which were successfully commercialized were the outcomes of the mutual contribution of government funding and the work of universities, federal research agencies such as ARPA, NASA and private companies such as Xerox, IBM and AT&T. Much of this work was focused on direct manipulation of objects on computer screen, spreadsheets, text editing and the drawing programs. Regarding software system development for industrial use computer-aided-design (CAD) and computer-aided-manufacturing (CAM) systems and tools were among the most outstanding innovations during the period after World War 2 until 1980. After the adoption of the digital computer and computerization many Computer Aided Design (CAD) related facilities emerged. While working at GE, Dr. Patrick J.

Hanratty developed the program for Numerical Tooling Operations (PRONTO) which was the first commercial numerical control programming system in 1957. This program is also the first commercial Computer Numerical Control (CNC) system. In 1963, Ivan Sutherland at MIT introduced Sketchpad, the first drawing program that had graphic user interface, as a part of his PhD thesis at MIT. Then came the 3D CAD system from Timothy Johnson as a part of a project funded by U.S. Air Force. The first use of CAD and CAM in industry was in the automotive industry by General Motors in 1964 (Myers, 1998). The software called Design Automated by Computer (DAC-1) was mutually developed by General Motors in Detroit and IBM after they joined their effort in the late 1950’s in the name of which aimed to develop a computerized car design system. GM used this system to design automobiles until late 1960’s. An engineer, by using CAD, could easily perform tasks such as defining shapes, analyzing strains and stresses, check mechanical forces and generate engineering drawings. These drawings were digitally coded information which could be used to control factory machinery. The CAD was a breakthrough innovation for the manufacturing industry also in a sense that, after its adoption the design of prototyping became possible more rapidly with the aid of computers as compared to using hand tools. Later, with the integration of CAD and CAM systems the turn-around time for prototype production decreased even more.

Further and related to business, electronic mail was first enabled by the U.S. Pentagon’s Advanced Research Project Agency Network (ARPANET) which became operational in 1969. The internet is another product that evolved out of military based scientific research sources. The Pentagon’s Advanced Research Project Agency (ARPA) team facilitated in the establishment of the first computer link between UCLA and Stanford Research Institute d by 1971 there were more than 20 connected sites. This was the first application leading to development of the Internet. Later, 1981 the development of BITNET (Because It’s There Net) came out as an application of computer-linked communication among universities which built the link between a military developed and applied technology to the more open system that later became the Internet. BITNET was launched first between the mainframe computers of City University of New York’s (CUNY) Ira Fuchs and Greydon Freeman from Yale University. Later, it expanded to other academic institutions which laid the ground of today’s Internet.

Another technology that improved manufacturing process was the invention of bar code scanning technology in the 1970’s which made it easier to classify and track input-output materials during factory production. Likewise was the development of photocopy technology in business, after the first public adoption of the photocopy machine by Xerox in 1959, the usage of electronic calculators after 1970's and the typewriter as well as word processing technology after the innovation of IBM Magnetic Tape Electric Typewriter in 1964 (Gordon, 2016:451-452). The Electric Typewriter produced considerable work- time savings and accuracy to the office department‘s work at manufacturing facilities. All of this illustrates that the extent of factory automation is very much related to advances in computer technology.

It is important to note that the ground laying inventions and innovations, which are still the main source of today's manufacturing automation, were made during the period beginning in the 1940's and which lasted until the 1980's. The invention and incremental adoption of digital computing in manufacturing business brought more swiftness, accuracy and quality to the production process. As a result, better quality and more work could be delivered in a shorter period. Also, with the introduction of semiconductors such as the transistor and the designing of the integrated circuits the microprocessors emerged. With this breakthrough invention, progressive powering and adoption of computers were achieved. To illustrate, the power of chips (the integrated circuits) making up the microprocessor has doubled every 18 months from 1971 through 2006 and the micro electronic technology which made this possible is still valid today. This doubling every 18 months came to be known as Moore's Law.

By the end of 1970's, also in parallel with the developments in engineering software beside the remarkable advances in the computer hardware, the computerization of factories reached a level where product design and automation of the production process in the selected areas could be accomplished with the aid of computers. The diagram in Figure 2.8 shows the level of the industry automation at the beginning of the 1980's.

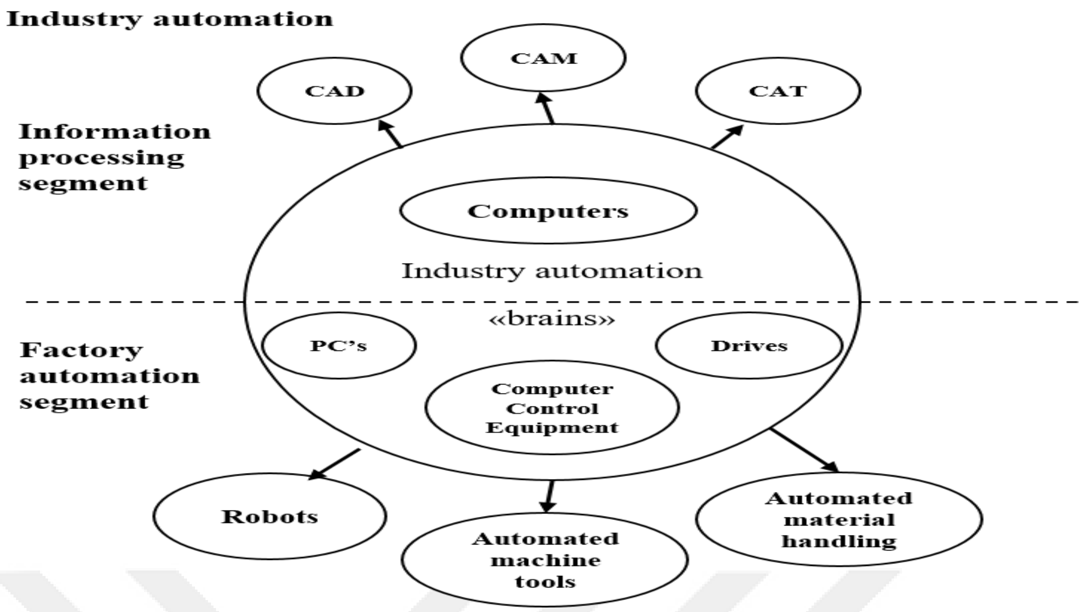

Figure 2.8. Industry automation. CAD/CAM unifies the range of advanced computer technologies in the factory

Source:C. A. Hudson (Hudson, 1982)

During the period after 1980, much focus was given to more integration of computer-aided design and the manufacturing process (CAD/CAM). The aim of this was to develop functional and standard interfaces between design engineers and manufacturing, between machine and machine centers and between individual users and machines. The computer aided manufacturing concept comprises five main features: tools design, machine control, materials and process planning, robotics and management of the factory. Tool design is related with engineering design of the products to be manufactured as well as their integration with factory machinery. CAD and simulation techniques are used within that scope.

Machine automation consists of a variety of control techniques. In the late 1990s computer numerical control (CNC) machines were directly controlled by mini computers that ran on a software that could be easily programmed to execute manufacturing tasks.

This materials and process planning feature focused on a standardized fabrication system which was based on the optimized planning of all impacting factors and resources including timing, material flow and processing. The main idea was to utilize all the production related resources at a maximum level while minimizing inventory. This stage also revolutionized the Fordist mass production system which was in use in manufacturing until the middle of the 1970’s.

With the level the robotics science had reached by the end of 1970’s robots could perform material handling functions, they could position work pieces and also do jobs such as drilling, welding and conduct test inspections. In addition, robots could be programmed and re –programmed via feedback that was automatically received during the process through visual or tactile sensors. The bottleneck with the further development of industrial robots was their high installation costs as well as the level of ease for their programmability.

The last feature of the computer aided manufacturing system is factory management. This feature describes the control of the fully integrated manufacturing system which consists of various levels of control systems adopted to manage individual machinery or robots as well as the bigger manufacturing cells (Hudson, 1982). The work from the 1980’s on focused on integrating the data basis of the CAD and the CAM systems. The aim was to have the design and manufacturing bodies talk with each other and act in full harmony based on the same language.

In 1976 the United States Air Force launched a program at the US Air Force Materials Laboratory called ICAM (integrated computer aided manufacturing) which aimed to develop techniques, tools and systems to computerize and bridge the many sub phases of design, fabrication, distribution and the management system as a whole. The system to be developed was based on the common sharing of data between various departments and units within the manufacturing plant. This program was a $100 million development which targeted batch manufacturing in the air and space industry. The final goal was to constitute a fully integrated manufacturing system that would be applicable to all segments of the manufacturing industry. In the period after the 1980’s much work was focused on data architecture and software development. Systems integration, i.e., the full integration of the manufacturing system, is one topic which is still evolving today by the manufacturing industry within the scope of automation and digitalization.

Regarding manufacturing systems, Fordism and mass production principles took effect in the United States between 1930 and mid 1970’s. The system of mass production was adopted by other parts of the industrial world, especially after World War II. With that influence the world economic growth rates from 1940 and onwards until 1970's was tremendous. The average growth rate between 1940 and 1950 was 1.7 percent per year. In the period of 1950-1964 the average growth rate was 4.7% per year. Then, the growth rate increased slightly to 4.8% from 1964 to 1974. Then between 1974 and 1984 the average growth rate went down to 3.1 percent and in the time frame of 1984-1994 it remained at 3 percent (Manyika et al., 2015:15). In the same time frame, the growth trend was similar to the growth of the manufacturing output. There has been a steady increase in both market demand and industrial output until the end of 1970's. For example, using the American automobile industry as an example, there were more than 8 million cars on yearly average produced in the United States within the time frame of 1970 and 1980 when in April of 1978 the production volume reached the all time high figure of 9.92 Million units annual basis. In the following years there has been a steady decline when a short while after 1990 the monthly produced cars in the United States went down to around 6 million units per year ("United States Car", 2018).

In essence, the fundamental principle of Fordism was that "Everything the factory produces has already been sold". This was an assumption which was based on endless market potential which assumes that all supply will be absorbed regardless. The world oil crisis of the 1970's changed that reality. The growth rate of the industrialized countries dropped suddenly to 2.7% between 1973 and 1979. The personal income power dropped and the market was saturated. It is important to note that the Keynesian Welfare State policies which supported the Fordist manufacturing model, experienced crisis at the same time.

After the 1970's Fordism was phased out and the Post-Fordist era faded and the manufacturing system was transformed into "Flexible Manufacturing" which was redefined in 1990's and became called "Lean Manufacturing". Those systems had their roots based in the system developed by the Japanese automobile manufacturing company Toyota in the 1970's and was based on a "Just in time delivery (JIT)" methodology as well as related outsourcing principles.

Regarding manufacturing industry within the period of 1930 and 1980, with the aid of digitalization and robotization in factories the trend went into more of a value-added focus and the importance of unskilled labor became less important. Within the same frame of reference work was focused on increasing the quality, productivity, energy efficiency, cost reduction and compliance with government regulations. Technically, this was achieved through a transition to factory automation which stands for digital monitoring and process control during the production process. During the flow, computers and microprocessors were processing the data, the sensors were converting analog information to digital data and the actuators were converting computer decisions into the modification of the processing tools. In essence, in major industries such as the steel, automotive, chemical and the petrochemical industries, electronic and computer control was already prominent in the 1970's. However, even at the beginning of the 1980's the adoption of the electronic systems in the offices and for personal use was limited. Besides, the cost of building an industrial robot was not economically quite feasible yet in every segment of the manufacturing process when compared with labor rates. Therefore, robots were mostly used in the hazardous jobs (Abelson, 1982).

2.5. The Industrial Progress in the United States (1930-1980)

During the period 1870-1930, apart from the change in the standards of living the impact of the advancements played out in terms of productivity (output per hour) and real GDP growth. There has been a steady increase in both of these terms and also in the Total Factor Productivity (TFP), the measure of the pace of innovation and technology when labor and capital induced productivity is removed from TFP. However, for the period following 1930 until 1950 there was a sharp and remarkable increase in all of these measures. The TFP made a great leap forward and the real GDP more than doubled. As shown in Figure 2.9 the output per hour figures made noticeable increases until 1970. Based on the data, there was a big leap in the United States in terms of productivity and GDP growth.

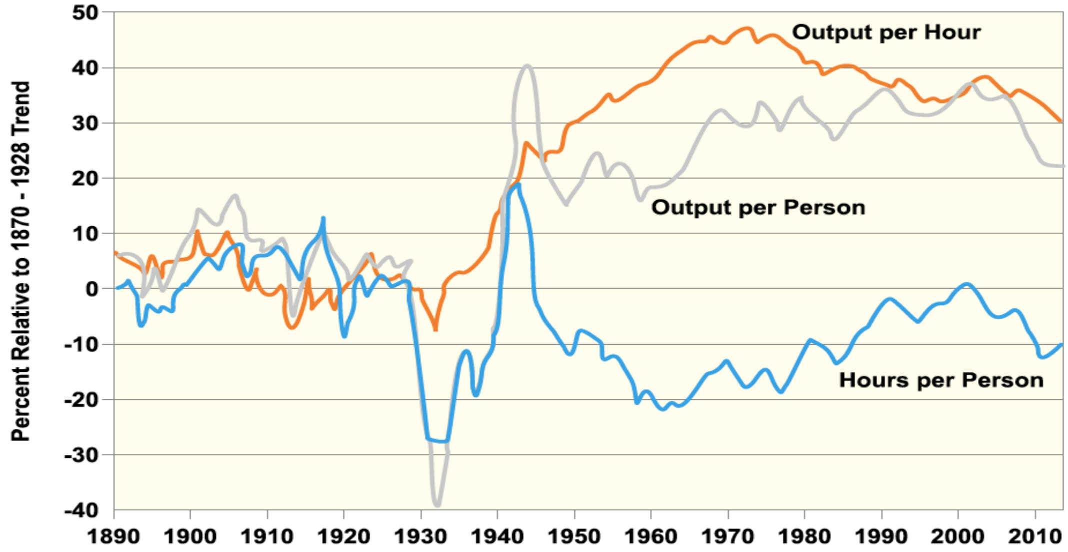

Figure 2.9. Log ratio of actual values to extension of 1870-1928 trends of output per hour, output per person, hours per person, 1890-2014

Source: Robert J. Gordon (Gordon, 2016:540)

Also, as sown in Figure 2.2, again within the same period, there was a very steep increase in the industrial output per capita figures in the United States after the 1940's, a clear indication of a rise in productivity and an increase in the new investments in manufacturing establishments and equipment.

First, it is helpful to know the components of productivity in order to be able to elaborate more on the role of the underlying factors. In this respect Figure 2.10 shows the average annual growth rates of output per hour and its components for the time span of 1890-2014 in the United States.

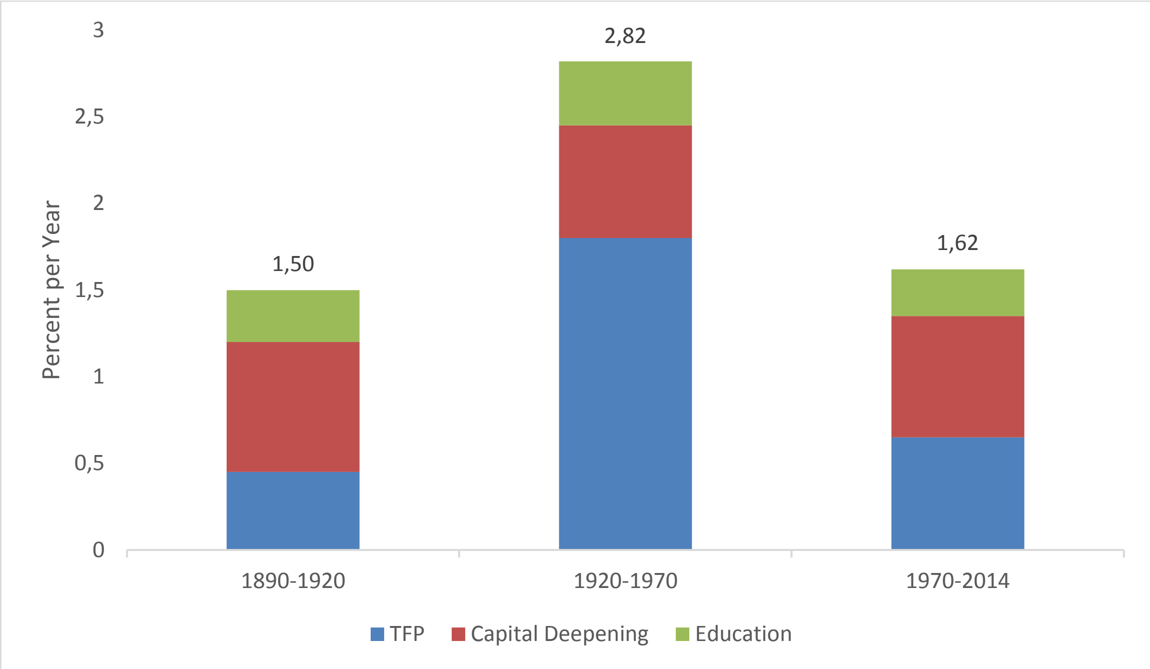

Figure 2.10. Average annual growth rate of output per hour and its components, selected intervals, 1890-2014

Source: 1879-1923 (1963), Tables A-8 and A-12; 1926-1929, U.S. Department of Commerce, Foreign Commerce and Navigation of the United States for the Calendar Year 1929, Vol. 1, Tables XII and XXIV (as cited in Gordon, 2016:).

The effect of education and capital deepening through the selected period is almost equal for the three selected intervals (Figure 2.10). However, the TFP growth, indicating the role of innovation and technology for the time interval 1920 to 1970 is almost triple in comparison to the other intervals. Before laying out some arguments to explain this rise it is important to make a remark. According to Paul David, who set out the analogy between the evolution of electric powered machines and the electronic computer, there is a certain period between the time when a breakthrough invention is made and some period of time after that before its impact is fully reflected in productivity growth. This effect is described as the productivity paradox in the literature. David gave the example of the Thomas Edison's Pearl Street Power Plant which was opened in 1882 and the productivity growth that came along with the electrification of the manufacturing in 1920, after four decades had passed. Similarly, the internal combustion engine was invented towards the end of the 19th century but the wide usage of passenger cars only happened decades later. What matters is the time of the first commercialization of the innovation rather than the date of the invention. This thesis is also supported with the 2009 study of Alexopoulos and Cohen, "The Media is the Measure: Technical change and employment, 1909-49". They analyzed the period between 1909 and

1949 and on the basis of that study they claimed that commercialization of technology should be the measure for the pace of innovation not the use of a patent(s) since it only refers to the inventions (Alexopoulos and Cohen, 2009:10-11). The same argument could be made for the Internet and related IT development because investigators kept searching for related increases in productivity going back to about 1990 but evidence of it did not surface until much later.

Also, the revolution in the production system came along with Henry Ford's introduction of the first assembly line dates back to 1913. Prior to that time, in 1908 for example, there were only 8,000 registered motor vehicles in the United States. Though in the 1930's the number of the registered vehicles had risen to 26.8 million. The fundamental conclusion is that the impact of mass production and electric powered tools on the creation of prosperity was felt in the decades following their invention. This evidence held true up to and through the 1950's as well. Those were the years when the productivity growth rate moved into an upward (David, 1990). Therefore, it may be argued that one factor adding to the industrial success of the 1930-1980 period of the United States was the continuity of the impact of the innovations of the 1870 -1930 period and the still unexploited inventions of the 1920's.

Figure 2.11 shows the very large growth in TFP after the decades following the 1920's, when growth peaked between 1940-1950 and then slowed and then came further down to hit the lows in 1980 then went up again to remain around the levels of present day values Though these values are much lower than the same TFP values reached at the period of 1920-1970. This data is evidence that the impact of the inventions and the related innovations of the 1870 -1970 period, had a longer lasting and more influential impact on the productivity than the inventions and innovations of the period from 1970 till the present day. Arguably, the introduction of the Ford assembly line principle combined with the adoption of the electrically powered machinery caused a remarkable impact on the TFP growth beginning in the 1920's and lasting through the1950's. This claim can be supported by observing the figures of the horsepower used by the prime movers and the kilowatt-hours of electricity production used for the same time period (Table 2.4). These figures show that the electrification has continued through the 1950's. This fact also supports the case for productivity growth as well as the factory investment growth for the same time interval.

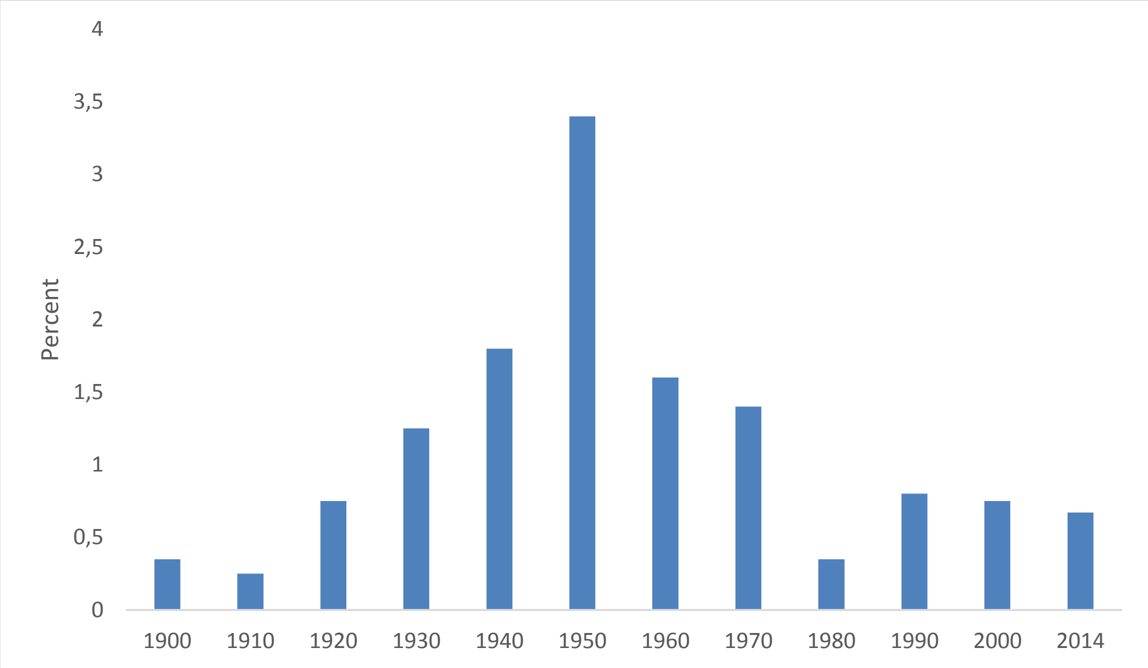

Figure 2.11. Year average annual growth in total factor productivity, 1900-2014

Source: Robert J. Gordon (Gordon, 2016:547)
Note: The average annual growth rise is over the ten years prior to the year shown.

Table 2.4. Horsepower of prime movers and kilowatt-hours of net production of electricity, 1929=100, selected years 1899-1950

	1899	**1909**	**1919**	**1929**	**1940**	**1950**
(1) Variable Depreciation Private Equipment Capital in 1950 Dollars	34	57	82	100	120	164
Horsepower						
(2) Automotive	0	1	16	100	176	309
(3) Factories	49	84	101	100	110	170
(4) Farms	13	34	76	100	156	231
(5) Electric Central Stations	5	13	33	100	134	220
(6) Average of Auto, Factories, Farms	20	40	64	100	147	237
(7) Ratio of Horsepower to Equipment Capital	61	70	79	100	123	145
	1902	**1912**	**1920**	**1929**	**1941**	**1950**
(8) Variable Depreciation Private Equipment Kilowatt Hours	39	63	84	100	123	164
(9) Industrial Establishments	14	54	70	100	177	242
(10) Electric Utilities	3	13	43	100	178	357
(11) Total	5	21	48	100	178	333
(12) Ratio to Equipment Capital	13	34	58	100	145	203

Sources: HSUS Colonial Times to 1957, Series S2, S6, S11, S13, S19, and S33

It is evident from Table 2.4, Line 6 that for every 100 units added to the production system designated as the average for the automobile industry, other factories and farms between 1902 and 1929, more than 137 units were added between 1929 and 1950. This comparison for the automobile industry is even more staggering as the figure shows an increase from 100 units in 1929 to 309 units in 1950. This outcome is due to the increase in both the total number and the horsepower of vehicles in use. To illustrate, Ford's 1913 Model T car had twenty while a 1940 Model Chevrolet had a horse power of eighty-five. The same is true for buses and trucks. Regarding the registration figures, between 1929 and 1941 the total number of registered trucks increased by 45 percent and that for the buses more than tripled.

Within the same context, the sharp increase in electricity production for industrial establishments and electric utilities from 1929 to 1930 tell us that the electrification of the industry continued at a rapid pace through the 1950's. The efficiency that came with electrification is another fact that supports the increase in productivity during this time period (Gordon, 2016:559-560).

It is also important to emphasize changes in the ratio of horsepower and electricity production per unit of equipment capital. The big and steady rise in both of the ratios from 1930's through the 1950's show that a sustainable increase in output is related to increased efficiency in the manufacturing sector. The efficiency that originated from the advancements in technology and the adoption of new systems in manufacturing industry transformed the American manufacturing industry to a more productive economy. As recognized from the data set, for the period 1920 through the mid-1950's manufacturing tools and equipment became more powerful due to increased electrification. Also, with the adoption of the Ford assembly line system fewer workers were able to create the same product. Consequently, the American manufacturing industry became the trademark for fast and standardized mass production.

The other important factor that has contributed to the economic growth for the period of 1930-1970 is the expansion of available government capital which came along with New Deal policies which became more prominent during the war years, especially from 1940's through the 1950's. In the 1930's and 1940's the U.S. Government provided funding for investments in infrastructure projects such as the Golden Gate Bridge, the Bay Bridge, Tennessee Valley Authority (TVA) Dam Project, Hoover Dam Project and to factories for the production of military goods especially during the WWII Period (1942-1945). Within the same period, as a strategic decision the government also built a 1,300 miles long petroleum pipeline between Texas and New Jersey. For the fifteen-year interval between 1930 and 1945 covering the first years following the Great Depression and the War time period afterwards, private capital slowed in its contribution to the investments in new manufacturing facilities. Thus, the U.S. Government stepped in to narrow the gap in the needed capital. Henry Ford's huge aircraft mass production plant at Willow Run, Michigan is an example that benefited from the greater availability of government capital. By 1944, 650 aircrafts were produced a month from the Willow Run assembly lines. During that time almost all of productive equipment and facilities were financed by the government and but operated by private companies. It is important to note that the total amount of machine tools in the United States doubled from 1940 to 1945. As a matter of fact, the new equipment was more modern and more efficient than the previously held stocks of equipment where the capital came from the private sector (Gordon, 2016: 552-553).

The War time period of 1940 and 1950 is the time when the highest jump in TFP occurred. There were special characteristics of this period. During this time all machines were operated at very near full capacity. For example, the capacity use rate for the steel industry was 97 percent in 1941. Besides, supply and the capital constraints during the war period forced all private companies to innovate both product and process technologies. The circumstantial pressure forced the manufacturing industry to become more efficient by finding and applying newer techniques. As an example, the Kaiser freighter ship, which was scheduled to be built in 1942 in 8 months was put together in a few weeks. In addition, owing to collaboration between the two shipyards at Richmond California and Portland, Oregon, manufacturing time was cut to four days. The work was spilled between many shipyards and the separately pre-fabricated parts were assembled later. Similarly, Pontiac auto factory had reduced the cost of the Oerlikon anti-aircraft defense system by 23 percent. At the same time factories converted their production so they could manufacture other products. To illustrate, jewelry makers produced artillery fuses, lawn mowers manufacturers produced shrapnel shells, postal meter manufacturers produced bomb mechanisms, and so on. Even Henry Ford's huge car factory was converted into a plant producing B-24 bombers. In essence, during this period there was ongoing innovation through trial and error. Combined with the utilization of the full capacity operation a very remarkable efficiency gain was achieved. It is worth noting that all accumulated knowledge during the war period was subsequently translated into producing civilian goods and services and thus resulting in permanent efficiency gains in the post war period. The capacity and the capability of the manufacturing industry were explored to the highest extent. Also, the special energetic activity of the war period helped workers and managers build self-confidence and gave them hope for the future (Gordon, 2016:549-552).

Moreover, as an additional factor the low immigration rate and high tariff polices forced the United States to live through a relatively closed economy from 1930 to 1960. As an outcome manufacturing industry outsourcing became limited and wages of factory workers went up. Arguably, from another perspective this had a positive impact on the U.S. manufacturing sector as well as the economy as a whole by increasing the amount of domestically innovative investments and by reducing income inequality among the people.

The TFP growth between 1950 and 1980 is based on the impact of the continuous positive transformation of the manufacturing industry through automation and the application of computing technologies. Automation was achieved through the adoption of programmable electronic control units in factories. At the same time the speed and the power of factory machinery and tools could be controlled by means of computers and microprocessors such as the speed and cycles of electric motors which today are powering most of the machinery.

2.6. The Innovations and the Transformation of the American Manufacturing Industry (1980-2018)

In the United States, after the 1973 world oil crisis, but mostly after the turn of the 1970s decade, post war welfare state polices were totally abandoned and the new policies reflecting the philosophy of neo liberal politics based on the public choice model which assumes the roll back of the state to its basic position of execution judiciary and defense functions only and at the same time providing minimum public services. The more market-oriented environment aimed to reduce national government support and intervention to the minimum.

Within the same period, as the general purchasing power and market demand diminished, companies started to look for better pricing strategies in order to remain competitive. For the manufacturing industry it meant cutting production costs as much as possible. This outcome set forth a new trend of moving less value-added manufacturing abroad and retaining the more value-added manufacturing. This new trend was consistent with the notions of off shoring and de-industrialization. Also, the same environment pushed manufacturing industry to seek a systematic transformation within itself. The traditional mass production system, which was based on a “whatever is produced will be sold” strategy was transformed into more flexible and lean manufacturing systems, where inventory and production volume was linked to fluctuating market demand.

The breakthrough inventions which created the most remarkable impact on productivity and efficiency in manufacturing for the period following 1930’s until the 1980’s are mainly the computer, transistor and the microprocessor. Also, with the integration of the control technology factory automation was achieved during this period. This development was a transformation from mechanical control to electronic control of factory equipment and the manufacturing process. After the 1980’s there have been further advance in microelectronics, computer, communication, control technology and material science. In particular, with the widespread use of computers in business after the early 1980’s followed by the adoption of internet after the mid 1990’s automation and digitalization in the manufacturing industry reached more sophisticated levels up to the present time. In particular, the adoption of Internet in business life became prominent after the invention of web browsers, search engines and e-commerce after 1995. In the following period, alongside the improvements in material science and microelectronics the merging of the computer and communication technology led to the introduction of smart phones in the early 2000’s. Further, in the same period the advances in the field of electronic sensors, computer science, machine and control technologies increased the capabilities of industrial robots.

In terms of manufacturing, the period 1980 until 2018 can be characterized as having more digitalization through the widespread adoption of the information and communication (ICT) technologies and also with advanced robotics science which is associated with artificial intelligence as well as machine learning technologies that have been developed with advances in computer science and electronics. Other outstanding tools which are possible with today’s technology are the power of big data processing and cloud computing. Big data management and processing become possible as the computing power and Internet speed have reached the elevated levels with advances in microelectronics. Cloud computing is another feature that is associated with the power of the Internet. With this technology, instead using a local server the network of remote servers is used to store, manage and process data.

In essence, all these technologies are also being applied to factory production especially within the frame of integrated design, management and production.

The information technology (IT) revolution which began in the early 1960's gained speed and became more comprehensive from the 1980's until the present day. At the end of 1970's although the digital revolution had already changed the way the information was being received, processed and transformed it had not been used in all aspects of life. Especially, the adoption of the electronic systems in the offices was quite limited. The introduction of personal computers (PC) increased the personal productivity within that regard. In 1981 the first PC was produced by IBM with a chip manufactured by Intel (the Intel 8088 chip) and the operating system incorporated by Microsoft. The improvement started in the business world at the offices with the electronic filing of documents and the electronic emailing between workstations which were connected through local networks. At that time the word processing and spreadsheet calculation features of the computer were used for business purposes.

The rise of the Internet became possible with the extended reach of the World Wide Web in the early 1990's after its first server was installed in the United States at the Stanford Linear Accelerator System in 1991. In the manufacturing sectors, as early as the 1980's employees were sending emails to each other within factories. Though with the access to the World Wide Web the exchange of emails became possible among suppliers, sub suppliers, clients, governments and any other entities who were distantly located from each other. Even the inter country exchange of information became easier. In addition, cheaper phone calls were possible through the use of data. Another novelty related to the Internet was the introduction of web browsing technology which made access to information much easier. The first web browser was created by the National Center for Supercomputing Applications in 1993 and was called Mosaic. Then the Netscape browser emerged in 1994 and was followed by Microsoft's Internet Explorer in 1995. In between the search engines emerged were developed between 1993 and 1998 which gave the user the possibility of an extended search and navigation on the web. Excite (1993), Yahoo (1994), AltaVista (1995) and Google (1997) were some examples for some search engine providing companies born within that period. In 1998 first GoTo and afterwards Overture Services were the first companies to develop sponsored research which operate by combining the basic elements such as advertiser-provided content, advertiser-provided bids, review process, matching of advertiser process to user queries, display of advertiser content and the process that gather data, meter clicks and charge advertisers. Yahoo bought Overture Services in 2003 and started branding with Yahoo Search in 2005. Also Google adopted a similar model in web search developed by BeFirst in 1999 and developed it further into click feedback in 2002 (Fain and Pederson, 2006).

