

THE DYNAMICS OF DESIGN-MANUFACTURING LAPTOPS:
HOW TAIWANESE CONTRACT MANUFACTURERS MATTER IN THE
HISTORY OF LAPTOP PRODUCTION

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THE DYNAMICS OF DESIGN-MANUFACTURING LAPTOPS: HOW TAIWANESE CONTRACT MANUFACTURERS MATTER IN THE HISTORY OF LAPTOP PRODUCTION

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This dissertation aims to open the knowledge production “black box” of laptop contract manufacturers in Taiwan and their factories in China from 1988 to 2012. By examining their engineering practices, I demonstrate the complexity and changing dynamics of design-manufacturing laptops across different time periods, which not only refutes a perception of linear progress from manufacturing to design for Taiwan’s industry, but also challenges the idea that manufacturing lacks innovation and importance. I show how manufacturing and design capability are equally crucial and argue that it is also the intensive interaction between design and manufacturing, internally and externally, that matters. I develop a concept, field knowledge, to describe this interactiveness that involves frequent multiple-sited and trans-organizational exchanges between actors from heterogeneous backgrounds.

My research, based on extensive interviews, unpacks the sociotechnical process in producing laptops that involves the transnational flow of people, ideas, and materials. In Chapter One, I show how Taiwanese producers designed their first laptops in the late 1980s based primarily on design engineering capability and how they learned to specialize the

development process through collaborating with brand-name firms. In Chapter Two, I explore the complexity of the product development process, analyzing how the relations between design and manufacturing are intertwined. Chapter Three covers the issue of ever-thinning margins for producers and the practice of field knowledge that enabled them to create useful knowledge through constant interaction with internal and external partners to reduce costs. In Chapter Four, I analyze how these manufacturers, as mediators in the production world, have been contained and standardized by powerful partners. In Chapter Five, I examine how large-scale factory relocation from Taiwan to China after 2001 affected the practices and the lives of employees engaged in a permanent struggle between rootedness and mobility. I also show how their manufacturing capability was ever expanding, along with growing design expertise.

Overall, this dissertation problematizes the production process and demonstrates the changing dynamics of design-manufacturing laptops within their social and historical context, arguing that it is the proficient capability of both design and manufacturing, and the effective integration between them that increases and maintains laptop consolidation.

BIOGRAPHICAL SKETCH

Ling-Fei Lin earned an M.A. in Science and Technology Studies from Cornell University, an M.A. in Social Sciences from the University of Chicago, an M.A. in Journalism from National Taiwan University, and a B.S in Atmospheric Sciences from National Taiwan University.

謹獻給在天上的父親 林清雄

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INTRODUCTION

THE INVISIBLE CONTRACT MANUFACTURERS: RESITUATING DESIGN AND MANUFACTURING

This research project aims to open the “black box” of the knowledge between design and manufacturing of laptop contract manufacturers (CMs) in Taiwan between 1988 and 2012. During this period, the proportion of laptops worldwide produced by Taiwanese manufacturers dramatically rose from zero to over ninety percent. Previous literature has focused primarily on analyzing the factors contributing to industrial development within high-tech production, such as the role of the state, corporate strategies, and flexible production networks. My dissertation project aims to supplement this literature by exploring the question of what unique knowledge and special practices are produced by laptop CMs that contribute to the consolidation of laptop production in the hands of Taiwanese companies. A secondary question then is how does this laptop production consolidation, in turn, shape the knowledge practices of these companies?

Traditionally, manufacturers are seldom the protagonists in product innovation stories or in the history of computing, which tend to feature individual inventors, researchers, or teams of designers. The invisibility of manufacturers is especially serious for contract manufacturers. While manufacturing activity is in general invisible, or blackboxed, contract

manufacturing could be said to have “double invisibility” or to be “doubly blackboxed,” as these manufacturers are largely unknown to users and outsiders, although they are an important intermediary actor between production and consumption. Furthermore, the place of manufacturing artifacts is seldom regarded as a major site of knowledge production (for a discussion of the literature, see the section below). This situation is not surprising, as manufacturers are often thought to play only the role of implementing design plans. In other words, there seems to be a hierarchical relation between the knowledge of design and the knowledge of manufacturing. My study of laptop production attempts to flatten this hierarchy of knowledge and to demonstrate that there is strong feedback, or a reverse flow, in the *design-manufacturing* process (I use the compound word, design-manufacturing to express the inseparability of design and manufacturing in the industry). My study shows that the CMs require a strong interaction and even synchronization between design and manufacturing teams, both internally and externally, in order to produce products that are competitive.

The relative distributions of design, production and consumption of laptops is worthy of exploration. Laptops are a commodity that is on a large-scale of global consumption. It is not surprising that the primary base for laptop manufacturing factories is in mainland China, being the world’s most populous nation, especially after its adoption of open policies. However, when we consider that more than 90% (2008-2012) of the laptops produced worldwide needed the engineering efforts of the small island of Taiwan, this high

concentration of engineering practices in Taiwan and in a few of large CMs, is truly remarkable.

This concentration may indicate that only a few firms produce and retain the specialized know-how involved in the design and manufacturing of laptops. Therefore, the primary issue to be addressed in my project concerns the particular knowledge and practices that these Taiwanese CMs produced. What is this specialized know-how? How is it generated or shaped? Does it conversely influence the forces that shape it?

Problematizing and Resituating Design and Manufacturing

To explore these inquiries, I problematize two important sets of category in the industry. The first set is concerned with the idea of design and manufacturing. The primary business model of Taiwanese laptop producers since the late 1980s has been to offer both design and manufacturing services (the so-called ODM model) for their brand-name clients. But what do "design" and "manufacturing" in a contract manufacturing business mean? By examining the diversified activities that design and manufacturing are comprised of, I explore the middle processes that take place after the brand-name customer's product concepts or proposals are produced and before the laptops are assembled in the factory. Specifically, I examine *both a design process that is close to factories and a manufacturing process that is distant from factories*. That is, I explore a design process that is resituated from its office to

the factory floor and a manufacturing process that is resituated from the factory floor to the office.

One reason that I analyze this “in between” process is to distinguish manufacturing which many people usually associate exclusively with the labor process on factory floors from that of design, which is often connoted with only mental work. However, I argue that it is not merely the action of final assembly carried out by workers or machines in the factory in the final moments that counts as “manufacturing” or “production.” There are much richer dimensions to the machine-making process. I consider that everything in the contract manufacturing process before the final assembly can count as both “design” and “manufacturing,” and that there is no clear boundary to distinguish these two activities of contract manufacturers.

The second set of category I problematize apply to the actors’ category—cost. I examine the actors’ notion of cost through the lens of knowledge production. For example, if low cost is one of the main advantages of Taiwanese firms, what specialized knowledge and practices contribute to the cost reduction? How are they shaped and produced? Also, is it easy for the related knowledge to travel?

