EXAMINING THE RELATIONSHIP BETWEEN CONTRACT MANUFACTURING INVENTORY EFFICIENCY AND INFORMATION SYSTEM INVESTMENT: AN EMPIRICAL STUDY OF THE U.S. MANUFACTURING SECTOR

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ABSTRACT

In this thesis, we conduct an empirical study on how contract manufacturing drives the change in inventory levels and what role the information system plays under the contract manufacturing strategy. Contract manufacturing commonly exists in the manufacturing sector. Original equipment manufacturer (OEM) prefers to simplify its inner operating processes, so OEM outsources the manufacturing process or assembling process to the contract manufacturer (CM). The utilization of outsourcing strategy optimizes the operation structure and management hierarchy. In the OEM-CM supply chain network, enterprise-wide information system not only performs as the platform for information sharing, but also lubricates the internal and external information flow exchange. A supply chain network with efficient communication can achieve outstanding operation performance. We launch an industry-level research to investigate the integrated utilization of contract manufacturing and information system, and examine the relationship between contract manufacturing inventory and information system investment.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

The historical study indicates that contract manufacturing accounted for approximately 60% of the total product cost of the U.S. manufacturing industry by the end of 1980s (Ballou, 1992). A Recent study on electronics industry points out that contract manufacturing contributed 265 billion dollars in 2008 and may hit 327 billion dollars in 2014 (Parker, 2009). According to these numbers, it is obvious that there is still a high demand for contract manufacturing in the modern supply chain. Some scholars also find that information technology support such as information system has a moderate effect on manufacturing operation and resource planning (Chen and Li, 2013). This chapter will provide overviews of the modern supply chain management, contract manufacturing, information system, and inventory management. Then we will introduce the research motivation, research objectives, and the structure of the thesis.

1.1. Overview of Modern Supply Chain Management

As the basic operation stages of the manufacturing industry, procurement, production, and distribution used to be managed separately. Manufacturers have to keep a larger inventory to buffer the uncertainties (Thomas and Griffin, 1996). However, to stay competitive and improve customer service in the modern business environment, manufacturers adopt supply chain management: integrated planning of procurement, production, and distribution (Tan, Lyman and Wisner, 2002).

The operation strategies and marketing strategies are various between different manufacturers. The type of supply chain depends on what strategies the manufacturer applies. If the manufacturer concentrates on fulfilling customer demand, which means it needs to replenish the finished goods inventory in time. Then the operator will use vertical integration to establish the entire production line from raw material sourcing to finished goods distribution (Guan and Rehme, 2012). A successful example of vertical integration is Starbucks Coffee. Starbucks controls and adjusts its manufacturing, inventory control, and sale channel right after receiving orders from the customer, the order data is processed using its company information system (Teitelbaum, 1992). Some other manufacturers choose the channel assembly supply chain, they outsource partial or even the entire production line. Thus, they do not hold the materials and supplies inventory, parts and components inventory, or even the finished goods inventory to minimize the operation complexity and costs. In other words, the original equipment manufacturers outsource their assembly work to the contract manufacturers. For example, electronic manufacturer Apple. Inc. outsources the manufacturing process to its contract manufacturing partner, Foxconn and Pegatron (Dou, 2013). Apple only focuses on new product research and development and finished product marketing.

1.2. Overview of Contract Manufacturing in Supply Networks

During the past twenty years, economic globalization forces the original equipment manufacturers (OEMs) to become more competitive. In order to achieve this objective, OEMs have to reconsider the operating cost, customer service level and investment in product innovation (Handfield et al., 1999; Niezen and Weller, 2006). Realizing this problem, OEMs choose to outsource manufacturing processes to the contract manufacturers (CMs). Many scholars indicate contract manufacturing strategy can benefit the operation and development of the manufacturing companies. The utilization of contract manufacturing enables OEMs to take advantage of the CMs' product capability. Contractual mechanisms also free up OEMs own capital and let them have more resources to focus on core competencies (Schilling and Steensma, 2001; Plambeck and Taylor, 2005; Bardhan, Mithas and Lin, 2007; Cheng, 2010; McCarthy, Silvestre and Kietzmann, 2013).

We have witnessed OEMs using contract manufacturing strategy successfully in different industries. For example, the OEM-CM pair, Apple-Foxconn. Foxconn obtained approximately 80% of the iPhone 6 assemble orders and all of the iPhone Plus assemble orders from Apple in 2014. Thus, Apple can concentrate on their focal objectives such as new product design and marketing. Other OEM-CM pairs have been mentioned by researchers as well, such as Dell-Quanta Computer, Intel-Venture Corporation, and Honeywell-Scantron (Cheng et al., 2012). Some other OEMs prefer the multi-supplier strategy in contract manufacturing. For instance, NIKE is the one of the leading sportswear manufacturers in the United States. Because of its product diversity, it has 715 contract manufacturing factories spreading in 44 countries around the world, including Mexico, Poland, Australia and Southeast Asia countries (NIKE, 2014).

1.3. Overview of Information Systems in Supply Chain Management

Information system (IS) enhance the information sharing and logistics integration of the OEM-CM supply chain network. Researchers have found that OEMs and CMs connected by efficient information systems can substantially eliminate the information distortion and delay. The timely information sharing in turn leads to operation processes optimization (McCarthy, Silvestre and Kietzmann, 2013). Furthermore, information system between OEMs and CMs can provide real-time communication and data processing. Information system supports and optimizes the mechanism of inventory management tools such as the just-in-time (JIT) inventory management, material requirements planning (MRP) inventory management and enterprise resource planning (ERP). Therefore, manufacturers can achieve better operation performance, inventory performance and customer satisfaction (Prajogo and Olhager, 2012, Lee et al., 2000, Gaonkar and Viswanadham, 2001; Ribinovich, Dresner and Evers, 2003).

In recent years, manufacturers launch the implementation of big data and cloud computing to upgrade their information systems. The new technologies bring revolution to manufacturing industries: big data and cloud computing integrate the product quality management, sales and marketing management, human resource management and ERP. Supply chain managers can monitor, control, and respond in one integrated dynamic information system platform (Xu, 2012). Big data and cloud computing leaders such as Amazon, Microsoft, and Google have already been providing public cloud computing services. We can infer that, the number of firms seeking the benefits of cloud computing is continuous increasing.

1.4. Overview of Inventory Management in the Supply Chain

The term inventory level has appeared in many supply chain management researches, and operation management studies. Scholars use it as a parameter of inventory efficiency (Rajaagopalan and Malhotra, 2001; Cheng et al., 2012). The inventory has been specified into three categories: materials and supplies (MS) inventory, work in process (WIP) inventory and finished goods (FG) inventory. Studies point out that OEMs tend to push their inventories to CMs and contract manufacturing may have different effects on MS inventory, WIP inventory, and FG inventory. Moreover, researchers believe that the integration of information system can significantly benefit the inventory performance (Saldanha et al., 2013).

1.5. Research Motivation

We find timeliness related gap between our research and previous similar studies. Cheng (2011) used the 1997 and 2002 Economic Census data by the U.S. Bureau of Census in his research regarding with the contract manufacturing. The data of information technology investment he used was from the National Income and Product Accounts (NIPAs) database by U.S. Bureau of Economic Analysis (Cheng, 2011). The datasets are not systematic due to the differences in the statistical sample and statistical approach; the differences may amplify the errors in the data analysis. More than ten years has passed since 2002; his data cannot reflect the current status of the manufacturing industry. During the period from 2002 to 2012, we have witnessed new technology implementation and economic development. We have reasons to query whether the effects of contract manufacturing and information system investment on inventory level have changed or not. The 2012 Economic Census data of U.S. manufacturing sector was newly released in August, 2014 by U.S. Census Bureau. We are motivated to launch a new study using the newly updated industry level data. We want to identify the possible changes in the contract manufacturing and information system investment after the broad adoption of big data, and cloud computing occurred around 2010 (Xu, 2012).

1.6. Research Objectives

There are multiple objectives of this thesis:

1. To examine the effect of contract manufacturing and information system investment on inventory levels of respective industries in the entire U.S. manufacturing sector;

2. To empirically investigate how the integration of contract manufacturing strategy and information system investment take effects on the inventory efficiency of the U.S. manufacturing industries.
3. To perform a quantitative analysis, and to test a set of hypotheses.

1.7. Thesis Outline

The rest of the thesis is organized as follows. In Chapter 2, literature reviews discuss the possible factors that have effects on manufacturing inventory, followed by a set of hypotheses. The hypotheses are concerning the impacts of contract manufacturing and information system investment on inventory levels in manufacturing industries. In Chapter 3, the data sources and research method are reported. The thesis then presents linear regression data analysis and hypotheses results in Chapter 4. In Chapter 5, we will discuss the hypotheses testing results, implications of our findings, and limitations of our research. Finally, a conclusion of the relationship between contract manufacturing and information system, and inventory levels in U.S. manufacturing industry will be presented.

CHAPTER 2. LITERATURE REVIEWS AND HYPOTHESES

In this section, the literature describes the general concept of contract manufacturing, information system investment, and inventory management. Moreover, the theoretical background of factors associated with inventory efficiency will be given. We refer to the works of various scholars to develop our hypotheses and research models; the emphasis is on the mechanism of how contract manufacturing and information system investment affect the inventory level.

2.1. Contract Manufacturing and Supply Chain Management

Contract manufacturing (CM) is a type of outsourcing strategy. Original equipment manufacturer (OEM) outsources its entire or partial manufacturing processes to the external contractors based on contracts and agreements (Han, Porterfield and Li, 2012). The outsourced manufacturing processes may include parts and components production, finished goods assembly, OEMs just need to push the fully assembled, packaged finished products to the market (Kim et al., 2002; Shy and Stenbacka, 2003). Due to the pressure of fierce competition, abolition of trade barrier, and the development of transportation and communications, contract manufacturing is widely used by OEMs to enhance their supply chain performance (Hülsmann, Grapp, and Li, 2008; Golini and Kalchschmidt, 2011).

Because of the increasing competitive environment caused by the globalization, original equipment manufacturers are seeking cooperation with contract manufacturers to lower their costs and optimize the resource allocation. Plambeck and Taylor (2005) indicate that OEMs close their production plants and outsource the manufacturing processes to CMs. At the same time, CMs have high capability to supply multiple OEMs and reach economies of scale (Cheng et al., 2012). For example, Apple outsources most of its orders to Foxconn so that Apple can allocate more funds and resources for the design, research and development of the new generation product. Hence, both the OEMs and CMs can concentrate on extending the advantages of their core competencies.

In the 1980s, vertical integration was quite a common phenomenon that existed in most of the manufacturing companies. Vertical integration is an expanding strategy to achieve management centralizing, cost and lead time reduction by buying and merging the upstream suppliers (Breandán Ó, 1996; Swink, Narasimhan and Kim, 2005). However, in the modern manufacturing industries, the product life cycle becomes much shorter than the old times. Manufacturing companies have to take more effort to concentrate on product innovation and quick response marketing service (Nassimbeni and Sartor, 2007). Contract manufacturing makes it the way to reduce the manufacturing operation complexity. It is also possible to obtain inventory efficiency by adopting JIT and other improvement methods no matter domestic or international (Golini and Kalchschmidt, 2011).

However, contact manufacturing also has several disadvantages such as locked contract, poor supplier management and communication (Feeny, Lacity and Wilcocks, 1995; Quinn 1994; Bardhan, Mithas and Lin 2007). The agreements or contracts between the OEMs and CMs are usually fixed and unchangeable during the contract period. Once the market demand or the material price has significant fluctuations, OEMs and CMs cannot make adequate adjustments in a timely manner, which means they lack the ability to mitigate the risks. Aside of market uncertainties, the unknown of suppliers' capacity and quality control could incur extra operating cost and additional inventory of OEM (Ren and Zhang, 2009). So OEMs have to think about these challenges and find out solutions first before they utilize contract manufacturing.

2.2. Information System Investment for Supply Chain Management

The implementation of information system considerably progresses information sharing and logistics integration between the OEM and its CMs. Numerical experiments show that information sharing could reduce the operating cost and inventory level (Gaonkar and Viswanadham, 2001). In logistics integration practice, information system help manufacturers make more accurate and precise forecast of production supplies usage; it is a significant optimization to enhance the JIT inventory management and the MRP inventory management. With the help of these management optimizing tools, OEMs can improve their inventory performance as measured by inventory forecast and lead times. (Weill, 1992; Ribinovich et al., 2003).

Information system plays as a coordinator between the OEMs and CMs; the internet-based information system provides a real-time transaction and data communication to collaborate the JIT and MRP adoptions. For example, Dell realizes a systematic inventory reduction by the integrated solutions of its information system. After Dell customers place orders by phone or online, Dell will approve the orders, and then the order will be sent to its suppliers via the information sharing system. The suppliers can get the exact amount and type of the materials and components in few hours, at last the supplies will be delivered shortly from the nearby warehouses (Kapuscinski et al., 2004). Thus, the final products can be assembled in eight hours and are ready to ship within five days. Previous research has shown that enterprise-wide information system used in managing inventory benefits to MRP and JIT adoptions (Germain and Dröge, 1995).