Also, with the further utilization of the Internet technology e-commerce emerged which changed the shape of trade and became an alternative to retail shopping. Amazon, founded in 1994, first went into the book business and then gradually increased market share for the next three decades. Amazon moved e-commerce services into a much wider array of consumer products including food. As of today, Amazon is the world’s most valuable company with a brand value of US$ 150.8 billion and with a market cap of approximately US$ 1 trillion as of September 2018. The rise of e-commerce also changed the way businesses operate overall. For instance, gigantic stores such as Wal-Mart became the biggest consumer of data which enabled it to accurately predict consumer behavior and also use it to determine their competitor’s strategies. However, the rise of e- commerce also had a negative impact on the employment and also on GDP as shopping malls, furniture stores or the building product manufacturing industry became threatened.

The adoption of computers both by households and by businesses increased more rapidly after 1995 because by means of web browsers and search engines people could make use of the Internet to a greater extent by enabling access to lots of information, services and activities. It would able be to do things it could not do before. Some examples are: being able to make hotel, airline, restaurant reservations or purchasing movie tickets. The rise of e-commerce also coincides with the same timeline as it also enhanced options for Internet users. In the United States the adoption of PC’s reached 30 percent in the first thirteen years and after the release of the first browser, Mosaic in 1993, it went up in parallel with the wide and continues usage of the internet until the present day. As of today, Internet access reaches almost 90 percent of the potential users. There is the possibility for people and businesses to communicate not only by using the PC’s but also through various applications such as Whatsapp, Facebook, Twitter, LinkedIn and so on which are also operating on smart phones. In essence, the adoption of the Internet changed after 1995 with the introduction of the web browsers, the search engines and the e-commerce. These developments combined can be described as one kind of information & communication technology (ICT) revolution or internet revolution which had a game changing effect on variety of aspects of personal life, social life, academic life as well as on the general scope of the manufacturing and service industries.

As a part of communication technology there has also been a remarkable leap in the telephone technology between 1980 and the present. Mobile phones emerged first in 1983. Later with the integration of computers and the mobile phones smart phones were introduced, first the BlackBerry in 2003 and then iPhone in 2007. This progress also contributed to digitalization of the factory production. With the smart phone technology monitoring and controlling of the factory machines as well as the manufacturing process became possible from any distance at the tip of the fingers as long as there was Internet access for the user. From the historical perspective, the computer revolution that happened in the 1930-1980 timeframe laid the ground for the Internet & communication revolutions in 1995 and in the 2000’s.

Regarding the hardware technology, after the first prototype of the microprocessor in 1959 the introduction of the first commercial microprocessor by Intel (Intel 4004) in 1971 brought a new view of the computer revolution which continued with the emergence of the first Personal Computers (PC) at the beginning of the 1980’s and coming to the present when the processors are operating within the smart phones though much greater power. The cofounder of Intel, Gordon Moore made a forecast in 1965 about the power of computer chips. He predicted that chip density, the main source of computing power, would be doubled every 18 months. In fact, his projection was true until the 1990’s. Past that period the power of the computer chip doubled even more, with a rate of doubling every 18 months until 2006. Since 2006, the doubling speed in density of the chips slowed to a much slower pace; to every four to six years. To make an illustration, in 1971 the first microprocessor introduced by Intel, the Intel 4004 had 2,250 transistors (Tuomi, 2002). On the contrary, in 2014 the Intel 15-Core Xeon Ivy Bridge had 3.31 billion transistors. It is worth noting that computing speed does not solely depend on the chip density. Despite the fact that it is the main determining factor there are other contributing factors such as advances in material science. From 1982 until 2001 computer power has increased 30% more than the growth rate before the 1980’s. On the contrary, the cost per computation task has dropped. Between 1945 and 1980 the decline in cost per computation task has been 37% per annum whereas after 1980 the cost decline on yearly basis was 64%.

From a different perspective, at the beginning of 1980's although United States was among the most productive nations in the world, it's manufacturing productivity growth rates in terms of output per hour had significantly soared in the time interval of 1970 to 1980 as compared to other industrialized countries. The productivity growth rate of the United States was 2.9 percent between 1969 and 1973 and 1.6 percent from 1973 to 1979. Much focus has been placed on the development of the computerized factory system and automation. To achieve that, both hardware and software systems needed to be strengthened (Hudson, 1982). So, after the early 1980's the work on industrial automation concentrated on the full integration of design and drafting systems with manufacturing systems as well as process control. In general, such integration has persisted from 1980 until the present day.

Overall, the continuous development in microprocessor technology has brought an enormous and previously unthinkable increase in data transfer and processing speed. This made possible the connection and communication of physical devices including the components of machines and control units through the internet, by means of sensors and computers, in a very speedy way. This concept is today called the Internet of Things (IoT) and is related to smart manufacturing. In the same way and with powering up of the microprocessors and computers, remarkable achievements have been achieved in control technology. In the beginning of 1980's only position control was possible. Thorough the years the technology has advanced so that control technology could be applied with force control. Some examples are press, forging, extrusion and rolling machines as well as manipulators which are all used in heavy manufacturing such as the steel and automotive industries.

On the other hand, with respect to industrial robot technology, there has not been a breakthrough innovation within this time span except for gaining more versatility, flexibility and efficiency. In essence, although in a limited scope the primary technology was already in place before the 1980's. General Motors introduced the first robots in 1961. However, because robots are mechanical devices controlled by microprocessors, any improvement in the processing speed directly affected the capacity of industrial robots. Nonetheless, there has been progress in design quality and in computer software that serves as the interface between user, machine and process. In parallel with the noticeable developments in the hardware, software and the control technology smaller size, more powerful and more agile robots were produced. They could be easier programmed and controlled as compared to the past. Most importantly they became very cost efficient at the same time.

An important difference to mention about the usage of robots in the manufacturing industry between late 1970's and today is that while in the 70's the robots were mostly used for applications in material handling and welding, today they are used in a variety of fields including the assembly process. Further, the progress in the sensor and vision technology improved robotic sensitivity. Advances in the area of artificial intelligence after the 1980's brought additional advantages to the field of robotics primarily with the development of algorithms that could replicate intelligent performance with minimum human intervention. As of today, the more affordable, flexible and the technical capable industrial robots have been adopted for wide range of applications in most of the main industrial sectors such as iron and steel, petrochemical, energy, textiles and automotive industries.

Overall, the advancements in the computer and electronic control technology combined with the expedited data processing capabilities with the support of internet has increased the level of automation in the factory production systems. In today's terms, the new system is conceptualized as digitalization in manufacturing.

Since beginning of the industrial revolution, the ultimate goal of manufacturing industry for adopting better technologies has always been to achieve better productivity rates, produce products with better quality and to bring simplicity as well as comfort into the whole manufacturing process. Within the same context, many production systems, plant configurations, managerial methodologies and manufacturing techniques have been adopted by the manufacturing industry by being continuously shaped with advances in technology as well as the effect of social science innovations. In this respect, the mass production system, which was invented and first applied to the automotive industry by Henry Ford in 1908, is an important blueprint that transformed the whole manufacturing industry first in the United States and then in the whole world. This system was based on a moving assembly line and the mass production of identical parts, through large machinery and division of labor.

The mass production system has been applied to diverse sectors other than the automotive industry and influenced the manufacturing industry all over the world until the end of the

1970's. Mass manufacturing was a term which referred to producing standardized products in large quantities with high efficiency. Within that respect economies of scale justified the low cost as long as demand was sustainable. However, especially after the world economy went into crisis in the 1970's producing based on the old principles of the mass production system was no longer efficient. This forced manufacturing to go through another revolution in technical and managerial aspects as the single purpose mass production machinery was replaced by flexible machinery which was multitask purpose and programmable. As an example, in 1988, with the aid of this kind of equipment for the first time the GM factory was able to switch the production to manufacture 1989 model prototype cars for the weekend and switch back to the routine production on Monday at the beginning of the shift. The new flexible manufacturing equipment enabled the manufacturers to reduce batch sizes and therefore shorten the production cycles. The outcome was faster response to demand fluctuations which resulted in less back orders winding up with higher efficiency. With the adoption of the flexible manufacturing system, as an example, General Electric cut design and production time of a circuit breaker from three weeks to three days. As another example, the Allen Bradley Company, that makes electric controls, started to ship orders the day after they are received. Overall, this new flexible manufacturing system was a conversion from mass production to a make to order basis.

Technically, the flexible manufacturing system was made possible with advances of CAD/CAM technology as well as industrial automation and their wide integration into manufacturing processes. Consequently, computer integrated manufacturing (CIM) prevailed in manufacturing. This outcome triggered a change in general manufacturing strategy. There were organizational changes at the managerial level as well as redefinitions of the jobs at the workstations for plant workers. For the most part, the whole lay out of the plant has been changed. Most importantly, the technological changes had a remarkable effect on reducing the inventory due to a revolution in logistics and logistical control and the designing costs to very low levels. In particular, the lower design costs and wider capabilities for designing contributed to a strategic change where products began to be developed by teams of manufacturing managers, process engineers and designers. From the engineering perspective the product and process engineering functions have been integrated. Thus, companies have expanded their product lines and also gained capability for frequent product improvements. The organizational changes included giving multiple responsibilities to workers based on a multidepartment approach, adopting a parallel team approach rather than the sequential one, outsourcing of some jobs and many other flexible working arrangements. All these have also affected the marketing strategy of the companies. With the adoption of this new system a more flexible marketing strategy was needed. Basically, the flexible manufacturing system as a whole redefined and redesigned the relation between design, manufacturing and marketing. In essence, all the production steps from procurement to quality control were restructured.

Overall, the integration of CAD/CAM technology with the new organizational and management structures produced successful results in the American manufacturing industry. For instance, Ford, reduced the development time for its new models by one third and the Lockheed Corp.'s Aeronautical Systems Group achieved a decrease in design and manufacturing time for sheet metal by 96 percent, from 52 days to 2. The productivity gain was 80 percent (Milgrom and Roberts, 1990).

Within the same scope, another manufacturing system was invented by Eiji Toyoda and Taiichi Ohno at the Toyota Motor Company in Japan after World War II and had been developed earlier by Toyota Motor Company engineers between 1948 and 1975. This system called as the Toyota Production System (TPS) was mainly based on the principle of eliminating waste or any process that consumes resources without adding value to customers. Literally, the Toyota business approach provides just-in time delivery and more options to clients, foresees harmony with suppliers, involves workers in decision making and a more efficient production manufacturing system for the companies. In general, TPS combines plant automation with the people by developing everything from a human-centric standpoint. The same manufacturing system was later the topic of a very extensive industrial research program at the Massachusetts Institute of Technology (MIT) called the International Motor Vehicle Program (IMVP). This five-year research effort involved fourteen countries and was led by the social scientist James Womack from MIT. Out of this research, which was done with an educational perspective, the TPS was redefined with a different terminology called lean manufacturing which was erected on substantially the same principles. This concept was later described as a distinct value creating managerial system which could be applied to all manufacturing and non-manufacturing industries, by Womack, Jones and Roos in their 1990 book "The Machine that Changes the World: The Story of Lean Production" (Womack, Jones and Roos, 1990). Then, again by Womack and Jones in their 1996 book "Lean Thinking" (Womack and Jones, 1996). Literally, the "Lean

Manufacturing" and "Lean Thinking" in Womack's view is based on three main principles: The first is a system based on seamless product flow with minimum waste time; the second principle is a cultural environment where everybody is motivated to continuous self-improvement; and, the third one is a production system which purely depends on demand (Barney and Kirby, 2004:36). In other words, manufacturing is not undertaken until there is a demand for the output and the same way, input materials are supplied only at the appropriate time – when they are needed for production. Overall, it is an optimized supplier, inventory, manufacturing and client management system.

The TPS was first applied in manufacturing industry in the United States in 1984 through the joint effort of General Motors and Toyota at GM's Fremont, California plant, which was one of the lowest ranking production facilities of GM in terms of quality, productivity and morale of the workforce at that time. The old GM plant was reborn with a new partnership between GM and Toyota called as New United Motor Manufacturing Plant (NUMMI). It involved a transfer of knowledge from Toyota to GM. The TPS methodology was fully adopted and applied in the following years. After five years of operation the plant had been transformed from the worst to the best plant of GM. Nevertheless, the change in business culture and the production methodology was imminent and paid off right at the beginning. The IMVP plant assembly survey data in Table 2.5 and 2.6 show the improvements in different measures in comparison with the values from selected manufacturing plants. In principle, the inventories were taken based on just-in-time basis to save on costs. Besides, defects are immediately exposed and fixed at their source, for instance on the assembly line, before cars enter the warehouse to be repaired on a separate stage. Moreover, job classifications are reduced and replaced by a rotation methodology through cross trained workers who bear duties for repair, housekeeping, preventive maintenance and quality control (Babson, 1995:6) and (Barney and Kirby, 2004:35-36). It is clear from the IMVP survey fact sheet that the TPS system brought increased productivity, decreased the time for the recognition of defects per car and diminished the inventory of parts with the just-in – time delivery methodology.

Table 2.5. General Motors Framingham versus Toyota Takaoka versus NUMMI Fremont, 1987

	GM Framingham	Toyota Takaoka	NUMMI Fremont
Assembly Hours per Car	31	16	19
Assembly Defects per 100 Cars	135	45	45
Assembly Space per Car	8.1	4.8	7.0
Inventories of Parts (average)	2 weeks	2 hours	2 days

Sources: IMVP World Assembly Plant Survey

Table 2.6. Summary of assembly plant characteristics, volume producers, 1989 (averages for plants in each region)

	Japanese in Japan	Japanese in North America	American in North American	All Europe
Performance:				
Productivity (hours/veh.)	16.8	21.2	25.1	36.2
Quality (assembly defects/100 vehicles)	60.0	65.0	82.3	97.0
Layout:				
Space (sq. ft./vehicle/year)	5.7	9.1	7.8	7.8
Size of Repair Area (as % of assembly space)	4.1	4.9	12.9	14.4
Inventories (days for 8 sample parts)	.2	1.6	2.9	2.0
Work Force:				
% of Work Force in Teams	69.3	71.3	17.3	.6
Job Rotation (0= none, 4=frequent)	3.0	2.7	.9	1.9
Suggestions/Employee	61.6	1.4	.4	.4
Number of Job Classes	11.9	8.7	67.1	14.8
Training of New Production Workers (hours)	380.3	370.0	46.4	173.3
Absenteeism	5.0	4.8	11.7	12.1
Automation:				
Welding (% of direct steps)	86.2	85.0	76.2	76.6
Painting (% of direct steps)	54.6	40.7	33.6	38.2
Assembly (% of direct steps)	1.7	1.1	1.2	3.1

Sources: IMVP World Assembly Plant Survey, 1989, and J. D. Power Initial Quality Survey, 1989.

The aim was to produce good quality at low cost. The first Nova Chevrolet came out of the assembly line in 1984. Overall in the NUMMI plant, the increase in productivity was achieved right at the beginning. The joint venture between Toyota and GM continued until the plant was shut down in 2010 when GM pulled out due to bankruptcy and Toyota did not want to continue alone. Unfortunately, the NUMMI plant experience could not be fully utilized and transferred to other GM plants due to various reasons, one being the decentralized management structure of GM.

Basically, after the adoption of the mass production system at the beginning of the 20th century technological developments have enabled manufacturing systems to evolve gradually towards lean and smaller batch sized systems after the 1950's. Through the years, mass production transformed into mass customization. The principle was that the core output product remained basically the same but offered more varieties with minor changes depending on various customer preferences. A common example is the basic cola appearing in diet, zero calories and regular form.

Today manufacturing industry is seeking a balance between scale and flexibility. Because the upfront investment in planning, designing, tooling, buying, programming and installing can only be amortized with sufficient production volume. In that sense, "Just-in time" manufacturing and the flexible manufacturing systems are among the prominent strategies in place to optimize the process and minimize cost. Gradually, after the 1950's centralized and fully integrated factories of mass production were transformed into supply chains where many parts of the process were outsourced even including considerable to off-shore suppliers after the 1980's showing the effect of globalization and neo liberal policies. Nevertheless, manufacturing is still, as in the past, being conducted at locations near cities with large and diverse labor supply, good transportation networks and infrastructure as cost of production and cost of delivery to the customer are both critical factors of success as it is today.

In due course technological developments and the organizational changes led to development of the advanced manufacturing systems. Technically, these systems are primarily based on the integration of ICT technologies into manufacturing processes and includes all aspects of the value chain. Literally, advanced manufacturing relies on three main components: efficient production, intelligent production and effective organization. It is the outcome of the evolution of manufacturing towards more value added, better quality, improved market responsiveness and more flexibility.

From the technological standpoint, the aerospace industry was the leading industry using the advanced manufacturing technologies because the conditions encountered require materials to be lightweight, strong and temperature as well as corrosion resistant. Those attributes are achieved through the development of composite materials including glass, metal, carbon and ceramics as the key essential materials. In essence, the major advanced manufacturing technologies were first used in the aerospace industry and later adopted also by the other industries using composite materials, robotics, laser beam welding and additive manufacturing (Crawford, 2017:1).

Robotics is an advancing field in the manufacturing industry. The wide use of robots is viewed by some to increasingly replace human labor and thus create improved productivity. In the 20th century robots were already being used in hazardous jobs such as painting and welding. With improvement in electronic control technology and in sensor capability and their wider application to tasks such as assembly of parts, inspection, drilling, fastening, dispensing and sealing greater productivity and efficiency were achieved.

Laser beam welding is a higher precision welding technology as compared with the other welding methods. With this technology it is also possible to weld dissimilar materials as opposed to traditional welding techniques which do not have this opportunity. Also, because of the heat transfer is being limited to the material to be welded no crack or weakness occurs at the joints.

Innovative additive manufacturing technology evolving from rapid prototyping, layered manufacturing and 3D printing brings high flexibility to the manufacturing industry and eliminates some of the traditional manufacturing steps such as tooling and programming, and manufacturing designing. With this new concept called as digital manufacturing CAD engineering design files are transformed into fully functional goods. Literally, the evolution of additive manufacturing into the digital manufacturing system enables development of a firm interconnected network to be established between different additive manufacturing equipment through servers, internet and computer software (Chen, Heyer, Ibbotson, Salonitis, Steingrimsson and Thiede, 2015). With this technique one cell, called the additive manufacturing machine, is able to produce a final product. Literally, it is a shift from the design of manufacturing to the design of products. Moreover, the construction technique that produces with thin layers gives the flexibility needed to reduce the component count for the final object to be produced. This reduces product weight and eliminates excess features such as fasteners all of which optimize functionality and waste reduction.

Generally, digital manufacturing brings a new scope to manufacturing industry as it reduces dependency on large volume production and enables workers to produce what they need at the time of their preference and enable liberty to live where they like. This is the outcome of the reduced need for the logistics firstly since designs could be digitally transferred. Secondly, goods could be produced at locations near to the end user instead of at locations closer to the supply sources. This trend could be designated as de-centralized manufacturing. From another perspective, digital manufacturing brings flexibility of producing at locations of consumption (Rhoades, 2005; Attaran, 2017). In fact, the partial transformation of conventional manufacturing to additive manufacturing is related to the advancement of process technology. Additive manufacturing, as opposed to the traditional manufacturing methodologies where material is being formed by parts of it being removed, is rather based on the technique of many linear layers to be combined to produce one product.

Different additive manufacturing technologies are currently being developed and adopted all over the world by various companies mainly in the U.S., Germany and Japan. Additive manufacturing brings a new perspective to the conventional metal and plastic manufacturing industry that is based on casting, molding, lathe cutting and forging processes. Though the technological level although as more commercially used in the plastic industry has not been fully developed yet to enable replacing conventional methods applied in the metal industry for serial production. In the polymer industry 3D printers are being widely used in medical industry commercially for the manufacturing of some body parts such as artificial bones, dentures and dental implants. In the future there is the possibility that most of human organs could be produced through 3D printers. Besides, as of today, polymer 3D printers are very widely available for use at educational institutions for children and even at home and for the whole family for producing many kinds of tool, toys, home appliances, etc. The level that technology has reached today shows an indication for the future which may have considerable impact on the whole manufacturing process for many goods and commodities. The transformation in manufacturing might be partly already happening for some segments of the industry, from mass manufacturing to custom based and privately tailored manufacturing in house.

In 2017, the global market for manufacturing industry is estimated to be about $12.8 trillion which is about 16 percent of world’s $80 trillion economy (Taylor-Kale and Simpson, 2017). In comparison, the market share of additive manufacturing industry was at about $ 3.07 billion in 2013, reached 8.8 billion in 2017 (Taylor-Kale and Simpson, 2017) and is expected to increase to $21 billion by 2020 (Attaran, 2017). The data shows that the market share of additive manufacturing is at a very low level as compared to traditional manufacturing industry for a number of reasons. First, the gathering of a critical mass of industrial contributors is quite limited at this stage. Also, the output quality of the products is still below current standards as compared to the parts produced with traditional manufacturing techniques. The cost of production is another bottleneck which is way higher than conventional serial production costs. As of today, the 3D printing methodology in metals is mostly used for prototyping and for the manufacturing of some critical and low volume parts such as the “fuel nozzles” of the gas turbines. Particularly, light and complex components are mostly suited for advanced manufacturing technology. Currently, many universities as well as R&D centers at state and private institutions are constantly working towards bringing the technology to a higher level in order to improve productivity, cost-effectiveness, design and process quality. Though, if additive manufacturing to some degree replaces conventional manufacturing technology or if the economic impact of this transformation is a remarkable one, it will remain open question ended at this point as the technology is yet in the developing phase and its industrial application is limited. If advanced manufacturing becomes more widespread there will also be additional issues which will have to be resolved such as the recyclability, toxicological impacts on the environment, work safety, job losses, logistics and standardization. At this point there is insufficient data available to make a viable assessment.

United States has a prominent role in the development of emerging technologies in the manufacturing industry through the support programs of the U.S. Government, especially the U.S. Department of Defense and work created at MIT, University of Texas, Carnegie Mellon University, Stanford University, University of Sothern California, University of Michigan, Johns Hopkins University and others, and National Laboratories such as Sandia and Los Alamos.

Regarding the future perspective, it is likely that various factors will shape the evolution and transformation of the manufacturing industry. Most probably, the trend will be focused more on technologies that will create bigger value added, less labor intensity and higher efficiency. A recent global CEO survey conducted among the top executives from U.S., China and Europe shows the future emerging advanced manufacturing technologies ranked in an order of importance (Table 2.7).

Table 2.7. Global CEO survey: ranking of future importance of advanced manufacturing technologies by executives

Advanced Manufacturing Technologies	**US**	**China**	**Europe**
Predictive analytics	1	1	4
Smart, connected products (IoT)	2	7	2
Advanced materials	3	4	5
Smart factories (IoT)	4	2	1
Digital design, simulation and integration	5	5	3
High performance computing	6	3	7
Advanced robotics	7	8	6
Additive manufacturing (3D printing)	8	11	9
Open-source design/Direct customer input	9	10	10
Augmented reality (to improve quality, training, expert knowledge)	10	6	8
Augmented reality (to increase customer service & experience)	11	9	11

Source: Deloitte Touche Tohmatsu Limited and U.S. Council on Competitiveness, 2016 Global Manufacturing Competitiveness Index

As an example, from the list, a determinant factor that is likely to impact manufacturing industry will likely be related with the developments in the field of materials. According to Professor Jochen Schneider, chair for materials chemistry of the RWTH (Rheinisch Westfaelische Technische) Aachen University, the materials are becoming smarter, in other words, they would be able to react to changing conditions without the intervention of the humans. Some examples of the latest developments in this field are self-reporting and self-healing materials. Within that concept materials would induce magnetic signals to induce various chemical changes that may happen in the media (i.e., the metals, composites or ceramics). Also, for instance, in case of some crack initiation, if the healing agent is introduced, the material would cause the healing agent to react with oxygen automatically as the crack will be closed by itself. Likewise, there are advanced man-made materials available, which would generate electromagnetic signals if there were changes in their chemical structures. Those materials could be classified as communicative materials. Those improvements in science and technology change the way the materials are manufactured and the position they are being utilized within the manufacturing process. For instance, if the materials are able to heal themselves and the machines which have many of these kinds of parts would also be able to report themselves on their conditions, engineers would be able to make designs with less tolerances. As a result, machines will become lighter that would bring savings in fuel. Besides, someone will know when the cycle time of a machine or any of its parts will be approaching an end. Consequently, many maintenance processes will be simplified. All these outcomes will mean more efficiency and lower product, process and labor costs (Pretty intelligent, 2017).

Based on the above analysis it is clear that factories of the future will be based on the principle of swift and seamless flow of parts and data through well-connected networks. The concept of industrial Internet of things (IIOT) defines a system of building sensors to be used to communicate data between factory equipment and smart devices as well as enabling machine-to-machine communication. Also, with the further integration of these machine learning tools and artificial intelligence technology into smart factories it will be possible for the manufacturing equipment to correct errors autonomously and instantaneously.

In essence, as it has been the case right from the beginning, the future of manufacturing process will depend on the three key factors which are material, system and process. The parameters for measuring success will be quality, cost efficiency and the mechanical & physical properties of the end products. Within this context, it will be possible to produce components with more complex geometries and less weight. Another way of transformation manufacturing may be in the field of the asset flexibility. With the new concept of shared flexibility, factories for instance, may be manufacturing simultaneously for the aerospace and the automotive industries.

There can be little doubt that research and development will continue at a higher pace while basic and applied science outputs will be the basis for the forthcoming innovations. In the future, innovation labs and the universities are expected to play a major role in accelerating the transformation of manufacturing. However, the presence of the manufacturing establishments in various industrial sectors will be very necessary for the future and they will be the determining factors behind the progress. Because, it is a fact that product and process development can only be optimized with trial & error methods within the industry. In other words, the output of R&D work provides inputs for the industry. Therefore, as it is stated within the concept of the industrial commons (Pisano & Shih, 2012) the close proximity and harmonic collaboration of universities, R&D institutions, factories, suppliers, traders and clients is necessary to support the sustainability of the innovation ecosystem.

Also, with the aid of digitalization the commons will be more closely linked with each other through swift and seamless data flow. Innovation labs will receive feedback both from the manufacturing plant and the end user, while the manufacturing plant will receive feedback from the end user and at the same time will provide feedback to innovation laboratories. This way the data will be processed and converted into viable information that will be used to detect the flaws and improve the product or the process.

2.7. Industrial Progress in the United States (1980- 2018)

At the beginning of the 1970's manufacturing could not be renewed as fast compared to the preceding period since World War II. However, after the commercial adoption of microprocessors and the Internet in the 1970's and 1980's respectively there was a remarkable expansion in the manufacturing industry again. The influence of these inventions was felt with a growing intensity since. This argument can be supported by the metrics of resurge in the productivity growth rates in the period of 1994-2004 (Figure 2.12) although employment in manufacturing continued to a steady decline after the 1970s (Figure 3.9). Especially within the period between 2010 and 2018, with major progress in data processing software and automation technologies, the manufacturing industry became more digitalized. The concepts of the Internet of things and digitalization are related with these transformations. The newly advancing manufacturing technology called additive manufacturing is also bringing a new scope to manufacturing industry, particularly for the production the critical parts especially in the air and space, automotive, defense and the medical industry. However, the impact of those advances on productivity is early to measure at this time.

In the period after the 1980's the TFP growth in the United States picked back up again after the slow-down in the 1970-1980 period due to the impact of the world oil crisis. It is apparent from Figure 2.10 that the period of 1994 and 2014 shows the highest surge. This outcome may be attributed to the impacts of the advances and inventions in the ICT field in the period of 1970 and 1995 and especially to the invention of the Internet, web browsing, search engines and e-commerce. The great advances in the powering of the computers, the developments in the software industry and the fast adoption of Internet overall had a positive effect on productivity. These inventions also laid the ground for the transition to an enhanced digitalization in the manufacturing industry.

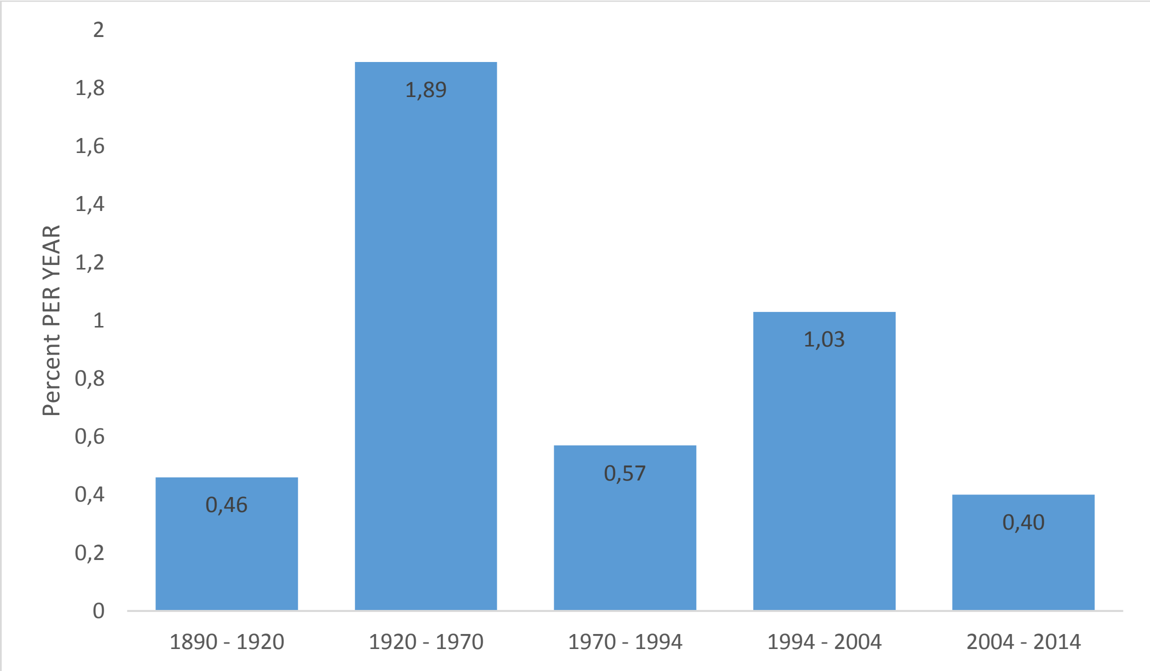

Figure 2.12. Annualized growth rates of total factor productivity, 1890-2014

Source: Robert J. Gordon (Gordon, 2016:575)

The comparison of narrower time intervals in terms of actual growth rates since 1948 re-confirms the trend shown with the TFP growth rates. The actual growth for the time span of 1994-2004 is 2.26 and it holds a second place standing next to the highest growth rate time interval of 1948-1970 when the post war government welfare policies were in effect and when the world global trade was surging. It is also noteworthy that this post war period until 1970 is the time when the computer and electronic revolution was happening and when the standards of living for the American people were remarkably improving with the impact of the innovations of the period and the strong surge in manufacturing output. The average productivity growth per year for this period was 2.71 (Table 2.8).

Table 2.8. Actual and forecast growth rate of output per hour, 1948-2040

	Actual Growth	**Education Adjustment**	**Growth Net of Education Adjustment**
1. 1948-1970	2.71		
2. 1970-1994	1.54		
3. 1994-2004	2.26		
4. 2004-2015	1.00		
5. Weighted Average of 1970-94 and 2004-15	1.38	-0.30	1.08
6. Forecast Growth 2015-40			1.20

Source: Output is GDP from NIPA Table 1.1.6. Hours are unpublished series for total-economy hours obtained from *BLS*, (Gordon, 2016: 635)

The productivity growth which slowed after 1970 with the impact of the world economic crisis picked up again after 1994. This trend can be attributed to the ICT revolution that emerged with invention of the web search engine and e-commerce with the wide expansion of internet-based technologies. This period represented the transition of the business and manufacturing industries from traditional methodologies to web connected digital technologies. The fast transition in the business world was supported with the above average advancement in the computer hardware manufacturing industry as well as in software technologies. In this respect, the rise of rate of computational speed is an important parameter to show as an example to support the argument that ICT revolution is an important parameter for the productivity growth in the period after 1994. It is a fact that the computational speed is directly proportional to the speed of the microprocessor and this in turn depends on how many transistors could be embedded per chip. As a baseline Moore's law, which was set out by Gordon Moore, Co- founder of Intel in 1965, stated that the chip density would double every 18 months (Tuomi, 2002). This translates into an annual growth rate of 34.7 percent for transistors per chip. However, in the period of 1997 and 2006 the doubling density came down to fourteen months which was way above the average. The annual growth in computational speed during that period peaked at 60.1 percent and in the next interval of 2006 and 2014 it went back down below average as 11.5 percent (Gordon, 2016:446-447) (Figure 2.13). This discussion provides a good example showing the positive correlation between innovation, manufacturing technology and productivity.