I start with 1988 because it is the founding year of Quanta Computer, the first laptop CM in Taiwan and the largest laptop maker in the world for more than the past ten years. Another historical milestone is the year 2001, when the Taiwanese government started open

investing in the laptop industry in China. Within a few years, over 90% of Taiwanese laptop manufacturers had moved their main factories to China (through their own investments) in order to further reduce their labor costs. But despite that move, most of the engineering work is still based in Taiwan. This study stops in the year 2012, the year in which a second wave of factory relocations to inland China became a reality.

Intellectual Contribution

The dissertation will examine and contribute to the enduring themes of tacit knowledge, local knowledge, and knowledge that travels in the literature of science and technology studies (STS). The tension between universal knowledge and local knowledge has been an important topic for studies of the production of scientific knowledge, yet few STS scholars have explored how knowledge and practices regarding industrial production illustrate these themes. Since industrial manufacturing is such an important economic activity, and is one of the most vital sources of the technical objects that permeate people's daily lives in most countries today, to dismiss knowledge production history of these industrial manufacturers fails to address its importance in the economic and social history in the modern world thereby maintaining a salient "missing link" in STS. While industrial knowledge studies are present in areas such as sociology, economics, anthropology, and business management, I believe that STS can contribute to the studies with close and critical

examination of the inner world of the knowledge production process, knowledge content, and related disputes.

The intellectual contribution of the dissertation also lies in its ability to supplement the history of computing (for individual discussions, see below) with regard to its neglect of manufacturing activities, especially contract manufacturing. The history of computing has been typically design-centered, brand-centered, and Western-centered, since it is mostly the history of major companies and their design efforts that have been documented. Important players such as Taiwan, a major site of hardware manufacturing, and India, a major site of software contract manufacturing, and other countries such as South Korea and Singapore since the 1980s, are largely missing from the history of computing (see below).

Similarly, in sociological, historical, and ethnographical studies of technology that concern manufacturing and engineering, most of the attention has been focused on the design process, the automation from adopting machines, and the skills and craft knowledge of workers in the factory. Also, to some extent, they have focused on innovations in manufacturing processes and industrial engineering, which were initiated by Taylor (1911). However, my project explores the extended process between the abstract concept and actual assembly in the factory. Namely, I examine the entanglement between design and manufacturing effort after a product concept is obtained from a brand-name firm and before the product is assembled in the factory. Good product concepts and plans alone do not

guarantee good products. There are much richer, situated, and contingent dimensions involved.

Studies of the Mobility of Knowledge

A main contribution that this project can make is toward supplementing the ideas of “local knowledge versus knowledge that travels” and “tacit knowledge versus explicit knowledge,” two tensions that endure in science and technology studies (STS). I call the combination of these two ideas, “studies of the mobility of knowledge;” one focuses more on geography and the other more on the human body. The objectivity and universality of scientific knowledge has been an important inquiry, from Karl Mannheim (1936) and Ludwik Fleck (1979 [1935]) to Thomas Kuhn (1962), in their emphasis on the social dimensions for producing scientific knowledge. The local and contingent character of science has been emphasized by scholars who went into laboratories to try to observe the very process of the formation of scientific knowledge (Latour and Woolgar 1979; Knorr-Cetina 1981; Lynch 1985). The subsequent development of the sociology of scientific knowledge and actor-network theory has continued to stress the role of local practices, albeit at the same time showing how knowledge travels.

One of the earliest thinkers to pay attention to knowledge mobility was Michael Polanyi (1958), whose notion of “tacit knowledge” not only challenges the standard view of objective scientific knowledge but also indicates that certain kinds of knowledge are hard to

codify and difficult to communicate in a way that travels from one local site to another. Scholars such as Harry Collins (1985) and Donald MacKenzie (1996) assert the importance of such tacit components of knowledge. In contrast, Bruno Latour's (1987) notion of "immutable mobiles" highlights the manipulation and rationalization of knowledge by scientists to make knowledge mobile, immutable, and combinable. The notions of local knowledge and lay knowledge also challenge the authority of universal scientific knowledge (Geertze 1983; Wynne 1996; Epstein 1996).

As for technology studies, many scholars stress the heterogeneity of technological knowledge. Different approaches, including the sociotechnical-systems approach (Hughes 1983), actor-network theory (Latour 1987; Callon 1986; Law 1987), the social construction of technology (Pinch & Bijker 1987), and the users' study (Cowan 1987; Woolgar 1991; Kline & Pinch 1996; Oudshoorn & Pinch 2003) all stress the contingent and heterogeneous components of knowledge that lead to changes of technology. Feminist studies of technology also provide another way of looking at technology. There is gendering of technology regarding its design, marketing, and usage (Cockburn & Ormrod 1993); such gendering of technology is profoundly cultural rather than natural (Oldenziel 1993), and there is mutual construction of technology and gender (Wajcman 2004).

In my dissertation, I closely examine the heterogeneity of technological knowledge and daily practices in an industry that produces high-tech products for the world. Given the

globalization of the division of labor and the laptop market itself, there are tensions between the ways through which knowledge and practices can travel or remain localized. It is this struggle between the local and the global, and between tacit and explicit knowledge, that is a core consideration in my dissertation. I will, however, develop a new idea, field knowledge, to look at my actors' knowledge activities that can supplement these important ideas in STS.

The History of Computing

This dissertation will also contribute to the growing literature on the history of computing by emphasizing the role of manufacturers rather than only that of designers or major brand-name companies. It aims to discover some missing components in the history of computing, where there is almost no voice and no history of manufacturers (Edwards 1996; Ceruzzi 1998; Campbell-Kelly and Aspray 2004; Akera & Nebeker 2002). In addition, non-Western computer actors, except for Japan (Takahasi 1980) and China (Maier 1988), have seldom been researched in this area. The situation is not surprising, as the history of the computer typically is Western-centered and design-centered.

The semiconductor industry has been a major focus of academic research on knowledge creation in computer-related manufacturing. The difficulties of manufacturing semiconductor products are so huge that they often reshape the direction of design (Choi 2007; Bassett 2002; Lécuyer 2005). Some scholars even argue that in the semiconductor

industry, the most “upstream” activity is manufacturing rather than design (Wang & Chen 2006: 26). Hence, the traditional hierarchical relation between design and production is then partially subverted. In my project about the laptop industry, that hierarchical relation will also be challenged.

Studies of Manufacturing and Engineering

The technology studies literature on manufacturing knowledge offers a variety of studies of manufacturing processes, including the scientific management of Taylorism (Nelson 1980; Jones 1997), the mass production and standardization of Fordism, flexible mass production (Hounshell 1985; Jones 1997), lean production and the just-in-time model of Toyotism (Castells 1996), and other post-Fordist models (Jones 1997). There are also works about innovations, such as interchangeable parts (Smith 1977; Hounshell 1985; Alder 1999). These manufacturing technologies and approaches to production were primarily generated by engineers, managers, and inventors, with the aim of managing production.