2.2.1 Information System Hardware

The information system investment includes both hardware investment and software investment. Hardware of the information system includes computers, internet infrastructures, and portable devices. The type of portable devices various. For example, the smartphones, Radio Frequency Identification (RFID) transmitters/receivers, and Bar Codes readers, etc. (Tserng et al., 2005; Lin, Lo and Chiang, 2006). Regarding the hardware nowadays, the implementation of cloud computing has shifted the accuracy of big data forecasting and analyzing greatly. In particular, manufacturers can purchase the service from the public cloud provider such as Amazon Web Services (AWS) instead of spending money on building the traditional server farms themselves. There are also companies providing long-term and highly customized services, such as SAS. Cloud computing is entering the manufacturing industry and acting as a primary enabler (Xu, 2012). However, some other researchers point out that public cloud computing may cause security issues and may not fit their current enterprise resource planning (ERP) processes (Hofmann and Woods, 2010).

2.2.2. Information System Software

The enterprise-wide information system software has already been used widely in the modern manufacturing industries (Wu and Ellis, 2000). There are many welcomed and powerful commercial information system software such as SAP, Microsoft Dynamics, and Oracle. For example, SAP has been widely adopted by manufacturers in different industries. It has several variants like SAP ERP, SAP SCM, and SAP PLM which cover resource planning, supply chain management, product life-cycle management respectively. SAP ERP can consolidate the information flow and filter the duplicated information to avoid wasting of the resource. The SAP software is also a platform providing the real-time connection between the manufacturers and customers which improves both operational efficiency and customer service level. Shell purchased the SAP system to proceed the company-wide financial closings in order to realize continuous process improvement. With the help of this system, Shell can have a global view of its operational performance, and it has recently upgraded its SAP software to make it compatible with cloud computing (SAP, 2014).

2.3. Manufacturing Inventory Types

The annual survey of manufacturers run by U.S. Census Bureau categorizes the manufacturing inventories into 3 categories: materials and supplies (MS) inventory, work in process (WIP) inventory and finished goods (FG) inventory.

- Materials and supplies inventory refers to all materials and parts used for primary manufacturing.
- Work in process inventory includes ready for assembly parts, components, and other intermediates.
- Finished goods inventory refers to for sale products storing in the factory warehouse or distribution center (Vastag and Montabon, 2001; Oke and Szwejczewski, 2005).

To have a better understanding of the classification of the inventory types, we list some examples in the automotive industry. Steel plates and aluminum plates belong to the MS inventory. Tires, batteries, and car frames are in the WIP inventory. FG inventory includes finished cars and car accessories.

This thesis uses the economic census data to conduct data analysis. Some longitudinal studies analyzed the historical data from 1960s to 2000s and found that the industry-level inventory of U.S. manufacturing sector has a decreasing trend during this period (Rajagopalan and Malhotra, 2001; Swamidass, 2007; Irvine, 2003). However, with respect to the MS inventory, WIP inventory, and FG inventory respectively, scholars discovered different historical trends. Rajagopalan and Malhotra (2001) analyzed the data of U.S. manufacturing sector from 1960 through 1994 conducted by U.S. Census Bureau. The research found that only the MS inventory and WIP inventory had significantly declined. Meanwhile, the FG inventory had a slightly decreasing trend.

2.4. Supply Chain Factors Associated with Inventory Efficiency

2.4.1 JIT

JIT refers to just-in-time inventory management, also known as Kanban. This concept originated from Toyota and was first introduced to the U.S. manufacturing industries in the early 1980's. It advocates that the materials and supplies should be delivered directly to the work-in-process area with the right amount, to the right place and at the right time. The goal of JIT inventory management is to cut down the costs of inventory inspection, handling, damage, and maintenance to the utmost (Epps, 1995; Rosenberg and Campbell, 1985; Chhikara and Weiss, 1995).

Over the last three decades, we have witnessed that JIT practice in many manufacturers worldwide. Numerous literature documented that the successful implementation of a JIT approach can achieve lower production cost, better product quality, and less response time of finished good delivery (Nakamura, Sakakibara, & Schroeder, 1998; Beard and Bulter, 2000). As mentioned in the contract manufacturing literature, the manufacturing and assembling oriented contract manufacturers are easy to achieve economies of scale.

2.4.2 Square root law

Square Root Law (SRL), the theory states that the total numbers of safety stock can be predicted by multiplying the total inventory by the square root of the number of centralized or decentralized warehouses divided by the number of current warehouses. In brief, the overall inventory level in the supply chain network is in direct proportional to the square root of the number of warehouses. It means the less the warehouse locations, the lower the inventory level (Evers, 1995). Contract manufacturing makes it possible for the OEMs to push the inventory to contract manufacturers and upstream suppliers, thus, OEMs can minimize the numbers of their warehouses. In other words, contract manufacturing facilitates the inventory centralization in the supply chain network (Croxton and Zinn, 2005).

2.4.3 Bullwhip effect

Bullwhip effect refers to a phenomenon that order variance becomes greater when moving upstream in a supply chain network. The effect can amplify from stage to stage in a multi-stage supply chain (Lee et al., 1997; Sucky, 2009; Ouyang and Li, 2010). The increasing variance of order may extra demand for warehouses, production capacity, and product stocks when the actual market demand remains stable (Chatfield et al., 2004; Coppini et al., 2010). Some scholars identify the major causes of the Bullwhip effect as incorrect demand prediction, supply shortage, lead time variation, order batching, and price fluctuation (Lee et al., 1997).

Contract manufacturing involves the upstream of a supply chain network. It can be regarded as an additional stage comparing with a typical supplier-manufacturer-retailor supply chain network. Contract manufacturing is the extra stage between supplier and manufacturing (Sucky, 2009). In other words, the suppliers have higher upstream level under the contract manufacturing strategy; therefore, the Bullwhip effect will make the demand variance even greater. The products from contract manufacturers usually have longer leading time. Severe delay of order information update from OEM may occur due to the insufficient communication between OEM and CM. These factors can amplify the Bullwhip effect and lead to higher inventory level (Cheng, 2011).

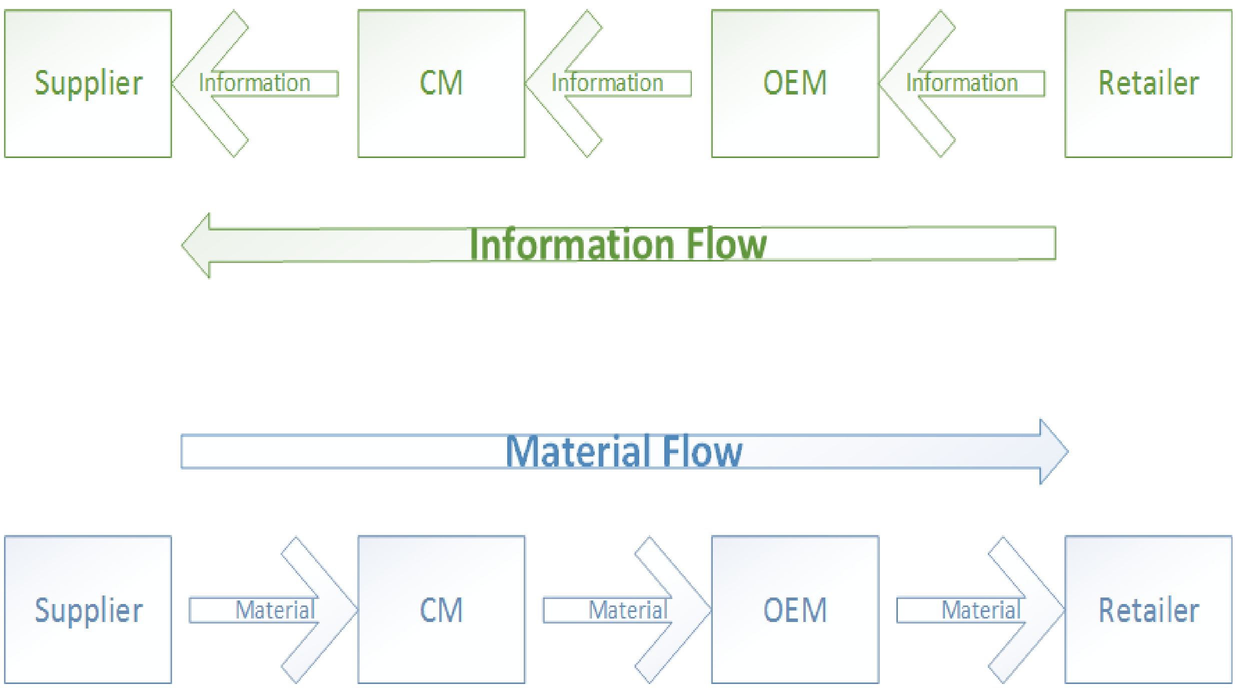

Figure 1. Multi-stage Supply Chain Structure

Figure 1 illustrates the direction of information flow and material flow in a multi-stage supply chain network. The information distortion is positively associated with the increase of supply stages. Bad information distortion can cause a larger amount of material flow from the supplier to the retailer, material flow includes raw materials inventory, work-in-process components inventory, and finished goods inventory. The Bullwhip effect will increase all inventory categories.

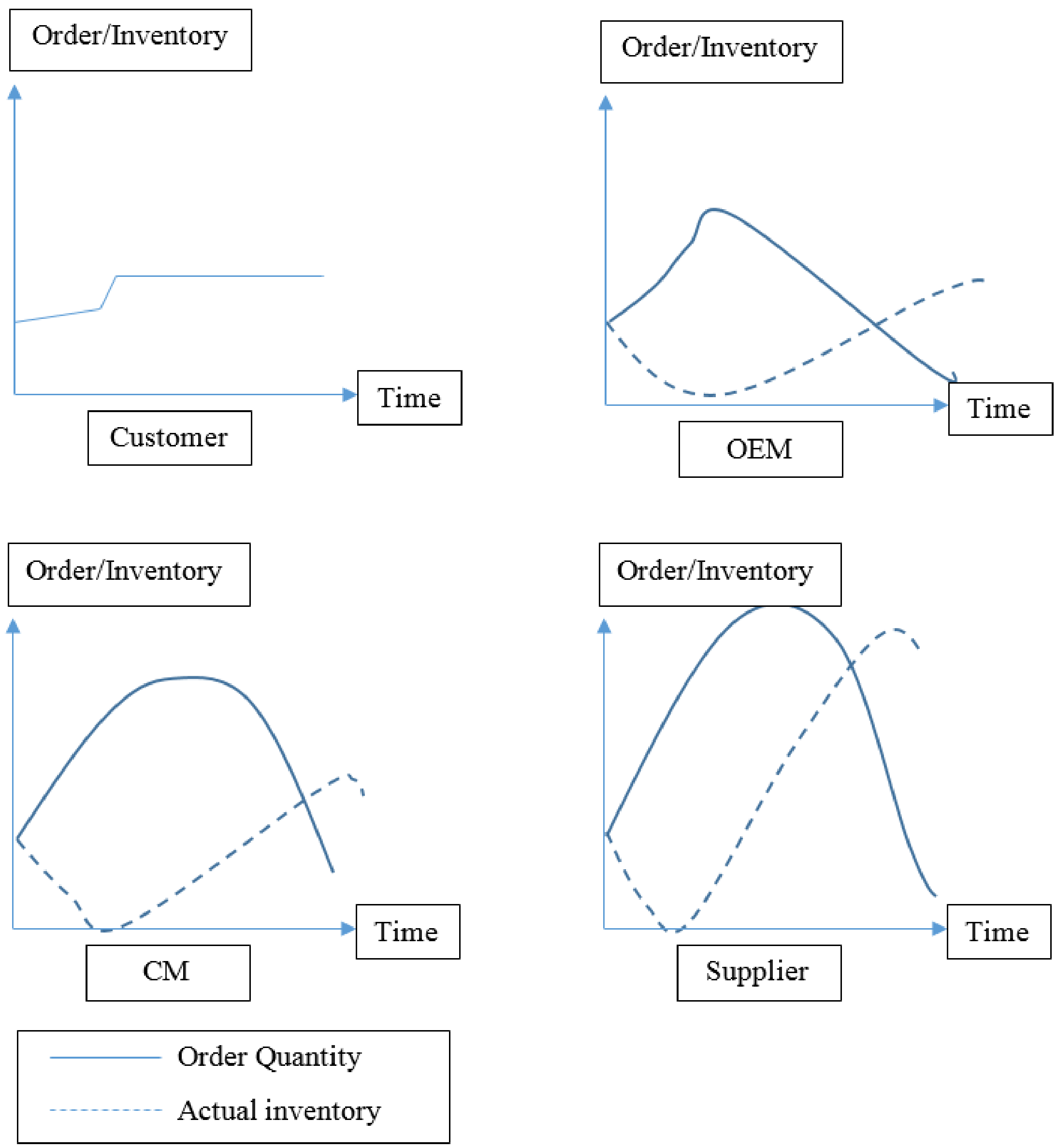

Figure 2. Bullwhip Effect Fluctuates the Order Quantity

A stream of studies utilizes statistical methods to analyze the order variances and compare the orders submitted with and without information system. Scholars find that the information system can reduce the Bullwhip effect and help to allocate the inventories of the entire supply chain network efficiently. However; the Bullwhip effect cannot be eliminated (Chen et al., 2000; Ouyang, 2007). Figure 2 shows how the Bullwhip effect fluctuates the actual demands in an OEM-CM supply chain.