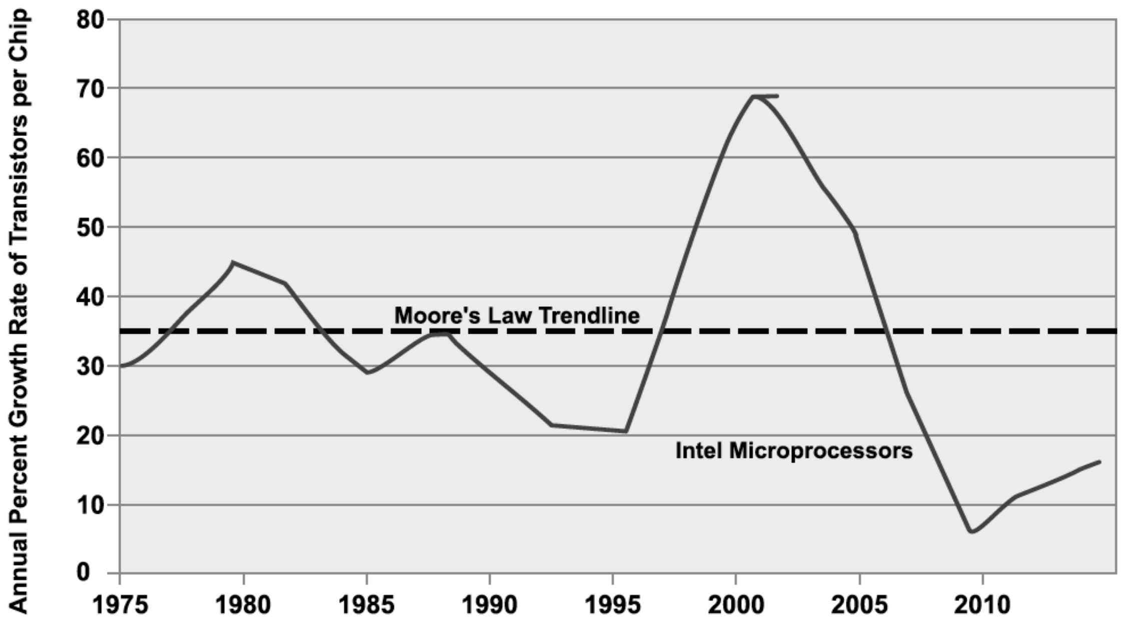

Figure 2.13. Moore’s law versus actual increase in the rate of the number of transistors on a chip, 1975-2014

Source: Robert J. Gordon (Gordon, 2016:447)

Within the same concept there are different approaches to explain the decline in the growth rate of the computational speed for the computers below the average after the period of 2006. Based on the business and consumer ICT spending share of GDP between 1950 and 2013 a slow growth is noted between 1985 and 1995 then a negative growth can be detected between 2000 and 2005 followed by a marginal positive growth until 2013. The total business and consumer ICT spending as a share of GDP peaked in 2000 to 8 % after it declined again (Gordon, 2016:448). The slow growth rate period overlaps also with the period of slow growth rate in the computational speed of the chips and the slow productivity growth of the United States economy.

In this context the change of the processing power of microprocessors may be analyzed as an indicative parameter for making an assessment of the impact of the development of technology on productivity for the present day and the future. Within this line the matter of fact is that after 2006 there is a remarkable decrease in the growth rate of the processing speed which depends on the number of transistors per unit and the advances in material science. There are two answers to this behavior. It could be either because that the demand from the overall industry and individual consumers slowed since the current speed required to execute the tasks is at satisfying levels. The other argument could be that there is a bottleneck which means the current technology in microelectronics, optics and material science is not at sufficient levels to maintain the level of growth in processing times and sensitivity. To illustrate, based on industrial data, processing times of sensors which were used in the manufacturing industry in the 1990's was 1.5 mili seconds for one cycle. In other words, the time needed for reading through the sensors, processing of the data and the rechanneling of data to the control units would just consume that amount of time. In comparison, as of today the same process happens in 40 microseconds. This huge difference brings considerable savings to processing times, besides the improved accuracy in measurement with sensors.

Moreover, the improved processing time in the processing cycle increases the efficiency of factory production, especially in serial production, because once there are more units manufactured per hour and secondly since with the more advanced manufacturing equipment there will be less labor demanded. However, for the case of manufacturing the improvement in technology is not the only determining factor, especially in mass production industries such as steel, aluminum and automotive vehicles and parts. One other factor is the limit of demand for the manufacturing output in terms of domestic consumption as well as slowing export demand. Another factor is the labor policy of governments that subsidize employment. Therefore, there is a double-edged sword effect which one side urges labor reduction that comes with more automation and robotization while on the other side job creation is another aim for providing prosperity. Hereby, the transition of skills of the workforce is another reality. From the perspective of the mass production manufacturing sector the growth rate of the processing and computing speed may be in line with the demand depending on circumstances. However, from the standpoint of other industrial sectors such as the medical or the defense industry this is not the case. More processing speed and accuracy will definitely increase the capability and the quality of the process to be executed. Some examples are robots executing medical surgery, or missiles hitting their targets with more accuracy. These fields are illustrations to the cases where technology dictates the demand. This idea has also been set forth by the scientist Ikka Tuomi in his 2002 article "The Lives and Death of Moore's Law" (Tuomi, 2002). Tuomi mentions that that when Gordon Moore made his prediction regarding future developments of integrated circuits in 1965, he had foreseen an exponential increase in processing and computational power and his assumption was based on the fact that technical capabilities would be unlimited for the future. However, according to Tuomi, the exponential growth of power would soon come to its limit of technical capability. Also, a report prepared by a group of experts called "International Roadmap for Semiconductors" supported the same idea as it accentuated Moore's law as a reference for future developments in chip manufacturing technology and predicted that the technical capabilities would approach their limits by 2016 (Tuomi, 2002). This forecast of the past is close to what is occurring today as in the form of a bottleneck in technology. Finally, it is also important to emphasize that by technological capability it is not only meant putting more transistors into per unit space. There may be other issues related to physics, material science, miniaturization and scaling technologies.

In essence, the chip industry is an important element within the ICT sector as the processing and computational power very much depends on the power of chips. Both the microprocessor and the memory unit of the computer consist of chips. Therefore, the state of chip technology is also a determining factor for the state of the ICT sector. From past observations on the power of the ICT sector it is clear to see that technology has been the front-runner for constituting demand for other sectors, especially for the manufacturing industry. Factory machinery and robots have been adapted to what has been available in terms of speed and accuracy. In other words, the manufacturing industry tried to catch up with the increasing power of the ICT industry. Another related fact is that ICT is a complementary sector and has become more and more integrated with manufacturing industry at an increasing pace after the 1980's to the present. Eventually, by correlating the falling growth rates of the manufacturing value added figures and general productivity growth rates in America after 2006 it can be argued that the technological bottleneck has a determining role within this trend. Overall, it is clear that at present science and technology are advancing progressively as they have done since the early years of the humankind. However, the impact this creates today may not be as comprehensive and extensive as it was in 1870 and 1970 when the breakthrough innovations which stemmed from inventions such as the steam engine, internal combustion engine, electric motor, jet engine, computer and microprocessor had more impact on economic growth and development. On the contrary, the adoption of television was much faster when it went from 5 to 65 % between 1950 and 1955 (Gordon, 2016:416) as compared with the adoption of computers.

Overall the productivity growth between 1930 and 1970 could not be matched within the following period until 2018. It can be argued that at the period after the 1970's the inventions and innovations did not bring complete revolutions to the life styles of the people or to the manufacturing systems as it was the case in the period before then. As laying out the case with some examples until 1980 most of the developments in housing and travelling had already occurred. With respect to the building industry the modern house concept with full utilities was already in use. The difference between today and then could be the in the changes in design, the usage of more advanced building materials such as better insulation products with better R values or in the quantity as well as availability of houses with modern features such as with the central air condition units Also recently the totally wired house has become a reality. Again, with respect to housing, the modern kitchen with home appliances in the1980's had almost the same equipment as of today except for being less digital and operating with lower efficiency. Regarding airplanes, the transition from piston to jet planes had already been completed in the 1970's. The air travel quality between then and today is comparable. Similarly, there has been little improvement in the travel with the motor vehicles concept after the 1970's. The interstate highway system had already been completed by the 70's. The change is in the more comfortable travel conditions with better equipped cars, more speed and better fuel economy with advanced engine designs as well as more safe vehicles. On the other hand, the invention of the internal combustion engine changed the way people travel completely. Similarly, with the invention of the airplane people were able to do air travel. This was another game changer. In the same way, the invention of the steam engine and the electric motor changed the whole manufacturing system. Nonetheless, the computer was another breakthrough invention which had a similar impact. Those inventions have had an impact across a very great spectrum. In comparison, the advances in science and technology in the period since the beginning of 1980 have been more in the mode of improvement in quality, incremental progress and building on the existing technologies except for the ICT revolution which had its impact on economy between 1994 and 2006. Therefore, technology change's impact on productivity and GDP growth has been relatively smaller in the past decade or so.

On the other hand in the recent years, the autonomous vehicles are evolving very rapidly with intermediate safety technologies now on most autos sold as 2019 year vehicles; also the rise of total electric vehicles is growing very rapidly. Also new technologies such as additive manufacturing, smart manufacturing, Internet of things and artificial intelligence are progressively integrated with the industry and business life. However it is rather early to measure their real impact on economic growth and prosperity.

It follows out that from 1850 until 2018 a number of breakthrough innovations, which were clearly possible through the advancements in science and technology, have triggered numerous transformations in the manufacturing industry resulting in the progress in the manufacturing technology, management structures and labor skills. The outcome was a continuous increase in productivity which resulted in sustainable economic growth. The proof is in the economic data of the United States who has been the leading economic power of the world since the beginning of the 20th century and has been the leader in creating the biggest manufacturing value added output in the world between 1900 and 2010. America has always had a thriving manufacturing industry since the second half of the 19th century and has had a precedence in the most prominent fields of science and technology. Also the services industry in the United States has well advanced in parallel with the manufacturing industry.

The thriving manufacturing industry also has created a very big impact on prosperity. As an example in 1926 United States was producing almost 45% of the world industrial output, 80 % of the world's automobiles and 50% of the global steel, electricity and crude oil (Norcliffe, 1997). In 1929 the total percentage of trucks and automobiles per household registration in the U.S. had reached almost 90% (Gordon, 2016:377). Nonetheless by 1940 already, all urban homes were wired. 94% of the houses in the urban areas had clean water and sewage and more than 80% had interior flushed toilets, 73 % had gas for cooking and heating and more than 55% percent had refrigerators (Gordon, 2016:5). These facts show that America's superiority in manufacturing and the huge improvement of prosperity of the American society coincides with the same times.

Consequently, the analysis of the transformation of manufacturing in the United States supports the case that a well progressing manufacturing industry which is continuously advancing in terms of productivity with the aid of science and technology, also supported by a well established service industry, is the main driving force of economic growth and prosperity.

It is also another outcome of the analysis of the time frame of 1850 and 2018 that certain periods had more growth rates than the others. It is seen that the century of 1870 and 1970 has the highest growth rate in the world when compared with other times (Gordon, 2016). Especially the TFP average growth rate data for the United States (Figure 2.12) show that the fastest rate within the period of 1890 until the present day has been reached in the time interval 1920 and 1970 when the breakthrough innovations, which stemmed from inventions such as the steam engine, internal combustion engine, electric motor, jet engine, computer and microprocessor, have occurred. In parallel, these innovations had also the positive impact on the manufacturing industry in terms of productivity, income equality and skilled human capital . As a result, the thriving manufacturing industry has fueled economic growth and development within this period. On the other hand, in the United States in the following period after the early 1970's until 2008, there has been detected a slower economic growth, increased unemployment in the manufacturing industry , continuously increasing trade deficit and a distortion in income equality. The same period coincides with the time when de-industrialization prominent. Therefore, it can be argued that there exists a positive correlation between the prominence of a thriving manufacturing industry and prosperity. Within the same context, it is hence noteworthy to elaborate more on the mechanisms which lie behind the successfully improving ecosystem of manufacturing and innovation.

CHAPTER 3

MANUFACTURING IN THE U.S. ECONOMY: THE IMPACT ON ECONOMY AND THE PRESENT STATE

The first goal of this chapter is to display the factors which are lying behind the successful economic growth of the United States in the 20th century and unveil the role of manufacturing therein. The second goal is to analyze the economic outcomes of the period of de-industrialization between the mid 1970’s and 2008 and the following years through the present day when re-industrialization is the recent trend. Within the same context it is also aimed to elaborate on the concept of the “ The Integrity of Manufacturing and Innovation” which argues that a sustainable improvement of prosperity can only be achieved through a sustainable ecosystem of the manufacturing plants, R&D facilities, universities and skilled human capital which are all collaboratively working with full integrity and are located in close geographical proximity.

In the last century, United States has been the leading manufacturing country of the world. During World War II, manufacturing provided more than 33% of civilian jobs in the U.S., but that share has decreased to 8.53% as of July 2018 (BLS, 2018b). Today, the United States still has a notable amount of manufacturing capacity in terms of establishments and resources. Although China became the leading manufacturing economy in the world in 2010, the United States maintains a strong second-place standing. The value added by U.S. manufacturing facilities is more than $2 trillion a year, which is equal to the next following countries (Japan, Germany and South Korea) combined. The value added output of U.S. manufacturing industries totaled $2,244.3 trillion in 2017, that is about 11.6 % of the U.S. gross domestic product value (BEA, 2018a). From that measurement perspective United States contributes to 18 percent of worlds total manufacturing value added output which is about US$ 12.9 billion for 2017 (World Bank, 2017).

Today in the United States manufacturing is the fifth largest employer after health care and social assistance, retail trade, accommodation and food services. With 2016 figures, the manufacturing industry employs 12.35 million people (BLS, 2017). The total annual payroll is $656.8 billion and the average annual payroll per employee in the sector is $56,591 while the average annual payroll for all sectors is $50,396. This is an important indicator from the income creation point of view. Also, according to United States Census Bureau statistics for 2015 the total value of shipments for the manufacturing industry was $5.5 trillion and almost 6 out of 10 U.S. export dollars comes from manufacturers (United States Census Bureau, 2017).

From another standpoint manufacturing has the highest multiplier return rate as each dollar spent in manufacturing brings another $1.81 to the economy and for one manufacturing worker employed there are four other workers employed in other sectors (NAM, 2018).

3.1. Industrialization, De-Industrialization and Re-Industrialization

United States has become world's most productive economy as it surpassed the U.K. at the turn of the 19th century with the industrial production output (Figure 3.1). Then the gap between U.S. and other nations widened and during the World War II the output per worker became 30-50 percent higher than the other industrialized nations in almost all branches of industry. The leading position of the United States continued through the 1980's although the gap between the rival nations has since been closed (Figure 3.1).

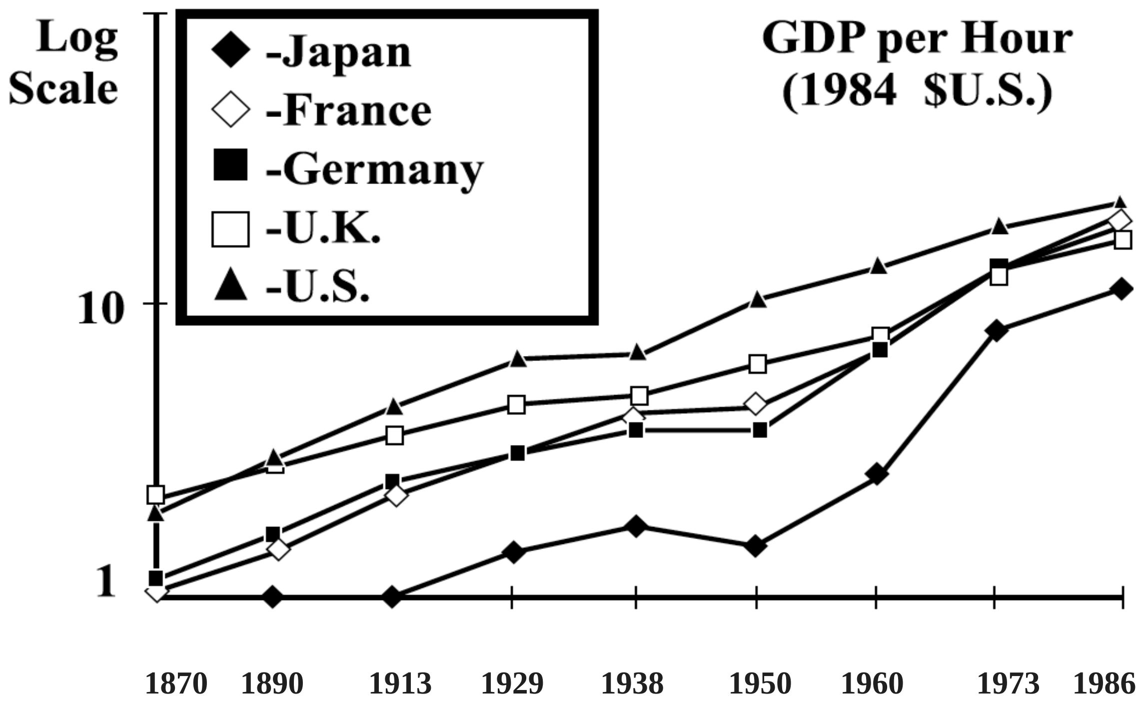

Figure 3.1. Gross domestic product per hour, 1870-1986

Source: Based on the data from Angus Maddison (Maddison, 1987)

American success in creating economic growth and prosperity since the beginning of the 19th century can be attributed to various factors at different times. At the period until World War II America built up its industry by applying the mass production principle in almost every sector such as steel, automotive, machine, chemical and electrical products manufacturing. The lead in manufacturing was accompanied by highly productive agriculture which had an impact on increased wage rates and living standards. The other important contributing factors to the growth included the abundance of natural resources and the availability of world’s largest domestic market. In essence, this period can be associated with economy of scale, capital intensity, standardization and the exploitation of natural resources (Nelson and Wright, 1992). Within the same period, before the beginning of World War I United Sates had started to establish the infrastructure to establish its own science-based infrastructure to integrate that with its well established and growing manufacturing industry. The large corporations were established and there was a big expansion of private sector research labs. General Electric, DuPont, AT&T and Kodak have established research laboratories at that time. Technological innovation was conducted in such industrial contexts from iron and steel making to inorganic chemicals such as soda or chemical materials like dyes and plastics. The foundation of the research labs for the manufacturing industry continued at a very high pace during World War II and the post war period (Figure 3.1).

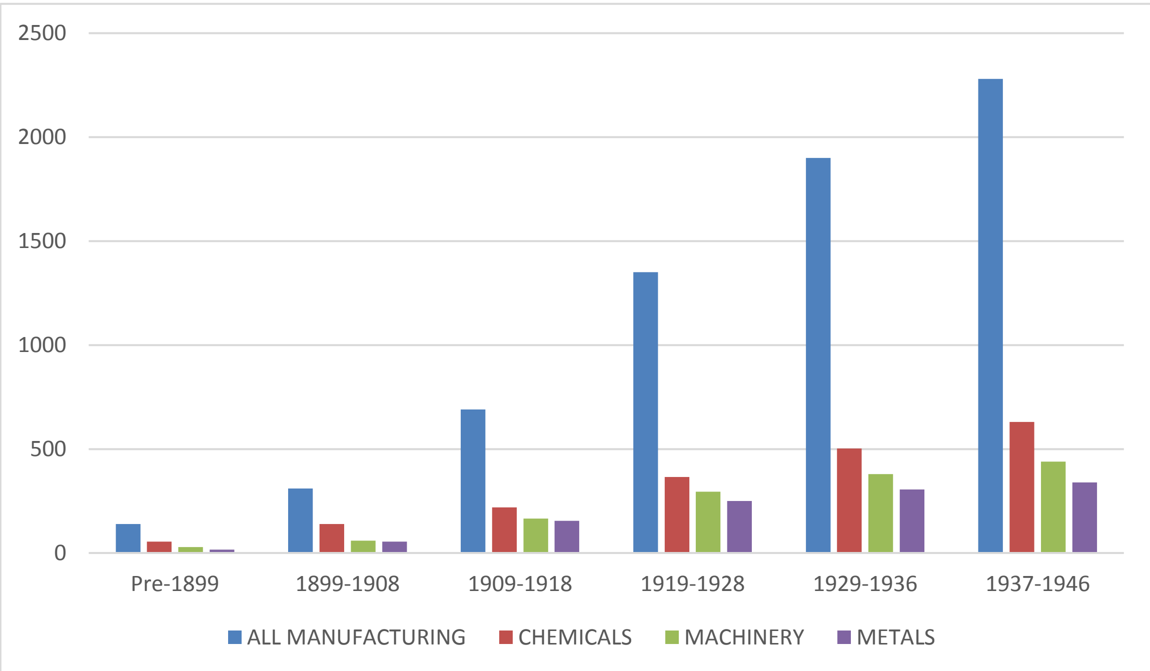

Figure 3.2. Laboratory foundations in U.S. Manufacturing

Source: David Mowery and Nathan Rosenberg, N. (Mowery and Rosenberg, 1989:62-63)

After World War I stronger import barriers were levied by the Fordney – McCumber Tariff of 1922 and then by the Hawley-Smooth Tariff of 1930. The world's largest domestic market was, though, sufficient to support fast economic growth and productivity increases.

It is also important to recognize the role of education. By 1890, the ratio of university students per 1000 primary students in the United States was 2 to3 times more than the same figure for any other country. This discrepancy has been more than maintained as the tremendous growth of the American Industry continued (Nelson and Wright, 1992). The emphasis was placed on the quality of the education. The effort was to train engineers who have an understanding of both practical manufacturing as well the formal science knowledge. For instance, in 1919 M.I.T., created a course in its electrical engineering program which split the time for the students between the Institute during course hours and at companies like General Electric, AT&T, Bell Labs, and Western Electric (Noble, 1977:192).

The period during World War II is the time when mass production started to be integrated closely with science-based technologies. The big expansion of American companies performing R&D work created a need for more engineers and scientist, especially in the post war period when newer technologies in electrical and chemical fields had emerged. In the following period education programs were improved and diversified in order to meet the demand of the surging enrollment in the field of applied sciences and engineering. New qualified science and engineering programs were launched, and the university research system developed extensively. Accordingly, many scientists and engineers were trained at universities with the goal of achieving new and better production process designs (Figure 3.3) Also, American universities like M.I.T. began close collaboration with industrial corporations. During that period experience, specialized training and organized R&D worked hand in hand in order to advance technology (Nelson and Write, 1992).

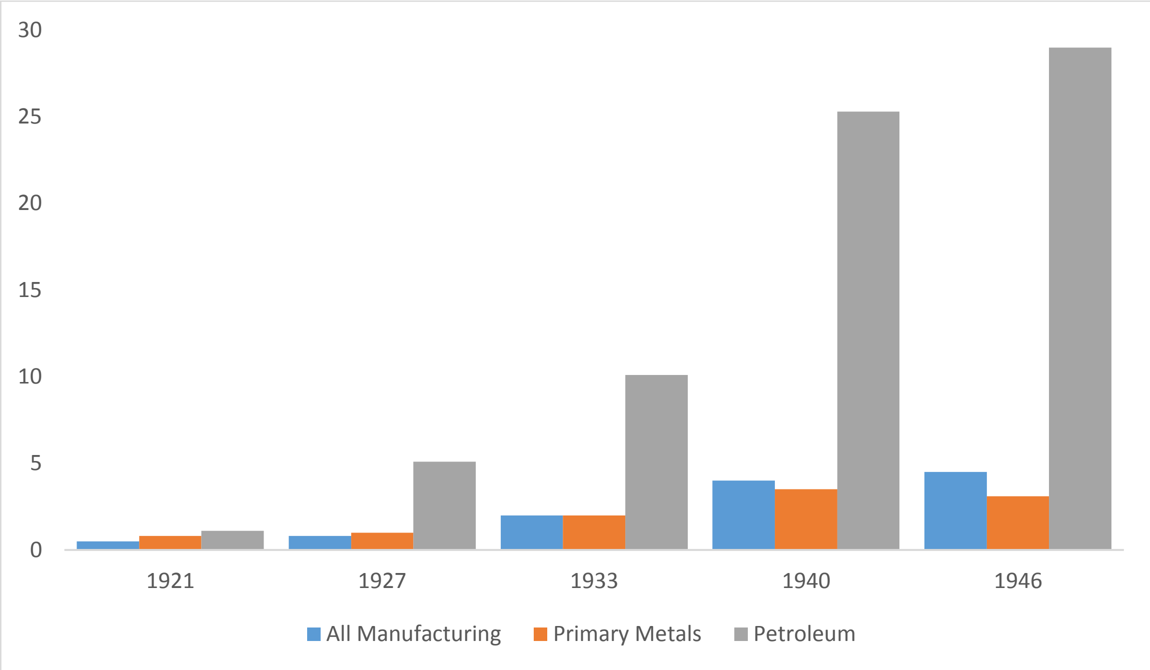

Figure 3.3. Scientists and engineers per 1000 wage earners

Source: David Mowery and Nathan Rosenberg, N. (Mowery and Rosenberg, 1989:64-71)

In the post war period science & technology became closely associated with industry. There was also a remarkable surge in R & D investment. The National Science Foundation (NSF) and the National Institute of Health (NIH) operated programs to provide public funding for basic research at universities. Besides, the Department of Defense and the Atomic Energy Commission provided large scale research funding for applied sciences, particularly in the field of material science and electronics. In addition, the R & D departments of private companies had expanded tremendously. To illustrate, between 1953 and 1960 the total R&D expenditures increased by a factor of two. Also, the total number of scientists and engineers employed at industrial research jobs increased from 50,000 in 1946 to 300,000 in 1962 (Nelson and Wright, 1992). As a combined impact of all these developments United States once again became the lead in high technology industries similar to its lead in mass manufacturing. The share of high technology export products is an indicator (Figure 3.4).

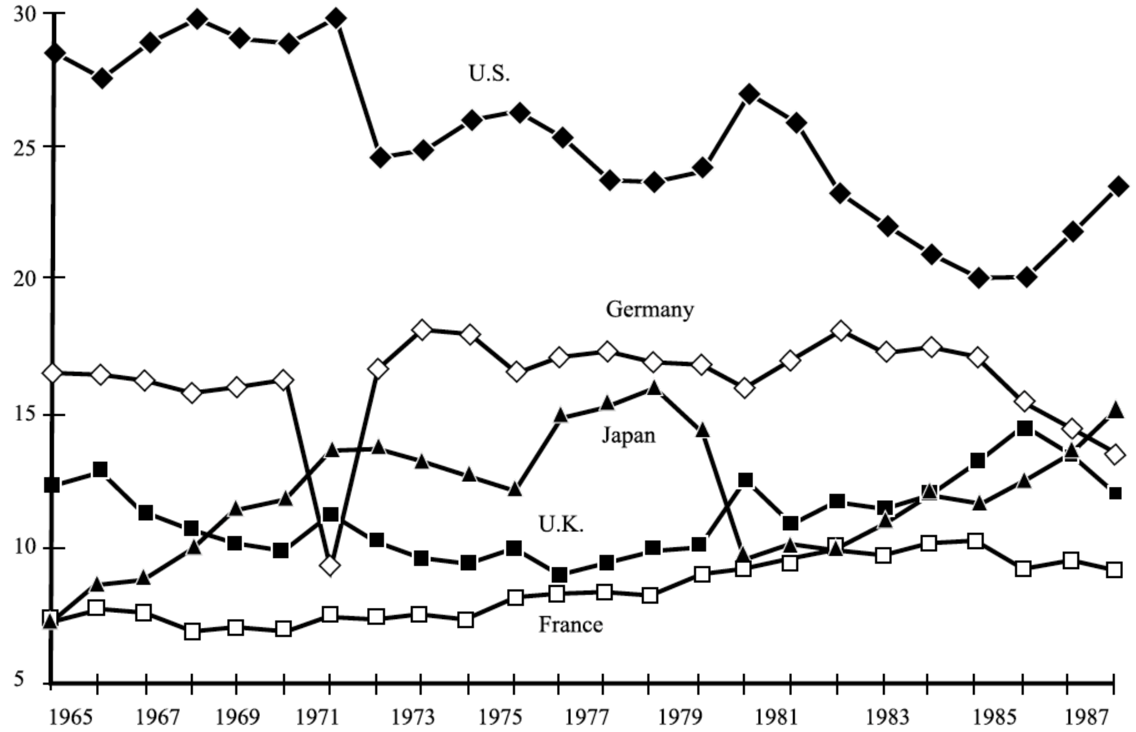

Figure 3.4. Country shares of world high- technology exports, 1965-1988

Source: U.S. National Science Board [1987, Appendix Table 7-10; 1989, Appendix Table 7-10; 1991, Appendix Table 6-7] (as cited in Nelson and Wright, 1992)

As it is apparent from Figure 3.5 that U.S. imports in high tech products steeply rose, especially after 1983, catching up with the exports in 1985 and causing a trade deficit from then onward. This happened because the growth of the imports had a bigger rate than the growth of the exports for that time frame. The undisputable discrepancy of industrial superiority which existed between the United States and the other parts of the world since the beginning of the 20th century has diminished particularly in other sectors such as automotive, consumer electrical products and steel making.

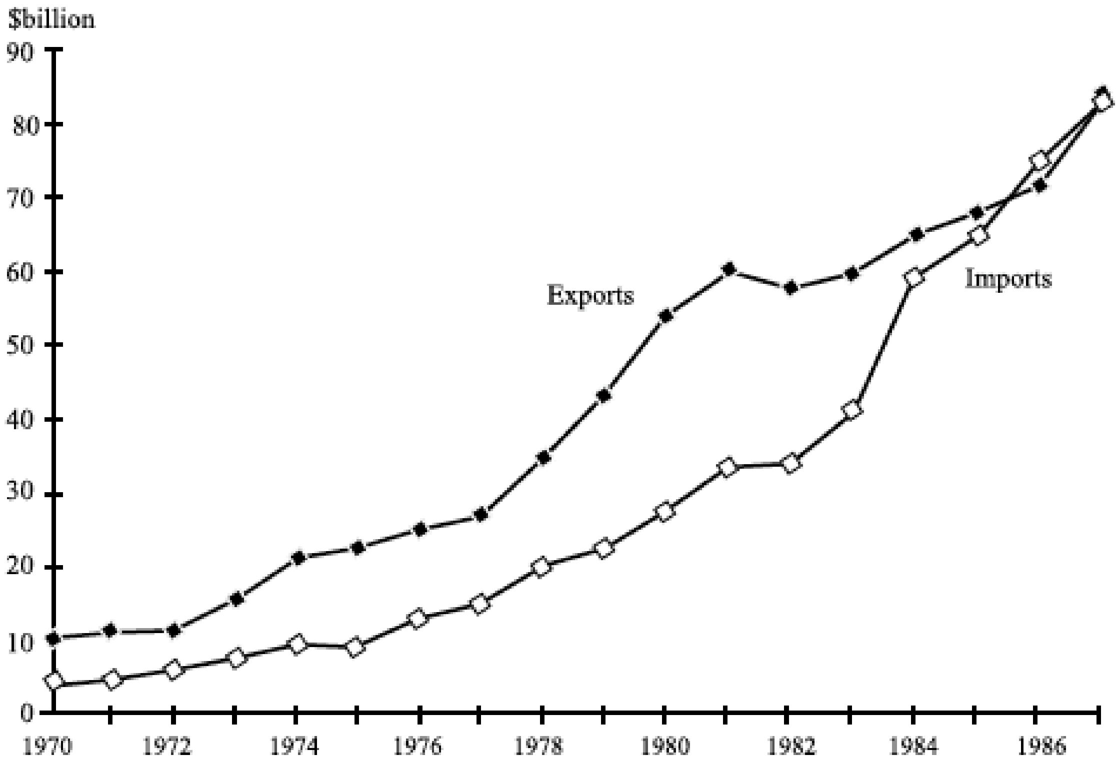

Figure 3.5. U.S. trade in high- technology products, 1970-1987

Source: U.S. National Science Board [1989, Appendix Table 7-14] (as cited in Nelson and Wright, 1992)

According to Richard R. Nelson from Colombia University and Gavin Wright from Stanford University there are different explanations and arguments set forth for this trend. Firstly, it could be argued that the internationalization of business due to globalization has caused the American companies to loose the advantage they were holding over other countries for years in terms of access to cheap natural resources, home grown technology, world largest market and educated man power. Secondly, while other nations have also increased their level of investment in technology development foreign companies were, at the same time, also able to penetrate the U.S. market or access the resources in the United States which liberal trade opportunities made possible. Finally, it is also that some American companies moved part of their operations abroad either to make use of cheaper labor or to expand their markets. After that happened they even exported back to the United States from their country; some portion of the import numbers represent the value of U.S. companies exporting back to the United States (Nelson and Wright, 1992).

In essence, the natural rise in the living standards in other parts of the world has created more competition. The above noted developments have caused the United States to take another position in the world of rising globalization which emerged after World War II. The American companies too assumed a strategy of exploiting the benefits of the new situation.

It is also important to make the note here regarding the technological leadership of the Unite States. Although the other countries in Europe or in Japan, made massive investments in industrial R&D and in scientific and engineering education after the 1950's in an effort to catch up with the U.S., they were in short of social capability (Nelson and Wright, 1992).

With the adoption of the neo liberal policies in 1980's and in line with the principles of the Washington Consensus in 1989 the trend of the American manufacturing industry has taken a different direction. Generally, the common new trend of outsourcing the conventional segments of industry, keeping the design work at home and focusing more on the service sector together characterize the drivers of this new trend. The concept was de-industrialization. During this period many manufacturing facilities were off-shored, especially to Asia with the philosophy of outsourcing the low value-added jobs to low-cost labor countries and keeping high value-added work at home. Though this policy has resulted in an increased unemployment rate at home. As a matter of fact manufacturing industry has been the main driving force for the creation of wealth and permanent progress.