A second body of knowledge regarding manufacturing uses a Marxist approach, and focuses on the worker’s skills and craft knowledge. Both the notions of “deskilling” workers through adopting more machines and rationalized methods (Braverman 1974) and the politics of technology choice for shifting control over production from workers to managers (Noble 1984) are concerned with how workers’ skills are gradually taken away from them and

controlled by management. But in the meantime, some scholars argue against the notion of deskilling by asserting the possibility of “reskilling,” or the readjustment of workers’ skills (Zuboff 1988; MacKenzie 1984).

As for engineering knowledge, it was once largely missing in the literature. It was argued in 1989 that engineering knowledge, or the role of engineers, was “invisible” and never was “a problem” for research in the social sciences (Downey et al. 1989). But this situation changed later when scholars studied design knowledge (Vincenti 1990), engineering science (Kline 1992), and the design process (Bucciarelli 1994). Another approach explores the “mind’s eye” of visual thinking and the visual culture of engineers with regard to their communication and knowledge production (Ferguson 1992; Henderson 1998).

Thus in the literature we have management and engineering knowledge regarding manufacturing processes, knowledge that concerns the skills of workers, and knowledge of engineering that pays attention to science, design knowledge, or visual representation. However, few scholars specifically examine knowledge across design and manufacturing. This missing aspect is my dissertation’s focus.

With regards to Taiwan’s industrial development, scholars from the social sciences have researched the subcontracting network and micro entrepreneurship in Taiwan (Shieh 1992), the production networks in Taiwan’s garment and computer industries (Pan 1998), the socioeconomic factors in developing the computer industry in Taiwan during the 1980s

(Tengli Lin 2000), the industrial technology characteristics of semiconductors (Wu & Lin 2000), the networks and the organization of the semiconductor (Chen 2003), as well as the learning region of the high-tech industries in Taiwan (Hsu & Saxenian 2006). My project will contribute to this line of literature by examining the mundane design-manufacturing practices and even the knowledge content of these contract manufacturers.

Field Knowledge, and the Dynamics between Design and Manufacturing

The integration and interaction between design and manufacturing is worthy of further exploration. The general tendency has been to take a design-centered approach in innovation studies. This approach implies a hierarchy of knowledge between design and production, regarding design as rules, and production as the implementation of rules. However, we know that “actions do not simply follow rules” in a mechanical way (Bloor 1973; Collins 1985; Lynch 1993) and that action is always “situated” (Suchman 1987, 2007). Thus, a better understanding of the relationship between design and manufacturing is crucial. In the case of laptop production, the relations between design and manufacturing are very closely related, so I often use the term of “design-manufacturing” (or just D-M) to denote their inseparability in the making of laptops.

Because of this intertwining of design and manufacturing in the laptop industry, the relations of production (which are the social relations specific to a particular mode of

production, according to Marx) have plural possibilities. Several of my interviewees said that Quanta computer has been very manufacturing-centered. Their factory even has the right to return the design plans to the design teams if they are difficult to mass-produce. By contrast, another laptop producer, Wistron Corporation, was very design-centered. The two contrasting cultures concern not only a power differential, but also an epistemic discrepancy. The principles of “design for manufacturing” or “manufacturing for design” will generate different bodies of knowledge for the industrial players. Also, in different time periods, the dynamics between design and factory teams also show difference. Thus, the dynamic and changing relations between the two form a persistent theme in the dissertation.

In exploring the knowledge-related activities of these Taiwanese contract manufacturers, I examine one of their specific advantages and contributions in the industry: cost reduction. Knowledge and practices regarding cost reduction concern neither purely scientific-engineering knowledge nor merely skills and tacit knowledge. As my study finds, it is also not sufficient to call their knowledge production activity a form of local knowledge, tacit knowledge, or situated knowledge. I therefore develop the notion of *field knowledge* to describe CMs’ active and interactive efforts in transforming ideas into things. Field knowledge shows an aggressive type of the dynamics between design and manufacturing with a strong tendency to link and consolidate the relations between them. The design and manufacturing teams can come from both inside and outside partners. In my cases, numerous local

suppliers are one of the most crucial outside partners, who have helped the laptop producers to move forward in a rapid and flexible way.

Field knowledge is a concept that represents a type of knowledge production practice in a field that involves frequent multiple-sited or trans-organizational exchanges between actors from heterogeneous expertise or backgrounds. *Field* has two major levels of meaning in my study. The first is physical and spatial, as in “fieldwork,” which refers to the outside or heterogeneous environment that is beyond one’s own routine and well-controlled workplace. The second meaning is partially borrowed from Bourdieu’s (1990) notions of field and habitus, but it is not confined to his definition. I use “field” to also emphasize that it is important to know how power, and one’s own and others’ relative positions, are situated in the industry. In other words, it is concerned with social fields.

Field knowledge is knowledge that is generated in both action and interaction. It is a knowledge production process that extends beyond the single person, department, or company. For example, to reach goals such as reducing cost, actors need to constantly interact with other departments or partners and actively gather information or ideas from their fields that concern both technological and social factors. The factor of cost is centrally embedded in every plan and practice. It requires the actors to find and integrate knowledge from heterogeneous sources. Overall, I argue that field knowledge, which involves a carousel-like working style that helps generate useful knowledge for quick innovation through engaging with

numerous partners, is an important practice that enables the concentration of worldwide laptop production in Taiwanese companies, which I will elaborate on in both Chapters 3 and 4.

Research Methods and Sources

Selection of Firms

As mentioned above, the two main companies studied in this research are two of the largest laptop contract manufacturers in Taiwan: Quanta Computer, and Wistron Corporation (formerly, Acer's CM department), but occasionally in this dissertation I also will discuss a third company, Compal Electronics. Choosing how many cases to study is always tricky. Choosing a single company can lead to a very in-depth study, but since there are a few different business models among the Taiwanese CMs, it is promising to do some degree of comparison. Therefore, I decided to study multiple players.

To make the research feasible, I decided to choose either two or three to study, and originally, I chose three companies (Quanta, Compal, and Wistron). Although I finally received official letters of support from all three of them, it was still difficult to arrange interviews with these busy engineers and managers, especially since accepting interviews might lead to a risk of leaking commercial confidentiality and making their brand-name companies unhappy. As the research progressed, it turned out that an important contingent factor, the "snow-ball effect" (interviewee introducing another interviewee), works much better

with Quanta and Wistron, so I had to change my plan. In the end, I conducted many more interviews for these two companies. Moreover, when I was writing, I found it hard to build in-depth accounts from my interviews with Compal due to the limited data I had. I needed to reset my goal and focus on Quanta and Wistron, supplemented with Compal's development when needed.

I chose to focus on Quanta and Wistron not only because the former is the first laptop producer in Taiwan, but also because it has become the world's largest notebook manufacturer in the last fifteen years. Wistron also has had a high ranking worldwide in the recent decade (third, in most years). More important, the two companies display contrasting business models within the industry. While Quanta keeps its "multiple customers" strategy unchanged, Wistron has transformed itself dramatically from a player with both its own brand and contract manufacturing (CM) businesses to one that embraced only CM business after 2001 (the own-brand business was kept in Acer, and Wistron spun off from Acer).