2.5. Effects of Contract Manufacturing on Manufacturing Inventory Level

According to square root law, the less the warehouse locations, the lower the inventory level will be. OEMs are motivated to forward the inventory management to upstream suppliers together with the operational processes. Thus, CMs can consolidate the warehouses seeking lower inventory level to achieve cost reduction and distribution optimization. Bullwhip effect will also force the OEMs outsource the whole production processes to CMs. Because OEMs can reduce the supply chain stages that operated by themselves, less supply chain stages of OEMs mean that minor Bullwhip effect on OEMs (Sucky, 2009).

2.5.1. Effects of contract manufacturing on MS inventory level

OEMs are pushing the materials and supplies purchasing towards their CM partners to cut off their operational complexities such as the transportation and warehousing of the raw materials. Thus, they can focus on the high-value design and marketing aspects of the business (Gaonkar and Viswanadham, 2001). The modern OEMs usually do not specialize in product manufacturing; they are more likely to set their sights on new product development and technology innovation (Chen and Li, 2013). For example, NIKE prefers to set its sights on design and research of new products, the manufacturing process has been outsourced to its CMs in China, Mexico, and Southeast Asia countries. Meanwhile, these CMs also accept contracts from Adidas and Puma. This phenomenon widely exists in manufacturing industries such as NVIDIA (OEM) and TSMC (CM), Apple (OEM) and Foxconn (CM). Therefore, when using contract manufacturing, OEMs do not operate MS inventory, the level of MS inventory decreases.

H1. The higher the contract manufacturing utilization, the lower the MS inventory level

2.5.2. Effects of contract manufacturing on WIP inventory level

The utilization of contract manufacturing can also benefit the industry's WIP inventory performance. Since the WIP inventory contains value-added parts and components, usually the WIP inventory requires better storage environment and more frequent maintenance. OEMs are more willing to push the WIP inventory to CMs. By pushing the WIP inventory to CMs, the OEMs can maintain a lower amount of WIP inventory. Therefore, OEMs can reduce the cost of warehouse facility and operation for WIP inventory. In order to mitigate the risks of WIP inventory out of stock, OEMs usually outsource the parts and components to multiple CMs. The multiple CMs strategy can make the CMs more competitive so that the OEMs can receive products with better quality and cheaper price.

H2. The higher the contract manufacturing utilization, the lower the WIP inventory level

2.5.3. Effects of contract manufacturing on FG inventory level

Many of the contract manufacturers are located outside of the United States. As a result, for their OEMs who tend to achieve advantage of the quick response strategy, CMs need to prepare sufficient FG safety stock to buffer the sudden change of market demand, materials, and components prices fluctuations. Jain, Girotra and Netessine (2013) point out that in order to reduce the risks of transportation delay and other uncertainties, it is necessary for CMs to maintain a higher safety stock of FG inventory. However, it will not prevent the FG inventory level of OEM from going down.

H3. The higher the contract manufacturing utilization, the lower the FG inventory level

2.6. Effects of IS investment on manufacturing inventory level

2.6.1. Effects of IS investment on MS inventory level

Information system provides real-time monitor, it can help avoid information asymmetry and provide the manufacturing planners with capability information (McCarthy, Silvestre and Kietzmann, 2011). OEMs can utilize the order on demand strategy; they can require the right amount of materials and supplies deliver to the right manufacturing plant at the right time after they approve new orders. Thus, the materials and supplies can be put into production shortly rather than laying in the warehouse.

H4: The more the IS investment, the lower the MS inventory level

2.6.2. Effects of IS investment on WIP inventory level

Small WIP inventory strategy benefits the Hi-Tech manufacturing industries as it moderates the risk of new technology updating. According to Moore's law, the performance of the microchip would double every 24 months (Moore, 1998). It means the product life cycle of microchip parts and components is relatively short in the Hi-Tech manufacturing industry. The rapid technology innovation and new product replacement require manufacturers maintain a lower and more reasonable WIP inventory level.

H5: The more the IS investment, the lower the WIP inventory level

2.6.3. Effects of IS investment on FG inventory level

In order to control the risk of a sudden increase in the market demand and other uncertainties, OEMs usually set sufficient safety stock level as a buffer in case of these risks. However, the modern enterprise-wide information system make significant changes in that situation due to its automatic real time report and transaction capabilities. For instance, P&G and Wal-Mart's distribution centers are connected by an automatically information system that will send alerts to P&G for out-of-stock products and provide producing and shipping suggestions to P&G (Wailgum, 2007; Saldanha et al., 2013). With the help of information system, OEMs can eliminate the market information distortion and make a more convincible forecast. Thus, they can lower both the level of safety stock and the total finished goods inventory.

H6: The more the IS investment, the lower the FG inventory level

2.7. Effects of the CM and IS integration on inventory level.

There is no literature that investigates how information system - contract manufacturing integration drives the inventory level. The utilization of the information system under contract manufacturing strategy can neutralize the flaws of contract manufacturing. Specifically, information system enhances the information sharing between the CM and OEM by centralizing the information flow. The information system also enhances the utilization of JIT and MRP for both OEMs and CMs. Moreover, it helps the supply chain manager to monitor and control the production capability of the CMs as well (Rabinovich, Dresner and Evers, 2002). Supply chain managers' in time production adjustment assures that CMs can just keep the proper amount of work-in-process components inventory. Therefore, CM can obtain sufficient information in time and improve the demand forecasting; the Bullwhip effect can be significantly reduced. Both CM and OEM can make a quick response adjust their purchasing, manufacturing, and shipping based on an information system, thus, the overall inventory level will go down.

H7: The better the CM and IS integration, the lower the MS inventory level

H8: The better the CM and IS integration, the lower the WIP inventory level

H9: The better the CM and IS integration, the lower the FG inventory level

2.8. Summary of Hypotheses

Contract manufacturing reduces the MS inventory level and WIP inventory level but leads to higher FG inventory level.

H1. The higher the contract manufacturing utilization, the lower the MS inventory level

H2. The higher the contract manufacturing utilization, the lower the WIP inventory level

H3. The higher the contract manufacturing utilization, the lower the FG inventory level

Information system investment help to realize inventory level reduction.

H4: The more the IS investment, the lower the MS inventory level

H5: The more the IS investment, the lower the WIP inventory level

H6: The more the IS investment, the lower the FG inventory level

The integration of contract manufacturing and information system can reduce the overall inventory level.

H7: The better the CM and IS integration, the lower the MS inventory level

H8: The better the CM and IS integration, the lower the WIP inventory level

H9: The better the CM and IS integration, the lower the FG inventory level

FIGURE 2 below presents a theoretical framework which summarizes the hypotheses. Summarizing the discussions above, we propose a research framework that incorporates our hypotheses regarding the relationship between contract manufacturing and information system investment on inventory level. According to the literature reviews, we consider contract manufacturing, information system investment, and CM-IS integration as the three main factors associated with the MS inventory, WIP inventory, and FG inventory. Each factor can pair with the three inventory categories and generate three hypotheses.

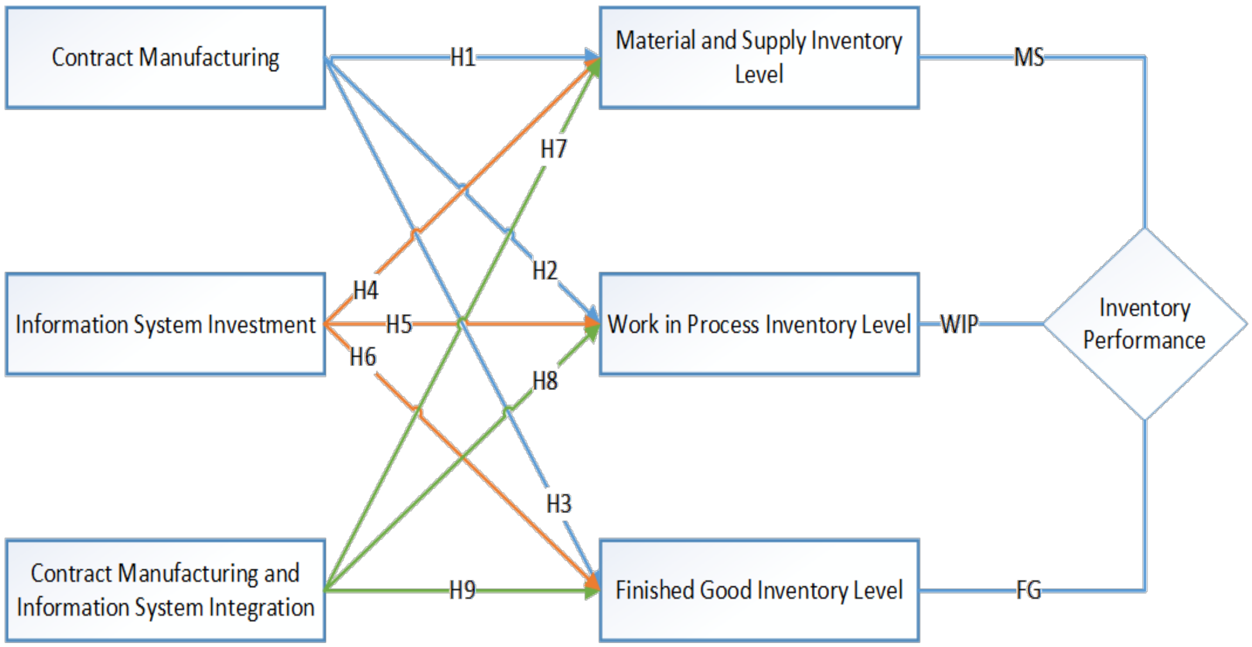

Figure 3. Hypotheses Framework

CHAPTER 3. DATA AND RESEARCH METHOD

We collect the industry-level data of U.S. manufacturing sector to conduct the data analysis. The Economic Census is conducted by U.S. Census Bureau every five years since 1997. We will use the 2002, 2007, and 2012 Economic Censuses data to investigate the recent changes in contract manufacturing, information system investment, and inventory level. The regression model is developed to test the significance and coefficient of contract manufacturing, information system investment, and interaction of CM and IS on inventory level.

3.1. Data

We use the annual industry-level data of U.S. manufacturing sector to conduct the analysis. We obtain the data from the website of U.S. Census Bureau. First we use the American Fact Finder function on the website to search all the economic census data. At last we export the Excel files below respectively (U.S. Census Bureau, 2002; 2007; 2012). Concrete data obtaining steps are displayed in Figure 4 through 9.

- *Manufacturing: Industry Series: Detailed Statistics by Industry: 2002, Economic Census of the United States*
- *Manufacturing: Industry Series: Detailed Statistics by Industry: 2007, Economic Census of the United States: 2007*
- *Manufacturing: Industry Series: Detailed Statistics by Industry: 2012, Economic Census of the United States: 2007*

We provide a step by step instruction for the 2012 economic census data obtaining below. The data obtaining procedure of the 2002 economic census data and 2007 economic census data goes the same way. Step 1: Open the home page of U.S. Census Bureau. Point at Data button, then move to Data Tools and Apps. Step 2: Click the American FactFinder button, a new page shows in Figure 5 will open. Step 3: Click the Advance Search button, and then type the keywords *2012 economic census* in the search box and click GO button. This step shows in Figure 6. Step 4: Find the data of detailed statistics by industry and click on it. Step 5: Click on the Download button and export the data as Excel files.