However, there has been a counter argument to this economic development approach claiming that in the recent years that this trend has changed for the developed nations and that the service sector has become more important and manufacturing should mostly be left to underdeveloped or developing economies. The basic thought of this argument stems back to the sociologist Daniel Bell who claims that the economies through the years undergo a natural transition from agriculture to manufacturing and then to services. He thinks the knowledge is the driving force and the transition is healthy (Bell, 1973: Foreword, 1-47). This theory has been widely popular in the early 1980's. Also in the recent years, Michael Porter from Harvard Business School argued that high values are at the services and not in manufacturing and therefore focus should be given to excel in services (McCormack, 2006). Those who support this thinking also claim that what matters most is "brain work" and as long as you control the design and engineering capabilities you can have it manufactured anywhere in the planet . This thought is the baseline for de-industrialization. This thesis, on the other hand argues that this argument has not prove itself totally correct and the proof lies in the period starting from early 1980's when that time served as a pre-beginning of the decline of manufacturing in the U.S. economy and the rise in Asian economies and the early stage of the impact of China manufacturing that has been based firstly on imitation innovation to supply the technologies needed to make globally competitive manufactured products in China (Yu, Pan and Stough, 2016). The recent trend in the United States, particularly since the early 1980's, of moving its manufacturing capacity to off shore, especially to Asia, has brought about a decline in the rate of real manufacturing output growth, manufacturing value-added growth, productivity growth and GDP growth . There happens to be also a misbalance in the income distribution of the U.S. population which coincides within the same time frame that unfolded after the 1980's.

On the other hand, the defenders of the policies of re-industrialization such as Gary P. Pisano and Willy C. Shih from Harvard Business School, lay out the concept of "industrial commons" (Pisano and Shih, 2012) to establish a link between manufacturing and prosperity. The supporters of this concept argue that prosperity could be created by focusing on the development of the manufacturing industries which advance through innovations and that the progress would only be possible with the clustering of universities, manufacturers, suppliers, R&D institutions and the human capital. Moving the manufacturing away to other locations will eventually result in a decrease in the innovation capacity and will result in the transformation of knowledge and the human capital to another ecosystem (Pisano and Shih, 2012; Khana, 2012; Zimmerman and Beal, 2002) .Therefore, keeping one of the commons components apart by off shoring manufacturing has brought long-term negative effects to American economic power (Pisano and Shih, 2012).

There is a strong relationship between design, construction and the input materials. The materials such as metal alloys, polymer-based substances and composites all have to be manufactured. Innovation in the field of material science is only possible with the collaboration of basic science, applied science and technology. In the same context, manufacturing facilities are needed to be present within reach to circulate the information back and forth between them and the scientific R&D facilities In fact, the great strides in merging IT and telecommunications technologies offset this to some extend: in such a case, communication can be substituted for face to face interaction for some part. However, the execution of the process still entails the physical presence of the people at the field of application. Within this context the technologies are tested, improved with the methodology of trail-and-error. As an end result there is a strong relationship between manufacturing and the design and the construction of the finished goods. Andy S. Groove, who was the third employee hired by Intel in 1968 and was the CEO between 1987 and 1998 when under his leadership Intel's market capitalization increased from 4 $ billion to $197 billion, supports this case by stating that new products are likely to be invented in places were they are already being manufactured (Khana, 2012: 13). The same idea is supported by Andy Liveris, the former chairman and CEO of Dow Chemical, stating in his book "Make it in America: The Case for Re-inventing the Economy" (as cited in Levinson, 2012) "Where manufacturing goes, innovation inevitably follows ".

It is also another fact that the manufacturing industry contributes almost to two thirds of U.S. domestic company R&D spending. Also in 2010 figures, the U.S. manufacturers employed 35 percent of all engineers as compared to 8.9 percent of all workers. From these statistics it can be argued that the manufacturing industry is supporting high skilled and high paid jobs (Levinson, 2012).

In the case of United States while the manufacturing share of real GDP remained constant since 1947 in the range of 11.3 % to 13.6% (Chien and Morris, 2017). Then there has been a decline in manufacturing employment numbers since the 1978. The number of manufacturing jobs in the U.S. dropped sharply from over 17 million in 2000 down to around 12 million in 2010 (Figure 3.9). This is due to some part the industrial automation and imported manufactured goods and but for the most part because of the movement of some of the manufacturing jobs out of the country as well as the economic consequences of the great recession in 2008 (Nager and Atkinson, 2015) and (Levinson, 2012). For the past few decades, the production of the traditional goods (textiles, shoes, apparel, furniture, etc.) has moved away to lower labor cost-countries. At the same time there has been very slow growth in the domestic manufacturing of the heavy industrial goods such as the steel, shipbuilding, commodity chemical production, etc. In essence, there has been a relocation and decline in the manufacturing capacity of some of the industry segments such as the ultra-heavy forgings, machine tools, metal cutting, etc. At the same time, although most of the inventions and the design work were made in the United States, many emerging technology manufacturing capacities and establishments such as photovoltaics (PV), semiconductors, processors, LED displays, energy efficient lightening components, fiber optic components, laser diodes, etc. have moved offshore as a result of managerial decisions. As an example, the photovoltaic cells were invented and commercialized in the United States. However, according to National Renewable Energy Laboratory (NREL) statistics for 2008, 27 % of the World PV production was done in Europe, 27 % in China, 18 % in Japan, 12 % in Taiwan and only 6% in the United States (Pisano and Shih, 2012: 8-13).

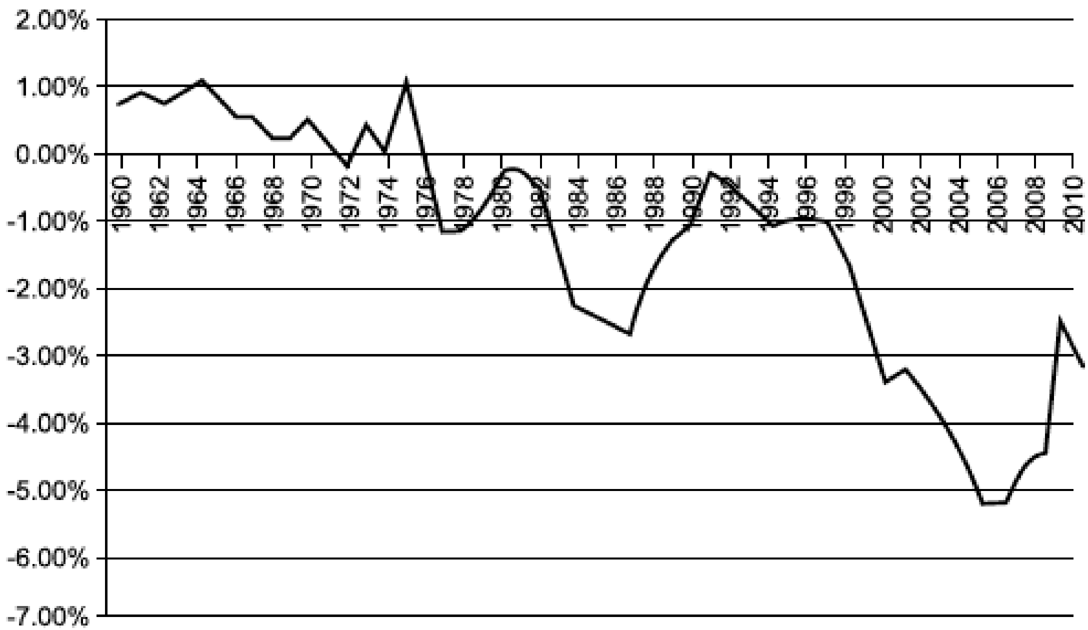

Figure 3.6. U.S. trade deficit as percentage of gross domestic product

Source: Bureau of Economic Analysis, National Income and Products Accounts Table 1.15, last revised January 27, 2012 (Pisano and Shih, 2012:4)

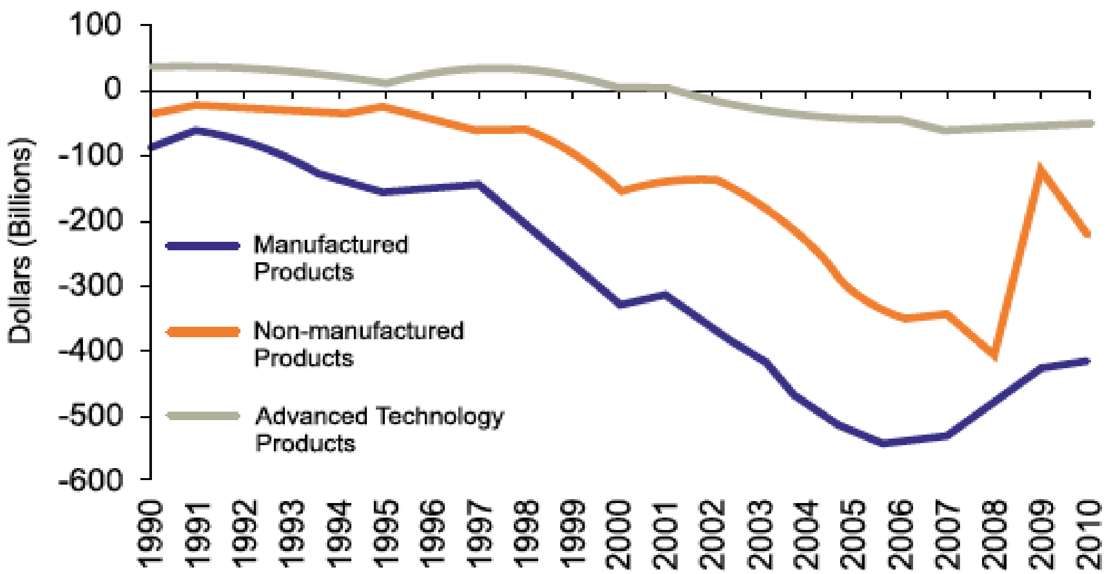

Figure 3.7. United States annual trade deficits in manufactured, non-manufactured and advanced technology products

Source: Based on data from International Trade Administration, National Trade Data [Global Patterns of U.S. Merchandise Trade, Balance, Manufactures, Non-manufactures, 1989-2013] (Nager and Atkinson, 2015:4)

It is clear from the from data presented in Figure 3.6 and Figure 3.7 that the trade deficit of the United States as percentage of gross domestic products correlates with the trade deficits of the manufactured, non- manufactured and the advanced technology products. Also, with the combination of data from Figure 3.8 it can be deduced that there has been a decline in manufacturing competitiveness since the beginning of 1970’s and that the rise in service exports is insufficient to offset the negative trade balance coming from the manufacturing sector. Still as of the present day the status of the manufacturing sector is the main determining factor for the trade deficit. Therefore, the presence of a competitive manufacturing industry is a key element for the gain and the maintenance of prosperity.

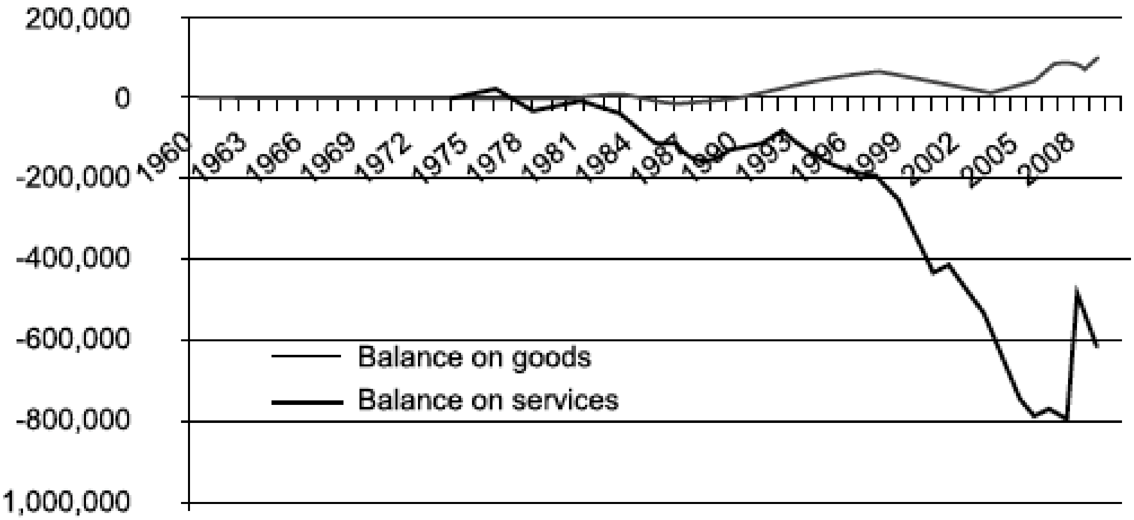

Figure 3.8. U.S. trade balance in manufactured goods versus services

Source: Calculated from Bureau of Economic Analysis data, U.S. International Transactions Accounts Table 1, December 15, 2011 (Pisano and Shih, 2012:5)

Obviously, productivity and competitiveness in the manufacturing industry could be improved through innovations. At the same time, the materialization of research and development work is only possible when a nation has the technical and operational capabilities required to manufacture products with various degrees of complexity. Because the product and process developments are performed through the methodology of trial and error (Pisano and Shih, 2012 and Khana, 2012). If the production system and the environment are not known the design task of a product becomes extremely difficult and unrealistic. Therefore, having easy access to manufacturing establishments which are in the vicinity is a great advantage. According to Garry Pisano and Willy Shih (Pisano and Shih, 2012), manufacturing and innovation share the same industrial common. They argue that the technological know-how, manufacturing capabilities, skilled workforce, suppliers, clients, universities, R&D institutions are all members of industrial commons (Pisano and Shih, 2012) that support a variety of industrial sectors. Those are factors that support each other and the absence of one of these would harm the whole system. Arguably, when the manufacturing is moved away from R&D innovation capacity will decline. Also, R&D capacity, including human capital, will re-locate in accord with the production decline. Within this context, it can be argued that off shoring of some of the manufacturing capabilities will have a negative long-term effect on the innovation capacity of the nation although with the advancements in the ICT field the ability to substitute communication for face to face interaction would offset this impact to a certain extend.

The presence of a local manufacturing industry builds a circle which involves the sub industries, suppliers, clients, traders and other service businesses that are all linked to the main or several core industries. There are also sub-industries that supply to and prosper through the main industries. As an example, in the automotive industry, there are big numbers of sub-industries such as the brake, wheel and tire manufacturers that serve the main industry. There are also the linked and dependent industries such as the steel industry which supplies a variety of products for the main body parts of the car. In general, the automotive industry has an extensive value chain consisting of OEM's, motor vehicle and parts manufacturers, infrastructure suppliers, motor vehicle and parts wholesalers, motor vehicle and parts dealers, automobile dealers, other motor vehicle dealers such as trucks and motorbikes, auto parts-accessories and tire stores and automotive repair and maintenance shops. The supply chain for just in time production in the automotive industry is not like other localized commons; it has a radius of at least 500 miles which is the distance that can be traveled by truck overnight to deliver inputs to the assembly lines. Therefore it is important to note that, as it is the case for the automotive industry, the industrial commons (Pisano and Shih, 2012) referred here are not just highly localized things.

From another aspect, the possession of some industries within the country is also essential for national security in case of conflicts such as wars, trade embargos, etc.

Also from the social perspective the manufacturing industry creates jobs and serves to establish a balance for the income distribution.

It is a fact that the de -industrialization policies and trends since the beginning of 1980's have mostly led to the relocation of some of the manufacturing industry out of the country and contributed to more attention on the design and the service sectors. According to the U.S. Department of Commerce, in 2017 the manufacturing value added was around US$ 2.2 trillion (Figure 3.13) but the trade deficit in goods was $795.7 billion (United States Census Bureau, 2018a) and $110.9 billion (United States Census Bureau, 2018b) of that consisted of advanced technology products. This is an unbalanced situation for United States as it leads the world in science and technology research. This outcome shows that the inventions and innovations are made in America, but the manufacturing is done in somewhere else. Therefore, the benefit of the investment is not fully realized in the United States. The policies generated and applied, especially after the great depression in 2008, have been fostering re-industrialization. The policies include but are not limited to lowering of taxes, enforcing trade laws, re-negotiating international trade agreements, addressing unfair trade practices, supporting domestic production, supporting domestic mining and so on.

It is clear that progress in the manufacturing industry is only viable with innovation and that is only possible if the industrial siting is in a commons. In other words, the ingredients such as the universities, manufacturing facilities, national and private labs, skilled- unskilled workforce and financial capital have to collaborate with each other and they have to be located in the areas within reach. The commons service area in, for example, the auto industry is relatively large: the clusters of many of the input producers are likely to be close but not all. Nonetheless, it can be strongly argued that there is a strong linkage between innovation and manufacturing and America's offshoring experience about some of the main industrial segments, which stems three decades back, has been shown to cause negative impacts in the long run in terms of increased trade deficit, slow-down in productivity growth and loss in employment. The current U.S. re-shoring policies aim to reverse this negative effect by reviving the industrial commons (Pisano and Shih, 2012) through reindustrialization.

3.2. Transformation of American Manufacturing: Prosperity, Employment and Income Distribution

In essence, the manufacturing industry has always been a significant job creator for America. According to U.S. Labor Department statistics for 2016 total workforce employed by the manufacturing industry is 12.35 million and it is the fifth largest employer after Professional and

Business Services (20.14 Million), Health care and social assistance (19.1 Million), Retail Trade (15.82 Million) and Leisure and Hospitality (15.62 Million). With 2016 figures, the total share of manufacturing employment in total non-agricultural employment is 8.52% (BLS, 2017). Also according to U.S. Census Bureau statistics, the average pay roll for all sectors in 2015 is $ 50,396 and the average pay roll for the manufacturing industry is $ 56,591 (United States Census Bureau, 2017).

Historically, the manufacturing industry of the United States has been a larger employer, especially during the World War II period when much of the workforce was needed to produce tanks, weapons and airplanes. In 1943 the total manufacturing employment was 16.5 Million and its share in the total employment was 39 percent. After the World War II there was a steady increase in manufacturing employment until 1979 when it hit the historical peak at 19.5 million. Afterwards there was a sharp drop (after the 2000's) and then a steady decrease until 2009 when it hit the bottom right after the great recession. Since, there has been a rebound and an increase from 11.5 up to 12.67 million people as of May 2018. It is also notable that while there has been a sharp decrease in the number of manufacturing workers there has been a steady fall in the total share of U.S. manufacturing employment within the total employment for decades (Figure 3.9). As of May 2018, the share of manufacturing employment within the total non-farm pay roll in the United States was 8.53% (BLS, 2018c).

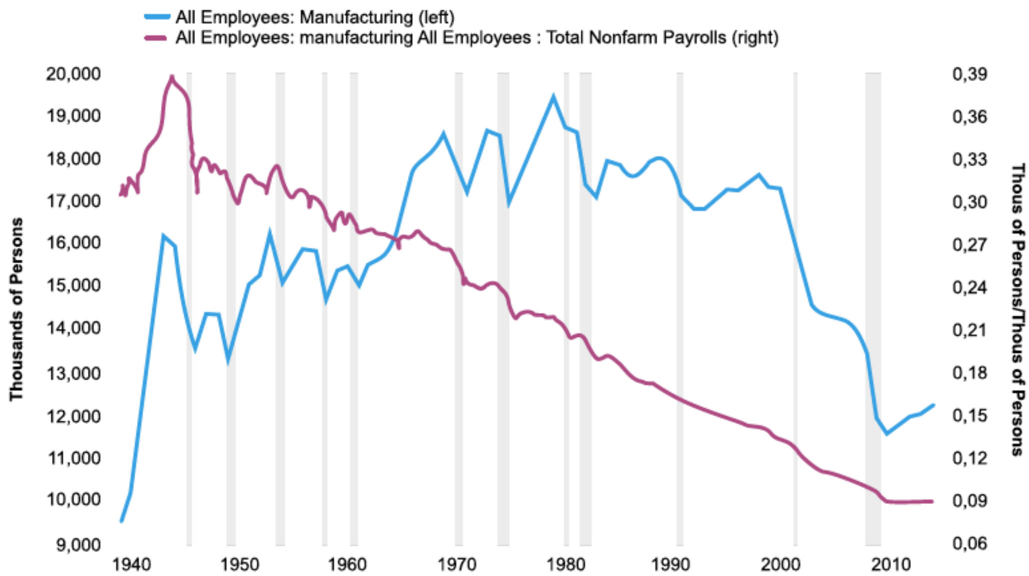

Figure 3.9. Manufacturing employment in the United States, 1940-2018

Source: U.S. Bureau of Labor Statistics (BLS, 2018d)

The reason for the shrinkage of the manufacturing employment is argued to be attributable to many factors such as automation, shift of some production to foreign countries (off-shoring) and the substitution of imports for some domestically manufactured goods. The service sector has, to some extent, compensated for the loss of jobs in manufacturing with the gain in productivity in the services.

Employment is the foremost important criteria for the manufacturing industry to create prosperity. Besides creating income directly to the employees in the manufacturing field it transfers prosperity to other industries such as the services, mining and agriculture. According to National Association of Manufacturers annual report for 2016 for one employee added to the manufacturing industry another 3.4 workers are added to the economy somewhere else. A study performed by Fred Zimmerman and Dave Beal for 232 manufacturing counties from 1988 to 1997 supports the hypothesis of the role of manufacturing in creating prosperity. The outcome showed that in the categories where manufacturing gained strength the employment increased between 37 to 63 percent whereas at the groups where manufacturing was declining the job growth appeared to be less than 10 percent (Table 3.1).

Table 3.1. Percent employment changes by major sector, 1988 -1997

CATEGORY	MFG.	CONST.	TRANSPORTATION & UTILITIES	WHOLE-SALE	RETAIL	F.I.R.E.	SERVICE	TOTAL
Hinterland Highspots	33.3%	59.4%	24.1%	14.6%	32.2%	19.4%	70.8%	36.7%
Metro Movers	53.8	54.6	50.9	63.5	46.8	43.4	92.2	62.8
Freeway Flyers	40.8	37.1	33.2	21.9	29.3	13.8	77.4	43.0
Gradual Growers	33.0	22.1	47.8	46.8	32.4	34.0	69.1	42.7
Smaller Sliders	-20.2	8.6	6.9	3.5	10.9	0.4	40.8	9.2
Midrange Sliders	-20.3	-3.3	2.2	-0.1	6.7	9.5	42.8	9.8
Sliding Goliaths	-25.1	-15.6	5.8	-3.8	-0.1	1.9	25.0	2.4
Total United States	-3.3	11.6	18.5	13.9	17.0	10.6	48.7	12.7

Source: University of St. Thomas and U.S. Census Bureau, County Business Patterns, 1988 and 1997 (Zimmerman and Beal, 2002:112)

The same pattern is noticeable in the poverty rates. The groups where manufacturing is declining, poverty rates were either worsening or stabilizing at higher levels. King's County in Brooklyn, New York is a good example. There, manufacturing had been in a long decline and the poverty rate rose by 17 percent (Table 3.2).

Table 3.2. Poverty rate and household income changes, 1989 -1997

CATEGORY	POVERTY RATE 1989	POVERTY RATE 1997	CHANGE 1989 TO 1997	HOUSEHOLD INCOME 1989	HOUSEHOLD INCOME 1997	%CHANGE 1989 TO 1997
Hinterland Highspots	13.4%	11.4%	Down 14.9%	$24,424	$35,225	44.2%
Metro Movers	9.1	8.8	Down 3.3	34,331	46,737	36.1
Freeway Flyers	12.0	11.1	Down 7.5	26,345	36,452	38.4
Gradual Growers	11.6	10.7	Down 7.8	31,277	41,851	33.8
Smaller Sliders	13.9	13.7	Down 1.4	25,685	33,398	30.0
Midrange Sliders	13.7	13.6	Down .7	29,485	37,613	27.6
Sliding Goliaths	12.3	13.5	Up 9.8	34,211	41,151	20.3
Kings County, NY	22.7	26.5	Up 16.7	25,684	26,108	1.7
Total United States	13.1	13.3	Up 1.5	30,056	37,005	23.1

Source: University of St. Thomas and U.S. Census Bureau, County Business Patterns, 1989 and 1997 (Zimmerman and Beal, 2002:113)

Income distribution is also an important indicator in the measurement of prosperity. It is obvious that the GDP and productivity growth rate figures which are affiliated with economic growth are not stand-alone factors emphasizing a healthy growth of prosperity among the people. Alongside economic growth, a well-balanced income distribution is essential to ensure that the major part of the population gets their share of benefits that came along with the increase in the living standards.

There are many factors which have been affecting the income distribution in the United States such as the status of education, the power of labor unions, minimum wage, effect of exports-imports, the role of high-low skilled immigration, government tax policies and automation that came with the advancements in technology.

Based on the data from Thomas Piketty, Emmanuel Saez, Alvaredo, Facundo and Anthony Atkinson from "The World Top Income's Database" (as cited in Gordon, 2016:609), Robert Gordon calculated the growth rates of real Income for the periods of 1917-1948, 1948-1972 and 1972 until 2013 for the top ten percent income portion, the bottom 90 percent income portion and for the average (Figure 3.10).

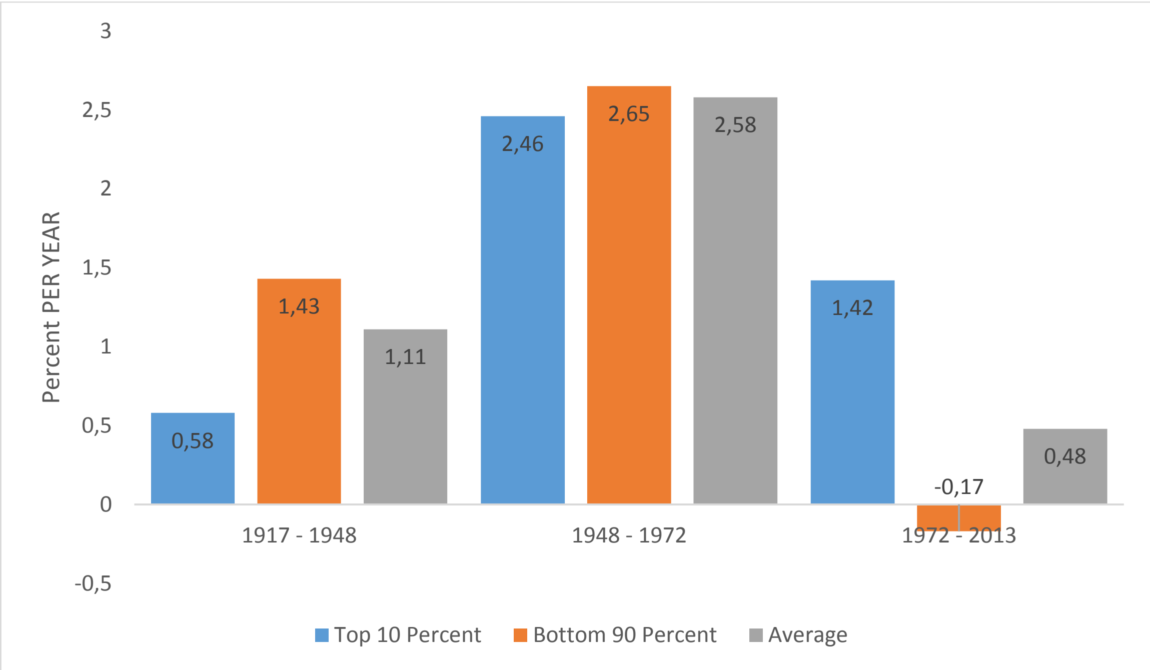

Figure 3.10. Growth rate of real income, top 10 percent, bottom 90 percent, and average, selected intervals, 1917-2013

Source: Robert J. Gordon (Gordon, 2016:609)

From the first time interval until 1948 the growth rate for the bottom 90 percent is double of that of the top 10 percent. This could be attributed to various factors such as the equalizing effect of the Great Depression, the welfare state polices which have followed, World War II, the formation of labor unions, the economic and social environment constituted after the widespread adoption of Fordism and the GI bill (The Servicemen's Readjustment Act of 1944), which enhanced college education and supported the formation of the middle class. In the second interval of 1948-1972 the growth rate for all portions of the population increases equally and with a more than a doubling of the growth rate compared with the previous time interval and with a five times bigger growth rate of the following time interval of 1972-2013 (Gordon, 2016:608-610). The third time indicates a fall in the average growth rates for all groups and also to a big gap between the income groups of the top 10 and the bottom 90 percent. This trend shows a distortion in the income distribution in the United States after the 1970's. Based on the 2000 U.S. Census Bureau report on the Nation's Changing Shape of Income Distribution, the Gini coefficient, which is an accepted measure for inequality among families, shows a noticeable increase after 1973 (Figure 3.11).

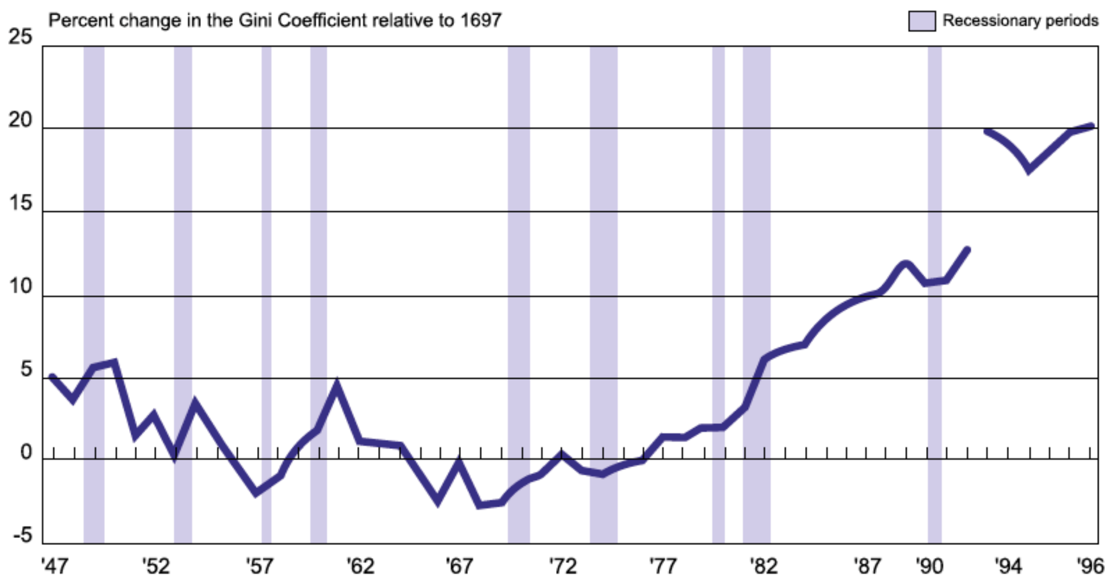

Figure 3.11. Change in income inequalities for families, 1947-1998

Source: U.S. Census Bureau, Current Population Survey, March 1948-1999 (Jones and Weinberg, 2000)

In their book: "Manufacturing Works" Fred Zimmerman and Dave Beal mention about a study, named "The Loss of Manufacturing in America" which has been done by a manufacturing manager called Paul T. Carson. They state that according to this work the income equality in the United States had increased in the late 1940's through the late 1960's when U.S. manufacturing was very strong. With the declining trend of the American manufacturing industry after the 1973 oil embargo the income inequality has gradually started grow (Zimmerman and Beal, 2002:116). Despite the fact that there need to be more studies to establish a more defensible claim that there is a link between manufacturing prominence and income equality, it may be argued that there exists a correlation. Because the historical data shows that the rise in income inequality and the decline of manufacturing employment occurred during roughly the same years.

3.3. The State of the American Manufacturing Industry at the Present Day

According to the U.S. Department of Commerce Bureau of Economic Analysis Data for 2017 the gross domestic product (GDP) of United States is US $ billion 19,485.4 (BEA, 2018a). With this figure U.S. is world's largest economy with an annual GDP growth rate of 2.3 % for 2017. The annual growth rate of U.S. GDP is shown on Figure 3.12 for the period of 1980-2018.

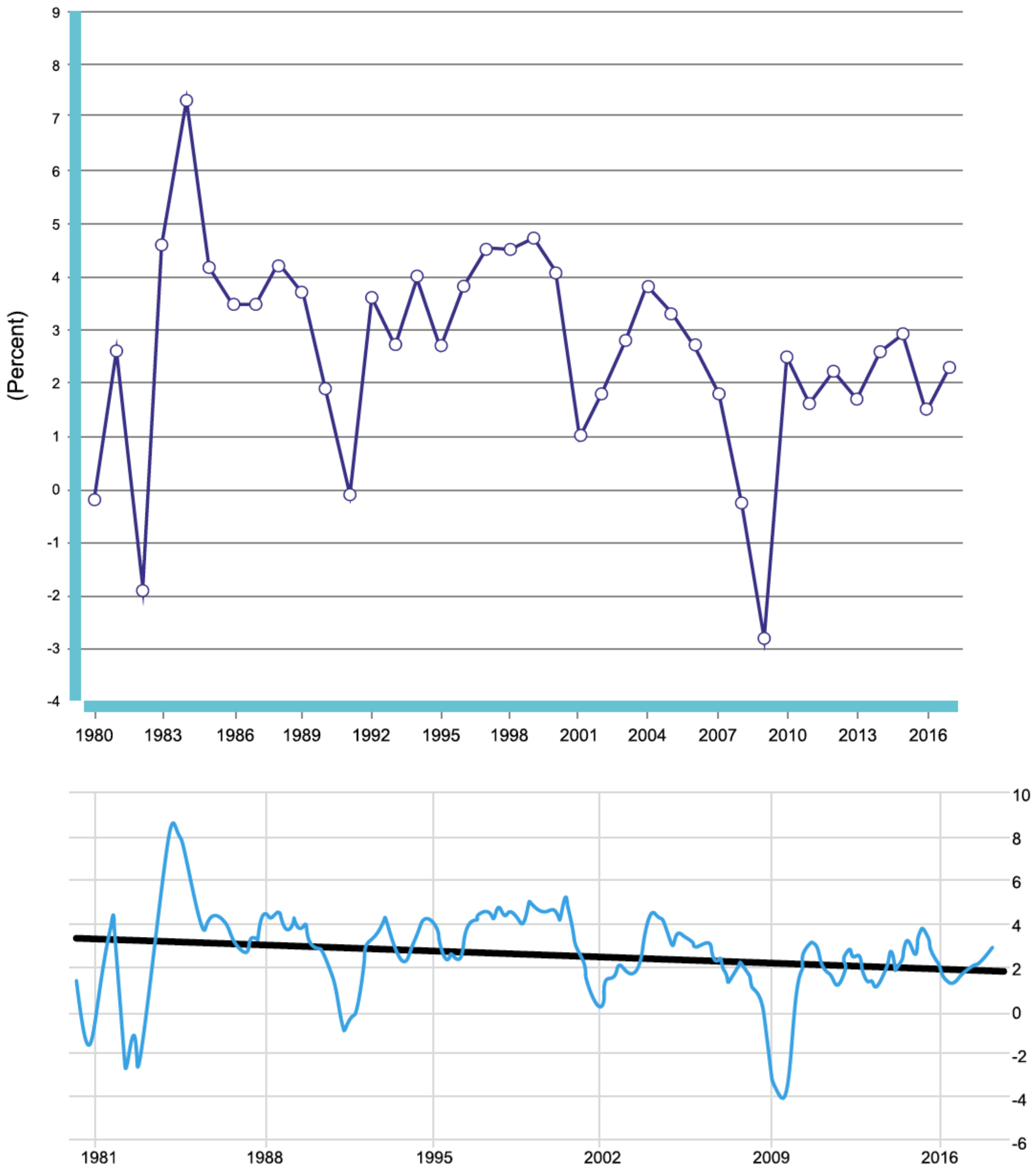

Figure 3.12. Annualized growth rates of U.S. GDP, 1980-2018

Source: Drawn based on the data from U.S. Department of Commerce Bureau of Economic Analysis, (BEA, 2018b)

As it is obvious from the graph, except for some specific years of negative growth rates there is a general diminishing trend for the annual growth rate for the United States GDP since from the early 1980’s through 2018. The same period also coincides with the time in the early 1980‘s when there was a trend of de –industrialization and when some of the manufacturing industry in the United States had begun to move their facilities outside of the country, mainly to Asia. An effort has been made to reverse this trend especially with the policies generated prominently after the economic crisis of 2008. Re- industrialization and re-shoring of manufacturing has been promoted with the support of Federal and Local Governments as well as the quantitative easing of the monetary policies of the Federal Reserve. The current Trump administration has even increased the level of government support for the aim of strengthening the manufacturing industry by imposing quotas to certain goods such as steel and aluminum as well as for some countries with whom the United States values itself in unfavorable situations. In addition, recent corporate tax cuts which increased incentives for the promotion of manufacturing investments on American soil, are other tools that have been introduced lately by the current U.S. Administration and are all aimed to serve to support re-industrialization.