Compal, ranking number two in the past 15 years, adopts a model similar to Quanta's with an unchanged multiple-customer CM model. I studied two "successful" Taiwanese CMs that employed different business models. It is also crucial to offer not-so-successful cases. But confined by the time and scope of dissertation work, I focused on the two selected CMs. The other players serve for comparative purposes when needed. Also, although I selected larger companies, I do not imply that smaller contract manufacturers are less important in

their knowledge production regarding design and manufacturing. Also, I will not argue that the two companies “represent” two models in the industry, as every company is unique in the industry’s history. There are still other varieties in the industry. For example, some CMs focus only on smaller local-channel/store-brand-name customers, and some serve only one single brand-name customer. But since a dissertation cannot cover all the CMs in Taiwan, a choice has to be made. Also, although Quanta and Wistron are the two main corporate actors I explore, historical accounts are not confined to them; more accounts from documents, reports, journal articles, and from other Taiwanese CMs, suppliers, and foreign brand-name companies will supplement as needed.

Strengths of Data and Research Methods

Methodologically, this dissertation draws primarily on qualitative in-depth interviews, supplemented by archival research, secondary literature, and news reports. I conducted about seventeen months of fieldwork in total in Taiwan between January 2010 and March 2011, and in the summer of 2012. I also traveled to Tokyo in 2010 for an interview and to Silicon Valley in 2011 for interviews and archival research. Since these contract manufactures’ factories have primarily been in China since 2001, I also made a short-term visit to Shanghai and Kunshan in China during the summer of 2012, in order to explore the changing relations and cultures between design and manufacturing due to the new geographical relocation.

In total, I conducted ninety-five interviews (with about seventy people, fifteen of them were interviewed twice or more, see the complete interviewee list in Appendix), and a total of 157.7 hours of interview time. I interviewed primarily Taiwanese engineers/managers, but also with a few Chinese workers and American managers. Most of the interviewees were Taiwanese engineers/managers, the focus of this study, but a few interviewees were Chinese workers and managers from some American companies. Most interviews were conducted face-to-face, a few were through Skype phone calls, and some were by email, especially for follow-up questions and when I stayed in Ithaca, New York.

Again, I focus on the Taiwanese engineers and engineer-managers of three larger laptop makers; thus, they made up most of my interviewees, although I also interviewed a few Chinese workers and managers who were in brand-name firms. I aimed to examine the CMs' past and present, mainly through these engineers' and managers' observations and interpretations of the world inside contract manufacturing.

I also conducted archival research in one American and one Taiwanese collection to study the early history of laptops. In the US, I examined early laptop documents at the Computer History Museum (CHM in Mountain View, California). In Taiwan, the main archive used is from the private collections of Kuo-Ting Li, stored in the Archives of the Institute of Modern History at Academia Sinica. Li (1910-2001) served as economics minister of Taiwan from 1965 to 1969, and was a key person in developing Taiwan's high-tech industries.

Rare Access to the Industry

One of the greatest difficulties in researching contemporary industry is to gain access to companies for academic purposes, but access was less of a problem for my project due to my past background as a journalist who covered hi-tech developments in Taiwan before I entered graduate school in the U.S. I was able to get access to many rarely acquired accounts from inside these CMs about their views of the production world. The Taiwanese CMs, especially their engineers and managers, are my research focus.

The strengths of the data for the dissertation are the rare access to the contract manufactures, and the large number of interview transcripts. Deducting certain failed/unclear recordings or non-crucial interviews, more than two million words of transcripts were generated, which formed a rich primary source for my current and future studies. The main advantages of in-depth interviews were that I could focus on asking the questions I was interested in and interact instantly with the interviewees with new questions based on their answers. In this semi-open interview research method, I obtained crucial topics or accounts beyond my original anticipation.

Limits of the Interview Method, and “Going Native”

Accessing industrial actors for social science and humanities studies is challenging. Many related studies require power-negotiations. The power of corporate interviewees often

supersedes that of the researcher, who is thus facing a situation of “studying up” or studying the cultures of the powerful (Nader 1974 [1969]). In my case, although I finally gained letters of support from the above three companies by the request of the IRB (institutional review board), the over-worked engineers or managers had no obligations to join my research, let alone risk disclosure of information that might anger their partners or major clients. Some people rejected interviews, some allowed only one interview, and some had no willingness to share any written documents (such as meeting minutes they had kept for years) even if they had some.

Another challenge of this research was to write a complete narration of a single event. Certain stories or accounts that seemed worthy of exploration, often lacked further details or were absent due to interview time constraints. Limited details (e.g., what, when, who, where, and how) partially resulted from the fact that they seldom kept working journals. Therefore, it was difficult for me to reconstruct and comprehensively describe events, which usually require extensive archives or participant observation. Also, the interviewees had their own ideas of what projects were more important to them, which made the subjects under scrutiny very divergent. Furthermore when a topic involved company secrets or confidentiality, they simply could not share it with me. As a result, I have numerous fragmented and smaller anecdotes, but do not have sufficient material to narrate certain events in detail and from multiple perspectives.

Furthermore, the main channel for gaining interviews resulted from a chain of introductions or the snowball sampling (Noy 2008). This method tends to locate the same network of people (usually friends rather than strangers or enemies), and consequently, multiple interpretations of events are not guaranteed, although this method has the potential advantage that a certain group of people can be deeply studied. Also, since I positioned my research as historically-oriented, I was interested in interviewing senior employees (who had worked in their companies for at least ten years, and had experienced changes in the industry and their companies, so usually they are either senior managers or even retired when I interviewed them) rather than young employees, so the data systematically lacked the latter's observations and voices.

Also, it was difficult to find relevant public documents about the CMs' views and detailed practices due to the nature of my research questions. Finally, accounts from brand-name companies, suppliers, shop floor workers, or other smaller laptop producers are largely absent mainly because they are not the main focus of this research.

When reading this dissertation, readers might question if I, as the researcher, stand "too close" to the perspective of these Taiwanese producers. The proper distance between researchers and actors (or the people who are under study) is an ever-present issue in many humanities and social science studies. Does the author speak from a perspective of his/her own (as an outsider or an objective "judge"), of the actors (the researcher aims to understand

the society under study from the inside), of the actors' opponents, of all of them, or of nowhere? This can be a question of the degree of "going native" (Kuhn 1970; Tresch 2001; Collins 2011).

In the research method of going native (such as participant comprehension), the researchers seek to go native by "actively taking part in the systems of knowledge being studied," and by crossing a line of objectivity to the extent that the researchers come to "experience the world in the same terms as the people he or she studies" (Tresch 2011: 303). Sometimes the researchers or the analysts have to disagree with the native members, but as Collins (2011) argued, the crucial problem is not whether the analysts are doing their best to become like a native, nor if they sometimes disagree with the native informants, but it is whether the analysts go too far in basing their analyses upon the perspective of a native member rather than that of humanities scholars or social scientists.