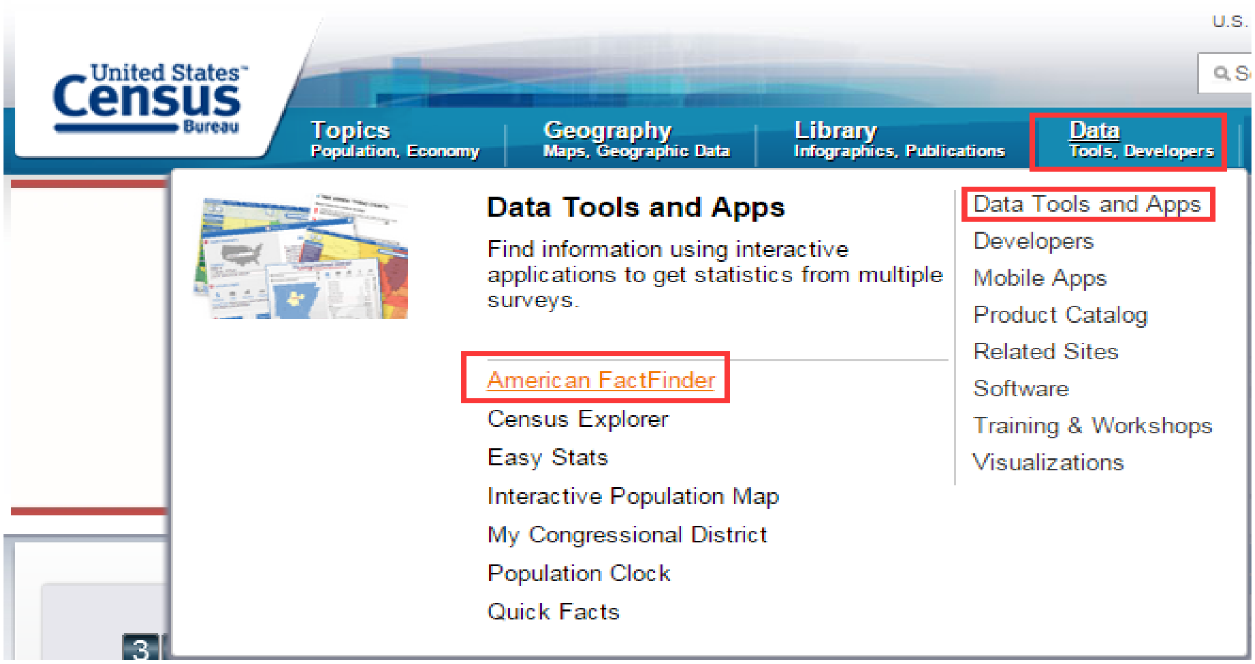

Figure 4. Data Obtaining Step 1

Figure 5. Data Obtaining Step 2

Figure 6. Data Obtaining Step 3

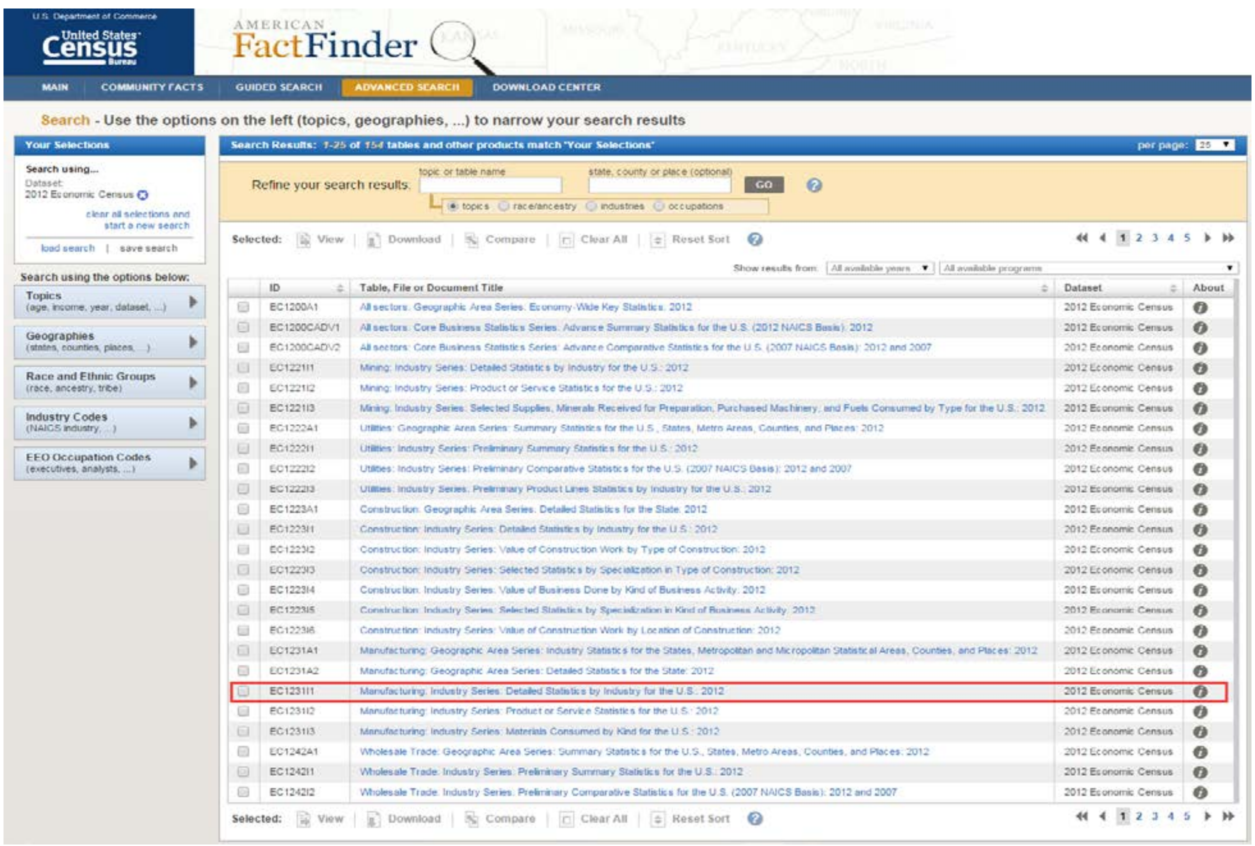

Figure 7. Data Obtaining Step 4

Figure 8. Data Obtaining Step 5-1

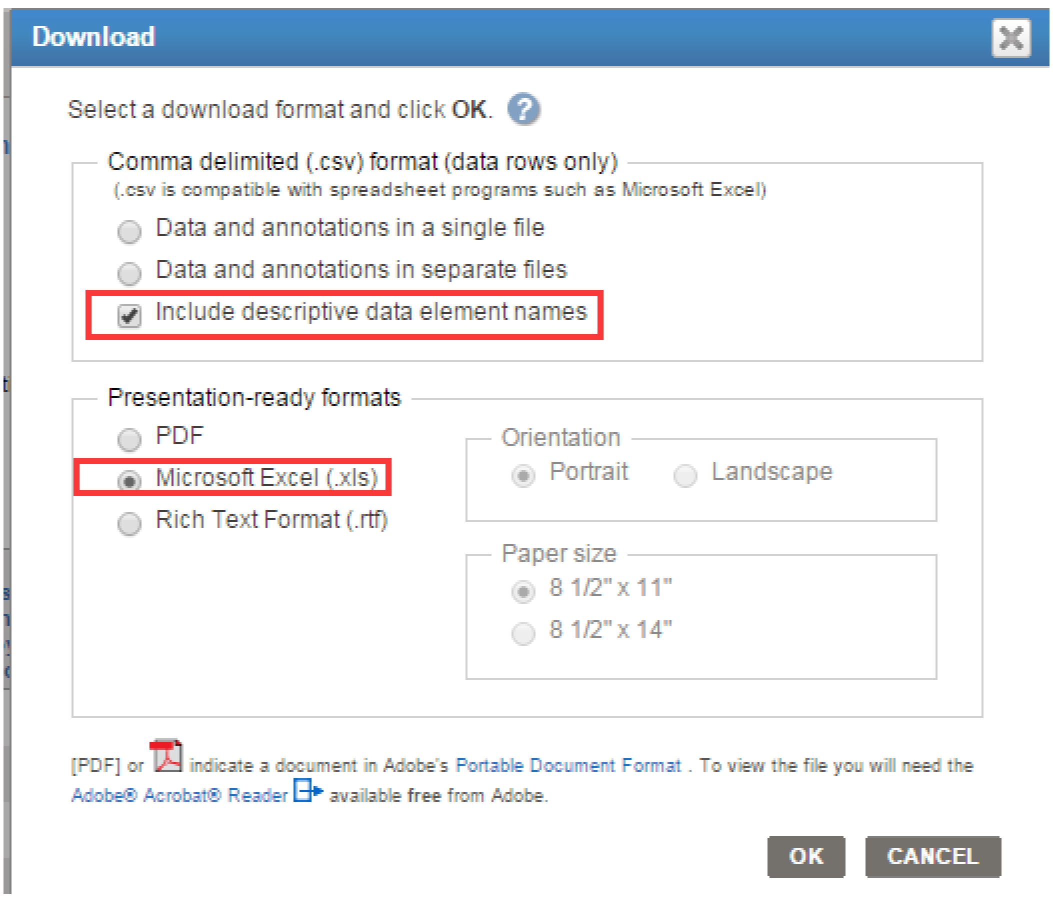

Figure 9. Data Obtaining Step 5-2

The U.S. Census Bureau introduces the 6-digit North American Industrial Classification System (NAICS) to specify different sectors of manufacturing in their economic censuses. There are approximately 435 industries with 300,000 establishments of the manufacturing sector included in the 6-digit NAICS classification system. The U.S. Census Bureau is a subordinate unit of the United States Department of Commerce; it implemented the NAICS in 1997. The nationwide economic census is conducted every five years; the 2002, 2007, and 2012 Economic Censuses data are available currently. Notably, the data of 2012 Economic Census is newly released on August 29th, 2014 which we believe is the most timeliness and detailed while the implementation of big data and cloud computing become widely launched since 2010.

The variables and methods we used in this paper have been verified in other scholars' studies (Rajagopalan and Malhotra, 2011; Schilling and Steensma, 2001; Brush and Karani, 1996; Cheng, 2011). The data sources we used are compatible with as the ones used by other researchers. The data items we used to optimize the variables are all collected from the 2002, 2007, and 2012 Economic Censuses by U.S Census Bureau.

We apply STATA as the statistical software to perform the analysis. The STATA has the function to filter the missing values of variables automatically. Since the data from several industries is being withheld due to the disclosure policy of U.S. Census Bureau, this auto filter can eliminate the null values of the disclosure data. As the amount of missing data is very limited comparing with the full data pool, the impact on the analysis of the entire manufacturing sector can be ignored.

3.2. Dependent Variables

Inventory levels. We calculate the inventory ratios for three inventory types: MS, WIP, and FG respectively to measure the inventory levels in this study. This method is developed by Rajagopalan and Malhotra (2001), earlier researchers have also applied the similar ratios to measure the industrial inventory level (Huson and Nanda, 1995).

MS inventory ratio is defined as the ratio of annual average MS inventory value to the annual materials costs.

$$INV_{MS} = \frac{MS\ inventory}{materials\ costs} \text{.............................Equation 1}$$

WIP inventory ratio is defined as the ratio of annual average WIP inventory value to the sum of annual materials costs and 50% value added.

$$INV_{WIP} = \frac{WIP\ inventory}{materials\ costs + 50\%\ value\ added} \text{.........Equation 2}$$

FG inventory ratio is defined as the ratio of annual average FG inventory value to the sum of annual materials costs and 100% value added.

$$INV_{FG} = \frac{FG\ inventory}{materials\ costs + 100\%\ value\ added} \text{........Equation 3}$$

Instead of the inventory dollar values, inventory ratios enable the data smoother and more comparable to other variables because the inventory dollar values of different industries across the manufacturing sector vary a lot. The 6-digit NAICS manufacturing industry data we used are collected from the 2002, 2007, and 2012 Economic Censuses by U.S Census Bureau.

3.3. Independent Variables

3.3.1 Contract manufacturing.

In order to convert the dollar value data into the variable that can be measured across the manufacturing sector, we define this variable as the ratio of dollar value of contract work costs to dollar value of total materials cost. This method is developed to measure the industry-level contract manufacturing usage of the U.S manufacturing sector (Schilling and Steensma, 2001). We obtain the dollar value of contract work cost and cost of materials from the 6-digit NAICS manufacturing industry data of 2002, 2007, and 2012 Economic Censuses by U.S Census Bureau.

$$\text{CM} = \frac{contract\ work\ cost}{total\ material\ cost} \ldots\text{..Equation 4}$$

3.3.2 Information system investment.

The U.S Census Bureau has expanded it economic census categories since 2007. It lists all the dollar value costs related to information system, including both the internal and external costs of computer hardware/software purchasing, data processing equipment/services purchasing, and communication services purchasing; these factors adequately cover the capital expenditures on information system. To make it comparable with other variables, we define a variable for information system investment as the ratio of capital expenditures on the information system to total capital expenditures. The capital expenditures on the information system are the sum of computer cost, data processing cost, and communication cost. Similar methods have been used to measure the utilization of information system investment in scholars' research (Dewan and Kraemer, 2000; Chun, 2003).

$$IS = \frac{computer\ cost + data\ processing\ cost + communication\ cost}{total\ capital\ expenditures}$$ …..Equation 5

The 6-digit NAICS manufacturing industry data we used are collected from the 2002, 2007, and 2012 Economic Censuses by U.S Census Bureau.

3.3.3 Contract Manufacturing and Information System Interaction

We define CM*IS as the value representing contract manufacturing and information system interaction. This method has been used several times by scholars (Cheng, 2011; Cheng et al., 2012). CM*IS is calculated as the product of CM ratio and IS ratio.