The contribution of the manufacturing industry to the economy can be analyzed through two parameters: gross output and value-added outputs at each sectorial category. The value added represents the difference between the gross outputs and the intermediate inputs by each industry. The sum of value added of all industries make up the GDP of the United States. Therefore, to show the contribution of manufacturing on the economy the growth of the manufacturing value-added output volume and the share of manufacturing in the total GDP are reliable indictors.

Although in the United States manufacturing value-added output shows a steady increase since 1997 except for a brief decline at the intervals between 2000 and 2001 as well as between 2007 and 2009, the percentage of the manufacturing value added within the total GDP shrunk from 21.6% in 1977 to 17.1% in 1987 and further to 11.6% in 2017 (BEA, 2018b) and (Table 3.3.).

Table 3.3. Value Added by Industry Group in current Dollar as a Percentage of Gross Domestic Product for Selected Years

	1947	1957	1967	1977	1987
Gross Domestic Product	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Private Industries	87.5	87.4	85.8	85.6	86.1
Agriculture, forestry, fishing and hunting	8.2	4.0	2.7	2.5	1.7
Mining	2.3	2.3	1.4	2.1	1.5
Utilities	1.4	1.9	2.0	2.3	2.6
Construction	3.7	4.7	4.6	4.6	4.6
Manufacturing	**25.6**	**26.9**	**25.2**	**21.6**	**17.1**
Durable goods	13.0	16.1	15.4	13.1	10.2
Nondurable goods	12.6	10.9	9.8	8.5	6.9
Wholesale trade	6.3	6.2	6.5	6.6	6.0
Retail trade	9.4	7.9	7.8	7.8	7.4
Transportation and warehousing	6.0	5.0	4.0	3.8	3.2
Information	2.5	2.9	3.2	3.5	3.9
Finance, insurance, real estate, rental and leasing	**10.4**	**13.1**	**14.2**	**15.0**	**17.7**
Professional and business services	**3.7**	**4.5**	**5.3**	**6.0**	**8.7**
Educational services, health care and social assistance	**1.9**	**2.4**	**3.4**	**4.6**	**6.0**
Arts, entertainment, recreation, accommodation and food services	3.2	2.7	2.8	2.9	3.2
Other services, except government	3.0	2.8	2.7	2.3	2.4
Government	12.5	12.6	14.2	14.4	13.9
Addenda:					
Private goods-producing industries	39.8	38.0	34.0	30.9	24.9
Private services-producing industries	47.8	49.4	51.8	54.7	61.2

Source: Gross Domestic Product by Industry for 1947–86. (Yuskavege and Nader, 2015:71)

It is also notable that for the same period the service industry has expanded larger than the manufacturing industry (Figure 3.13.).

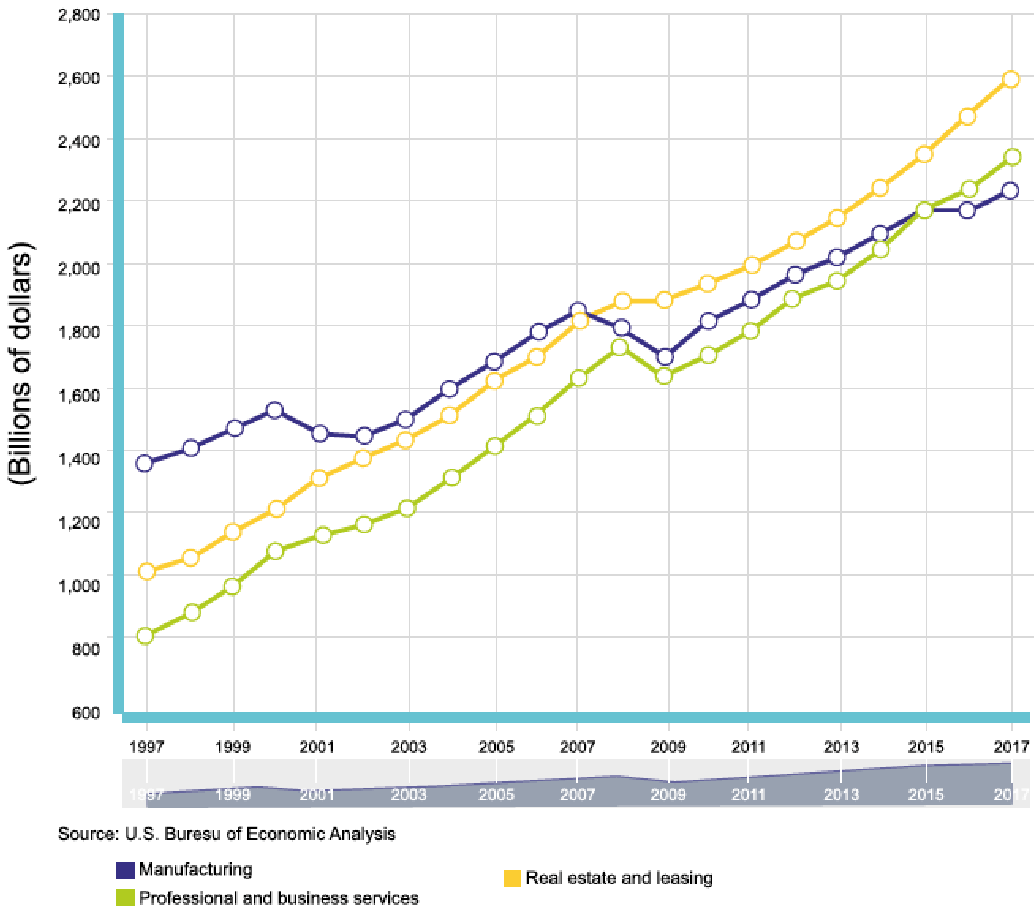

Figure 3.13. Value added outputs by industry, 1997-2017

Source: Drawn based on the data from U.S. department of commerce bureau of economic analysis (BEA, 2018a)

As per the data available between 1947 and 1987 the manufacturing value added growth rates based on 10-year intervals show the lowest average figures for the period of 1967-1977 and 1977-1987 (BEA 2018b). The slowing down of growth in these periods is attributable to certain factors such as the oil crisis in 1973 and the beginning of the trend of offshoring of some of the manufacturing businesses, the substitution of imports for some domestically manufactured goods and the rise of the service industry.

According to United States Department of Commerce Bureau of Economic Analysis data for 2017 the manufacturing value added in the United States was US$ 2,244 trillion and it constitutes 11.6% of the total U.S. Nominal GDP. Manufacturing is the second largest contributor to the GDP right after financial services. Based on the statistics of 2017 the total output of the manufacturing industry is US$ 6.04 trillion and this is the second highest figure among all other major sectors (BEA, 2018a).

Manufacturing is also the fifth largest employer in the American economy with 12,35 million employees which constitutes 8.52 % of the total non-agriculture workforce based on the statistics for 2016 (BLS, 2017a). The breakdown of the employment of the subsectors of the U.S. manufacturing industry shows that the leading sector is transportation and the equipment manufacturing which employs 1.47 million people (Figure 3.14). In 2017 there was a rebound in manufacturing employment as at the end of 2017 the manufacturing industry employment rose to 12.54 million.

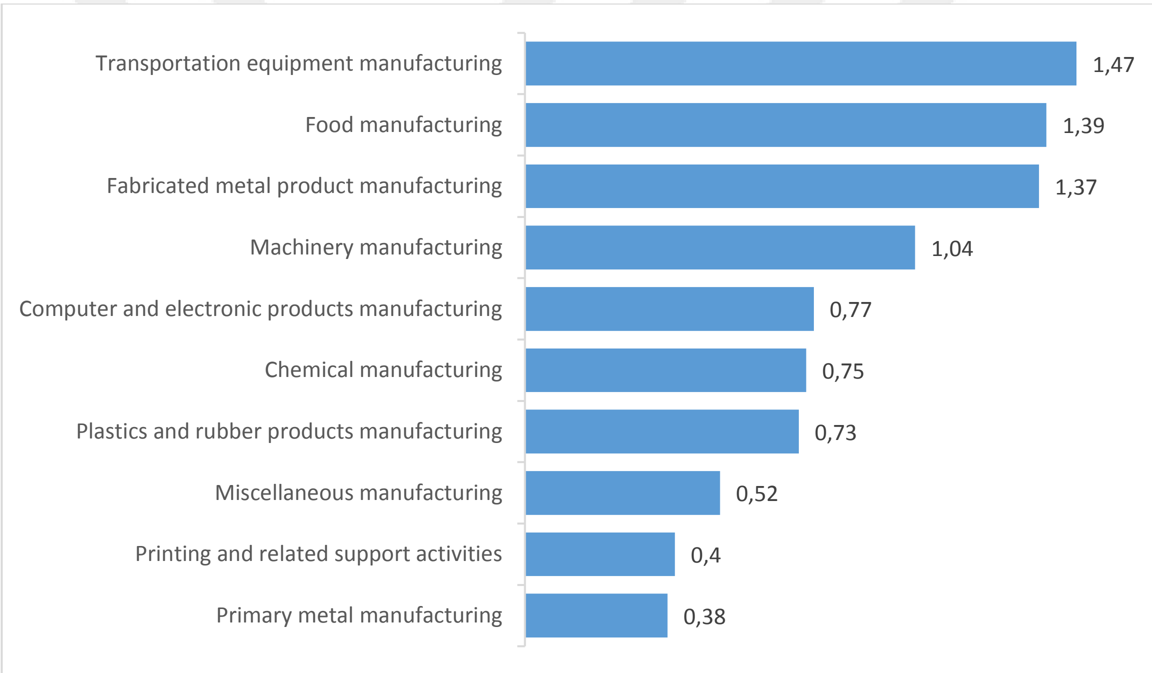

Figure 3.14. Top 10 subsectors by the number of employees (in millions), 2015

Source: Annul Survey of Manufacturers (United States Census Bureau, 2017)

It is also important to note that the contribution of each manufacturing sector to the economy changes over time since it is correlated with the general demand situation and the amount of value-added products being created at each time. In the time frame of 1850 and 1930, the machine manufacturing, the car manufacturing and the steel manufacturing industries were among the highest value-added supplying sectors. Then, in the period of 1930 and 1970 the electronic, the computer and the robotics industry became important in this regard. From 1980 until 2018, there were further advancements in the same industries besides the remarkable innovations in the ICT sector which accelerated with the adoption of the Internet, worldwide. Today, the manufacturing industry is on the verge of adapting mass customization, and transforming into smart factories with the aid of the newly introduced technologies such as 3D printing, Internet of things and artificial intelligence. These technologies have rapidly and simultaneously been adopted by the American Manufacturing Industry for the sake of increasing productivity and producing more value-added products.

Within the scope of manufacturing to the U.S. Economy the following data is provided by the "National Association of Manufacturers is an important indicator" (NAM, 2018). In the United States for every $1.00 spent in manufacturing, another $1.89 is added to the economy. That is the highest multiplier effect of any economic sector. The impact is even greater when the entire manufacturing value chain plus manufacturing for other industries' supply chains are taken into consideration. Based on the data from Manufacturers Alliance for Productivity and Innovation , for $1.00 in manufacturing value-added output the multiplier effect is $3.60. At the same time, for one manufacturing employee 3.4 workers are added to the economy elsewhere (NAM, 2018). According to the 2016 Annual Report prepared by "Manufacturing USA Institute" the U.S. advanced manufacturing industry is selling to and buying goods from 80 industries worth trillion of dollars. It has also a high multiplier as it supports 16 jobs in other parts of the economy (Manufacturing USA, 2016:1). Special focus is given on advanced manufacturing because despite the fact that these industries employ 45% of the manufacturing workforce they create a manufacturing output of 53 percent (Gascon and Spewak, 2017). The advanced manufacturing industries can be defined as the ones which spend more than $450 per worker on R&D and employ a minimum of 21 percent of people with high degrees of technical knowledge. According to the North American Industry Classification System (NAICS) thirty-five industries are categorized as advanced manufacturing industries ranging from auto manufacturing, electronics, fuel manufacturing to drugs. In general, an average employee working at those industries earn 40-50 percent more than a regular private sector worker (Gascon and Spewak, 2017). The President's Council of Advisors on Science and Technology Report of 2013 defines advanced manufacturing technology as depending on the use and coordination of information, automation, computation, software, sensing and networking besides making use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences such as nanotechnology, chemistry and biology. The biggest American advanced manufacturing companies by revenue are listed in Figure 3.15.

	National	Eight District
1	Apple (3342)	Emerson Electric (335) (St. Louis, Mo.)
2	Johnson & Johnson (3254)	MilliporeSigma (3254) (St. Louis, Mo.)
3	Gilead Sciences (3254)	Energizer Holdings (3359) (St. Louis, Mo.)
4	Intel (3344)	Hillenbrand (3339) (Batesville, Ind.)
5	Cisco Systems (3342)	American Railcar Industries (3365) (St. Charles, Mo.)
6	General Motors (3361)	Esco Technologies (3345) (St. Louis, Mo.)
7	General Electric (335)	FutureFuel (3251) (Clayton, Mo.)
8	Amgen (3254)	Kimball Electronics (3344) (Jasper, Ind.)
9	Pfizer (3254)	Escalade (3399) (Evansville, Ind.)
10	Exxon Mobil (3241)	Sypris Solutions (3363) (Louisville, Ky.)

Figure 3.15. Largest advanced manufacturing firms by revenue, 2016

Source: Based on data from Compustat (Gascon and Spewak, 2017)

It follows out that the economic success of the United States in the 20th century depends fairly on a productive manufacturing industry which is supported by a skilled human capital, a large sophisticated network of high quality universities and R&D institutions as well as the abundance of natural resources. Therefore, it can be argued that re-industrialization will have a positive effect on regaining the momentum on innovation since the close collaboration of skilled human resources, universities, R&D facilities and factories would be much more efficient when those commons are located in close proximity. In that way product and process development would be possible with the integration of science, theory, trial and error.

However, the de- industrialization trend in the United States which was experienced in the period after the end of Welfare State polices in the mid 1970’s and through the early 2000’s, with the influence of the neo liberal polices of early 1980’s, has created a negative impact on the U.S. economy overall which can be observed from a relatively lower productivity growth compared with the preceding periods of 1920-1970 (Figure 2.11) when industrialization was progressing with a higher pace. The negative effect of de-industrialization is also obvious from the negatively increasing trade deficit and the balance on goods in the period of 1976 and 2012 (Figure 3.6 and 3.8). It is also clear that the positive increase in the balance of services for the same period has been insufficient to offset the loss coming from the goods. De-industrialization has also caused a continuous loss of manufacturing jobs after the 1980's because of growing imports and offshoring of some industries. Also from the economic development perspective the imbalance in income inequality has increased steadily within the period of 1973 and 2013 (Figure 3.11). There happened to be a negative distortion in the annual growth rates of the real income for the bottom 90 percent of the society (Figure 3.10.).

In order to remedy the negative impact of de –industrialization United States has been imposing policies, most strongly after 2008, in favor re-industrialization. The aim has been set to strengthen the domestic production and re-shoring of the manufacturing from overseas. As of the present day the main focus is on revitalizing both the basic material industries such as the steel and other value added manufacturing industries related with computers, electronics and software. In essence, the modern industries related with ICT are rather complimentary to the traditional basic material manufacturing industries and the aim is to increase productivity and quality. It can be disputed that the positive evolutions such as the raise in the level of automation, the integrity of robotics and artificial intelligence with the factory production, the faster speed of data flow or enhanced computational speed, advancements in electronics and material science are in way both the outcome of and the cause for the improvements in the basic material manufacturing industry. As an example, the speed of a microprocessor is directly related with the attribute of the material it is made of. Nevertheless, the role of the basic material manufacturing industry such as the steel industry as well steel as the material, is as important today as it has been in the 19'th and 20'th Century. In the historical perspective, despite the manufacturing industry has been continuously transformed into a more value added form while the quality of steel has remarkably improved, its prominence, as a material is still as strong at the present day. Within this context, the automotive industry has been selected as the case industry to reveal data and findings to support this case. The automotive industry has been chosen for the reasons of being comprehensive in terms of network of sub-suppliers as well as diversity of industrial sectors involved; bridging the traditional industries such as steel and the very modern industries that are related with ICT and electronics; creating great amount of employment and being continuously up to date with the very latest technologies.

CHAPTER 4

THE CASE OF AMERICAN AUTOMOTIVE INDUSTRY AND MATERIAL TRENDS

It is first aimed in this chapter to reveal the nature of the American automotive industry and show its impact on the U.S. economy in general from today's standpoint and its historical transformation perspective. Nevertheless, the main goal here is first to analyze the trends in weight composition of the main materials which make up the standard American car through a certain period of time in order to detect the changes in the amounts of the basic metals used. Then the second goal is to analyze the itemized cost breakdown of a standard North American car in order to reveal the cost shares of material and labor. As a result, these findings are used to reveal the role and position of steel in the American manufacturing industry today and compare it with the past. The purpose is to elaborate on the vitality of the basic material industry in the United States.

4.1. Transformation and Its Impact on Economy

The American automotive industry, including its chain of supply, is the largest manufacturing sector in terms of contribution to the GDP and in creating employment. From research labs and supplier factories to assembly lines and dealership showrooms, the auto industry supports nearly 8 million American jobs which accounts for almost 5% of the total U.S. work force. The historical contribution of the automotive industry to the U.S. GDP has been between 3-3.5% (Hill, Cooper and Menk, 2010:1-2).

The motor vehicle industry is also a prime end-user for many materials. It supports many products from versatile industrial segments and hence has a very wide supply chain. The automotive industry is among the highest job multipliers with a factor of 7.25 (American Automotive Policy Council [AAPC], 2017:7-17). As a natural outcome, for one job created in the automotive industry there are many more jobs created in the aluminum, plastic, rubber, steel, glass, textile, electronic, computer chip, software industries and so on. Beyond those facts, what makes the automotive industry so unique is that, since the first mass produced passenger car in the United States, the Curved Dash Oldsmobile in 1901 in Detroit, the automobile industry has been a quick adopter of the versatile technologies that came in parallel with the ongoing innovations emerging from different fields. As of today, many autopilot, hybrid or electrical cars have already entered the market.

The automotive industry has been in direct contact with the end consumer who expects the sector to keep up with the latest technological standards. Some examples are the engine technology which seeks better efficiency, battery storage technology for the electric cars, computer and software technology which supports visioning and control and the material technology that supports the whole body and the parts. Therefore, the automobile industry can be described as a hot pot which blends the traditional and the modern industries and bridges the time gap in terms of technological evolution as a part of its nature. It is one of the unique sectors which establishes a linkage between old industries such as steel, aluminum and the very modern industries of the present day with all the updated features of technology in the field of ICT, solar, material science, additive manufacturing, internet of things and artificial intelligence.

Overall, the automotive industry is also regarded as the leading advanced manufacturing industry in the United States. The sector currently employs 39 percent of the advanced manufacturing workers and has also created 90 percent of the new advanced manufacturing jobs since 2009 (Gaskon and Spewak, 2017). In that sense the automotive industry is catching up with the very latest technologies and is one of the leading adopters. To illustrate, in 2010, both the electronic and the automotive industries have adopted more than 30,000 industrial robots which are sold globally, outpacing the other industries (Figure 4.1).

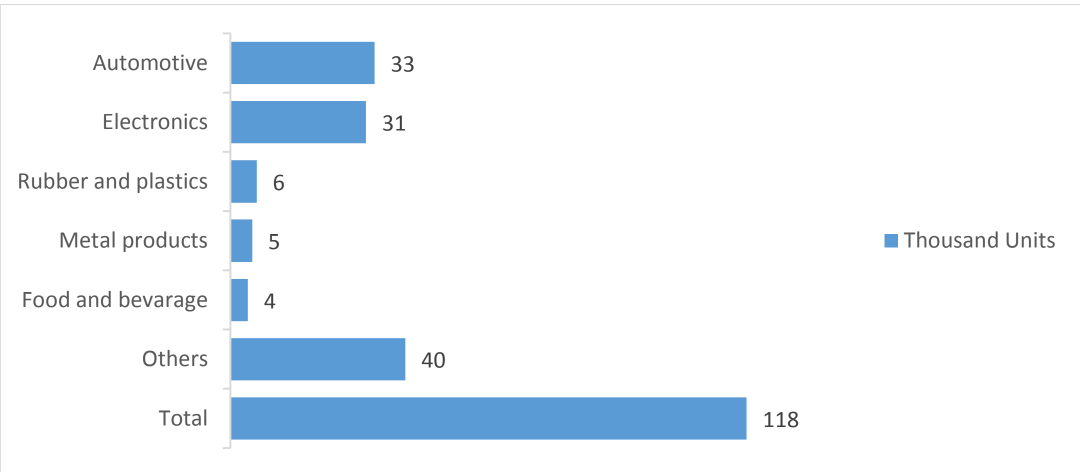

Figure 4.1. Global sales of industrial robots (2010)

Source: McKinsey Global Institute Report (Manyika et al, 2012: 89), International Federation of Robots; World Bank; McKinsey Global Institute analysis

Within that scope, the analysis of the transformation of the automotive industry could be regarded as a good indication for the transformation of the manufacturing industry as a whole. In this respect, after a brief assessment of the evolution of the American automotive industry and feedback on the status of the present day, the thesis analyzes the whole set of itemized cost data related with the car industry and the change of material trends in the production of an American car within the time frame of 1975 and 2014 in order to elaborate on the impact of the metal manufacturing sector such as steel and aluminum within the changing time line and also on the contribution of the other input factors including technology. Other outcomes are also deduced from the same data which are related with the impact as well as the changing characteristic of the labor force. Automotive manufacturing is categorized as high skilled and advanced manufacturing.

4.2. Historical Transformation of the American Automotive Industry in relation with Economic Growth and Prosperity

In 1929 the total percentage of trucks and automobiles per household registration in the U.S. had reached almost 90% (Table 4.1). Also, the same year 80% of the world's total motor vehicle production was performed in the United States (Norcliffe, 1997).

Table 4.1. Motor Vehicle (MV) registration per household, cars, trucks, and total, percentages, selected years, 1910-2010

Year	1910	1930	1950	1970	1990	2010
Automobiles per Household	2.3	76.8	92.6	140.8	143.2	112.1
Trucks per Household	0.1	12.2	19.7	29.6	58.4	94.5
Total Motor Vehicles per Household	2.3	89.2	112.9	171.0	202.3	207.3

Source: MV registration after 1995 from SAUS Table 1119, MV registration before 1995 from HSUS Series Df339-242, (Gordon, 2016: 377)

As it is also obvious from the table there was a sharp increase in the number of motor vehicles owned per 100 households from 2 in 1910 to 89 in 1930. That means that almost every household owned a motor vehicle by 1930.

After 1908, when Henry Ford installed the first assembly line and initiated grass roots mass manufacturing, notwithstanding the fact that that United States economy was growing based on its strong domestic market, American motor vehicle exports also dominated the world through 1934. This happened despite the fact that American cars were not produced to suite the requirements of the European market: neither in terms of size nor in fuel requirements (Figure 4.2). Ford's large-scale automobile producing company became a model of mass production for other industries in the United States as well as other parts of the industrial world. The model was underlying cost-effective serial production and comprised of organizational, managerial, financial and technological aspects (Nelson and Wright, 1992).

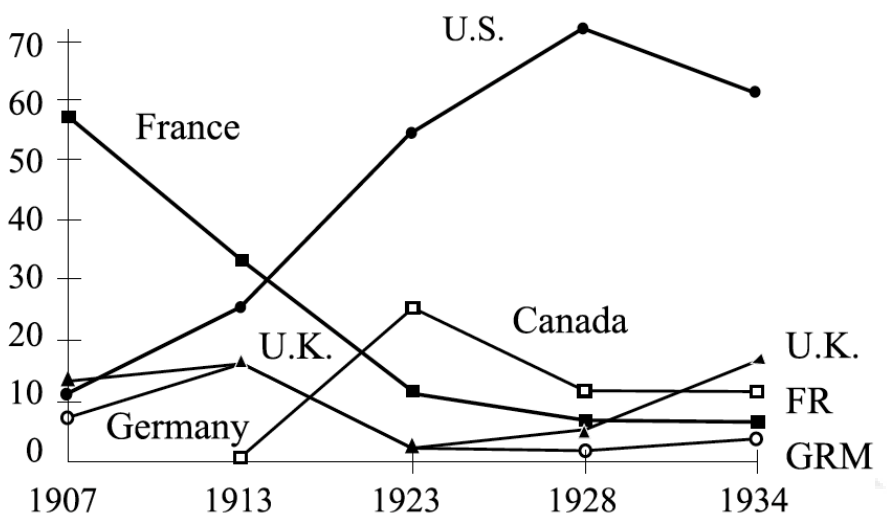

Figure 4.2. Share of motor vehicle exports, 1907-1934

Source: James Foreman-Peck (Peck, 1982)

This remarkable expansion of the automotive industry and market in America caused a positive change in the life standards of the American people. The level of prosperity increased with the freedom of personal travel which triggered many other opportunities such as motels, supermarkets on the roads, drive-in movies, drive-in restaurants, etc. People could also travel easier from any place they like and live the suburban areas without only a modest burden of travel to work. These are big improvements regarding economic development and prosperity. The increase in the quality of life is the major indicator of prosperity.

This noticeable transition of the society had been caused by the transformation of the automotive manufacturing industry which was able to offer low cost and competitive priced cars. This was possible with the adoption of the mass production system which relied on precision machinery and the assembly line technique that was pioneered by Henry Ford in 1908. A test of affordability between the 1923 Ford Model T, 1950 Plymouth (standard car equipped with bench seat, manual transmission and heater) and a standard car of 2012 is a good proof that supports this case. The Model T cost $265 which was equal to 11 percent of current-dollar per-household expenditure value for that year. The 1950 Plymouth cost $1,520 and the same value for that was 33 percent. Even the 2012 car, although somewhat improved equals 21 percent of per household consumption for that year. The result is that Ford Model T was twice as much affordable (Gordon, 2016:382).

In 1929 there were 5.3 million cars and trucks sold. In 1941 the number decreased down to 4.7 million but then in the post war period there was again another big leap when in 1950 7.9 million and in 1955 9.1 million cars and trucks were sold. This double up between 1941 and 1955 is due to the plant expansions in the industry that was supported by the Federal Government during World War II. This expansion had the positive effect on GDP, productivity and personal income. Working class families were able to afford their second car. This demand fueled and maintained the increasing supply of the factories (Gordon, 2016:379). With the same respect the car owned by 100 household's ratio has increased to 113 in 1950 and then made another big leap to 171 in 1970. Then the extension to 1990 and further to 2010 was very modest when it lingered around 200 (Table 4.1).

From the technical perspective, most of the quality and functionality features of the automobile were already loaded on cars by 1970. Regarding air conditioning, 50 percent of the cars were installed with it by1970 and 84 percent by 1983. Radio installation also speeded up after 1960's. In 1965 fifty percent of the cars had power steering and in 1970 half of the cars had power brakes. Besides, the cars were already powerful enough by the 1940's. In 1940 Chevrolet was offering 85 horsepower and Oldsmobile or Cadillac were offering 110 to 125 horsepower engines. All of them could maintain a speed at 100 miles per hour, which is far above the speed limits in the United States (Gordon, 2016:381-382).

From 1970 until 2018 the cars were further improved with the aid of technology in terms of fuel economy, safety and reliability. These findings also support the thesis that most of the breakthrough innovations that had an impact on the biggest portion of the society were achieved in the 100 year period from 1870 to 1970.

In the postwar years the automobile production and sales in the United States were dominated by the three American car manufacturers General Motors, Ford and Chrysler.

After 1970 in order to preserve productivity and competitiveness, the U.S. Automotive industry began to take measures because the imported market share of the U.S. Automotive Industry had risen from 1% in 1955 to 30% in 1987. Lean manufacturing, concurrent engineering and outsourcing of a greater share of design and development were among the major shifts (Brunnermeier and Martin, 1999: ES-2). The main target was to increase the level of interoperability between the participants of the big supply chain of the industry. The American automotive supply chain consists of four main elements: original equipment manufacturers (OEMs), first-tier suppliers, sub-tier suppliers, and infrastructure suppliers (Figure 4.3).

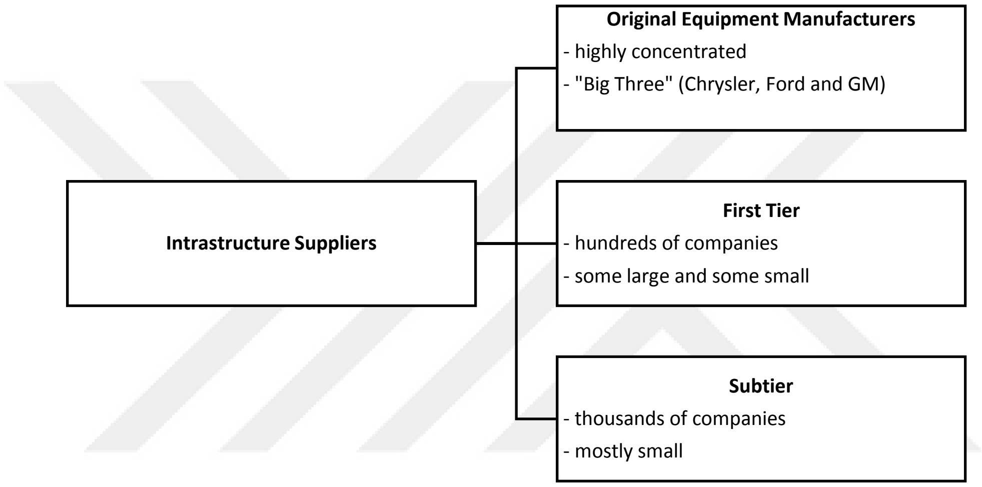

Figure 4.3. U.S. Automotive Supply Chain

Source: Report on Interoperability Cost Analysis of the U.S. Automotive Supply Chain, Research Triangle Institute Center for Economic Research

Exchange of data and drawings became another very important topic. Because it supported concurrent engineering where people from all entities collaborated on the improvement on issues like process and product development, design, performance and manufacturability. The outcome of this effort had a positive impact on the performance of the U.S. automotive industry as the lead time of a new automobile platform was reduced from 5 years in 1980's (Womack, 1989) to between 2-3 years at the end of 1990's (Brunnermeier and Martin, 1999: 1-2).

4.3. The State of the American Automotive Industry in 2017

Today every State in the U.S. can be described as an "auto state" since there are 226 assembly plants, manufacturing facilities, research labs, distribution centers and other facilities, located in 32 states across 115 Congressional Districts (AAPC, 2018:6). The gross output of motor vehicles, bodies, trailers and parts is US$ 736.3 billion according to the Bureau of Economic Analysis statistics (BEA, 2018a).

The share of U.S. automotive industry within the America's manufacturing production is 7.42% generating a value-added output of US$ billion 166.7 in 2017 figures. This equals to 0.9% of the GDP and shows a sharp rebound after 2009 when the value-added output of the automotive industry was 0.3% of the GDP. In addition, the motor vehicles and parts dealer contributed US$ billion 212.3 to the GDP in 2017 (AAPC, 2017). Figure 4.4 shows the changes in percentage of the value-added outputs within the GDP for the automotive manufacturers and dealers between 1997 and 2017.