My fundamental aim in this research is to make these invisible producers visible, and to look at the industrial world from their (neglected) perspective, therefore, it is natural that many accounts are from the CMs' views, and to understand them from their social and industrial context. The goal is not to present their accounts as hard facts, but also not to "correct" their perspectives as a moral judge all the time. Rather, I will show their ways of looking at the world while adding my own interpretations as a scholar of science and technology studies (STS). For instance, the idea of field knowledge is a category from my

analyst perspective rather than from the actors. Sometimes I will show disagreement with important arguments from the industrial actors. For example, when a few engineer-informants described themselves as though they were part-time workers for their brand-name clients, I respected their self-image in this potentially industrial class relation. I added my ideas why they might regard themselves in that way, while also disagreeing that they are truly the working class of the industry. In Chapter 4, although no respondents indicated that they imposed a high-low engineering culture to their Chinese colleagues, I argue that this imposition exists based upon my understanding of their company strategies in China. Maintaining a critical distance between the analyst's and the actor's perspective is sometimes a challenge, but readers should note these issues of actors' and analysts' perspectives before entering into the text of the dissertation.

Who the Actors Are: A Snap Shot

The 1970s and 1980s were a time filled with start-up entrepreneurship in the electronics, calculators, and computer industry in Taiwan. There were thousands of personal computers companies during that time. Several laptop companies have since expanded to multi-billion-revenue firms, but most of the early start-ups closed or operated on a small scale until the end of the century, when the large-scale laptop relocation to China occurred. The industry in Taiwan enjoyed their operational peak (in terms of fame and profit margin) during

the mid-late 1990s.

Most of the laptop companies' founders were in their 30s when they started their companies, who were born mostly between 1949-1952. Many founders of larger laptop companies graduated from famous universities and with a major in electrical engineering, electronics engineering, or computers, and control-related fields (see Table 1). Although these companies' founders do not represent the composition of their firms, their educational and work experience did show common characteristics of that time.

Table 1

The entrepreneur-engineers in Taiwan's laptop industry.
(Multiple sources. Organized by Ling-Fei Lin)

Name	Main Field	Background	Education
Kuo-yi Yeh (1941-)	Calculator Laptop	Co-founder of Inventec	Shilin High School of Commerce
Stan Shih (1944-)	Calculator PC Laptop	Co-founder and Chairman Emeritus of the Acer Group; Wistron was part of Acer and span off in 2001	National Chiao Tung University, Master (Electronics Engineering)
Stephen Lee (1949-)	Laptop Cell phone	Founder of Arima Computer	National Taiwan University, Master (Electrical Engineering, EE)
Barry Lam (1949-)	Calculator Laptop	Co-founder and Chairman of Quanta Computer	National Taiwan University, Master (EE)
Ray Chen (1949-)	Laptop Cell phone	President and CEO of Compal Electronics	National Cheng Kung University (EE)
C.C. Leung (1950-)	Calculator Laptop	Co-founder and President of Quanta Computer	National Taiwan University, Bachelor (Physics)

Terry Guo (1950-)	Component Smart phone Laptop Tablet	Founder and Chairman of Foxconn Group/ Hon-Hai Precision	China Marine Technical College; Associate's Degree
Simon Lin (1952-)	PC Laptop	Chairman and CEO of Wistron Inc.	National Chiao Tung University, Bachelor (Electrical and <i>Control</i> Engineering)
Yi-Cheng Chen (1952-)	Laptop Component	Founder of Twinheads Computer	National Taiwan University, Bachelor (EE)
Jonney Shih (1952-)	Motherboard Laptop Tablet	Former Acer R&D head, then Chairman of Asus	National Taiwan University, Bachelor (EE)
Tung Tzu-Hsien (1960)	Motherboards, Laptops Tablets	Former Acer R&D engineer, co-founder of Asus. Now Chairman of Pegatron, which separated with Asus	National Taipei University of Technology, Master (Computer Communication and Control)

The major group of people I interviewed for this dissertation, to a large degree, have backgrounds and expertise similar to the founders or top managers listed above, with education and experience in electrical engineering, electronics engineering or very related fields. In addition to universities, a group of these interviewees graduated from the junior college system, a then very popular five-year vocational program after middle school.

As my project focuses on the historical development of the industry, I primarily interviewed senior employees, who were either retired or became managers. In other words, most of my interviewees are engineer-managers, although at different levels of management. Most of them earned their degree in Taiwan. Few of them studied abroad. Most of them were

born in 1940-1960 (now in their 50s to 70s), and more than 90% of the interviewees are male. Although I describe them as a group with many similarities in this sketch, individually they have rich career and life experience that made them distinctive, which is an aspect that this dissertation is often unable to fully portray.

Chapters

I organize my dissertation into five main chapters and arguments that center on the theme of the dynamics of design-manufacturing laptops in their historical and social context:

Chapter 1 (the late 1980s-the early 1990s): This chapter shows that the Taiwanese laptop industry was established on their design engineering capability rather than their easy access to cheaper labor and factories in the early years. The linear image of progressing from inexpensive manufacturing to higher value design is a traditional myth about Asia's industrial development. More generally, it is also a myth that manufacturing-- in contrast to design-- is not innovative. We should note that one reason that Silicon Valley surpassed the East Coast of the US in the high-tech industry was because they engineered innovative manufacturing techniques. Also, since the early 1990s, Taiwanese CMs have learned about the product development process by working with well-known brand-name clients. Their innovation efforts then focused not only on the product level but also on the process level of making a machine. After this, both their factory capability and design-manufacturing integration was

enhanced.

Chapter 2 (the 1990s): In the chapter, I demonstrate the complexity of the product development process and problematize the traditional hierarchical knowledge division between design and manufacturing. I underline the idea that manufacturing activity seldom involves only the final assembly of a product by factory workers or machines. Rather, there is a much richer relationship between design and manufacturing. Also, manufacturing is important and its range extensive. My research flattens the hierarchy of knowledge production between design and manufacturing, and it shows that there is strong feedback from manufacturing to design, in this profoundly social process.

Chapter 3 (the 1990s- the 2000s): In this chapter, I argue that there are different innovations for reducing the cost of laptop production from the CMs, who have faced ever-thinner profit margins. I use the notion “field knowledge” to describe the dynamics of their knowledge practice. Field knowledge that involves constant exchanges between actors from different sites and organizations highlights not only the integrated design-manufacturing expertise of those producers, but also their aggressive and creative use of different resources from outside fields surrounding them. It represents an active and expanding practice oriented to the field. Here I also show that the Taiwanese CMs’ innovations with inexpensive technologies were diminished by their powerful brand-name clients.

Chapter 4 (1990s-2000s): In this chapter, I show that although these CMs created

numerous innovations, in the end, their innovation was still inevitably restricted and standardized by their much more powerful partners whose strategies included limiting product orders, knowledge support, or components procurement rights. Altogether, the dynamics between the expanding field knowledge of the CMs and the constraining force of standardization and containment from powerful partners help shape and explain those CMs' knowledge and practices today.