3.4. Control Variables

3.4.1. Capital intensity

We use capital intensity (CI) as a control variable because capital intensity reflects the investment in infrastructures and equipment. A higher level of capital intensity results in less labor investment and higher automation level, then higher automation provides more stable productivity. This mechanism may reduce the need for safety stock to mitigate the risk of supply uncertainties indirectly (Cheng, 2011). Scholars conclude that contract manufacturing allows OEMs meeting their operating requirements with fewer labor forces. So OEMs using contract manufacturing strategy are usually capital intense companies (Schilling and Steensma, 2001; Mason et al., 2002). In order to measure this variable, we calculated the ratio of the gross value of depreciable assets to the total value of shipments in each industry. Gross value of depreciable assets includes the value of all physical infrastructures and equipment.

$$\mathrm{CI} = \frac{gross\ value\ of\ depreciable\ assets}{total\ value\ of\ shipments} \text{……...Equation 6}$$

This method is developed by Brush and Karnani (1996). The annual data are collected from the 2002, 2007 and 2012 Economic Censuses by U.S Census Bureau.

3.4.2. Employments

OEMs outsource its business processes to CMs; the outsourcing activities create more positions for the contract manufacturing industry. Meanwhile, it decreases the number of employment of the U.S. manufacturing industry. The variable EMP can reflect the level of contract work used across the industries. E is calculated as the ratio of employees to establishments.

$$EMP = \frac{number\ of\ employees}{number\ of\ establishments} \text{………………..Equation 7}$$

3.4.3 Advertising

Studies find that advertising and promotional spending can increase sales, and sales have a close relationship with inventory holding. In order to guarantee the product availability and maintain the customer satisfaction at a certain level, the increase of sales results in the increase of safety stock (Sridhar, Narayanan, and Srinivasan, 2014). We control the advertising variable to measure the influence of advertising on inventory.

$$AD = \frac{Cost\ of\ advertising\ and\ promotional\ services}{total\ value\ of\ shipments} \text{………………..Equation 8}$$

3.5. Regression Model

This thesis will use the quantitative research method. We collect the 6-digit NAICS economic census data for year 2002, 2007, and 2012 from the official website of the U.S. Census Bureau. The code range of the manufacturing sector is from 311111 to 339999. We use a multivariable linear regression model to investigate the relationship between contract manufacturing inventory level and the information system investment. The expression of the regression model is as follows:

$$INV_{ij} = constant + \beta_1 CM + \beta_2 IS + \beta_3 CM*IS + \beta_4 CI + \beta_5 EMP + \beta_6 AD + errors \text{............Equation 9}$$

In this expression, INV_{ij} represents the inventory level for *i* category of inventory in industry *j*, CM is contract work ratio, IS stands for the information system investment ratio, CM*IS represents the interaction of contract manufacturing and information system, CI stands for the capital intensity ratio, EMP represents the ratio of employments to establishments, and AD is the ratio of advertising cost to total value of shipments.

CHAPTER 4. DATA ANALYSIS AND HYPOTHESES TESTING RESULTS

Our sample has a five years gap in census data of the U.S. manufacturing industries. The regression models are run with STATA to test the hypotheses. The variables are added gradually into the regression equations so that we can observe the relationships between each pair of variables. In this chapter, there are a descriptive data tables presenting the mean, standard deviation and correlations of all the variables. Furthermore, there are tables presenting the regression analysis of CM, IS, CM and IS interaction on MS inventory level, WIP inventory level, and FG inventory level, respectively. Finally, we conduct a complementary statistical analysis to study the overall trend during the ten years from 2002 to 2012.

4.1. Descriptive Statistics and Correlations

The sample can be regarded as panel data because it includes all manufacturing industries and is a time series data. Table 1 through 3 are the descriptive data and correlation coefficients of all variables of 2002, 2007, and 2012 respectively. The calculation of this data is executed using STATA software. The number of observations has some fluctuation in each census year due to different statistical caliber and information disclosure policy. However, according to U.S. Census Bureau, this undisclosed data is included in higher-level totals (U.S. Census Bureau, 2002; 2007; 2012).

Table 1. DESCRIPTIVE STATISTICS AND CORRELATIONS OF YEAR 2002

	Mean	Std. Deviation	INV_{MS}	INV_{WIP}	INV_{FG}	CM	IS	CI	EMP	AD
INV_{MS}	.1005	.0579	1							
INV_{WIP}	.0394	.0461	.2688	1						
INV_{FG}	.0547	.0390	.1248	.2232	1					
CM	.0329	.0440	.0453	.2038	.0163	1				
IS	.2158	.1901	.1896	.1194	.2112	.2573	1			
CI	.4288	.2251	-.0029	.0350	-.0539	-.0965	-.2374	1		
EMP	73.4332	88.3049	-.1823	.1067	-.1433	-.1372	-.1254	.0610	1	
AD	.0036	.0044	.1707	.0176	.1472	-.0319	.3192	-.2859	-.1338	1

Table 2. DESCRIPTIVE STATISTICS AND CORRELATIONS OF YEAR 2007

	Mean	Std. Deviation	INV_{MS}	INV_{WIP}	INV_{FG}	CM	IS	CI	EMP	AD
INV_{MS}	.0953	.0469	1							
INV_{WIP}	.0359	.0414	0.2328	1						
INV_{FG}	.0491	.0306	.2287	.1095	1					
CM	.0318	.0437	.0228	.3215	-.0919	1				
IS	.1789	.1978	.2917	.2333	-.0202	.2763	1			
CI	.4081	.2495	.0003	-.0467	.0324	-.0557	-.2628	1		
EMP	72.8651	109.8277	-.2235	.1995	-.1784	.1969	.1393	.0151	1	
AD	.0052	.0147	.1278	-.0311	.2346	.0448	.2397	-.0857	-.0943	1

Table 3. DESCRIPTIVE STATISTICS AND CORRELATIONS OF YEAR 2012

	Mean	Std. Deviation	INV_{MS}	INV_{WIP}	INV_{FG}	CM	IS	CI	EMP	AD
INV_{MS}	.0988	.0498	1							
INV_{WIP}	.0376	.0482	.1818	1						
INV_{FG}	.0477	.0279	.2197	.1769	1					
CM	.0302	.0392	.0851	.2827	-.0670	1				
IS	.2052	.2134	.2684	.4494	-.0328	.2901	1			
CI	.5548	.3311	.0187	.0129	.1029	.0736	-.2628	1		
EMP	64.4332	63.5579	-.1742	.2839	-.1929	-.0517	.2098	-.0078	1	
AD	.0038	.0059	.2412	-.0152	.2279	-0283	.2336	-.1262	-.2084	1

4.2. Hypotheses Testing Results

Table 4 through 6 are the result of linear regression analysis of MS inventory level, WIP inventory, and FG inventory level respectively for the year 2002. In Table 4, the signs of CM coefficients in model 4 and model 5 are positive and significant, Hypothesis 1 is rejected; the signs of IS coefficients in model 3 through 5 are all positive and significant, Hypothesis 4 is rejected; the signs of CM and IS interaction (CM*IS) coefficients in model 4 and model 5 are negative and significant, we find support for Hypothesis 7.

In Table 5, the signs of CM coefficients are all positive and significant, Hypothesis 2 is rejected. The signs of IS coefficients are all positive and significant as well in all models, so Hypothesis 5 is rejected. The signs of CM*IS coefficients in model 4 and model 5 are negative and significant, so we accept Hypothesis 8.

Table 4. RESULT OF REGRESSION ANALYSIS ON MS INVENTORY LEVELS OF YEAR 2002

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	.1024***	.0869***	.0878***	.0805***	.0715***
CM	-.0179		-.0040	.2309*	.2139*
IS		.0560***	.0559***	.0870***	0829***
CM*IS				-.7684**	-.7217*
CI					.0275*
EMP					-.0001**
AD					1.654*
R-squared	0.0002	.0343	.0337	.0499	.0962
Observations	458	444	433	433	422

+ $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

Table 5. RESULT OF REGRESSION ANALYSIS ON WIP INVENTORY LEVELS OF YEAR 2002

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	.0341***	.0313***	.0281***	.0208***	.0038
CM	.1913***		.1961***	.4319***	.4395***
IS		.0400**	.0269*	.0582***	.0570***
CM*IS				-.7713**	-.7282**
CI					.0195+
EMP					.0001**
AD					.3766
R-squared	.0401	.0242	.0513	.0740	.0986
Observations	458	444	433	433	422

+ $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

According to Table 6, the signs of CM coefficients are negative but not significant, so we still cannot accept Hypothesis 3. The signs of IS coefficients are all positive and significant; Hypothesis 6 is rejected. The signs of CM*IS coefficients are positive but not significant; Hypothesis 9 is not accepted.

Table 6. RESULT OF REGRESSION ANALYSIS ON FG INVENTORY LEVELS OF YEAR 2002

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	**.0543*** **	**.0467*** **	**.0460*** **	**.0476*** **	**.0461*** **
CM	**-.0207**		**-.0366**	**-.0895**	**-.0971**
IS		**.0366*** **	**.0434*** **	**.0364** **	**.0340* **
CM*IS				**.1730**	**.1881**
CI					**.0093**
EMP					**-.0001* **
AD					**.7182**
R-squared	**.0007**	**.0004**	**.0419**	**.0436**	**.0700**
Observations	**458**	**444**	**433**	**433**	**422**

+ p < .10; * p < .05; ** p < .01; *** p < .001

Table 7 through 9 are the results of linear regression analysis of MS inventory level, WIP inventory and FG inventory level respectively for the year 2007. In Table 7, the sign of CM coefficient is positive and significant in model 4, so Hypothesis 1 is rejected. The signs of IS coefficient in regression models for MS inventory are all positive and significant; the results reject Hypothesis 4. In model 4, the coefficient of CM*IS is negative and significant, Hypothesis 7 is supported.

Table 7. RESULT OF REGRESSION ANALYSIS ON MS INVENTORY LEVELS OF YEAR 2007

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	.0934***	.0823***	.0843***	.0770***	.0774***
CM	.0656		-.0670	.1587*	.0560
IS		.0748***	.0733***	.1014***	.0929***
CM*IS				-.6068***	-.2296
CI					.0182*
EMP					-.0001**
AD					.0973+
R-squared	.0039	.0920	.0889	.1372	0.1700
Observations	445	439	434	434	433

+ p < .10; * p < .05; ** p < .01; *** p < .001

Table 8. RESULT OF REGRESSION ANALYSIS ON WIP INVENTORY LEVELS OF YEAR 2007

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	.0265***	.0271***	.0217***	.0222***	.0148**
CM	.2790***		.2637***	.2483***	.3345***
IS		.0483***	.0327**	.0307**	.0453***
CM*IS				.0413	-.2800+
CI					.0001
EMP					.0001**
AD					-.1847
R-squared	.0927	.0534	.1255	.1258	.1537
Observations	445	439	434	434	433

+ p < .10; * p < .05; ** p < .01; *** p < .001

Table 8 shows that the CM coefficients are all positive and significant for WIP inventory; Hypothesis 2 is rejected. The coefficients of IS are positive and significant in all models; Hypothesis 5 is rejected. In model 5, the coefficient of CM*IS interaction is negative and marginally significant, so we consider Hypothesis 8 is still acceptable.

According to Table 9, the coefficient of CM is negative and marginally significant in model 3, it is negative and significant in model 5 at the same time, so these results support Hypothesis 3. None of the IS coefficients is significant, so Hypothesis 6 is not supported. We find the coefficient of CM*IS interaction is positive and marginally significant, this result is against Hypothesis 9.

Table 9. RESULT OF REGRESSION ANALYSIS ON FG INVENTORY LEVELS OF YEAR 2007

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Constant	**.0512*** **	**.0501*** **	**.0520*** **	**.0515*** **	**.0523*** **
CM	**-.0305**		**-.0704+**	**-.0565**	**-.1228***
IS		**-.0034**	**-.0006**	**.0011**	**-.0142**
CM*IS				**-.0374**	**.2174+**
CI					**.0084**
EMP					**-.0001** **
AD					**.5185*** **
R-squared	**.00118**	**.0005**	**.0098**	**.0102**	**.0992**
Observations	**448**	**443**	**437**	**437**	**436**

+ p < .10; * p < .05; ** p < .01; *** p < .001

Table 10. RESULT OF REGRESSION ANALYSIS ON MS INVENTORY LEVELS OF YEAR 2012

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	.0938***	.0852***	.0851***	.0736***	.0716***
CM	.1522*		.0370	.3275***	.2124*
IS		.0635***	.0607***	.1075***	.1135***
CM*IS				-.7961***	-.6729***
CI					.0167*
EMP					-.0001***
AD					.9195*
R-squared	.0148	.0735	.0735	.1400	.2049
Observations	349	346	340	340	336

+ p < .10; * p < .05; ** p < .01; *** p < .001

Table 10 through 12 are the regression results for MS inventory, WIP inventory, and FG inventory of year 2012, respectively. In Table 10, the signs of CM coefficients are positive and significant in model 1, model 4, and model 5, Hypothesis 1 is rejected. Coefficients of IS are positive and significant in all regression models; Hypothesis 4 is rejected. Since the signs of CM*IS coefficients are both negative and significant in model 4 and model 5, we accept Hypothesis 7.