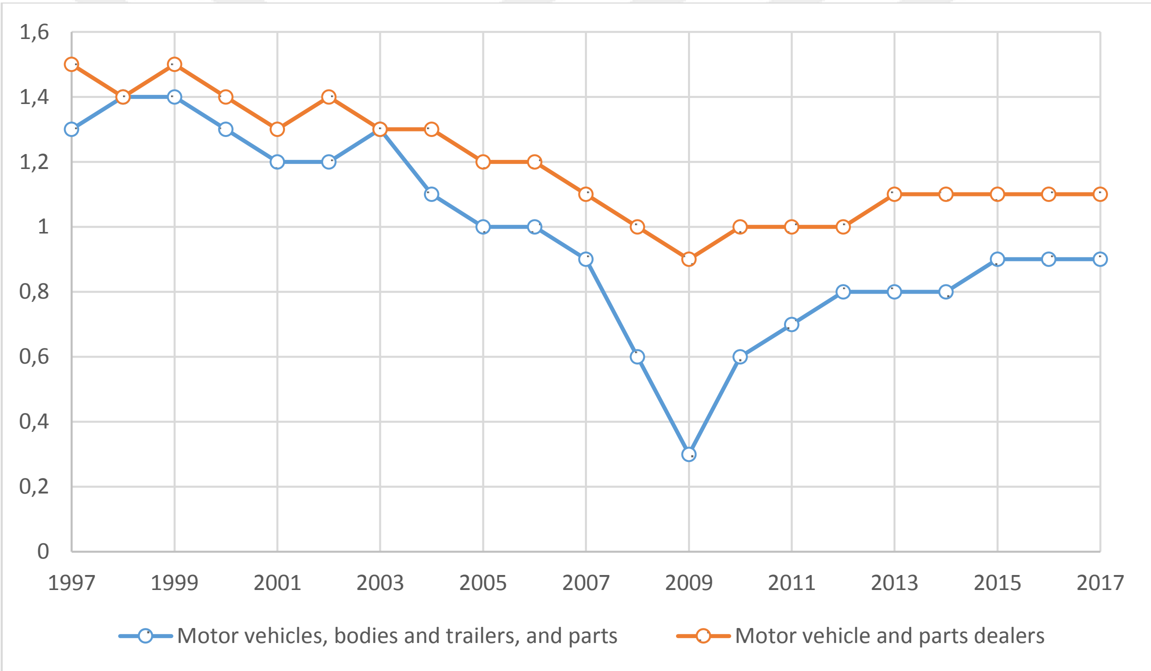

Figure 4.4. Value added by industry as a percentage of GDP, 1997-2017

Source: Drawn based on the data from U.S. Department of Commerce Bureau of Economic Analysis (BEA, 2018a)

The automakers and the suppliers to the automotive industry combined are the largest manufacturing sector in the USA which accounts for almost 3% of the GDP. In 2016 17.5 million cars and trucks were sold in the United States and 12.2 million cars and trucks were produced in 46 domestic automotive assembly plants (AAPC, 2017:7). The Fiat Chrysler Automobiles (FCA) US, Ford and General Motors has produced 6.6 million vehicles and the rest has been produced by foreign owned automotive companies (Figure 4.5).

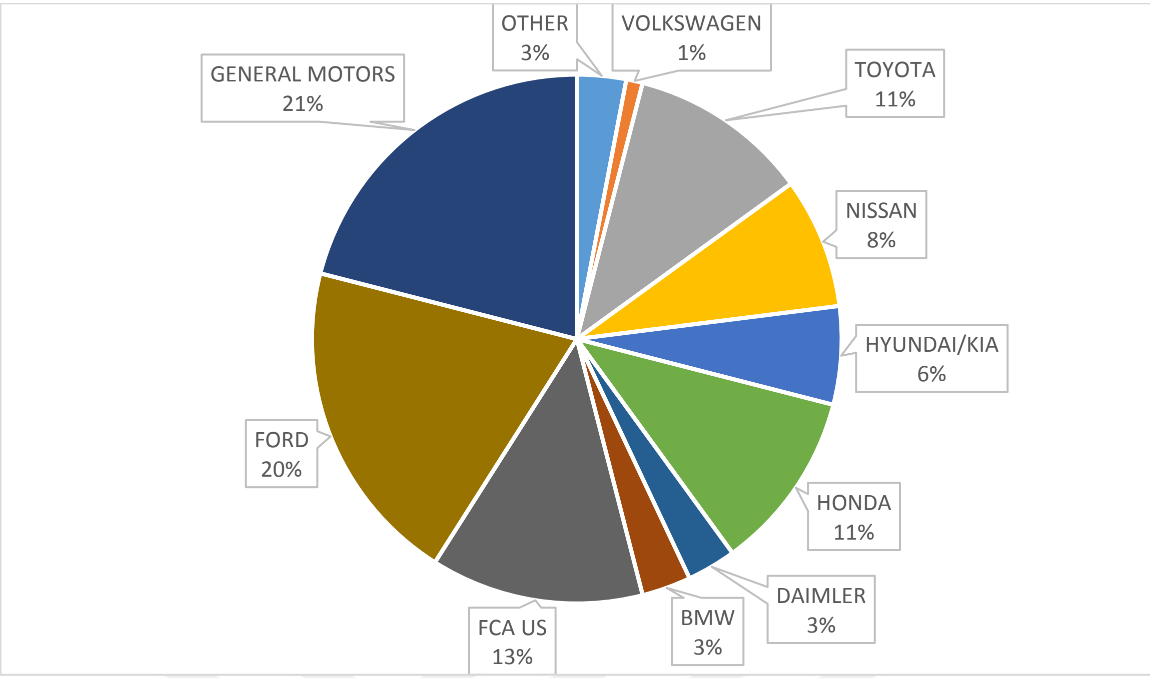

Figure 4.5. OEM's share of U.S. production (2016)

Source: AAPC Report on the state of the U.S. Automotive Industry [2017] (AAPC, 2017)

The automotive industry is also America's largest goods exporter. In 2017 total U.S. exports were US$ 2.3 trillion with US$ 1.3 trillion comprising capital and consumer goods. With 2017 figures U.S. exports for new/used passenger vehicles, light weight-medium-heavy trucks and automotive parts added up to $ 158 billion (International Trade Administration [ITA], n.d.). Figure 4.6 shows the top 5 U.S. exporters in 2016.

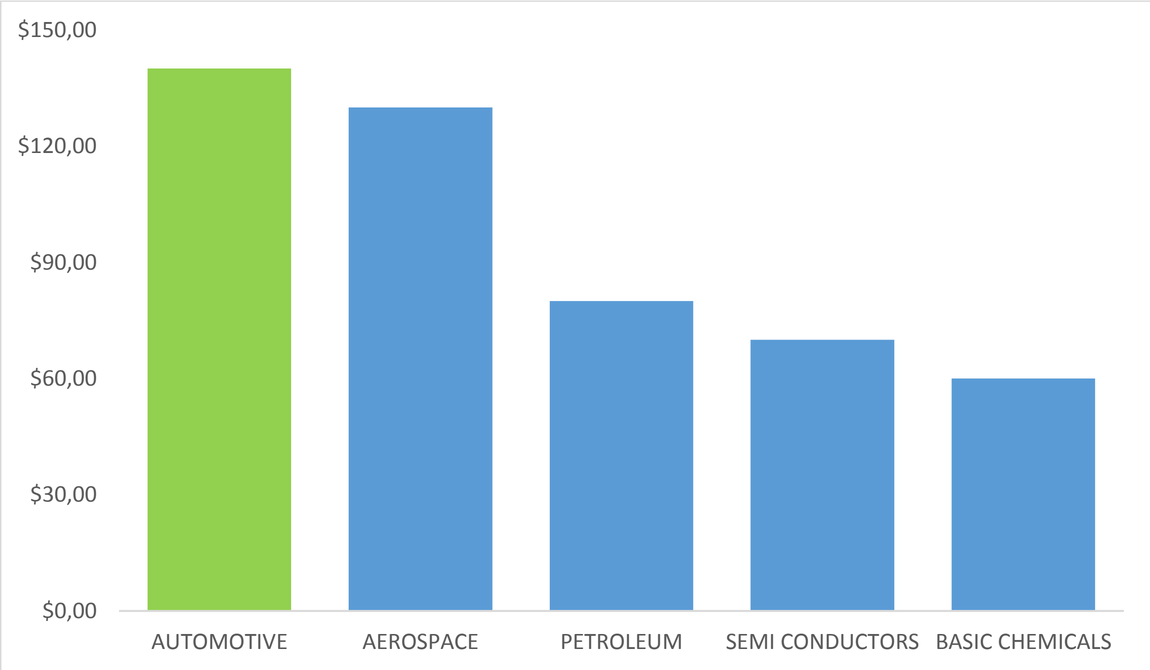

Figure 4.6. Top U.S. exporters in billions (2016)

Source: AAPC Report on the state of the U.S. Automotive Industry [2017] (AAPC, 2017)

Regarding labor, the 15 automakers in the USA directly employed about 393,000 people together. According to the U.S. Department of Labor Bureau of Labor Statistics. Each of these individual plants assembles a number of 8,000 to 12,000 different components and these parts are produced by more than 5,600 U.S. suppliers. So, the motor vehicles and parts manufacturers together employ over 950,000 people. The total workforce employed by the manufacturing industry in the United States in 2017 was 12.54 million. On the other hand, the whole automotive industry in the United States created a direct employment of approximately 4, 22 million jobs (Table 4.2). Adding all the suppliers it has been estimated the total industry would support more than 7.25 million U.S. jobs in total (AAPC, 2017:16). With the extended large supply chain (R&D, suppliers, assembly factories, dealerships, accessory stores, maintenance shops) the automotive industry is on the top of the list among the industries with the highest job multipliers (Figure 4.7). For one worker employed by the automaker assembly plant 7 workers are employed by the suppliers and the surrounding community (AAPC, 2017:7).

Table 4.2. Employment in the automotive industry

Automotive Industry Segments	Average Employment in thousands
Motor vehicles and parts manufacturing	952.5
Motor vehicles and parts wholesalers	337.5
Motor vehicles and parts dealers	2,008.3
Automotive repair and maintenance	923.7
Total	4,222

Source: U.S. Department of Labor, Bureau of Labor Statistics, 2017 (BLS, 2018e)

Automotive industry's contribution to economy is highest among the other manufacturing sectors. The Center for Automotive Research (CAR) uses the Regional Economic Development Model (REMI), which is not self developed rather adapted to the issue by REMI staff, in order to generate estimations of the economic contribution of the manufacturing operations (Figure 4.7).

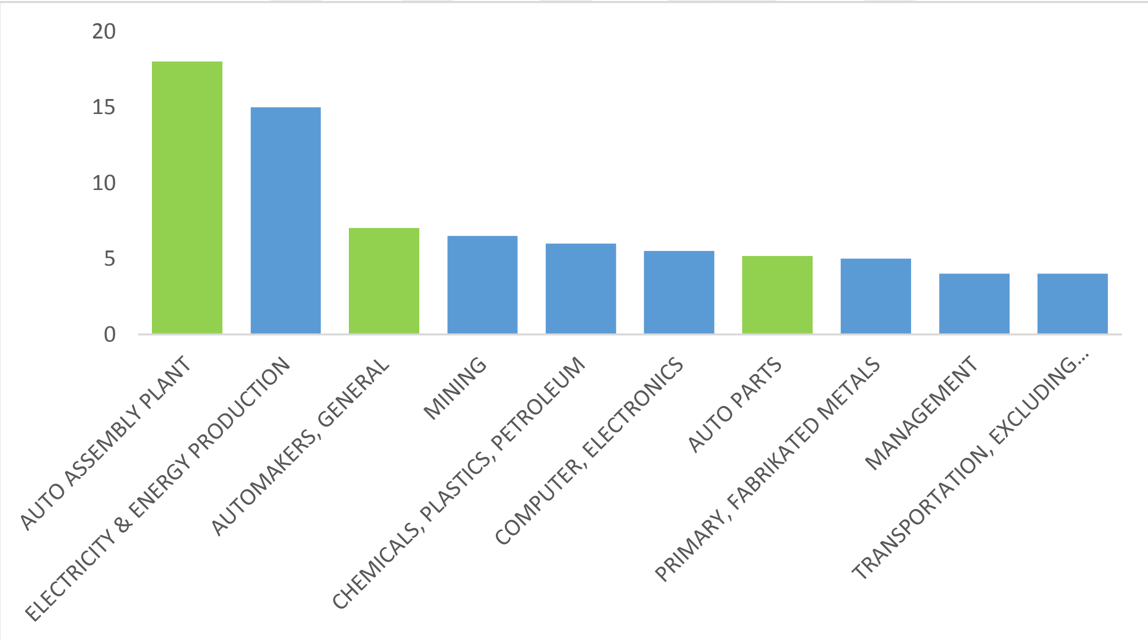

Figure 4.7. Industries with the top 10 highest job multipliers

Source: AAPC Report on the state of the U.S. Automotive Industry [2017] (AAPC, 2017)

From another perspective investment into the automotive industry is an important indicator that emphasizes the sustainability of the sector for the future projections. The U.S. Automakers over the five-year period of 2012-2016 made a total investment of $50.3 billion in assembly and parts manufacturing plants, R&D labs, administrative offices and other related facilities (AAPC, 2017:13). Money spent on R&D is another investment on innovation. The automobile assembly plants and the automobile part manufacturers spent approximately US$ 115 billion per year which is more than the software, electronic, chemical, aerospace, defense, oil and gas industries (Figure 4.8).

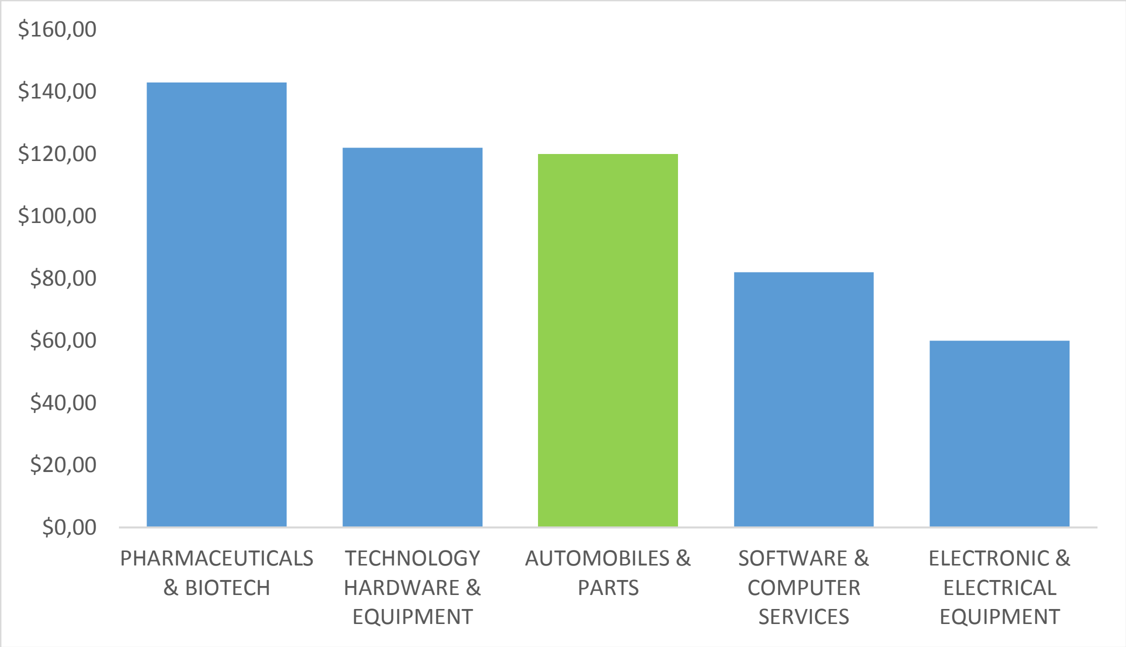

Figure 4.8. Top 5 industries for research & development

Source: AAPC Report on the state of the U.S. Automotive Industry [2017] (AAPC, 2017)

The U.S. automotive industry is a very innovation intensive one as globally, FCA, Ford, and General Motors, together, invest more than $18 billion in R&D every year (AAPC, 2017:5).

4.4. The Automotive Production Lines Production Cost and Labor

Historically, the automotive industry as well as the whole manufacturing industry has transformed from craftwork to the production lines. This has increased efficiency, productivity and lowered costs. In that respect, Ransom Eli Olds, the founder of Oldsmobile Motor Company, introduced the first assembly lines in car production and dominated the American market between 1901 and 1904. However, Henry Ford's car manufacturing plant, which started operation at Highland Park, MI in 1913, is regarded as the official benchmark for the first assembly line mass production plant because it was more efficient and systematic. Each worker on the workstation had one specific task. It took 93 minutes for the assembly of a Model T car from start to finish. This transformation in the manufacturing industry is also the turning point for the transformation of the whole manufacturing industry in several respects. From the technical point of view, it is mechanization supported by electrification and from the system perspective it is a shift to efficient serial production. Nevertheless, from the labor demand point of view it is a transformation from skilled to unskilled craft work.

In principle, the production line principle runs on division of labor, is a continuous repetitive process and requires less skilled workforce. Over time, despite the assembly line process, production process did not change in principle, with the advancement in technology the tools and machinery automation took place. As a result, some jobs have been replaced by robots. This had a positive impact on the production cost while causing a loss for the labor. Nevertheless, from the labor quality perspective, digitalization and automation has transformed labor demand in the manufacturing industry from unskilled to skilled again since there was a need for more trained and knowledgeable people to operate the machinery during the production process.

In the modern assembly lines, the pieces of the cars are being assembled by either humans or robots who are performing repetitive specific tasks. Most of the pieces and parts, such as the transmission, engine, brakes, etc., are being assembled and supplied by other plants.

In principle the automotive manufacturing process consists of four main segments which is stamping, assembly, welding and painting. Stamping is a pressing process that is used to put the metal into the desired shape. The input materials for the panels are supplied to the stamping plants in the form of metal sheets or pre-cut metal sheets which are called blanks. These sheet steels are mostly cut out from big coils which are supplied by steel plants. At some OEM's the complete cutting and pressing process is performed in house such as at the General Motors Grand Rapids Stamping Plant where sheet metal stamping is performed. This operation is done by various big stamping presses. Nonetheless, some smaller size metal automotive components of the fuel injection system such as brakes, drive trains, body & exterior are precision stamped and mostly supplied to OEM's by independent suppliers.

The next process in car making is assembly which refers to the mechanical fixing of various parts. Welding could also be counted as a part of assembly. In essence, it is a different technique of fastening the automotive parts. There are different types of welding technology such as laser, arc, brazing, gas, resistance and so on. After assembly, the parts are paint coated in order to protect the metal from chemical and physical damage. For instance, corrosion of steel is prevented through paint coating with corrosion resistance formulas. Usually electrophoresis technique is used for painting. It is a process which is based on the movement and deposition of the charged paint particles in an environment of applied electric field. Regarding the cost breakdown of the manufacturing process stamping constitutes 70 percent of the total while welding and painting operations constitute 20% and 10 % respectively (Monteiro, 2001:30, 54).

Here, it is important to note that to the current day computers, electronic control, robotics and ICT technologies are used in order to increase the level of automation of the whole automotive manufacturing process. Automation has been achieved especially in the material transfer between production lines as well as in the assembly, welding and painting processes. Robots have replaced workers for certain duties. According to the 2012 study of Canadian Automakers Union CAW), in the cost breakdown of a car, the labor only constitutes a small portion in the list with 4.2 percent whereas raw materials purchased auto parts stands for 57% of the total cost. In general, overhead, engineering, research and development account for 16% of the cost (Table 4.3).

Table 4.3. Cost Components: Average CAW – made Vehicle

Vehicle Manufacturing		
Purchased parts and supplies	57%	$ 23,095
Direct production labor	4%	$ 1,741
Production Overhead		
Warranty	2%	$ 767
R&D	3%	$ 1,242
Depreciation, amortization	4%	$ 1,738
Maintenance, repair, operations	2%	$ 767
Corporate Overhead		
General and administrative	5%	$ 2,009
Selling		
Transportation	2%	$ 986
Advertising	2%	$ 1,091
Dealer gross mark-up	4%	$ 1,497
Net profit		
Automaker profit margin	4%	$ 1,461
Sales Tax		
Average Canadian rate	12%	$ 4,984
TOTAL	**100%**	**$ 41,377**

Source: CAW estimates from: "Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers," United States Environmental Protection Agency, 2009; "2011 Detroit 3-UAW Labor Contract Negotiation," Center for Automotive Research, 2011;Kantar Media, March 2012; Industry Canada, Manufacturing Costs by Category: http://www.ic.gc.ca/cis-sic/cis-sic.nsf/IDE/cis-sic3361cote.html (CAW, n.d.)

Hereby it is important to note that today the “in house automotive manufacturing” is mostly limited to final assembly and powertrain manufacturing. However, the matter of fact is that the purchased materials and parts make up the greatest portion of the car cost. Even with a more plain manufacturing cost approach by including only the purchased materials, direct labor, maintenance, repair, operation and administrative cost items into the equation, the labor cost stands for 6.3 percent while the purchased materials represent 84 percent.

In comparison, another 2001 study on the production cost modeling for the European automotive parts manufacturing industry shows that in average for all components the material cost stands for 50 percent while labor stands for 9 percent (Monteriro, 2001:53).

It is clear that with the advances in ICT and automation technology the labor cost item has diminished. However, in general it can be argued that, as of today, automation and digital technology in the manufacturing process can only target the further reduction of the 4% factory labor cost and may be some portion of the 5 % overhead which includes some corporate labor work. On the other hand, the material cost constitutes the lion proportion of car manufacturing. Therefore, the advancements in the field of engine technology, electronic control, software and material science will be more or less the determining factors regarding the cost over performance ratio. Accordingly, the technological targets set for the automotive industry seem to be related to the development of more fuel efficient and powerful engines as well as with the production of stronger but lighter weight materials.

4.5. Metallic Material Trends and Technology in the Manufacturing of the American Car

Basically, in the manufacturing of the American car there have been various determining factors which set the outlines and impacted the manufacturing trend. The trends have been shaped mainly by the customer demands aside from the safety and environmental requirements which are independently set by government through regulations.

The foremost important factor for the automotive industry has been fuel economy. The measure for fuel economy is miles per gallon MPG) which indicates how many miles a car is able to travel with one gallon of fuel. This is directly related to fuel efficiency and hence the performance of the car. Therefore, the main trend of the automotive industry has been to increase the mileage per gallon. This is firstly possible with advancement in technology which makes it possible to increase the performance of the engine and eliminate losses in the powertrain during transmission. The improvements in material science, combustion technologies and digital control technologies increased the efficiency overall. On particular advances in material science have been important from two perspectives. First of all, better performance materials will be able to withstand higher operating temperatures and pressures giving better combustion efficiency in the engine besides providing more durability on other auto parts.

The second way to increase MPG is to decrease the curb weight of the car. This can be achieved by design and mainly by the selection of the right material mix. Historically and today, the main material which constitutes most of the car weight has been steel. Therefore, there has been a trend in replacing steel with other material alternatives such as aluminum, polymers, composites and also with High Strength and Advanced High Strength Steel (HSS/AHSS) which have better strength per weight properties. However, opposite to expectations, the curb weight of the vehicles has shown a fluctuating trend ending up with almost not much of a change in the curb weight for the past 40 years. In essence, the average curb weight of the U.S. Light Duty Vehicles (LDV) decreased from 4,060 lbs. from 1975 down to 3,221 lbs. in 1987 and then went back up to 4,072 pounds in 2014 (Dai, Kelly and Elgowainy 2016:1). The weight loss achieved from lightweight material selection has been regained through the addition of new automotive components which are related to driver comfort and safety requirements.

Historically, the decreasing trend in fuel efficiency (FE) between 1995 and 2004 could be attributed to the overall increase in the average weight, which was 1.4 percent per annum for the same period (Figure 4.9). After 1995 until 2014 the annual percentage decrease in weight clearly has contributed to the positive improvement in fuel economy.

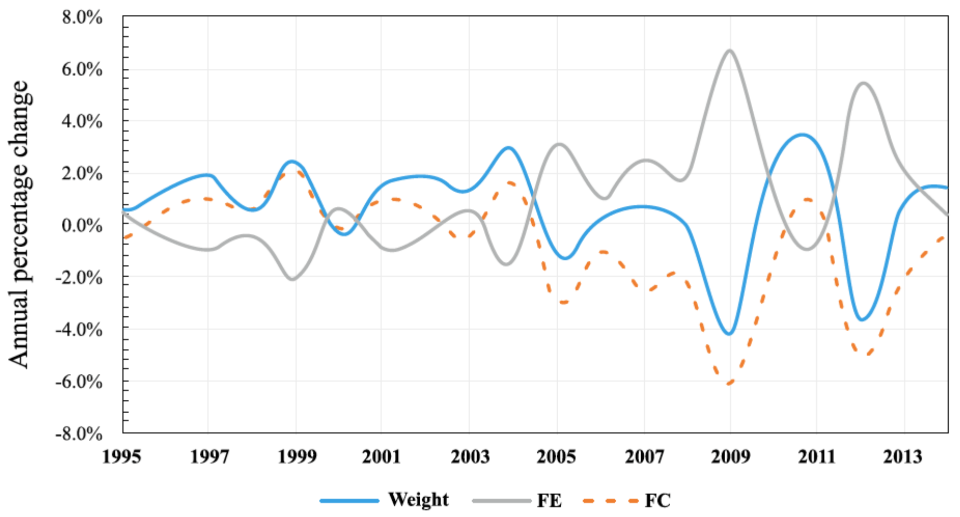

Figure 4.9. Annual percentage changes of weight, FE and FC for MY 1995-2014 U.S. LDV

Source: Argonne National Laboratory Report (Dai, Kelly and Elgowainy, 2016:6)

However, there are arguably other factors which clearly had an impact on the improved fuel efficiency such as increased engine performance, advanced tires with less friction and better aerodynamic designs (Dai, Kelly and Elgowainy, 2016:5-6). Especially between 2004 and 2015 there was a steady rising trend in both fuel economy and horsepower while the weight changed little. This could be attributed to the advances of technology and design techniques Figure 4.10).

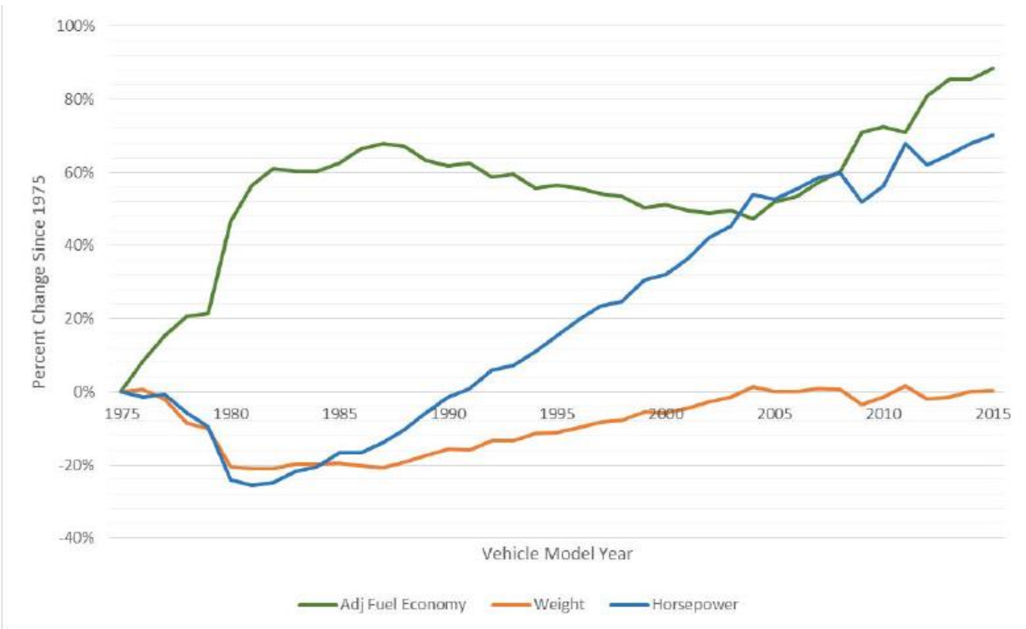

Figure 4.10. Fuel economy, horsepower and weight trends for U.S. light duty vehicle (ldv), 1975-2015

Source: Based on data from: Hula, A., A. Bunker, and J. Alson, Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015. , United States Environmental Protection Agency Annual Report (2015) (Hula, Bunker, Alson, 2018: a)

4.5.1. The Material Trends

According to the U.S. Vehicle Technologies Office 10 percent reduction in vehicle weight brings between 6-8% increase in fuel economy (“Lightweight and Propulsion Materials”, 2018). Therefore, the reduction in the vehicle weight while maintaining safety and performance is an important criterion for the automotive industry.

There are five main materials that are used in the manufacturing of automobiles. These are steel, aluminum, glass, rubber and plastics. Among them, steel is the foremost important material in the production of the car. Because it has the highest share in the weight composition. For instance of a 2014 model U.S. light-duty vehicle (LDV) steel approximately comprises 52.5 percent of the weight (Table 4.4). The curb weight of a 2014 model U.S. light-duty vehicle in average is 4,072 lbs. (1,848 kg). Also, steel is a material which bears the weight of structural loads.

Table 4.4. 1995-2014 U.S. light-duty fleet material content in lbs. per vehicle, curb weight in lbs., and FE in mpg

	1995 a	1996 b	1997 b	1998 b	1999 b	2000 a	2001 b	2002 b	2003 b	2004 b	2005 a	2006 a	2007 a	2008 a	2009 a	2010 a	2011 a	2012 a	2013 a	2014 b
Regular steel	1,630	1,636	1,649	1,669	1,662	1,655	1,652	1,649	1,646	1,650	1,634	1,622	1,644	1,629	1,501	1,542	1,458	1,346	1,361	1,379
High and medium strength steel	324	333	346	378	390	408	424	443	460	479	491	500	518	523	524	559	608	606	649	649
Stainless steel	51	53	55	59	60	62	63	64	65	70	71	73	75	75	69	73	73	68	74	73
Other steels	46	44	42	40	30	26	28	30	32	34	35	35	34	34	31	33	32	30	32	32
Iron castings	466	444	438	438	436	432	384	355	336	331	328	331	322	301	206	237	275	280	283	271
Aluminum	231	224	227	245	257	268	279	289	299	311	316	323	313	315	324	344	355	364	379	398
Magnesium castings	4	6	6	7	7	8	10	9	10	10	10	10	10	11	12	13	12	11	11	11
Copper and brass	50	51	53	53	52	52	66	69	70	71	59	61	53	64	63	65	67	72	73	71
Lead	33	34	35	35	35	36	37	35	35	37	37	39	42	45	45	40	41	37	36	36
Zinc castings	19	19	18	17	14	13	11	10	10	10	10	10	9	10	9	9	9	8	8	8
Powder metal parts	29	28	31	33	35	36	38	39	41	43	42	42	43	43	41	41	41	44	45	46
Other metals	4	4	4	4	4	4	4	4	4	5	4	5	5	5	5	6	5	5	5	4
Plastics and plastic composites	240	257	260	278	265	286	298	307	319	338	332	338	331	343	384	378	377	355	336	329
Rubber	149	154	158	166	159	166	163	168	169	172	173	174	189	185	212	200	222	210	203	197
Coatings	23	25	24	26	24	25	26	26	25	28	27	29	29	28	34	34	34	33	32	28
Textiles	42	41	47	43	42	44	45	45	46	51	48	48	46	48	53	54	48	49	50	49
Fluids and lubricants	192	198	199	201	204	207	208	209	210	210	210	211	215	214	219	226	223	217	222	224
Glass	97	99	100	99	101	103	104	104	105	105	104	105	106	106	93	94	98	95	96	96
Other materials	64	65	65	58	66	71	75	79	83	87	86	88	92	91	90	92	94	90	93	93
Total	3,694	3,715	3,757	3,849	3,843	3,902	3,915	3,934	3,965	4,042	4,017	4,044	4,076	4,070	3,915	4,040	4,072	3,920	3,988	3,994
EPA LDV curb weight c	3,613	3,659	3,727	3,744	3,835	3,821	3,879	3,951	3,999	4,111	4,059	4,067	4,093	4,085	3,914	4,002	4,127	3,977	4,015	4,072
EPA LDV FE (mpg) c	20.5	20.4	20.2	20.1	19.7	19.8	19.6	19.5	19.6	19.3	19.9	20.1	20.6	21	22.4	22.6	22.4	23.6	24.1	24.2

a. ORNL TEDB Editions 26-34
b. Personal communication with Ms. Stacy Davis from ORNL
c. EPA 2014

Source: Argonne National Laboratory Report (Dai, Kelly and Elgowainy, 2016:4)

Glass is primarily used in the windshields, side windows and rear- side mirrors. In the modern cars, glass is also being used in the navigation and computer screens as well as back up camera lenses. The total share of glass weight composition of a 2014 model light duty vehicle is 2.36 percent. This percentage remained almost the same as this level since 1995 (Table 4.4).

Rubber is mostly used in the tires. Seventy five percent of world's natural rubber production is used in the manufacturing of tires for the vehicles. In addition, rubber is also used in the production of parts like wiper blades, engine mounts, seals, hoses and belts. The total share of rubber weight composition of a U.S. light duty vehicle fluctuated between 4 and 5 percent between 1995 and 2014 (Figure 4.11).