Chapter 5 (after 2001): In the chapter, I examine relations of production in Chinese factories. Critical accounts (such as of the Foxconn employee suicides) often emphasize only the binary division between laborers and capitalist or between design and assembly. I instead show how the two poles on the design and manufacturing spectrum are gradually mediated and translated through many middle levels of engineering work and the mechanism of engineer contact layers. I examine how moving Taiwan's laptop factories to China (as their Chinese subsidiaries) after 2001 was also a transformation of CMs' knowledge production and practices based on new transnational design-manufacturing relations. Within this stage, the CMs' manufacturing techniques were even more extensive and its capability further growing, along with excellent design and D-M integration capability. This section delves into the changing knowledge relations among geographical spaces, engineers, workers, and robots with Taiwan's intention to keep the hierarchy of knowledge between Taiwan and China in a politically charged environment. I show the permanent struggle between emplacement

and mobility, and call for an (im)mobility analysis for factory relocation action.

CHAPTER 1

EMERGING THROUGH DESIGN ENGINEERING

In 1988, when Quanta Computer built one of Taiwan's first laptops, Taiwan had almost zero percent of the world's laptop market share. But by 1990, Taiwan's companies produced 11% of the world's laptops, and the share rose to 32% in 1996, and then to about 50% in 2000. The number reached 80% in 2007 (although with their subsidiary factories in China after 2001). In 2011, the top six laptop manufactures (Quanta, Compal, Wistron, Foxconn, Inventec, Pegatron) from Taiwan occupied more than 90% of global market share, with Quanta producing about 60 million units, Compal 56 million units, and Wistron 36 million units for a total of 200 million units worldwide in that year.¹ This first chapter is then dedicated to trace the highly consolidation phenomenon back to its emerging years.

Overall, the electronics production capability in East and Southeast Asia is well known today. The prevailing image of the rise of electronics industries in this region was often perceived to be rooted in inexpensive labor and manufacturing that led to an international division of labor. In exploring the emergence of the laptop industry in Taiwan, I will specifically examine whether the laptop industry in Taiwan follows this linear progressive image that the industry was first based upon simple assembly with cheap labor, and then gradually entered

¹ See <http://www.digitimes.com/news/a20101022PD211.html> or Table 2 in this very chapter.

the product design field by collaborating with well-known brand-name firms.

This linear progressive discourse is popular among media experts, industrial analysts, and scholars when describing Taiwan and greater Asia's high-tech industrial development history. For example, it is commonly stated that Taiwan's electronics industry developed from OEM (original equipment manufacturer) to ODM (original design manufacturer),² so its capability evolved from only manufacturing to also including design. The ODM model signifies that the company provides design services in addition to manufacturing services, and OEM involves only manufacturing services. In such cases, the earlier TV, radio, calculator, and then the later semiconductor, computer, and laptop industries in Taiwan are mixed together and categorized as the "electronics industry." As Taiwan began its "electronics industry" in assembling TVs and radios for foreign companies, on the surface, this "overall" image of electronics originated from manufacturing might not be unreasonable.

However, there are two aspects that we can examine further. First, we should question if this progressive image of "from manufacturing to design" is applied to every individual industry from the broad category of "electronics." In this case, is the laptop industry, which is one of the electronics industries, reduced to a similar historical narrative by this same progressive image? The second aspect we can examine is more subtle: does

² The electronics industry has two different and confusing usages for the term OEM. One usage is to distinguish it from ODM, as what I discussed in the text. The other usage refers to brand-name companies such as Dell or HP. What I use in this chapter will refer to the first meaning.

accepting the OEM order necessarily imply a producer has a better manufacturing than design capability? Why or why not?

Table 2

Taiwanese notebook Contract Manufacturers and their brand-name clients in 2011 (predicted). We can find that Quanta's total shipment (as a CM) was predicted to be 60 millions of units that year, surpassing the shipment of HP (as a brand-name firm), 50 million of units. Most CMs have multiple clients, and the vice versa (Source: *Digitimes*, October 2010).

Worldwide notebook makers and vendors shipment plans, 2011 (m units)										
	HP	Acer	Dell	Toshiba	Lenovo	Asustek	Samsung	Apple	Sony	Total
Quanta	23	5	4	5	4	5		9	5	60
Compal	2	25	10	9	7	3				56
Wistron	2	13	11		8				2	36
Foxconn	10		4			2		2	1	19
Inventec	9		<1	8						18
Pegatron		3		1	3	10				17
Flextronics	4		2							6
In-house				<1			12		2	
Total	50	46	32	24	22	20	12	11	10	

Source: Industry sources, compiled by *Digitimes*, October 2010

The Establishment of the Laptop Industry in Taiwan

The development of laptop production in Taiwan is in part rooted in the electronics industry which flourished there beginning in the 1960s, followed by the later rise of the calculator and the PC (personal computer) industries from the 1970s.

The Rise of Taiwan's Electronics Industry

After the outbreak of the Korean War in 1950, Taiwan received substantial U.S. aid during the Cold War period. Taiwan initiated export-oriented industrialization in the late 1950s and facilitated it in the 1960s when most Asian countries were still adopting an import-substitution strategy. With the help of American Aid, Taiwan built its first export processing zone in Southern Taiwan in 1966, which was considered to be a “success” since it attracted many foreign TV and electronics companies to establish assembly lines there.

These interactions with foreign firms not only integrated Taiwan into a globalized division of labor in electronics production, but they also helped the gradual formation of local parts and components suppliers in Taiwan. Later these local suppliers developed into a solid cluster and became very important in supporting further development in the information technology industries in Taiwan.³ The cluster of components suppliers provided an environment that nurtured frequent information exchanges among the producer actors in Taiwan.

Although enjoying economic growth after adopting the export-oriented industrial policy, Taiwan faced a series of diplomatic setbacks and other challenges. In the early 1970s it became hopeless for the Nationalist government to win battles and return to mainland China after more than two decades of separation with the mainland. In 1971, Taiwan exited from the United Nations; then in 1972, Japan broke off diplomatic relations with Taiwan; in

³See Pan 1998, K. T. Li 2005, Chang and Pan Wen Yuan Foundation 2006, and Chang and Yu 2002.

1973, the first global Oil Crisis occurred. These setbacks induced the Taiwanese government's decision to further grow its own economy, by developing the semiconductor and information industries.⁴ It was also in the 1970s that Unitron (環宇), San-Ai, Qualitron (榮泰), Inventec, Mitac, Multitech (later Acer Computer), and other calculator or computer system companies, which were founded by local people and local capital, began to appear.