In Table 11, the signs of CM coefficients are all positive and significant, Hypothesis 2 is rejected. The signs of IS coefficients are all positive and significant as well in all models, so Hypothesis 5 is rejected. The signs of CM*IS coefficients in model 4 and model 5 are negative and significant, so we accept Hypothesis 8.

According to Table 12, the signs of CM coefficients are negative but not significant, so we cannot accept Hypothesis 3. The signs of IS coefficients are various and not significant; Hypothesis

6 is not supported. The signs of CM*IS coefficients are negative but not significant; Hypothesis 9 is not supported.

Table 11. RESULT OF REGRESSION ANALYSIS ON WIP INVENTORY LEVELS OF YEAR 2012

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	.0270***	.0166***	.0134***	.0080*	-.0106+
CM	.3275***		.1815**	.3170***	.3901***
IS		.1003***	.0893***	.1112***	.1185***
CM*IS				-.3719**	-.5036***
CI					.0135+
EMP					.0002***
AD					-.5624
R-squared	.0762	.1995	.2182	.2339	.3120
Observations	348	344	339	339	335

+ p < .10; * p < .05; ** p < .01; *** p < .001

Table 12. RESULT OF REGRESSION ANALYSIS ON FG INVENTORY LEVELS OF YEAR 2012

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	.0487***	.0482***	.0495***	.0480***	.0434***
CM	-.0392		-.0418	-.0040	-.0580
IS		-.0031	-.0017	.0044	.0016
CM*IS				-.1038	-.0019
CI					.0115*
EMP					-.0001**
AD					.9825***
R-squared	.0032	.0006	.0043	.0079	.0966
Observations	348	344	339	339	335

+ p < .10; * p < .05; ** p < .01; *** p < .001

4.3. Complementary Statistical Analysis

Since the outputs of data analysis in different years varies. We decide to combine the samples in all three year of 2002, 2007, and 2012 to expand the sample size. The new regression runs serve as a complementary statistical analysis. We add two dummy variables and adjust the regression model to analyze the combined data of 2002, 2007, and 2012. These two dummy variables are added to the linear regression model to control the influence of different years. This method has been used several times in research papers (Schilling and Steensma, 2001; Cheng et al., 2011).

$$INV_{ij} = constant + \beta_1 CM + \beta_2 IS + \beta_3 CM*IS + \beta_4 CI + \beta_5 EMP + \beta_6 AD + \beta_7 Dummy2007 + \beta_8 Dummy2012 + errors \quad \text{...Equation 10}$$

4.4. Complementary Analysis Results

Table 13 is the descriptive statistics and coefficient of the combined data sample. Testing variables are also added incrementally into the regression model to study the influence of each variable on inventory level. D2007 and D2012 stand for the dummy variables in Table 13.

Table 14 through 16 are the results of the complementary regression analysis. In Table 14, the signs of CM coefficients are positive and significant in model 4 and model 5, Hypothesis 1 is rejected. The signs of IS coefficients are positive and significant in all regression models, so Hypothesis 4 is rejected. The signs of CM*IS coefficients are both negative and significant in model 4 and model 5, so we accept Hypothesis 7.

Table 13. DESCRIPTIVE STATISTICS AND CORRELATIONS OF COMBINED DATA SAMPLE

	Mean	Std. Deviation	INV_{MS}	INV_{WIP}	INV_{FG}	CM	IS	CI	EMP	AD	D2007	D2012
INV_{MS}	.0982	.0518	1									
INV_{WIP}	.0376	.0451	.2329	1								
INV_{FG}	.0507	.0333	.1793	.1755	1							
CM	.0317	.0425	.0476	.2651	-.0369	1						
IS	.1994	.2001	.2466	.2647	.0730	.2718	1					
CI	.4567	.2742	.0084	.0018	.0104	-.0296	-.2836	1				
EMP	70.6929	91.0700	-.1915	.1775	-.1586	.0315	.0627	.0118	1			
AD	.0042	.0098	.1298	-.0177	.1744	.0153	.2142	-.1138	-.1068	1		
D2007	.3639	.4813	-.0410	-.0293	-.0362	.0009	-.0775	-.1342	.0180	.0704	1	
D2012	.2815	.4499	.0080	-.0008	-.0564	-.0230	.0181	.2240	-.0430	-.0263	-.4734	1

Table 14. RESULT OF REGRESSION ANALYSIS ON MS INVENTORY LEVELS OF COMBINED DATA SAMPLE

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	**.0971*** **	**.0846*** **	**.0856*** **	**.0775*** **	**.0774*** **
CM	**.0467**		**-.0179**	**.2177*** **	**.1357** **
IS		**.0652*** **	**.0642*** **	**.0973*** **	**.0942*** **
CM*IS				**-.6831*** **	**-.4705*** **
CI					**.0187** **
EMP					**-.0001*** **
AD					**.3139***
Dummy2007					**-.0022**
Dummy2012					**-.0040**
R-squared	**.0014**	**.0619**	**.0598**	**.0971**	**.1321**
Observations	**1252**	**1229**	**1207**	**1207**	**1191**

+ p < .10; * p < .05; ** p < .01; *** p < .001

In Table 15, signs of CM coefficients are positive and significant in all regression models, the results are against Hypothesis 2. The signs of IS coefficients are positive and significant in all regression models, so Hypothesis 5 is rejected. The signs of CM*IS coefficients are both negative and significant in model 4 and model 5, so we accept Hypothesis 8.

With reference to Table 16, CM coefficients are negative and significant in model 3 and model 5, Hypothesis 3 is accepted as we predicted. IS coefficients are positive and significant in model 3 and model 4; Hypothesis 6 is rejected. CM*IS coefficients are not significant, Hypothesis 9 is rejected.

Table 15. RESULT OF REGRESSION ANALYSIS ON WIP INVENTORY LEVELS OF COMBINED DATA SAMPLE

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	.0296***	.0252***	.0212***	.0190***	.0051
CM	.2501***		.2169***	.2791***	.3540***
IS		.0625***	.0493***	.0581***	.0711***
CM*IS				-.1803*	-.4159***
CI					.0106*
EMP					.0001***
AD					-.2196+
Dummy2007					-.0004
Dummy2012					-.0008
R-squared	.0629	.0738	.1103	.1136	.1572
Observations	1251	1227	1206	1206	1190

+ $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

Table 16. RESULT OF REGRESSION ANALYSIS ON FG INVENTORY LEVELS OF COMBINED DATA SAMPLE

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	.0516***	.0487***	.0496***	.0488***	.0533***
CM	-.0261		-.0499*	-.0280	-.0816*
IS		.0103*	.0137**	.0168**	.0078
CM*IS				-.0634	.1040
CI					.0090*
EMP					-0.001***
AD					.5532***
Dummy2007					-.0056*
Dummy2012					-.0089***
R-squared	.0013	.0036	.0078	.0086	.0703
Observations	1254	1231	1209	1209	1193

+ $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

We create a hypothesis testing matrix to provide an overview of our hypothesis results. According to the hypotheses that we developed in Chapter 2, Hypotheses 1 through 3 are testing the moderate effects of contract manufacturing on inventory levels; Hypotheses 4 through 6 are testing the moderate effects of information system investment on inventory levels; Hypotheses 7 through 9 are testing the moderate effects of contract manufacturing and information system investment interaction on inventory levels.

With reference to Table 17 and previous regression analysis results show in Table 4 through Table 16, we find that both the contract manufacturing strategy and information system investment push up the inventory level of U.S. manufacturing industry. We also find that the interaction of contract manufacturing and information system investment can reduce the inventory level of materials and supplies and work-in-process. However, the contract manufacturing and information system interaction has no significant moderate effects on finished good inventory level.

The complementary analysis of hypotheses testing is consistent with the results of 2002, 2007, and 2012, except Hypothesis 3. The combined data sample of 10-year time span shows that the increasing of contract manufacturing can reduce the FG inventory level significantly. The explanations of the regression analysis results will be discussed in Chapter 5.

Table 17. HYPOTHESIS TESTING RESULTS

	CM			IS			CM*IS		
	H1	H2	H3	H4	H5	H6	H7	H8	H9
INV_{MS}2002	R			R			A		
INV_{WIP}2002		R			R			A	
INV_{FG}2002			R			R			R
INV_{MS}2007	R			R			A		
INV_{WIP}2007		R			R			A	
INV_{FG}2007			R			R			R
INV_{MS}2012	R			R			A		
INV_{WIP}2012		R			R			A	
INV_{FG}2012			R			R			R
INV_{MS}Combined	R			R			A		
INV_{WIP}Combined		R			R			A	
INV_{FG}Combined			A			R			R

*R=Rejected, A= Accepted

CHAPTER 5. DISCUSSION AND IMPLICATION

In this chapter, we first explain the regression analysis results. Then we give out the research implications based on our research results. At the end of this chapter, we will discuss the limitations of this thesis and ideas about future research.

5.1. Hypothesis Testing Results Discussion

Our linear regression results do not support all the hypotheses. Compared with previous research, we have some new findings on our research topic. In this part, we will provide detailed explanation to the hypothesis testing results.

5.1.1. The trend of Contract Manufacturing.

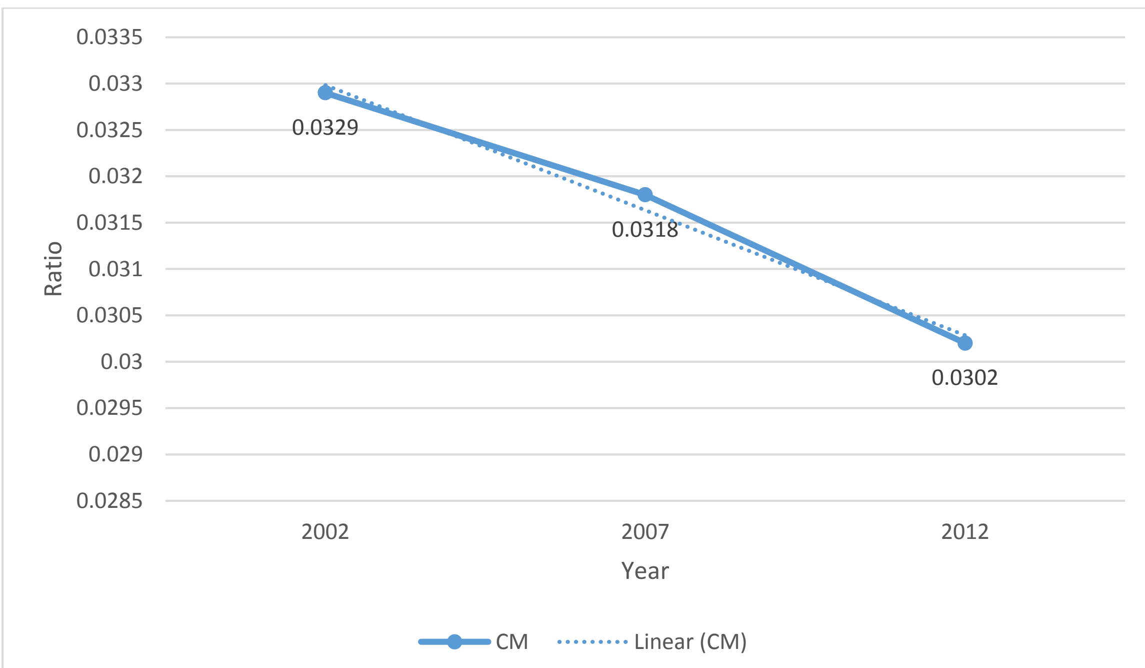

Figure 10. Trend of Contract Manufacturing Ratio

Figure 4 shows the trend of contract manufacturing; it has an obvious falling trend. The utilization of contract manufacturing kept dropping from 2002 to 2012. The contract work ratio slightly decreased by 8.2% from 2002 to 2012. The potential reason of the decreasing is that U.S. is moving its manufacturing work back to the states. Related reports start to appear in the business press since 2012.

In May 2012, The Wall Street Journal reported that the manufacturing plants of U.S. companies are moving back from China. In this article, it also mentioned that contract manufacturing has led to a 35% manufacturing jobs decline between 1998 and 2010. However, the situation started to change from this time. IHS Global Insight made a forecasted that the U.S. manufacturing jobs would increase 3.2% in 2010. A survey involved 105 companies that conduct in early 2010 indicated that 39% of the companies were thinking about relocating their manufacturing plants back to U.S (Wall Street Journal, 2012). In 2013, The Economist presented a special report on outsourcing and offshoring. The report stated that a growing numbers of U.S. manufacturers decide to move their manufacturing and assembling operations back. (The Economist, 2013). We find the evidence of the contract manufacturing utilization change. We get the actual data of employment in manufacturing from U.S. Bureau of Labor Statistics, the data shows the number of U.S. manufacturing jobs has continuous climbing since 2010 (U.S. Bureau of Labor Statistics, 2015). The increasing labor cost in traditional contract manufacturing countries made the U.S. based plants more attractive, as the cost gap is not that much as before. The domestic plants can realize better product quality control. Besides, the transportation period of components and finished goods reduces significantly. OEMs do not have to wait for several weeks to get their products delivered from the other side of the world. Furthermore, currency fluctuation also narrows the cost gap. In 2002, the exchange rate of USD to CNY was around 8.2, but in 2012, the exchange rate of USD to CNY was just around 6.2.