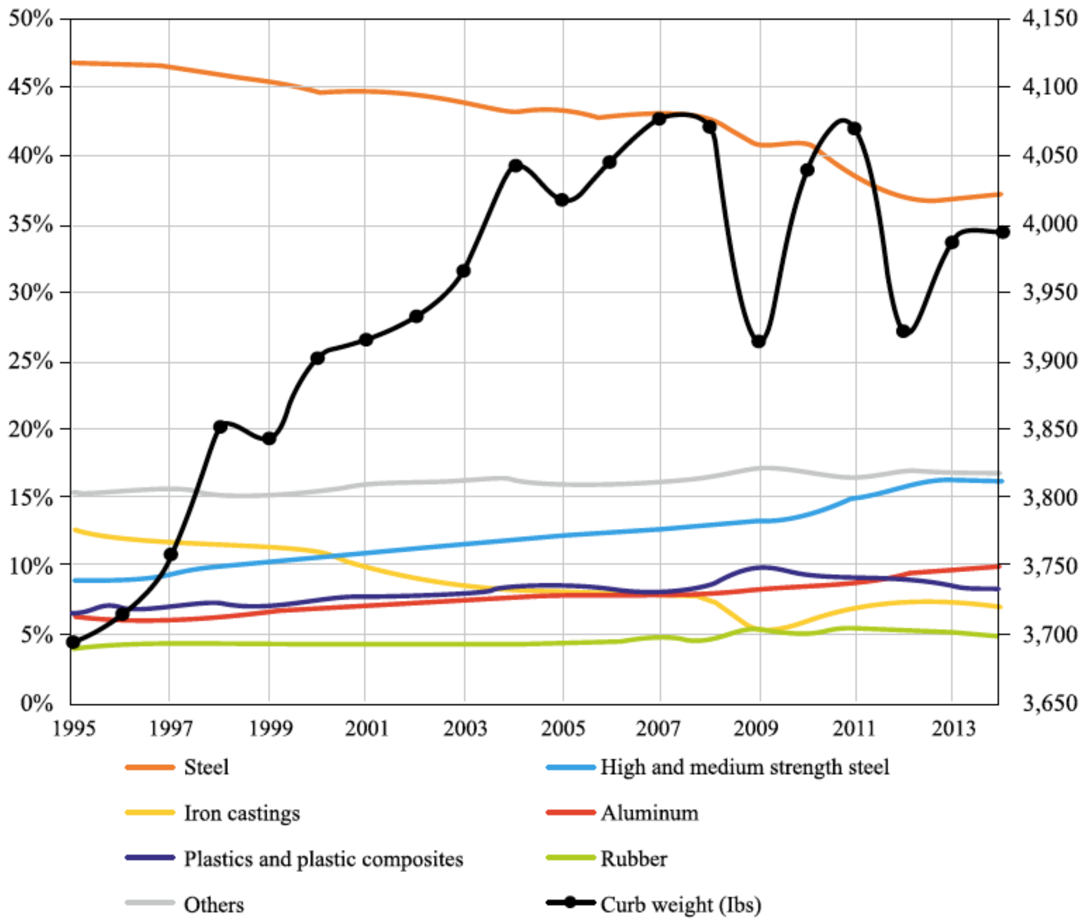

Figure 4.11. Historical trends of automotive material weight percentages for MY 1995-2014 U.S. LDV

Source: Argonne National Laboratory Report (Dai, Kelly and Elgowainy, 2016:5)

Plastics and plastic composites are increasingly being used in body structures and the engines of the cars due to their light weight. They are used in the production of various parts and pieces such as dashboard, gauges, dials, switches, air conditioner vents, door handles, floor mats, seat belts, airbags and tiny engine parts like handle on the oil dipstick. However, drawbacks of polymers are their lower resistance to high temperatures as compared to metals and also recyclability disposal difficulty. According to a 2015 United States Environmental Protection Agency Report the recovery rate for plastics from recycling is 9 percent (EPA, 2015). The use of polymers and their composites in the car manufacturing increased incrementally from 6-7 percent levels in the 1990's up to 8-9 percent levels after 2010 (Figure 4.11).

Aluminum is the second important material in the auto manufacturing industry after steel. Its consumption has continuously grown in the last 40 years. Its light weight provides advantage over mild steel as it brings weight savings up to 50 percent. In car design this allows for the downsizing which eventually gives rise to fuel economy and reduction in emission. Regarding safety matters, owing to its ductility aluminum can absorb twice as much crash energy as compared to the mild steel. Besides, the recyclability rate of aluminum is relatively high. According to the Aluminum Association, the rate is 90 percent in average.

Overall, the lightweight, strength and safety properties has led to the adoption of aluminum for the manufacturing of more parts of the motor vehicles with time. Historically, the first engine with aluminum parts was produced by Karl Benz in 1901. Later, in 1961 the British Land Rover company produced V-8 engine blocks with aluminum cylinders. In the following period aluminum began to be used in other automotive parts such as in wheels, hoods, trunks, doors, engines (e.g. cylinder heads) and powertrains (e.g. suspension joints, transmission casings) (aluminum.org, 2018:a). To illustrate, the use of aluminum in North American light vehicles increased steadily from 84 pounds in 1975 to 397 pounds in 2015 ("Aluminum consumption", 2018). Aluminum is mostly used in structural applications such as steering, suspension, sub frames, body, bumper & closures. In general, aluminum replaces mild steel and competes with flat rolled High Strength Steel (HSS), Advanced High Strength Steel (AHSS) and Ultra High Strength Steel (UHSS).

Despite the advantages of aluminum, the drawback is its relative higher price compared to steel and the price fluctuations of that metal. The use of aluminum in the North American Light Vehicles has shown a gradual increase from 2 percent in the 1970's to 5.1 percent in 1995 and reached to almost 10 percent as of 2014 (Figure 4.11). In the same year a total of 398 lbs. of aluminum was used on average in the manufacturing of U.S. light weigh vehicles when the curb weight was 4,072 lbs. (Table 4.5).

4.5.2. The Role of Steel in Motor Vehicle Manufacturing

Steel is the core material in automotive manufacturing and it is mostly used wherever structural strength is needed. Steel is used in almost all body parts of the car while aluminum is merely used in engine and powertrain castings.

In a 1975 U.S. Light Duty Vehicle (LDV) the steel had a share by weight in total of 61.2 percent. Eventually, the share of steel in the total weight of the LDV came down to 52.5 percent in 2014 (Figure 4.12). That is an 8.7 percent reduction in the total weight of steel after 40 years. However, this decrease is partly caused by the growing use of more of value-added and better quality steel (HSS/AHSS/UHSS steel) in substitute for mild steel and by the increasing share of use of aluminum as well as polymers in the making of various car components which had been produced by mild steel before. Figure 4.12 shows the vehicle mass breakdown by material in average for the 1975 U.S. Light Duty Vehicle (LDV) in comparison with the 2014 model.

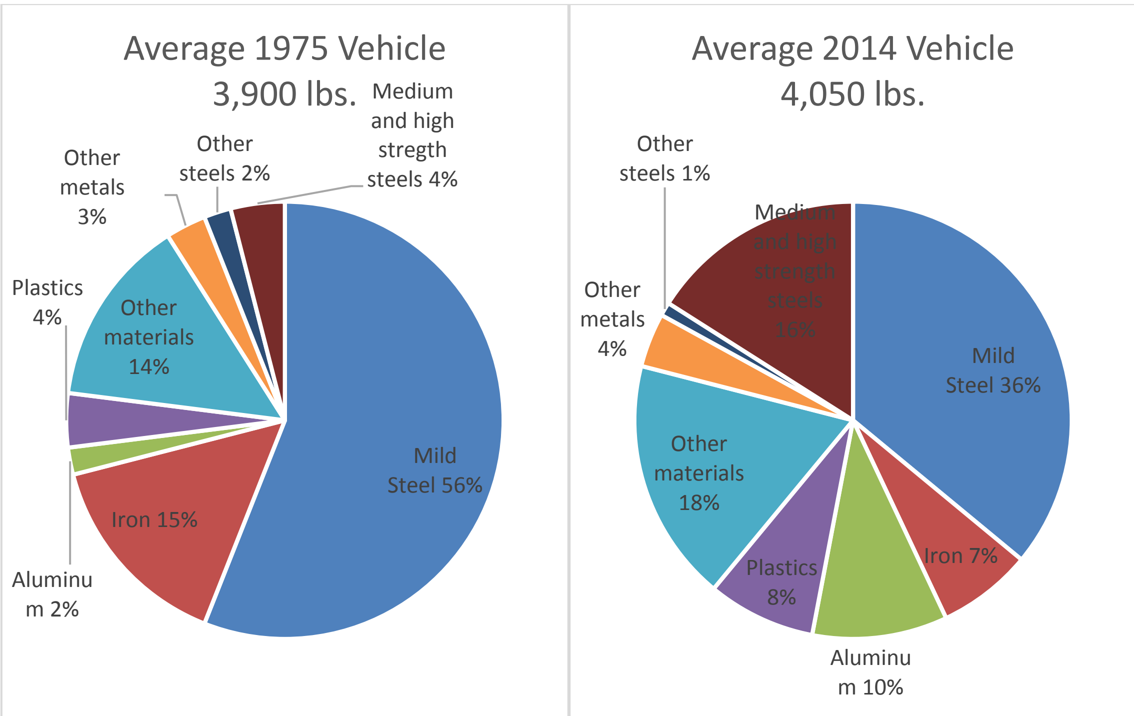

Figure 4.12. North American light vehicle segmented materials breakdown, 1975 and 2014

Source: Drawn with data from Ducker Worldwide (Schultz, 2015) and Argonne National Laboratory Report (Dai, Kelly and Elgowainy, 2016)

It is noteworthy that, based on the historical data as well as viable forecast reports which rely on scientific data, steel is still the major material in automotive manufacturing as of today and looks like it still will be for the foreseeable future. Its replacement is occurring with other materials in a very careful manner so as to maintain safety while making improvements in performance and production costs. Generally, substitute material for mild steel is primarily advanced high strength steel or high strength steel and secondly, aluminum. Technically, the substitute materials or composites have to bear the required strength, stiffness, temperature resistance, fatigue and ductility values provided by steel. Also, their cost of supply and availability should be close to such costs with steel.

In general, it can be stated that the key drivers for the automotive industry for the improvement of lightweight materials are fuel economy, agility, driving dynamics and CO2 emission issues. In particular, since the fuel economy (FE) and greenhouse gas emission are among the main concerns the Vehicle Technology Office (VTO) of Department of Energy (DOE) standards have been set for weight reduction for LDV's: 30 % for 2025 and 50% for 2050 respectively (Dai, Kelly and Elgowainy, 2016:8). These standards were set based on the Corporate Average Fuel Economy (CAFE) targets which aim to increase the FE to 54.5 MPG by 2025. The average FE for LDV's in 2014 was 24.2 MPG. The bar is set for a double increase and therefore the American Steel Industry is heavily investing for the development of advanced steel and new manufacturing technologies. Within that concept, many research projects such as "Future Steel Vehicle (FSV)" or "Advanced Steel Concept" are aimed developing new AHSS grades within the lightweight material concept. FSV was a three-year project which focused on steel intensive designs for electrified vehicles. The target was to reduce weight while improving material properties. As a result of the FSV project a 29 percent mass reduction and a 70 percent gas emission were achieved (Steel Market Development Institute [SMDI], 2018a). A further outcome, with the use of the 20 newly developed AHSS grade steels, which will be all commercially available by 2020, and innovative design techniques, 39 percent mass reduction might possibly be achieved on multiple applications which is almost equal to the mass reduction achieved by aluminum. In general, the new grades of AHSS enables automotive manufacturers to save by 25-39% on the total weight of the car compared to the use of conventional steel (AISI, 2018). The FSV project also aimed to develop steel which has strength levels that goes over 1,000 MPa (Mega Pascal).

The North American Steel Industry has been working in collaboration with the auto and steel industries through the Auto/Steel Partnership for the last 30 years on various projects in order to develop better quality steel that can be used as lightweight materials which in turn can replace mild steel. This partnership has completed various projects which aimed to improve FE and reduce emissions. For instance, the “Future Generation Passenger Compartment Project” achieved a 15 to 20 percent mass reduction in the passenger compartment of the vehicle with the wide adoption of AHSS, combined with design and manufacturing optimization techniques. In another case, the “Mass Efficient Architecture for Roof Strength” project, achieved a mass saving of 12 percent by using Ultra High Strength Steel (UHSS) through the development of a lightweight vehicle roof structure design which meets the roof-strength requirements set by the Government. Similarly, the “Lightweight Front End Structures Project” analyzed the cost-mass effectiveness of different variations of steel in the construction and design of front end automotive structure. The outcome was a 32 percent mass reduction through this project (SMDI, 2018b).

Lightweight materials are also being increasingly used in the aviation and wind industries. According to the 2012 report prepared by McKinsey on lightweight materials and their impact on the industry, the role of lightweight materials will grow in the automotive, aviation and the wind industry with an increasing pace for the next two decades. Particularly, the growth of usage for the automotive industry will be at the highest as it will almost double for this time frame. According to this report, although the aviation industry is currently using the most lightweight materials in terms of share, the automotive industry is expected to meet this level soon (Figure 4.13).

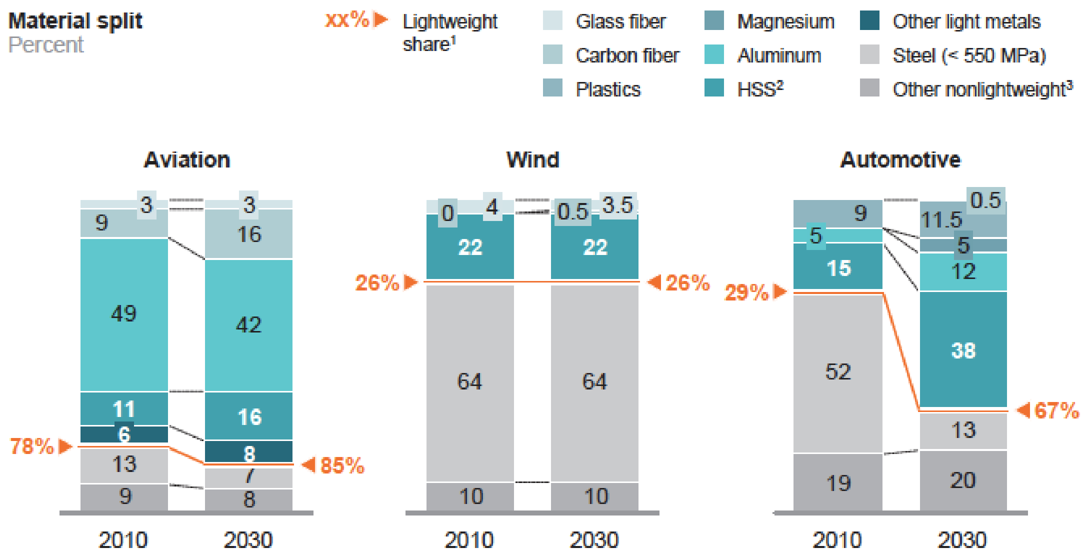

Figure 4.13. Share of lightweight materials in the industry: 2012 and 2030 forecast

Source: McKinsey report on lightweight impact on various industries (Heuss, Muller, Wolff, Starke, and Tschiesner, 2012:6)

Much scientific research is being conducted for the development of more superior lightweight materials and to expand their areas of application in manufacturing industry. However, the cost considerations are the constraints on the wide adoption of lightweight materials. Regarding the case for the automotive industry, all materials bring different attributes, but their cost per weight gain advantage varies (Figure 4.14).

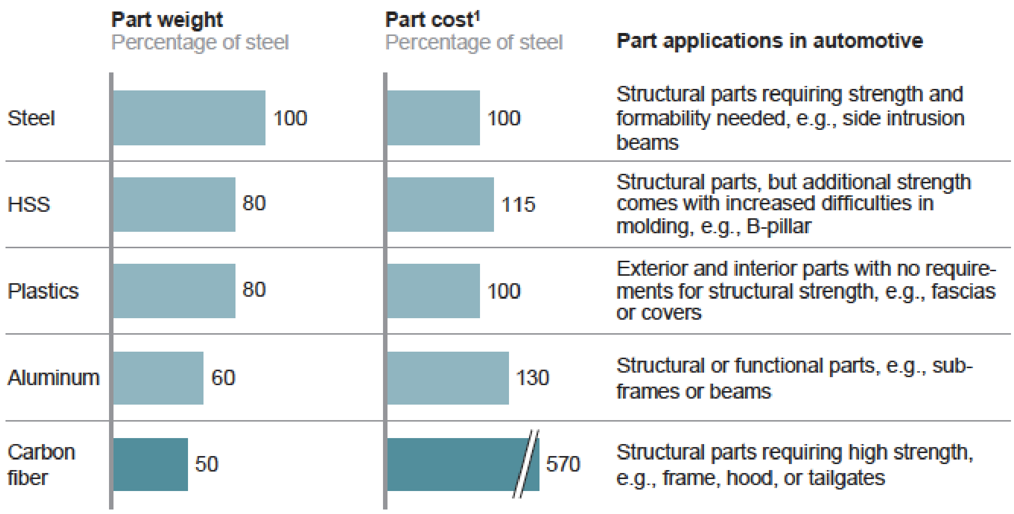

Figure 4.14. Price versus weight advantages for the use of light weight materials in the automotive fender

Source: McKinsey report on lightweight impact on various industries, (Heuss, Muller, Wolff, Starke, and Tschiesner, 2012:8)

It is apparent from the point of affordability that steel is the best material that bridges the price-performance gap as of the present day. Therefore, it is also a high probability that steel will play a key role in reaching the fuel economy and CO2 emission values mandated by the U.S. Government for 2025. Another advantage of steel usage in car making is the recyclability of the material. Each year approximately 14 million tons of steel, most of which comes from automobiles, are being recycled in the world. The recycling rate for automobiles is almost 100 percent (AISI, 2018).

According to Steel Market Development Institute and the latest industry research data, the newly developed grades of AHSS outperforms the competing materials and AHSS is the fastest growing material in the automotive industry owing to its performance flexibility, low cost, safety properties, high recyclability rate and mass reduction capabilities (SMDI, 2018b). According to an industrial research forecast prepared by Ducker Worldwide (Abraham, 2015), an American based intelligence and consulting firm, the average AHSS grade steel usage in a North American LDV will double thus growing from 254 lbs. to 483 lbs. in 2025 (Figure 4.15).

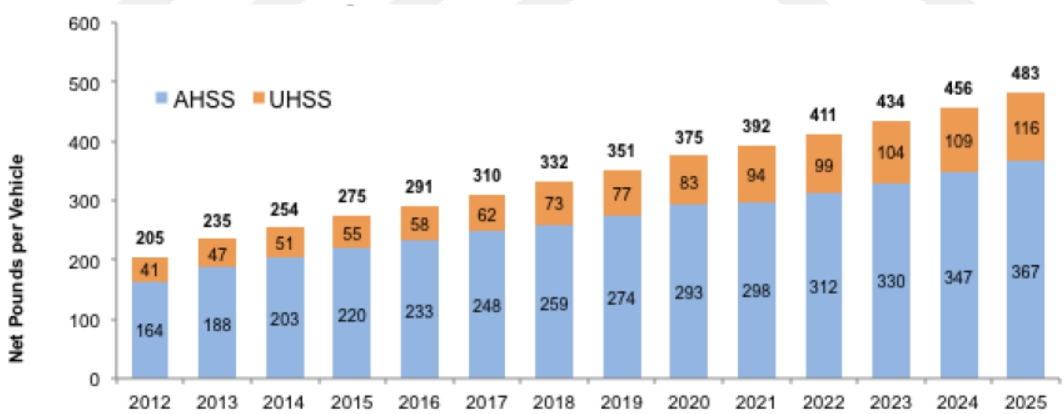

Figure 4.15. North American Light Duty Vehicle Advanced High Strength Steel (AHSS) and Ultra High Strength Steel (UHSS) utilization forecast

Source: Ducker Worldwide Analysis (Abraham, 2015)

According to the breakdown of economic sectors which uses steel in the United States in 1926, the automotive and the construction industries had a share of 14.5 percent and 19.5 percent respectively (Table 4.5). Based, on the annual steel consumption values of today the automotive industry share in the U.S. is 26 percent and the construction industry's share is

40 percent ("Steel demand", 2018). These, numbers are a good indication for the role of steel in American Industry today. Also, based on the statistics of the Iron and Steel institute, the total steel consumption of the United States in average goes in the vicinity of 130,000 metric tons per year in crude steel equivalent for the period between 1967 and 1977 while the same number goes around 110,000 thousand between 2006 and 2016 (International Iron and Steel Institute [IISI], 1978:24 and World Steel Association [WSA], 2017: 80).

Table 4.5. The breakdown of economic sectors using steel by percentage, 1926

Sector	Percentage
Railroads	23.5
Automotive	14.5
Building and construction	19.5
Machinery	4.0
Oil, gas, water and mining	9.5
Containers (Tin-plate and drums)	4.0
Agriculture	4.0
Others	16.0
Exports	5.0

Source: Iron Age, January 1, 1931 (Rogers, 2009:1945)

It can be concluded that steel as a material has been a very important cornerstone in the fast industrialization of the United States during and since the turn of the 20th century. After Henry Bessemer invented the process for producing steel inexpensively in 1856, the mass production of steel from molten pig iron became possible. This paved the way for the mass production of automobiles, airplanes, railways, buildings, etc. and laid the ground for industrialization and civilization. As it is also apparent from various industrial sectors such as the automotive industry, still as of today the steel remains to be the main material in the manufacturing industry in terms of quantity, especially in the composition of structural components. The only thing that has changed is the improvement in the quality which had a positive effect on the total weight composition of the manufactured goods. It played out that the conventional steel has been replaced with higher quality steel besides other metals, polymers and composites. Overall, with the contribution of science and technology, mass reduction has been achieved together with much improved strength, ductility and toughness. This is the transformation of steel into a more value-added state.

As it also shown through the case of the automotive industry, steel as of today is still the most optimum cost/performance balancing material. This attribute can be linked to the chemical structure of steel. Technically, it is an alloy of iron, carbon and many other elements such as manganese, silica, etc. In order to change the performance, other elements such as chromium, nickel can be added. Also, many other chemical and mechanical processes are applied such as heat treatment and forging in order to further improve the material properties. As a result, steelmaking is an ongoing product and process in development which harbors the most advanced scientific knowledge and adopts the most advanced technology. It is a joint effort of material science, machine technology, electronic control and ICT. Therefore, the advancement in steelmaking technology requires a close collaboration of the industry, R&D facilities and the universities.

The analysis of the weight composition trends and changes for the American Automotive Industry since 1975 supports the case that steel is still vital for the automotive industry today as it was in the past. Another outcome of the same analysis is that the steel has improved very much in quality through the same timeline and has been steadily transferred into a more value added material. It follows out that, as opposed to the belief that steel is a product of the old industry, there is huge amount of science and technology involved in the process development of steel making. Therefore some types of steels have a very high added value. The other analysis of the analysis of the itemized cost breakdown of a standard car also supports this argument as it reveals the fact that the material cost is a remarkable portion within the total. Therefore there is a continuous effort in developing lightweight materials in order to contribute to fuel efficiency. This fact makes the steel industry utilize science and technology to produce lighter but more superior steel alloys.

By considering the position of steel it turns out that a thriving steel industry is extremely vital for the United States as it was in the past 20'th Century not just because of the extensive industrial use of steel as a material but also for the purpose of developing more value added products. The recent re-industrialization policies aiming to support the domestic steel industry are therefore necessary.

CONCLUSION

This dissertation has focused on the function of manufacturing in creating economic growth and development. Nonetheless, in parallel it was aimed to reveal the factors behind the transformation of manufacturing industry and to elaborate on the effects it has had and continues to have on economic growth and prosperity.

It shows out that, historically, from 1850 until 2018, manufacturing industry has gone through a number of transformations which stemmed from either process or product development or in some cases from both. The transformations were clearly based on the advances in science and technology. Within the same time frame there have been changes in the contributions of the specific industrial sectors. The trend has always been towards producing more value-added. Especially, after the 1980's, with the impact of the world economic crisis in the early 1970's and the neo liberal policies that followed, there has been an ongoing offshoring activity for some industrial sectors to save costs. At the same time the service industry has been substituting for the manufacturing industry with a high pace both in terms of employment and the share of contribution to the GDP. There has also been a shift or transformation within the manufacturing industry. Once, traditional mass production, which was based "production determines the demand" philosophy has been substituted with lean and flexible manufacturing systems which have a production and inventory strategy based on real time market demand. Secondly, the manufacturing industry experienced a shift within itself from less value-added towards more value-added production. Advanced manufacturing technologies such as additive manufacturing, have been developed where production lines were supported with the tools of digitalization and robotics. Also, the sectors, which have been classified as high technology industries such as semiconductors, telecommunication, aerospace, and software technologies, etc. became more prominent. Nonetheless, in parallel with all these developments the so-called old industries such as the steel and aluminum still exist. Moreover, while those industries are continuously in progress in regard with product and process development with the contribution of the very high technology they are still the main suppliers of the main industrial sectors such as construction, automotive, defense, appliance, energy and packaging.

The thesis analyzes the case through the transformation of manufacturing in the United States in a time frame from 1870's through 2018. In order to elaborate more on the issue and to lay out more facts to support the argument of this dissertation, some part of the discussion has been focused on the American automotive industry. The automotive industry has been selected because it is a melting pot of various industrial sectors, it is a quick adopter of the latest technologies and it is a bridge between old and new industries like the steel industry and the ICT.

The first outcome of the dissertation is revealed during the examination of the chronological transformation of the manufacturing industry in the United States. The outcome is related first on how America became the successful world leader in manufacturing after the turn of the 20th century and then how this result had a noticeable positive impact both on economic growth and prosperity. Within the context of the dissertation it is argued that there exists a direct correlation between a strong manufacturing industry and solid economic growth and prosperity.

The period of 1870 and 1970 is the time when comprehensive breakthrough innovations are mostly diffused to various countries and industries in comparison to other centuries Also, in terms of data, the same century is the time when a relatively faster pace of economic growth occurred compared with all other times (Gordon, 2016). Among other factors most importantly the impact of manufacturing is the greatest and the influence of the manufacturing output on economic growth is more prominent within that time. As this thesis also argues, the impact of manufacturing on economic growth and prosperity is directly related with the density and the efficiency of innovations.

In evaluating the importance of the New Economy, which is a term used in the 1990's for the result of the transition from a manufacturing based to a service based economy, and the innovations that came along with the Internet and digitalization, in order to measure up, the New Economy has to equal the impact of the great inventions of the Second Industrial revolution in terms of life changing criteria and extent of the impact on society. A big increase in living standards was achieved through the invention of electric lighting, revolution in factory efficiency with the invention of the electric motor, flexibility and freedom that came with the automobile, saving time in travel achieved by the airplane, new materials achieved by the metal and chemical industries, ease of communication achieved by the telephone, arrival of live news and entertainment to the family parlor achieved by radio and then television, the raise in efficiency in business through the adoption of computers and the large improvements in life expectancy, health, and comfort achieved by urban sanitation and indoor plumbing (Gordon, 2000). We have not yet seen the impact on productivity from the existing advancement in technology such as cloud computing, internet of things, artificial intelligence, smart factories, additive manufacturing or even the radical increase in mobility through smart phones.

Literally, the American success until World War II is based on the quick adoption of the breakthrough innovations that came with advancements in science and technology and the mass production system, which were more widely applied after 1908. The other major contributing factors are the abundance of natural resources and the existence of a large domestic market which has sufficient wealth to meet the demand of the continuously growing manufacturing output. These developments have increased the efficiency and productivity in the manufacturing industry to the very high levels. Then, especially after the World War II, United States has very much accelerated investment into its national education system as well as into science and technology development. The investment has been both on human resources and physical capacity. Together with the thriving manufacturing industry United States also became the leader in the high technology production.

The impact of manufacturing is clearly seen both from the figures and the empirical observations in the century of 1870 until 1970. Compared to other times in history, this time frame, in particular between 1930 and 1970 is when productivity growth was at the highest level. Both the GDP and the personal income had been growing at a fast pace indicating steady economic growth. Also, from the economic development perspective, the same time frame, in particular between 1948 and 1970, is the period when there was a well-balanced income distribution and the disparity between the top ten and bottom 90 percent had the lowest rates compared with the other times in the history (Figure 3.10). Income inequality gradually began to increase after the oil embargo of 1973. Some studies analyzing the correlation between manufacturing and prosperity on a regional basis have shown that the increase in manufacturing jobs resulted in decrease in poverty. However, regarding the impact of manufacturing on income inequality, there is a need for more studies to strengthen the apparent negative correlation between the two. For present purposes it may be argued that there exists a negative correlation. Because the historical data shows that the rise in income inequality and the decline of manufacturing prominence in America occurred during roughly the same years.

Another positive impact of the manufacturing industry on prosperity comes from the indirect benefits in creating employment. Based on the data from Manufacturers Alliance for Productivity and Innovation, for $1.00 in manufacturing value-added output the multiplier effect is $3.60. Within the same line, for one manufacturing employee 3.4 workers are added to the economy elsewhere (NAM, 2018). According to the 2016 Annual Report prepared by "Manufacturing USA" the U.S. advanced manufacturing industry is selling to and buying goods from 80 industries worth one trillion dollars. It also has a high multiplier as it supports 16 jobs in other parts of the economy (Manufacturing USA, 2016:1).

More from the prosperity perspective, in the century of 1870 to 1970 the United States has been a clear front runner with a very big gap between it and other nations both in terms of economic growth and development. Many empirical observations on the living standards reflecting that time period support this case as well. As an example, already by 1929 at most American cities skyscrapers were built out of steel when other countries had no building structures anything like that. Besides, in the same year the United States was producing 80 percent of all cars in the world and 90 percent of each household owned a motor vehicle when in most of the countries only selective people were able to afford a car.

The period of 1900 to 1970 is clearly the time when America had the leading edge in manufacturing in the world. In the following period, the manufacturing value-added figures in the United States started to drop from 26 percent of total GDP level in 1967 to 12 percent levels in 2018 (Table 3.3) and (BEA, 2018a). For the same period manufacturing employment decreased from the 25 percent to 8.5 percent (Figure 3.9). There has been the drop by a factor of two in manufacturing value-added values and by a factor of three for the manufacturing employment figures. The downward trend could be attributed to various factors, such as the substitution of machines through automation, offshoring of some part of manufacturing, import substitution for domestic products or the change in the context of manufacturing where advanced manufacturing has altered some job definitions.

However, from the comparison of the numbers of the periods of 1870 to 1970 and 1970 until 2018, there has been a weakening of the manufacturing industry both in terms of contribution to GDP and to total employment which have caused a decrease in both productivity and income growth as well as deterioration in the income distribution. The growth rates of Total Factor Productivity (TFP), which is a measure of the impact of technology on productivity growth, is 1.89 on average between 1920-1970, 0.57 for 1970-1994, 1.03 for 1994-2004 and 0.40 for the period of 2004-2014 (Figure 2.12) It is clear that the period of 1920 to 1970 sticks out as the highest in TFP growth rate which also is referenced to the time when manufacturing was strongest in terms of value-added output as well as employment. This is also the period when breakthrough innovations transformed the manufacturing industry, the whole business and living standards of the people in radical forms. Also, the reason for a rise in growth for the period of 1994-2004 could be attributed to the impact of the Internet revolution after 1994.

Through the course of the transformation of manufacturing since the 1850's manufacturing has been at the core of creating prosperity. The advancements in the manufacturing industry have always been towards more value added and less labor intensity. This is based on a continuous relationship between technology and the manufacturing industry. During the time span of 1980 -2000, in the United States there was a prominent de-industrialization trend which had started mainly after the oil crisis in the early 1970's when the purchasing power decreased. The philosophy behind the de-industrialization trend in the West was the aim to reduce the in-country production costs through moving some part of manufacturing to the lower labor cost countries. This worked pretty well at the beginning but later in the following years, overdoing has led to many negative consequences to the U.S. economy such as loss of jobs, increasing trade deficits and weakening the competitiveness of the domestic manufacturing industry. The substitution of the service sector alone could not off-set the negative trade balance which was created from the decline in manufactured goods, either. The U.S. economy experienced the beginning of a steady and growing negative trade deficit after 1976 (Figure 3.6). After 2001, there even happened to be a negative balance in advanced manufacturing products (Figure 3.7).

Besides the cost and benefits of de-industrialization for the suppliers and buyers, the first negative consequence is the loss of employment and depressed wages. The proof is in the numbers that the share of U.S. imports in the GDP increased from 5.4 percent in 1970 to 16.5 percent in 1970. As some of the labor intensive jobs were offshored, domestically there were job losses and there has been a decline in the wages of the unskilled and middle skilled workers. Based on a recent analysis the imports from China between 1990 and 2007 are accountable for one quarter of the job losses in the American manufacturing sector besides other negative consequences such as lowered wages, decreased labor force participation rate, and an increase in publically financed transfer payments (Autor, Dorn, Hanson, 2013). Another specific example can be given regarding automobile parts. When the imports increased from $63 billion in 2001 to $138 billion in 2014, some U.S. part manufacturers either closed down factories or off shored their business to Mexico. Also, regarding the impact on the wages, the median wage in the automotive parts industry decreased $18.35 per hour in 2003 to $15.83 in 2013 (Gordon, 2016:614).

It is a fact that among the three industrial sectors manufacturing, services and agriculture, manufacturing has the highest rate of productivity growth (Table 1.1). It also employs one third of all engineers in America and contributes to two third of the U.S. total company R&D spending (Levinson, 2012). In other words, besides supporting high income advanced jobs manufacturing adds great deal to the ecosystem of science and technology development. The expected benefit is creating more value added manufacturing and increased productivity. From another perspective it can also be argued that, the productivity growth through technology rather than the reason for the job losses is actually the main condition for the manufacturing employment. Because low efficiency manufacturing plants will have a slim chance in surviving in today's competitive world (Levinson, 2012).