The Calculator Industry: A Direct Link to the Laptop Firms

The calculator industry in Taiwan played an important role in paving the road for laptops there. It is argued that, the calculator industry was the “mother of the notebook computer industry” in Taiwan.⁵ First, among most of the largest six notebook companies today, either the main founders or the companies themselves originated from the calculator industry. Compal and Inventec began as calculator companies. The two main founders of Quanta, Barry Lam and C.C. Leung, both started their business in the calculator industry, too. The main founder of Acer/Wistron, Stan Shih, began his own career also in a calculator company. These companies were all founded by young engineers, although the financial support was mixed. It was a time of active entrepreneurship in Taiwan, and many young graduates who received well education in engineering started their own companies one after another.

The second reason that links the laptop to the calculator industry is that the calculator

⁴ Hong, p. 27.

⁵ Amsden and Chu 2003 (Chinese), p35.

industry not only created a more significant and influential learning path than that of the television (TV) industry, but it is argued that it also began the trend to “change from OEM to ODM.”⁶

The calculator industry of Taiwan in the 1970s had begun to show an energetic engineering capability: engineers used reverse engineering to copy foreign calculators (mainly from Japan). They copied, and then tried to make some improvements on the design, before producing their new products. Because their overall costs were cheaper than those of Japanese products, many American importers bought Taiwan’s calculators. Even Japan began to outsource to Taiwan in the early 1980s.⁷ The calculator companies in Taiwan gradually learned how to design integrated systems. They caught the new wave of using LSI (large-scale integration) chips to develop new electronics products, and in addition, they learned from copying and observing, and acquired different techniques from their Japanese component suppliers to become expert at integrating a great number of parts and components into a small space. It is argued that these Taiwanese calculator companies’ competitive foundation relied mainly upon “detailed design capability” rather than on a low-wage workforce, because their costs were higher than some others.⁸

The Early PC Industry: Apple Clones and IBM Clones

⁶ Ibid, p35-41.

⁷ Amsden and Chu 2003 (Chinese), p35.

⁸ Amsden and Chu.2003 (Chinese), p35-41.

After the thriving of calculator companies, personal computer also started to emerge in Taiwan. One important event for the development of Taiwan's computer industry occurred in the early 1980s. In 1982, the Taiwanese government began to ban arcade video games in the domestic market, mainly due to the negative effects of having young people playing gambling machines in arcades. At that time, some Taiwanese makers were successful at copying the arcade games from the U.S. and Japan. They could soon replicate a game at an inexpensive cost.⁹ After the domestic ban, there were no guarantees that copying game machines would generate profit only from exportation; therefore, these companies and their employees faced a company transition crisis, which led a number of such makers to change to another new business: cloning the popular Apple II.

There had been a worldwide phenomenon of cloning the Apple II, which was launched in 1977. Apple II was an appealing product on the market because of its ease of use and flexibility rather than the significant innovations that were occurring at places like IBM or Xerox.¹⁰ Between 1982 and 1984, Apple initiated more than fifty lawsuits in sixteen countries¹¹ But, according to Apple, Taiwan accounted for 75% of their infringement problems. As a result, Taiwan was the main target in those suits.¹² Many players in Taiwan

⁹Special reports on "Where could the arcade-game industry go?" In *Economic Daily*, March, 9, 1982. The news clip in K.T. Li collections.

¹⁰ See Ceruzzi, 2000, the Apple II's spreadsheet application VisiCalc was a hit though. See also Campbell-Kelly and Aspray 2004 for Apple II's development.

¹¹ Burstein 1984, quoted in Lin 2000, p.128.

¹² Louis Kraar 1983, "Fighting the Fakes from Taiwan," *Fortune*. May, 30. Quoted in Lin 2000.

used reverse engineering techniques to copy the machine and produce Apple II compatibles, although some claimed that their products were not identical copies.¹³ In an era that had weak regulations regarding computer intellectual property (software copyright was also unclear even in the U.S. at the time), Taiwan had a boom in (partial) “imitations.” Following Apple’s legal actions, many Taiwanese players temporized and shifted their directions again: making IBM clones, since IBM adopted a strategy of open standards in personal computers. At that time, in addition to dismantling related machines from the market, many engineers had the “bible,” as they called it, from IBM, where they could check technical details, including circuit designs and BIOS (basic input/output system).¹⁴ The road to building IBM clones also met similar legal problems in 1984, when Acer exported their PCs to the United States. Acer commissioned ERSO (Electronics Research & Service Organization) of ITRI (Industrial Technology Research Institute) to develop an IBM-compatible BIOS for their PCs, but IBM still found copyright infringement. Later, by using the “cleanroom” method to re-develop an IBM compatible BIOS, ITRI successfully solved the infringement problem with IBM, and ITRI’s BIOS was finally licensed to five PC companies in Taiwan.¹⁵

13 Chang 1992. Shih 1996. Also see Tinn (2012) for the history of Apple II compatibles in Taiwan.

¹⁴ Interviews of three senior managers in the industry: “Rob” (12/31/2010), “Floyd” (7/23/2011), and “Yonathan” (5/25/2010). When I use quotation marks for interviewees’ names (always coded in first names, rather than last names) for the first time, they mean pseudonyms, which are adopted to protect those who do not wish to disclose their the personal information in my project. For more information about interviewees, dates, places, and duration of all my interviews, see the interviewee list in Appendix.

¹⁵ Shih 1996, p.81-86. Could also see Lin 2000 for a detailed account of ITRI’s effort in developing its own BIOS. A cleanroom in the manufacturing sector or scientific laboratories refers to a room with controlled and a low-level of pollutants in order not to affect the product or process proceeding in the

The issue of whether or not Taiwanese companies were imitating has been a controversial idea to explain the activities of all the industrial actors in this time period, especially when companies and organizations had different involvements and unique paths for developing information products. For example, Acer's Stan Shih thought that when most other Taiwanese companies were 100% counterfeiting the Apple II, Acer's (then it was still called Multitech) Microprofessor II was not. He said this 1982 Microprofessor II product was based on the concept of the Apple II, but Acer made a great effort to re-design the product to make it smaller and more compact in its design structure, and most importantly, it was not compatible with the Apple II at all. They never intended to just copy it.¹⁶ He was also worried that the arcade game vendors could possibly damage Taiwan's information industry if they were not helped by the government to transform themselves well, since some of them were copying information products already.¹⁷

Being called one of the "Pirate Kingdoms" at that time,¹⁸ and being under political-industrial pressure from the U.S. government and big companies, Taiwan began to change. However, even in the harsh moment of accusation, not all players were making clones. Indeed, some vendors might have been involved in bold and direct replication, but

room. The cleanroom method in the ITRI context means that all the engineers were isolated in a room for creating their own version of BIOS without referring to IBM's product design.

¹⁶ Shih 1996.

¹⁷ Special reports on "Where could the arcade-game industry go?" In *Economic Daily*, March, 9, 1982. The news clip in K.T. Li collections.

¹⁸ The term was very popular in Taiwan's media at that time, since *Time* magazines had a series of articles in 1982 discussing the cloning issues in Asia by using the term "pirate kingdom."

others were not. For example, ITRI (with its BIOS) and Acer (with its Microprofessor II) drew on available resources to make their own products, rather than resorting to cloning. Although the issue of imitation was disputed, it was under such a situation of half-imitation and half self-reliance that Taiwan as a whole built its capability in developing its early computer industry, which was not possible without a large group of capable engineers and their active entrepreneurship.