5.1.2. The Trend of Information System Investment

Figure 5 shows the trend of information system investment in U.S. manufacturing industry. The information system investment dropped from 2002 to 2007; then it went up from 2007 to 2012. We notice that the difference in the information investment ratio of year 2002 and year 2012 is only 0.0106, decreased by 4.9%. Though the U.S. economic census data shows the overall changing trend in the period from 2002 to 2012 is still dropping, we have reason to doubt whether it can reflect the current situation. Business press articles show that many of the manufacturing leaders are upgrading their information system in recent years. For example, Shell awarded a new contract to SAP for upgrading its information system into cloud-based (SAP, 2014). Amazon’s cloud computing service AWS generated 3.108 billion dollars revenue in 2013 and 4.644 billion dollars revenue in 2014 (Statista, 2014).

5.1.3. Trend of CM-IS Interaction Ratio

Figure 6 is regarding the ratio of contract manufacturing and information system investment over 2002, 2007, and 2012. The CM-IS interaction dropped from 2002 to 2007; then rose again after the fall. It is noticeable that decreasing rate between 2002 and 2007 is almost the same as the increasing rate between 2007 and 2012. Considering in conjunction with our complementary analysis results, the CM*IS interaction has a stronger dominant effect on MS inventory level and WIP inventory during the ten years from 2002 to 2012.

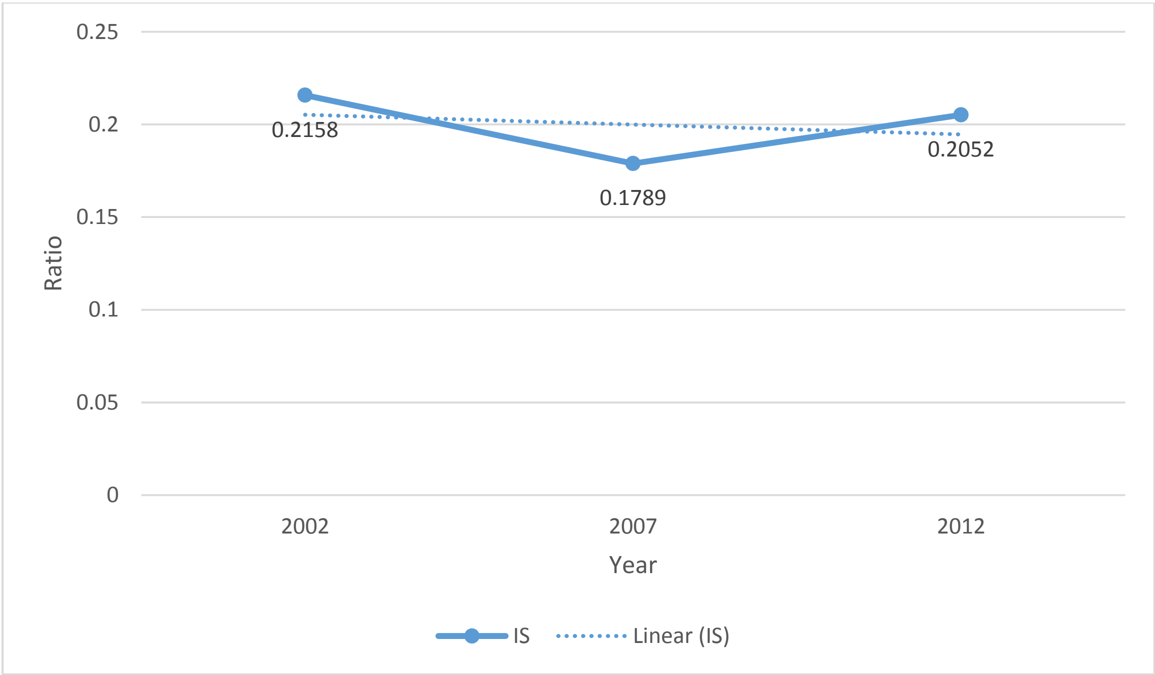

Figure 11. Trend of Information System Investment Ratio

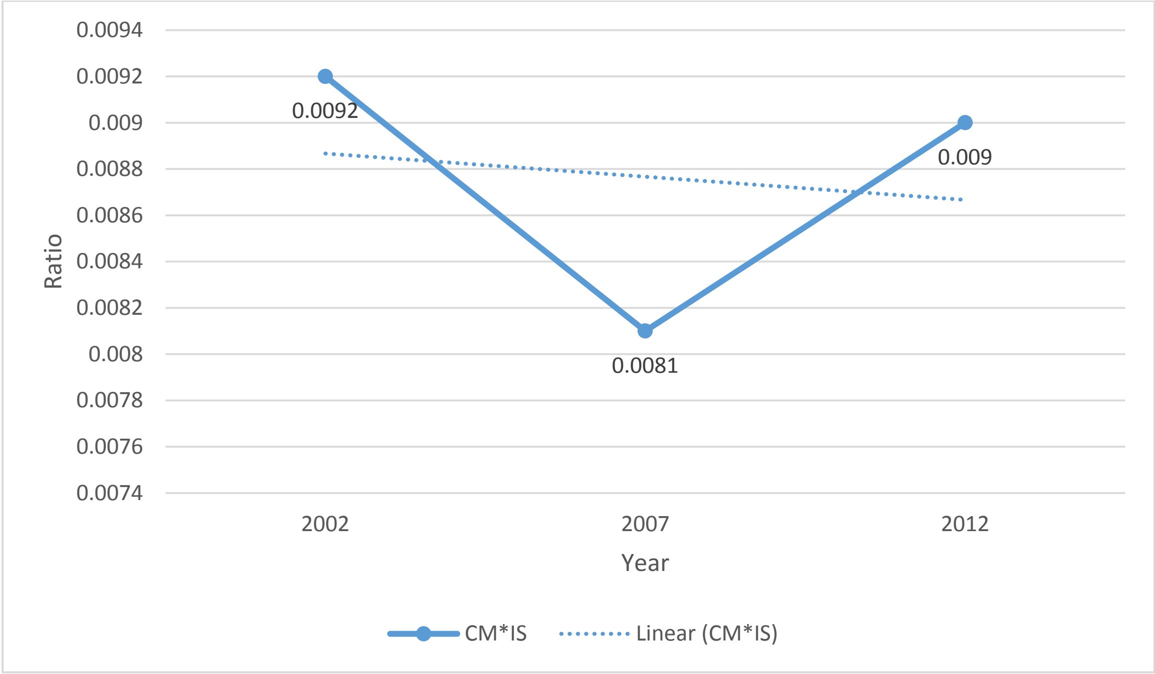

Figure 12. Trend of CM-IS Interaction Ratio

5.1.4. Trend of Inventory Levels

We develop the line charts below with the mean values of MS inventory, WIP inventory, and FG inventory respectively in Table 1 through 3. Since the trend of MS, WIP, and FG inventory are consistent decreasing, we can infer that the total inventory level decreased as well.

Figure 7 illustrates that from 2002 to 2007, the MS inventory was decreasing. Though the MS inventory was increasing from 2007 to 2012, the overall trend of MS inventory is still decreasing. The trend matches our research finding that the interaction contract manufacturing and information system investment can improve the raw materials and suppliers inventory efficiency.

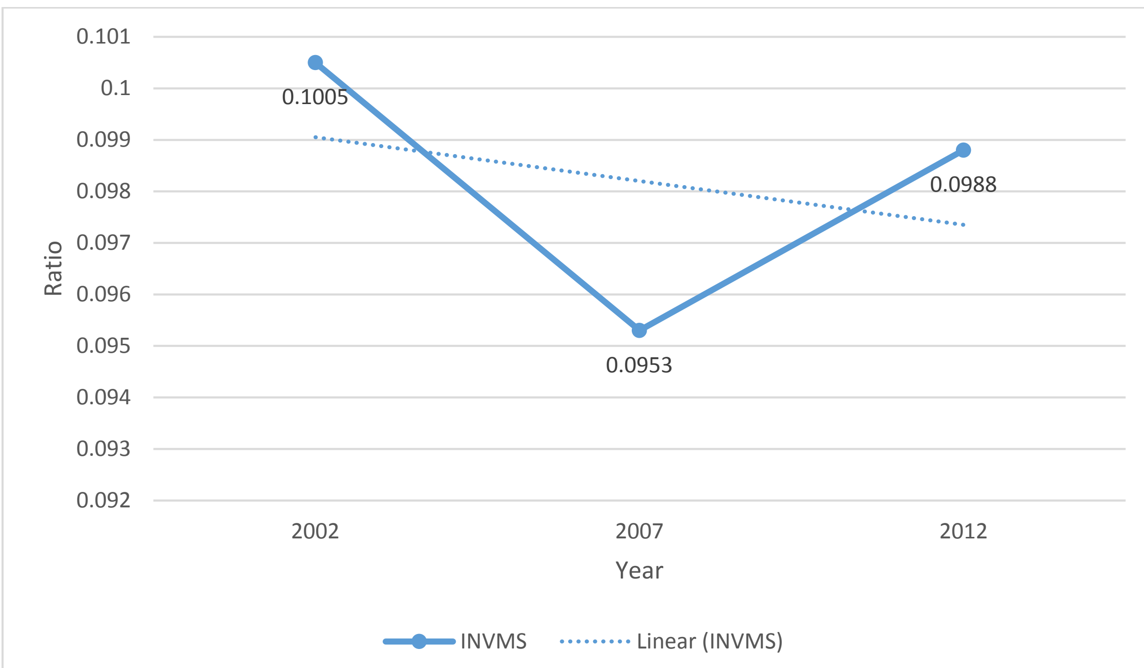

Figure 13. Trend of MS Inventory Level Ratio

Figure 8 illustrates that from 2002 to 2007, the WIP inventory was decreasing. Though the WIP inventory was increasing from 2007 to 2012, the overall trend of WIP inventory is decreasing. Our data analysis results support this changing trend, the interaction of contract manufacturing and information system investment can reduce the work-in-process inventory level.

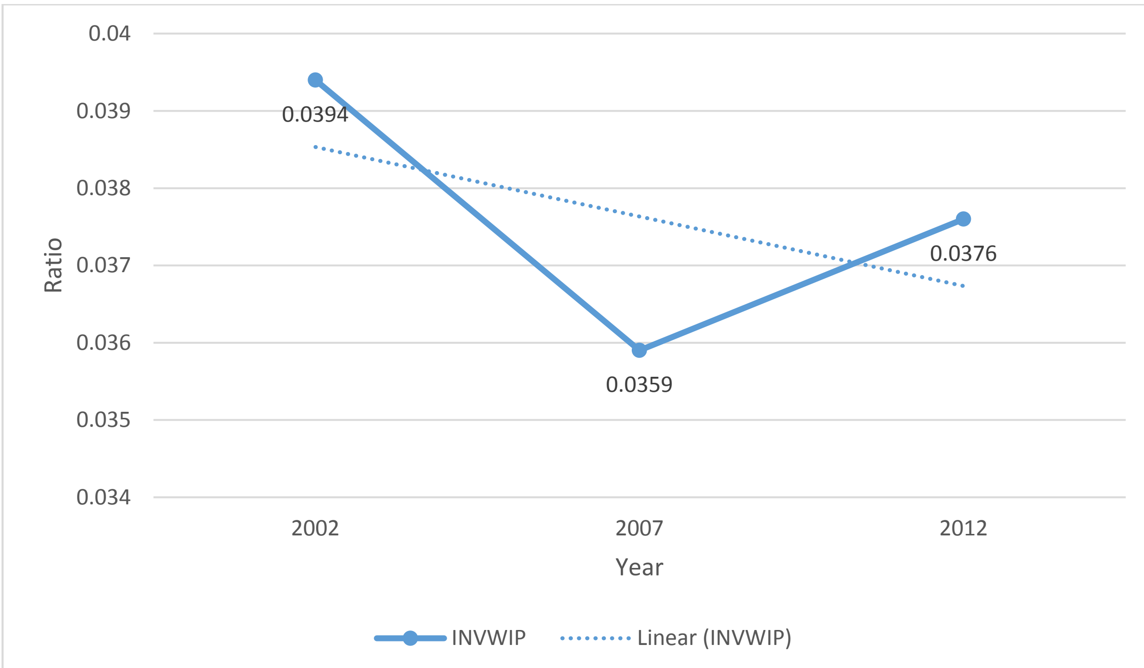

Figure 14. Trend of WIP Inventory Level Ratio

Figure 9 shows the changing trend of FG inventory from 2002 to 2012; the FG inventory ratio decreased from 0.547 to 0.447. The finished goods inventory level reduced by approximately 18.3% during this period. The interaction of contract manufacturing and information system investment is not the driving force of finished goods inventory level. The finished goods inventory is more relatively to sales. The market demand change has more influence on the finished goods inventory.