Consequently, as a first outcome of this dissertation, based on the historical facts I argue that there exists a positive correlation between manufacturing value added (output), manufacturing employment and productivity. In other words, there is a positive, and thus synergistic, relationship among the prominence of manufacturing, economic growth and prosperity

The second outcome of the dissertation accentuates the integrity and collaboration of the manufacturing industry, science and technology facilities and the qualified human power. This thesis argues that the excessive de-industrialization policies and trends of the United States which became prominent especially after 1980's has harmed the innovation ecosystem and even the capability of America to benefit from the inventions which are created on its own soil.

Within that concept I argue that advancement in applied sciences and technology is an ongoing process of trial and error. The scientific theories, design work and prototypes have to be tested out in the manufacturing facilities. Then feedback from experience of pilot testing in the manufacturing plant can be processed, evaluated, improved and sent back to the laboratory to be improved and tested again. Meanwhile, there may be some reclamation necessary at the manufacturing facilities. This process of continuous exchange of information and collaborative work ends up with the improvement of the existing process or product. This work requires a close collaboration between the universities, labs, engineering companies and manufacturing facilities. The geographical proximity of these commons is therefore important thus enabling increased innovation and effective application of innovation outcomes.

Advancements in technology has brought about many transformations in the manufacturing industry which has resulted in changes in the manufacturing structures as well as in the priorities among the industrial sectors. The trend has changed towards more value added and less labor intensity. The impact of the digitalization and automation in the production technology is expected to be negative in terms of employment and positive in terms of productivity and income. Actually, the more correct way of explanation is the shift from a less skilled workforce to a more qualified one in the production era. The thesis also argues that, despite this progressive evolution in science & technology the main segments such as the metal, automotive, air and space, electronic, chemical and biological industries still remain to play the determining role in the economic development as of the present day. As a matter of fact, the ICT and the service industries are rather the necessary but the complementary industries and that they are not the core stand alone factors within that regard. On the other hand the effect of the quantity and more importantly, the effectiveness of the technological innovations on the productivity of the manufacturing industry is undisputable. Thus, “in order to produce prosperity and to regain competitive advantage, America must continue to reinvest to product and process development in the main segments of its manufacturing industry” (Pisano and Shih, 2012). With the transformation of the manufacturing industry there has been a trend toward reducing direct employment. The decline in the U.S. manufacturing employment overall supports this case despite the fact that the reduction does not come solely from automation. In the US case after 1973, but mostly after 1980 the strength of manufacturing weakened because of decreased demand, purchasing power and distorted income distribution which have caused a slow-down in factory production. Also because of the quest to reduce production costs, considerable manufacturing was offshored after the second half of the 1970’s, predominantly accelerating after 1980’s. During the course of the shift from manufacturing to an increased service industry, despite the trend toward indirect job creation, mostly job losses have been compensated by the service industry rather than by employment in other supporting sectors of the manufacturing industry.

From another perspective in most cases the domestic production, as opposed to importing, has a more positive impact on indirect job creation. Because, there will be more push to use the domestic product for many reasons like government polices, easier access, availability, reliability and so on. For instance, the increase in percentage of the domestically made portion in the car industry yields in higher multiplier factors. Such that steel and aluminum are important portions of the car, hence domestically produced steel and aluminum will increase the quantity of domestically manufactured car parts and that will create more jobs in a natural way.

The ICT related sectors such as artificial intelligence , internet of things, robotic controls are being integrated into the manufacturing industry which increased efficiency and productivity during design, product and process development, production, testing, logistics, shipment, delivery, maintenance , marketing, sales and customer relations. Those sectors are relatively complimentary serving the main industrial sectors producing capital and consumer goods such as steel, aluminum, automotive, chemical, oil, air and space and electronic industry manufacturing.

In essence, breakthrough innovations like the internal combustion engine, electric motor, semiconductors, computer, microprocessor and Internet all served to increase speed, efficiency and productivity during manufacturing. They have also caused a change and evolution in the factory set up and production flow. To illustrate, the introduction of CAD/ CAM into the manufacturing industry increased efficiency and productivity while causing a change in the manufacturing flow chart and organization. This is a process development which caused structural transformation in factory production. In other words, a transformation in the manufacturing industry occurred which was caused by process development. The impact of this transformation has been rather on the improvement of efficiency and productivity just as was the impact of the introduction of mass production in the early 1900’s until the digitalization of the factory production at the present day.

There is also another level of “manufacturing transformation” when process development leads to product development. Within that scope, steel is an illustrative example. The steel making process developed and introduced by Henry Bessemer had two revolutionary implementations. The first one is the possibility of cost effective and large-scale steel production. The same process which is the basis of the converter technology is still the major methodology for producing steel as of today. In fact, this technology has enabled first Britain, then the United States, Germany, Soviet Union, Japan , South Korea and then China to make their own industrial revolutions as steel has been the core input material in many industrial sectors from construction to various segments of the manufacturing industry such as automotive, air and space, defense and so on. The second implementation of Bessemer’s innovation was opening a gateway for ongoing product development by means of process development. Basically, his process was based on blowing oxygen into molten pig iron to reduce carbon and impurities to convert the whole product into steel. As in principle with this process steel is the molten form, it gives the possibility to change the composition of the mix through different processes and through the addition of external additives. From 1850’s until now steel has been continuously developed as a product. The aim has always been to achieve improved strength, toughness and ductility properties per unit weight. Because eventually, better performance lightweight steel is expected to increase efficiency as well.

As it is also outlined in the case analysis of this dissertation about the historical material trends in Light Duty Vehicle manufacturing in America, there is no substitute for steel at this time. Although historically, there has been a slight decrease in total use of steel by weight, this reduction seems to be compensated by the use of better-quality materials such as advanced high strength steel (AHSS), besides aluminum and other composites. Nonetheless, based on scientific forecasts, steel seems to remain to be the major material in automotive manufacturing for the foreseeable future. A similar situation holds true also for other industries such as defense, aerospace, ship building, railway, construction and so on. Therefore, also as national security matter, in the United States there is an ongoing effort towards increasing the quality of steel through the collaborative work of the manufacturing industry, R&D facilities and universities. The sustainability of this effort depends on the existence of a strong national steel industry where the outcomes of research and development would be able to be tested and applied under real time conditions.

The bottom line is that the example of steel historically has caused the transformation of the manufacturing industry both through process and the product development. The process development first has led to the wide range use of steel which supported other industrial segments. With the mass production of steel, the mass production of automobiles, planes, ships, trains and airplanes became possible. The widespread use of these vehicles has improved the living standards of the people in a game changing manner. Therefore, it can be argued that the transformation of the steel industry following Bessemer's invention in the 1850's, a process innovation, has clearly increased the prosperity of the American people. Nevertheless, ongoing product development of steel has enabled steel to protect its position as a lightweight material in the continuously improving industry even as of today. As an example, the automotive industry use of lightweight materials matching the required safety standards is directly related to fuel economy. Fuel economy, on the other hand, is correlated with savings and as a result with economic growth. Eventually, as opposed to the common perception of defining steel manufacturing as an old industry, it reveals itself as a sector where the latest knowledge of science and technology has been intensively used for continuous process and product development.

Generally, it can be stated that, historically, the scope of manufacturing transformation is limited by either process or product development as well as in some cases by both. It can be argued that most of the transformations have been triggered by process development first that has led to product developments. However, the common attribute for all transformations has been an increase in efficiency which is reflected in the economy in the form of rising productivity. The bottom line is that the transformations in the manufacturing industry were triggered through either process or product development, or both, that were widely adopted by the whole industry and have in the end created long term positive impacts on both economic growth and prosperity.

Within this scope of the definition for the "transformation in manufacturing" some recently developed manufacturing technologies such as additive manufacturing or customized manufacturing are not in a position to replace the traditional manufacturing systems yet. It is also unknown if they will. Therefore, I argue that the ability of the future emerging technologies to transform the manufacturing industry will depend on the same criterion that is valid for the existing technologies. The transformation has to be comprehensive in nature and the impact on economic growth and prosperity ought to be remarkable.

REFERENCES

Abelson, P. H. (1982). "The Revolution in Computers and Electronics". ***Science, New Series***, 215 (4534), 751-753

Alexopoulos, M. and Cohen, J. (2009). ***The Media is the Measure: Technical change and employment, 1909-49.*** (Working Papers tecipa- 351). Toronto, ON: University of Toronto Department of Economics

Allen, R (1977), "The Peculiar Productivity History of American Blast Furnaces, 1840-1913", ***Journal of Economic History***, 37, 605-633

Allen, R (1981), "Accounting for Price Changes: American Steel Rails, 1879-1910", ***Journal of Political Economy***, 89, 512-528

American Automotive Policy Council [AAPC)] (2017). ***2016 annual contribution report on the U.S. Automotive Industry.*** Washington, DC: American Automotive Policy Council

American Automotive Policy Council [AAPC)] (2018). ***2017 annual contribution report on the U.S. Automotive Industry.*** Washington, DC: American Automotive Policy Council

Attaran, M. (2017). "The rise of 3-D printing: The advantages of additive manufacturing over traditional manufacturing ". ***Business Horizons,*** August 2017, 60(5), 677-688

Aubrey, J. (1949). ***Brief Lives.*** In Dick, O. L. (Ed.) London: Secker & Warburg, 317

Autor, D. H., Dorn, D., Hanson, G. H. (2013). "The China Syndrome: Local Labor Market Effects of Import Competition in the United States". ***American Economic Review***, 103 (6), 2121-2168

Babson, S. (1995). ***Lean Work: Empowerment and Exploitation in the Global Auto Industry***. Wayne State University Press, 6

Baily, N. M. and Bosworth, B. P. (2014). "US Manufacturing: Understanding Its Past and Its Potential Future". ***The Journal of Economic Perspectives***, 28(1), 3-25

Bairoch, P. (1982). "International Industrialization Levels from 1750 to 1980". ***The Journal of European Economic History,*** 11(2), 269-333

Barney, H. and Kirby, S. N. (2004). Toyota Production System/Lean Manufacturing. In B. Stretcher and S. N. Kirby (Eds.), ***Organizational Improvement and Accountability: Lessons for Education from Other Sectors***. Santa Monica, CA: RAND Corporation, 35-50

Bell, D (1973). ***The Coming of Post-Industrial Society: A Venture in Social Forecasting.*** New York, NY: Basic Books, Foreword, 1-47

Bilbao-Osorio, B., Dutta, S. and Lanvin, B. (2013). **The Global Information Technology Report 2013.** Geneva: World Economic Forum

Branscomb, L. M. (1982), "Electronics and Computers: An Overview", ***Science, New Series,*** 215(4534), 754-760

Broadberry, S. N. (1994), "Comparative Productivity in British and American Manufacturing During the Nineteenth Century", ***Explorations in Economic History,*** 31(4), 521-548

Brox, J. (2010). ***Brilliant: The Evolution of Artificial Light.*** Boston, MA/New York: Houghton Mifflin Harcourt, 164

Brunnermeier, S.B. and Martin, S. A. (1999). ***Interoperability Cost Analysis of the U.S. Automotive Supply Chain.*** (Final Report, Research Triangle Institute [RTI] Project Number 7007-03), Research Triangle Park, NC: Research Triangle Institute Center for Economic Research

Chen, D., Heyer, S., Ibbotson, S., Salonitis, K., Steingrimsson, J. G. and Thiede, S. (2015), "Direct digital manufacturing: definition, evolution, and sustainability implications". ***Journal of Cleaner Production***, 107 (2015), 615-625

Cobb, H. M. (2010). ***The History of Stainless Steel.*** Materials Park, OH: ASM International, 134-136

Dai, Q., Kelly, J and Elgowainy, A. (2016). ***Vehicle Materials: Material Composition of U.S. Light –duty Vehicles.*** (Argonne National Laboratory Report), Lemont, IL: Argonne National Laboratory Systems Assessment Group Energy Systems Division

David, P. A. (1990) "The Dynamo and the Computers: An Historical Perspective on the Modern Productivity Paradox". ***The American Economic Review,*** 80 (2), 355-361

Davis, R. M. (1977). "Evolution of Computer and Computing". ***Science, New Series,*** 195 (4283), 1096-1102

Devine Jr. W. (1983). "From shafts to wires. Historical perspective on electrification". ***Journal of Economic History, 43***(2), 347–372

Du Boff R. B. (1979***). Electric power in American Manufacturing, 1889-1958.*** New York: Arno Press, 97

Ezell, Stephen (2012). "Revitalizing U.S. Manufacturing". ***Issues in Science and Technology,*** 28(2), 41-50

Fain, D. C. and Pedersen, J., O. (2006). "Sponsored Search: A Brief History". ***Bulletin of American Society for Information Science and Technology,*** 32(2), 12-13

French, M. J. (1987). "The Emergence of a U.S. Multinational Enterprise: The Goodyear Tire and Rubber Company, 1910-1939". ***Economic History Review***, 40, 64-79

Gascon, C. S. and Spewak, A. (2017) "Advanced Manufacturing is Vital Across Nation, Including Eight District", Regional ***Economist***, 25(4), 18-20

Geels, F. W. (2006), “Major system change through stepwise reconfiguration: A multi – level analysis of the transformation of American factory production (1850-1930)”. ***Technology in Society***, 28 (2006), 445-476

Gordon, R. J. (2000). “Does the “New Economy” Measure up to the Great Inventions of the Past?”, ***The Journal of Economic Perspectives,*** 14 (4), 49-74

Gordon, R. J. (2016). ***The Rise and Fall of American Growth: The U.S. Standard of Living Since the Civil War. Princeton.*** NJ: Princeton University Press, 1-23, 120, 374, 375, 377, 379, 381, 382, 446, 447, 448, 451, 452, 499, 538, 540, 542, 543, 547, 550,551, 552, 553, 559, 560, 561, 568, 569, 575, 608, 609, 610, 614, 635

Hernandez et al. (2016). ***The Impact of Digital Technology on Digital Growth and Productivity, and its Implication for Employment and Equality: An Evidence Review.*** (Evidence Report No. 207), Brighton: Institute of Development Studies

Hobbes, T. (1651). ***Leviathan (Reprinted from the Original Edition),*** Oxford: Clarendon Press, 557 pp.

Hoke, D. (1980). “The Rise of the American System of Manufactures, 1800-1870: Smithsonian Institution, March 1978”. ***Technology and Culture,*** 21(1), 67-70

Hounshell D. A. (1984). ***From the American System to Mass Production, 1800–1932: The Development of Manufacturing Technology in the United States.*** Baltimore: Johns Hopkins University Press, 21, 23, 27, 44-49, 99, 250, 335, 351

Hudson, C. A. (1982). “Computers in Manufacturing”. ***Science, New Series,*** 215(4534), 818-825

International Iron and Steel Institute [IISI] (1978). ***A Handbook of World Steel Statistics.*** Brussels-Belgium. International Iron and Steel Institute Committee on Statistics

Internet: Abraham, A. (2015). ***Metallic Material Trends in the North American Light Vehicle:*** A report of Ducker Worldwide. Retrieved July 7, 2018, from Steel Market Development Institute web page: https://www.autosteel.org/~/media/Files/Autosteel/Great%20Designs%20in%20Steel/GDIS%202015/Track%202%20-%20Abraham.pdf

Internet: ***Aluminum consumption in light vehicles in North America from 1975 to 2028 (2018),*** Retrieved, August 11, 2018, from https://www.statista.com/statistics/496185/pounds-of-aluminum-per-car-in-north-america/

Internet: American Iron and Steel Institute [AISI] (2018). ***The Value of Steel in the Automotive Industry.*** Retrieved July 3, 2018 from https://www.steel.org/steel-markets/automotive

Internet: Canadian Automakers Union [CAW] (n.d.) ***Labor Cost, Vehicle Prices and Investment.*** Retrieved August 7, 2018, from http://www.caw.ca/assets/pdf/590-Auto_Price.pdf (07.08.2018)

Internet: Chien, Y. and Morris, P. (2017). ***Is U.S. Manufacturing Really Declining ?*** Retrieved September 7, 2018 from Federal Reserve Bank of St. Louis web site: https://www.stlouisfed.org/on-the-economy/2017/april/us-manufacturing-really-declining

Internet: Crawford, M. (2017). ***Four Advanced Manufacturing Technologies Used in Aerospace.*** Retrieved June 5, 2018, from https://www.asme.org/engineering-topics/articles/manufacturing-design/four-key-advanced-manufacturing-technologies-used

Internet: Environmental Protection Agency [EPA] (2015). ***Advancing Sustainable Materials Management: 2013 Fact Sheet. Assessing Trends in Material Generation Recycling and Disposal in the United States.*** Retrieved June 20, 2018, from https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_fs.pdf

Internet: Heuss, R., Muller, N., Wolff, V. S., Starke, A. and Tschiesner, A. (2012). ***Lightweight Heavy Impact.*** Retrieved August 20, 2018, from McKinsey &Company web site: https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/automotive%20and%20assembly/pdfs/lightweight_heavy_impact.ashx

Internet: Hill, K., Cooper, A. and Menk, D. (2010). ***Contribution of Automotive Industry to the Economies of all 50 Fifty State and the United States.*** Retrieved August 4, 2018, from the Center for Automotive Research (CAR) web site: http://www.cargroup.org/wp-content/uploads/2017/02/CONTRIBUTION-OF-THE-AUTOMOTIVE-INDUSTRY-TO-THE-ECONOMIES-OF-ALL-FIFTY-STATES-AND-THE-UNITED-STATES.pdf

Internet: Hula, A., Bunker, J. and Alson, J. (2015). ***Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2015*** (United States Environmental Protection Agency [EPA] Trends Report). Retrieved September 8, 2018, from The Transportation Research Board web site: https://trid.trb.org/view/1377968

Internet: Industry Commission [IC] (1995). ***IC Research and Development Report.*** Australian Government Publishing Service, Canberra, 15 May 1995 (Report no 44). Retrieved February 2, 2018, from Australian Government Productivity Commission web site: https://www.pc.gov.au/inquiries/completed/research-and-development/44randdv1.pdf

Internet: International Finance Corporation [IFC] (2018). ***Manufacturing Overview and IFC's Priorities in Manufacturing.*** Retrieved September 10, 2018, from https://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate_site/manufacturing/priorities/manufacturing_strategy

Internet: International Trade Administration [ITA] (n.d.). ***Automotive Team: Industry Trade Data.*** Retrieved May 5, 2018, from https://www.trade.gov/td/otm/autostats.asp

Internet: Jones, A., F. and Weinberg, D., H. (2000). ***Current Population Reports: The Changing Shape of the Nation's Income Distribution, 1947-1998. United States,*** June 2000 (Report No P60-204). Retrieved August 5, 2018, from United States Census Bureau web site: https://www2.census.gov/prod2/popscan/p60-204.pdf

Internet: ***Lightweight and Propulsion Materials (2018),*** Retrieved June 26, 2018, from https://www.energy.gov/eere/vehicles/lightweight-and-propulsion-materials

Internet: Manufacturing USA (2016). ***2016 Annual Report of Manufacturing USA.*** Retrieved January 5, 2018, from https://www.manufacturingusa.com/sites/prod/files/Manufacturing%20USA-Annual%20Report-FY%202016-web.pdf

Internet: Manyika et al., (2012). ***Manufacturing the Future: The Next Era of Global Growth and Innovation.*** Retrieved June 15, 2018, from McKinsey & Company web site:https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Operations/Our%20Insights/The%20future%20of%20manufacturing/MGI_%20Manufacturing_Full%20report_Nov%202012.ashx

Internet: Manyika et al., (2015). ***Global Growth: Can Productivity Save the Day in an Aging World.*** Retrieved June 5, 2018, from McKinsey & Company web site: https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Employment%20and%20Growth/Can%20long%20term%20global%20growth%20be%20saved/MGI_Global_growth_Full_report_February_2015pdf.ashx

Internet: McCormack, R. (November, 2006). "Council on Competitiveness Says U.S. Has Little to Fear but Fear Itself; By Most Measures, Is Way Ahead of Global Competitors". ***Manufacturing and Technology News***. Vol 13, No.21. Retrieved August 6, 2018, from http:/www.manufacturingnews.com/news/06/1130/art1.html

Internet: Mokyr, J. (1998), "The Second Industrial Revolution, 1870-1914", Retrieved December 25, 2017, from https://pdfs.semanticscholar.org/769c/a06c2ea1ab122e0e2a37099be00e3c11dd52.pdf

Internet: Nager, A., B. and Atkinson, R., D., (2015). ***"The Myth of America's Manufacturing Renaissance: The Real State of U.S. Manufacturing"*** Retieved July 20, 2018, from the Information Technology & Innovation Foundation [ITIF] web site: http://www2.itif.org/2015-myth-american-manufacturing-renaissance.pdf

Internet: National Association of Manufacturers [NAM] (2018). ***Top 20 Facts About Manufacturing.*** Retrieved May 7, 2018, from http://www.nam.org/Newsroom/Facts-About-Manufacturing/

Internet: National Research Council Board on Manufacturing and Engineering Design (1998). ***Visionary Manufacturing Challenges for 2020.*** Retrieved August 8, 2018, from https://www.nap.edu/catalog/6314/visionary-manufacturing-challenges-for-2020

Internet: Santacreu, A. M. and Zhu, H. (2018). "Manufacturing and Service Sector Roles in the Evolution of Innovation and Productivity". ***Economic Synopses,*** 2018, Number 2. Retrieved May 26, 2018, from Federal Reserve Bank of St. Louis web site: https://doi.org/10,20955/es.2018.2

Internet: Schultz, R. A. (2015). ***Metallic Material Trends for North American Light Vehicles.*** Research report prepared by Ducker Worldwide. Retrieved October 1, 2018, from Steel Market Development Institute (SMDI) web site: https://www.autosteel.org/-/media/files/autosteel/great-designs-in-steel/gdis-2007/21---metallic-material-trends-for-north-american-light-vehicles.ashx

Internet: ***Steel demand in the United States as of 2017, by sector (2018).*** Retrieved September 9, 2018, from https://www.statista.com/statistics/752484/us-steel-demand-by-sector/

Internet: Steel Market Development Institute [SMDI] (2014-a). ***Future Steel Vehicle Overview.*** Retrieved July 9, 2018, from https://www.autosteel.org/research/growth-of-ahss

Internet: Steel Market Development Institute [SMDI] (2014-b). ***Steel is the Solution to Achieve 54.5 MPG by 2025.*** Retrieved July 9, 2018, from https://www.autosteel.org/research/growth-of-ahss

Internet: Taylor-Kale, L. and Simpson, T. (2017). ***3D Printing and the Future of the US Economy.*** Retrieved September 9, 2018 from ATKearney web site: https://www.atkearney.com/operations-performance-transformation/article?/a/3d-printing-and-the-future-of-the-us-economy-article

Internet: Tuomi, I. (October, 2002). "The Lives and Death of Moore's Law", ***First Monday*** 7 (11), 1-30. Retrieved, July 20, 2018, from https://firstmonday.org/ojs/index.php/fm/article/view/1000/921

Internet: U. S. Bureau of Economic Analysis [BEA] (2018-a). ***Interactive Access to Industry Economic Accounts Data: GDP by Industry***. Retrieved October 4, 2018, from https://apps.bea.gov/iTable/iTable.cfm?ReqID=51&step=1

Internet: U. S. Bureau of Economic Analysis [BEA] (2018-b). ***Interactive Access to Industry Economic Accounts Data: GDP by Industry (Historical).***Retrieved October 27, 2018, from https://apps.bea.gov/iTable/iTable.cfm?reqid=147&step=2&isuri=1

Internet: U.S. Bureau of Labor Statistics [BLS] (2017). ***Employment by major industry sector.*** Retrieved April 21, 2018, from https://www.bls.gov/emp/tables/employment-by-major-industry-sector.htm

Internet: U.S. Bureau of Labor Statistics [BLS] (2018-a). ***Manufacturing: NAICS 31-33***. Retrieved May 12, 2018, from https://www.bls.gov/iag/tgs/iag31-33.htm

Internet: U.S. Bureau of Labor Statistics [BLS] (2018-b). ***All Employees: Manufacturing.*** Retrieved October 27, 2018, from Federal Reserve Bank of St. Louis (FRED) web site: https://fred.stlouisfed.org/graph/?g=cAYh

Internet: U.S. Bureau of Labor Statistics [BLS] (2018-c). ***Economic News Release, Table B-1. Employees on nonfarm payrolls by industry sector and selected industry detail.*** Retrieved June, 12, 2018, from https://www.bls.gov/iag/tgs/iag31-33.htm

Internet: U.S. Bureau of Labor Statistics [BLS] (2018-d). ***All Employees: Manufacturing and Manufacturing/Total Non Farm Pay Rolls.*** Retrieved June 12, 2018, from

Federal Reserve Bank of St. Louis (FRED) web site: https://fred.stlouisfed.org/graph/?g=k9pT&utm_campaign=myfred_referrer&utm_medium=exported-chart&utm_source=direct

Internet: U.S. Bureau of Labor Statistics [BLS] (2018-e). ***Automotive Industry: Employment, Earnings and Hours.*** Retrieved May 5, 2018, from https://www.bls.gov/iag/tgs/iagauto.htm

Internet: ***United States Car Production (2018).*** Retrieved October 1, 2018, from https://tradingeconomics.com/united-states/car-production

Internet: ***United States Census Bureau (2017).*** Measuring America: Manufacturing in America 2017. Retrieved June 12, 2018, from https://www.census.gov/library/visualizations/2017/comm/manufacturing-america-2017.html

Internet: ***United States Census Bureau (2018-a).*** Trade in Goods with Advanced Technology Products. Retrieved November 12 , 2018, from https://www.census.gov/foreign-trade/balance/c0007.html

Internet: ***United States Census Bureau (2018-b).*** Trade in Goods with World, Seasonally Adjusted. Retrieved November 12, 2018, from https://www.census.gov/foreign-trade/balance/c0004.html

Internet: World Bank (2017). ***World Development Indicators: Structure of Output.*** Retrieved October 28, 2018, from https://data.worldbank.org/indicator/NV.IND.MANF.ZS

Internet: World Bank (2018.-a). ***World Manufacturing Value Added (% of GDP).*** The World Bank Data. Retrieved May 28, 2018, fro https://data.worldbank.org/indicator/NV.IND.MANF.ZS

Internet: World Bank (2018.-b). ***China, Manufacturing Value Added, Current (U.S. $).*** Retrieved September 3, 2018, from https://data.worldbank.org/indicator/NV.IND.MANF.CD?locations=CN+%28-CN

Internet: Yu, Y, Yu, J, Pan, X., Stough, R. (2016), "The Rise of China's Innovation Economy: "Opening Up" Policy to Manufacturing Maturity, and on to Innovation Based Economic Growth and Labor Market Dynamics?", ***SSRN Electonic Journal***, Retrieved July 1, 2018, from https://dx.doi.org/10.2139/ssrn.2820864

Internet: Yuskavage, R. E. and Nader, M. F. (2005). ***Gross Domestic Product by Industry for 1947–86.*** Retrieved June 17, 2018, from US Bureau of Economic Analysis web site: https://www.bea.gov/scb/pdf/2005/12December/1205_GDP-NAICS.pdf

Jessop, B. (1992). Fordism and Post Fordism: a Critical Reformulation. In M. Storper and A. J. Scott (Eds.), ***Pathways to Industrialization and Regional Development***. Routledge, 42-63

Khana, R. (2012). ***Entrepreneurial Nation: Why Manufacturing is Still Key to America's Future***. New York City, NY: McGraw-Hill books, 13

Landes, D. S. (1998). ***The Wealth and Poverty of Nations.*** New York, NY: W.W. Norton and Co., 301

Leontief, W. (1953). "Domestic Production and Foreign Trade: The American Capital Position Reexamined". ***Proceedings of the American Philosophical Society,*** 97(4), 332-349

Levinson, M. (2012), "Why Reindustrialization is the Road to Recovery", ***New Labor Forum,*** 21(3), 10-15

Maddison, A. (1987). "Growth and Slowdown in Advanced Capitalist Economies". ***Journal of Economic Literature,*** 25(2), 649-698

Maddison, A. (1999, January 11). Poor until 1820. ***The Wall Street Journal,*** p. 8

Mansfield, E (1993). "The Diffusion of Flexible Manufacturing System in Japan, Europe and the United States". ***Management Science***, 39 (2), 149-159

Milgrom, P. and Roberts, J. (1990). "The Economics of Modern Manufacturing: Technology, Strategy, and Organization". ***The American Economic Review,*** 80(3), 511-528

Mokyr, J. (2002). ***The Gift of Athena: Historical Origins of the Knowledge Economy***, Princeton, NJ: Princeton University Press, 79, 89

Monteiro, A. J. M. (2001). ***Production Cost Modeling for the Automotive Industry, Master Thesis,*** Universidae Tecnica De Lisboa, Instituto Superior Tecnico, Lisbon, Portugal, 30, 54

Mowery, D. and Rosenberg, N. (1989). ***Technology and the Pursuit of Economic Growth.*** Cambridge: Cambridge University Press, 62-71

Muhleisen, M. (2018). "The Long and the Short of the Digital". ***Finance & Development***, 55(2), 4-8

Myers, B. A. (1998). "A Brief History of Human- Computer Interaction Technology". ***ACM interactions***, 5 (2), 44-54

Nelson, R. R. and Wright, G. (1992). "The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective". ***Journal of Economic Literature,*** 30(4) 1931-1964

Noble, D. (1977). ***America by Design: Science, Technology, and the Rise of Corporate Capitalism.*** Oxford: Oxford University Press, 192

Norcliffe, G. (1997), "Popeism and Fordism: Examining the Roots of Mass Production". ***Regional Studies,*** 31(3), 267-280

Peck, J. F. (1982). "The American Challenge of the Twenties: Multinationals and the European Motor Industry". ***Journal of Economic History***, 42(4), 865-81

Pelz, W. A. (2016). Becoming an Appendage to the Machine: The Revolution in Production. In ***People's History of Modern Europe.*** London: Pluto Press, 52

Pisano, G. P. and Shih, W. C. (2012). ***Producing Prosperity: Why America Needs A Manufacturing Renaissance.*** Boston, MA: Harvard Business Review Press, 4, 5, 8, 9, 10, 11, 12, 13, 46

Pretty intelligent: Smart Materials; self healing, communicative, and soon, even more? (2017, July 31). ***Beyond Surfaces,*** 6-13

Raber, M. (2017). "It would be impossible to estimate the value of these works…" Mass Production at Springfield Armory during the Civil War, ***Arms & Armour,*** 14 (1), 70-98,

Reenen, J. V. (1997). "Employment and Technological Innovation: Evidence from U.K. Manufacturing Firms". ***Journal of Labor Economics,*** 15(2), 255-284

Rhoades, L. J. (2005). "The Transformation of Manufacturing in the 21 st Century". ***The Bridge,*** 35(1), 13-20

Rogers, R. P. (2009). ***An Economic History of the American Steel Industry.*** New York, NY: Routledge

Romer, P. M. (1996), "Why Indeed in America? Theory, History, and the Origins of Modern American Growth". ***The American Economic Review,*** 86 (2), 202 -206

Rosenberg, N. (1963). "Technological Change in the Machine Tool Industry, 1840-1910". ***The Journal of Economic History,*** 23(4), 414-443

Rotman, D. (2013), "How Technology is Destroying Jobs", ***The MIT Technology Review***, 116(4), 28-34

Schmenner, R. W. (2001). "Looking Ahead By Looking Back: Swift, Even Flow in the History of Manufacturing". ***Production and Operations Management***, (10), 1, 87-96

Smith, C and Wise, M. N. (1989). ***Energy and Empire: A Biographical Study of Lord Kelvin. Cambridge.*** Cambridge: University Press, 660

Smith, G. O. (1919). ***The Strategy of Minerals.*** New York, NY: D. Appleton and Company, 288

Watson R, Crawford M and Farley S. (2003). ***Strategic Approaches to Science and Technology in Development.*** (Policy Research Working Paper No. 3026). Washington, DC: The World Bank

Wilensky, H. L. and Lebeaux, C. N. (1958). ***Industrial Society and Social Welfare: the Impact of Industrialization on the Supply and Organization of Social Welfare Services in the United States.*** New York, NY: The Russell Saga Foundation, 401 pp.

Womack, J. P. (1989). ***The U.S. Automobile Industry in an Era of International Competition: Performance and Prospects.*** (Industrial Productivity Working Paper), Cambridge, MA: MIT

Womack, J.P. and Jones, D.T. (1996). Lean ***Thinking: Banish Waste and Create Wealth in your Corporation***. New York, NY: Simon &Schuster, 350 pp.

Womack, J.P., Jones, D.T. and Roos, D. (1990). ***The Machine That Changed the World.*** New York, NY: Free Press, 352 pp.

World Bank Group Strategy (2002). **Information and Communication Technologies.** Washington, DC: World Bank Group Strategy

World Steel Association [WSA] (2017). ***Steel Statistical Year Book 2017.*** World Steel Association. Brussels- Belgium: World Steel Association Economics Committee

Wright, G. (1990), "The Origins of American Industrial Success, 1879-1940". ***The American Economic Review***, 80 (4), 651-668

Zimmerman, F. and Beal, D. (2002). ***Manufacturing Works, The Vital Link Between Production and Prosperity.*** Chicago, IL: Dearborn Financial Publishing, Inc., 112, 113, 116

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Yayınlar

1. Özer-İmer, I. and İmer, S., T. (2020) "The Political Economy of Restructuring in Science and Technology in Turkey", ***European Review*** (index in SSCI, forthcoming, 28(3)
2. İmer (2016) "The Issue of Controlling Technology & the Role of the Government in the Development of the 'National and Regional Innovation Ecosystem' with the case in the United States", ***Yeni Türkiye,*** 89 (2), 171-184

Hobiler

Yürüyüş, Kitap okuma, Seyahat, Aikido

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