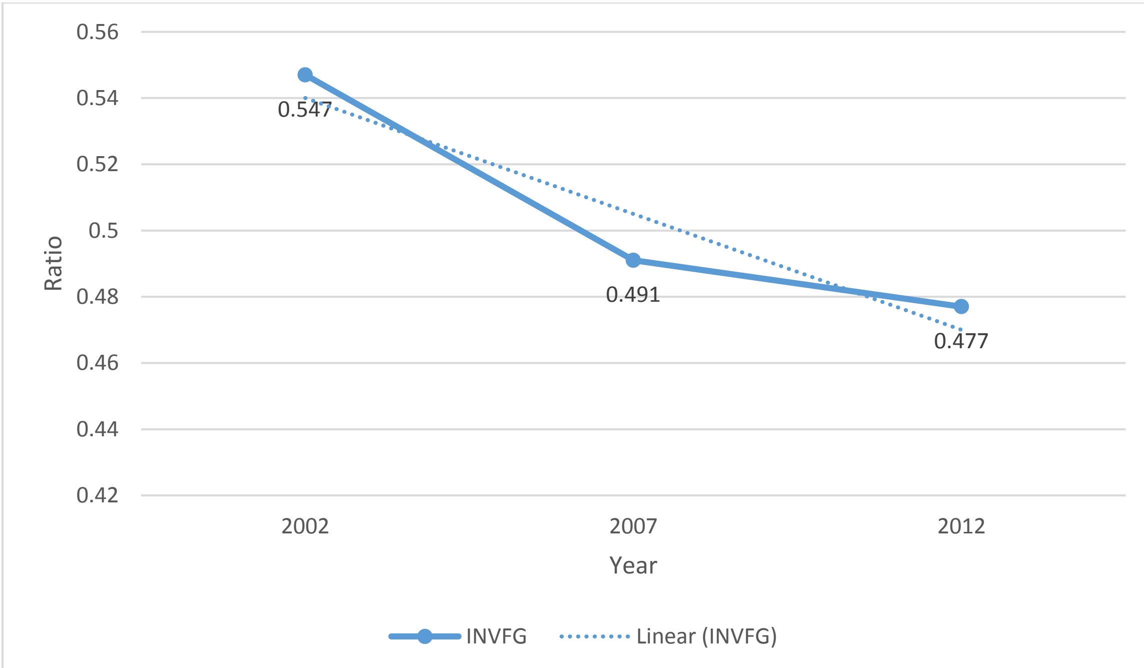

Figure 15. Trend of FG Inventory Level Ratio

5.1.5. Summary of the Hypothesis Testing Results

We summarize our research findings as follow,

1. Independent effect of contract manufacturing does not benefit the MS inventory level.
2. Independent effect of contract manufacturing does not benefit the WIP inventory level.
3. Independent effect of contract manufacturing does not benefit the FG inventory level.
4. Independent effect of information system investment does not benefit the MS inventory level.
5. Independent effect of information system investment does not benefit the WIP inventory level.
6. Independent effect of information system investment does not benefit the FG inventory level.

7. The interaction of contract manufacturing and information system investment have negative moderate effects on MS inventory level.
8. The interaction of contract manufacturing and information system investment have negative moderate effects on WIP inventory level.
9. The interaction of contract manufacturing and information system investment do not have significant moderate effects on FG inventory level.

Our regression results on contract manufacturing indicate that the Bullwhip effect dominants the manufacturing inventory efficiency. Contract manufacturing strategy will increase the overall inventory level. The interaction of contract manufacturing and information system investment mitigates the Bullwhip effect. Information system facilitates the information flow between OEMs and CMs. The order quantity fluctuation is being well controlled. Therefore, OEMs achieve a reduction of MS inventory and WIP inventory.

As we discussed in 5.1.1, some of the manufacturers relocate their plants back in the United States. The transportation cycle is greatly shortened. So the lead time is greatly reduced, the manufacturers can keep a lower safety stock and maintain the customer satisfaction at the same level at the same time. Other factors dominant the change of FG inventory, so the influence of CM-IS interaction is neutralized. Some scholars find that production flexibility and the number of dealerships are the key factors affecting finished good inventory level in the automobile industry. When sales are increasing, high production flexibility allows a company replenishes its inventory in a short time. Thus, the company can maintain its safety stock at a lower level. Less number of dealerships also means a high level of inventory consolidation (Cachon and Oliveres, 2010).

5.2. Research and Managerial Implications

The thesis focuses on the effects of information system investment on manufacturing inventory level under the contract manufacturing strategy. No scholar has concentrated on this topic before; this is our unique contribution to the supply chain studies on U.S. manufacturing industry. According to our findings, the interaction of contract manufacturing and information system investment is still benefiting the manufacturing industry.

The findings of our current research provide suggestions for U.S. manufacturers to realize inventory efficiency improvement. The results of contract manufacturing show the Bullwhip effect dominants. However, there may be other factors drive the inventory increasing, the possibility challenges researchers to investigate on other driving forces that affect U.S. manufacturing inventory performance under contract manufacturing strategy.

Our complementary analysis indicates that contract manufacturing strategy can benefit the finished goods inventory on a long-term basis. Contract manufacturing can reduce the finished goods inventory of U.S. manufacturers, many OEMs do not handle the finished goods inventory any longer. The finished goods are shipped to the customers directly from the contract manufacturers. OEMs may try this business model to minimize the cost of finished goods transportation and inventory handling.

Though the supply chain inventory will increase under the contract manufacturing strategy, the inventory of the U.S. manufacturing sector remains at a low level because the OEMs outsource parts, components, and even the whole manufacturing process to CMs, CMs take over the inventory of materials and supplies and work in process from OEMs. However, since most CMs are located in low labor costing countries outside U.S., there are many uncertainties between the OEMs and CMs. For example, the long lead time may cause OEMs have difficulties in replenishing WIP inventory and FG inventory. Because CMs have certain constraints such as production capacity, inventory capacity, and transportation restrictions, they cannot make quick response to parts, components, and finished goods manufacturing and distribution (Cheng, 2011; Plambeck and Taloy, 2005). These factors force the OEMs to hold a higher level of safety stock to guarantee the product availability and maintain the customer service level. In order to reduce the influence of the uncertainties in OEM-CM supply chain network, supporting methods should be applied. The supporting methods include utilizing inventory optimizing tool align with OEMs and CMs, implementing electronic data interchange (EDI) to improve the information transmission speed.

In order to achieve continuous improvement in inventory efficiency, the U.S. manufacturing industry should not only keep utilizing the contract manufacturing industry, but also put more investments on information system building across the supply chain network. OEMs should cooperate with CMs, as well as the logistics providers, to collaborate the supply chain operation and proceed the inventory optimization.

Since the cloud computing technology can greatly enhance the information system performance, the manufacturers should also try to build a more efficient cloud-based information system. Big data and cloud computing have become more and more important in supply chain network planning, information sharing, operation monitoring and controlling, and improving the customer service level. During the Alibaba *11.11 shopping festival* in 2014, 171 million orders had been placed within 24 hours, Alipay (Alibaba's online transaction system) processed 30,000 payments per second during peak periods. All of the data processing was completed by Alibaba's cloud computing system. Orders sent in seconds to the OEM participants, such as NIKE Inc., and GAP Inc. (Alizila, 2014; Alibaba, 2014; Mozur and Osawa, 2013). Thus, the OEMs have time to reallocate their inventories and contact their CMs to adjust production plan. An optimal integrated information system should be able to cover the entire supply chain, from retailers to suppliers. OEMs may extend their information system to reach the CMs and other upstream suppliers.

5.3. Limitation and future research

There are several limitations with respect to our present research. The 2007 Subprime crisis and the worldwide economic crisis in 2008 are the interference factors of our study. We do not know how the crises can actual act on U.S. manufacturing industry, but the global economic recession may impact contract manufacturing activities. The scholar also indicates that there is a close relationship between inventory change and GDP during recessions (Hornstein, 1998). However, our datasets are certain data points; the data analysis results cannot reflect the continuous influence of the economic recession on U.S. manufacturing industry. Future research needs to take these factors into consideration.

In addition, our original data sample are data points of certain years obtained from the U.S. Census Bureau. The year by year time series data may better describe the changing trend from 2002 to 2012. However, the year by year data of U.S. manufacturing industry do not provide necessary data for the regression variables generating. Moreover, in the 2002 economic census, the information system investment data was not specified by hardware investment and software investment. If the data is separated, we can investigate the information system hardware investment and information system software investment respectively and compare the difference.

Our results imply that the interaction of contract manufacturing and information system investment are not the driving force of finished goods inventory level. Maybe because the finished goods inventory are more relative to sales. The market demand change has more influence on the finished goods inventory. The exact reason needs to be identified.

We can only find very limited information about the change study in contract manufacturing utilization of the U.S. manufacturing industry. Most of the current available information are from the business press, but not from the academic journals. According to our data analysis findings, there should be a significant trend that U.S. manufacturing industry is moving its manufacturing and assembling processes back to U.S. instead of outsourcing them to traditional labor intensive countries. Other reports indicate that, some of the large manufacturers choose to relocate their manufacturing and assembling plants in Mexico. Mexico is a member under North American Free Trade Agreement, as known as NAFTA. Canada is also a member of NAFTA. According to Industry Canada, there are ten major motor vehicle assembly plants in Canada. Among them, Chrysler has two plants; Ford has one plant; General Motors have three plants (Industry Canada, 2015). Different locating area of contract manufacturers may need different inventory buffer strategies, the mechanism needs to be investigated.

When doing the literature reviews, we find that scholars propose the new term cloud manufacturing, refers to designated cloud computing system for manufacturing that is a new supply chain information technology (Xu, 2012). Future research can specify the information system investment into cloud computing, we believe cloud manufacturing will become a new era of the supply chain integration study.

Our research analyzes the industry-level contract manufacturing and information system investment of the entire U.S. manufacturing industry, and their influences on the U.S.

manufacturing industry inventory levels. Not all the manufacturing industries implement contract manufacturing strategy, an industry like flour milling (NAICS CODE: 311211) barely use contract manufacturing. We are wondering whether the result will change if we narrow our research scope and concentrate on those industries rely on high levels of contract manufacturing, such as electronic industry and automobile industry.

CHAPTER 6. CONCLUSION

Though OEMs are trying to move the manufacturing processes back, it does not mean they are going to retake the manufacturing work in-house. Contract manufacturing is still an important supply chain strategy. We have witnessed OEMs using contract manufacturing strategy successfully in different industries. The rising contract manufacturing cost in China does not prevent Apple from outsourcing its assembling work to Foxconn. Information system investment have been found very useful to improve the overall supply chain performance. This thesis examines the effect of contract manufacturing and information system investment on inventory levels of respective industries in the entire U.S. manufacturing sector. We also empirically investigate how the interaction of contract manufacturing strategy and information system investment take effects on the inventory efficiency of the U.S. manufacturing industries.

The thesis reviews literature on contract manufacturing, information system investment, and interaction of contract manufacturing and information system investment to evaluate their moderate effects on inventory levels. We apply just in time inventory management, square root law, and Bullwhip effect as the factors associating with inventory efficiency. We develop hypotheses based on the direct impact of these factors on inventory levels. When square root law takes effect, it will help reduce the inventory level under contract manufacturing strategy. When Bullwhip effect takes effect, it will lead to inventory increasing under contract manufacturing strategy.

In this thesis, we collect the industry-level data of U.S. manufacturing sector to conduct the data analysis. The Economic Census is run by U.S. Bureau of Census every five years since 1997. We use the 2002, 2007, and 2012 Economic Censuses data to investigate the recent changes in contract manufacturing, information system investment, and inventory level. We develop a linear regression model to test the significance and coefficient of contract manufacturing, information system investment, and interaction of CM and IS on inventory level. The results support the Bullwhip effect theory that contract manufacturing may push the MS inventory, WIP inventory, and FG inventory to higher levels. The information system investment cannot function independently to realize inventory level reduction. The MS inventory and WIP inventory can be significantly optimized by the interaction of contract manufacturing and information system investment. Since FG inventory is more like sale and demand driven, the CM-IS interaction does not have a significant influence on it.

Our study gives suggestions on inventory efficiency improvement under the contract manufacturing strategy. Inventory level optimization cannot be realized when contract manufacturing and information system investment being used separately. Using contract manufacturing strategy alone will increase the overall inventory level because Bullwhip effect fluctuates the order quantity between each supply chain members in an OEM-CM supply chain network. Contract manufacturing and information system investment should be jointly implemented between OEMs and CMs, only the combined action can come into effect on facilitating inventory efficiency.

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