Quanta's Humble Start and Their First Laptops: Adopting a Trial and Error Method

A company with annual revenues exceeding 25 billion US dollars in 2013, Quanta was founded in a small apartment in Taipei in 1988. Nevertheless, the founders, Barry Lam and C.C. Leung had already had years of experience in making calculators. Back to 1972, when Lam studied computers in graduate school, he and his classmate and later long-time good friend, Sayling Wen, wanted to found a factory when they were still in the Electrical Engineering graduate school of National Taiwan University. They visited the Chairman of San-Ai Electronics Chong-Fu Kao and asked him to consider supporting them.

Lam said that Kao gave him a broken calculator and asked him to repair it. He successfully repaired it, and as a result they started the calculator business, which they thought was suitable for Taiwan in the 1970s – the beginning of a digital era of semiconductors and integrated circuits (IC). Lam said, when the circuits were all on ICs, it

was not difficult for them to commercialize a calculator product.¹⁹

A year or so after Sai-Ai's calculator business, due to the shift of the interest of San-Ai's main investor to stereo systems, Lam and Wen left Sai-Ai and founded Kinpo Electronics in 1973 with investments from the Chao-Ing Hsu family. At Kinpo, their primary business was still designing and making calculators for both their own brands and for foreign companies. This model of designing and manufacturing products (ODM) was popular in the calculator industry, and it would later be adopted by many Taiwanese desktop and notebook companies.

In 1980, Lam thought it was time to develop a computer business, which for him was the real "big" business. At this point, Kinpo received computer monitor and terminal orders from Qume (later part of ITT), which was a U.S. company, but was founded by an overseas Chinese David Lee. Kinpo started a new company Compal to manufacture Qume's monitors and terminals. A big fire in 1987 in Kinpo/Compal's factory in Taoyuan, Taiwan forced Barry Lam and C.C. Leung to leave the Kinpo group, for which they had worked for almost fifteen years. Leung was another founder of Quanta, now the Vice Chairman and President of Quanta, who joined Sai-Ai with Lam and later founded Kinpo together with Lam and three other partners. In 1988, they left Kinpo/Compal due to the fire, and rented a small apartment

¹⁹ Interview with Barry Lam, Computer History Museum. *ibid.*

in Taipei to start their new business.²⁰ Small computer or electronics start-ups had been popular in Taiwan at that time, especially for the active computer motherboard industry. It was common that a few engineers who were good friends to others to form such companies.²¹

In the beginning, it was not clear what type of products Quanta should develop.²² The only thing they knew was that miniaturization of computers would be a good direction. Because of LSI (large-scale integration) and new display technology, calculators became much smaller, and personal computers were shrinking in size as well.²³

Quanta wanted to make smaller computers, but one problem was that none of the engineers at Quanta, merely eight (including Leung) in total, had made a computer before. Nevertheless, they did not do things from scratch, because they were familiar with many of the components suppliers from their early experience with calculators. Among them, some were good at software, some at hardware, while some others were good at mechanical, battery, or EMI (electromagnetic interference). Leung said that there was no single person that contributed the most, because no one could cover everything. The eight of them worked together to try to design their own products. They collected information, drew on the “bible” from IBM, dismantled others’ computers, mainly from Japan’s Toshiba and the U.S.’s Zenith,

²⁰ Leung (9/7/2010).

²¹ Interview with Roger Huang (12/31/2010), who is one of the earliest Quanta employees.

²² Huang (12/31/2010), and Leung (9/7/2010).

²³ Leung (9/7/2010).

and then discussed together what they could do.²⁴ Also, Leung said that if there had been no support from some components suppliers, such as Conner from the U.S., which was willing to sell them their new 3.5-inch drive (rather than the 5-inch format that was dominant at that time), Quanta might not have made a small-size product, especially when they were still such a small new company.²⁵

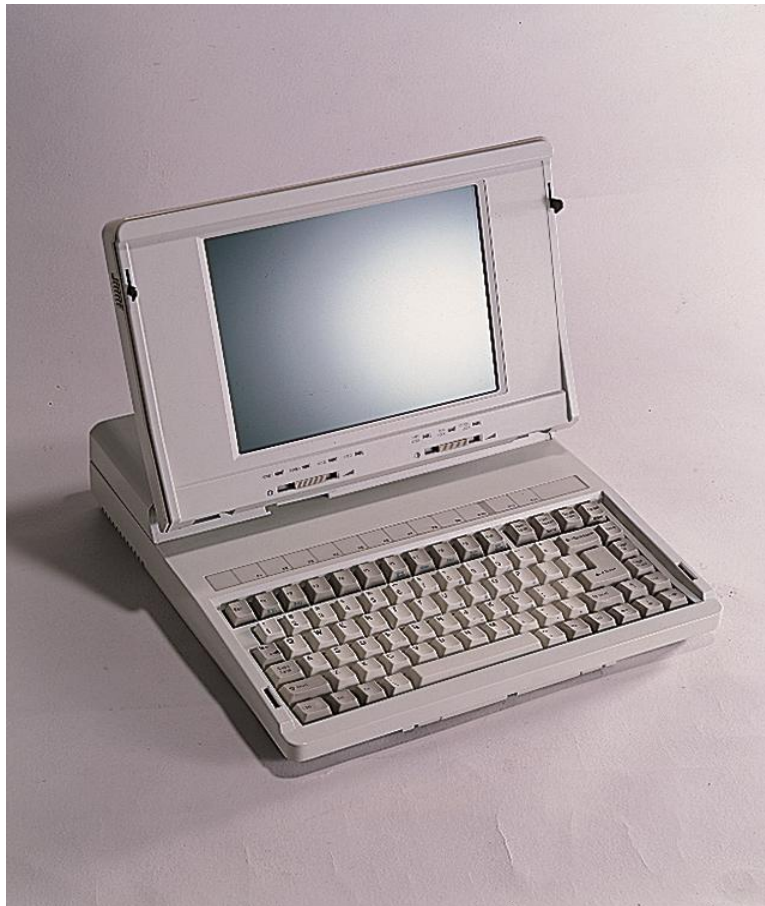


Figure 1.1

Quanta's first laptop QC201, 1989. It weighed about 16 lbs (Courtesy of Quanta).

²⁴ Huang (12/31/2010), and Leung (9/7/2010).

²⁵ Leung (9/7/2010).

When Quanta decided to make a laptop computer in July, 1988, it took just over a month for them to produce a model that could be sold in late August. But it still took another three months for them to debug the machine, because “every part had its problem.” It was through the process of solving problems one by one that they gained a more reliable computer.²⁶

One of the most special features in the machine was that it was composed of many existing parts and components designed for much bigger desktops, because at that time, laptop-specific parts were not yet available on the market. Leung said that it was agreed among his customers that Quanta’s first product was fairly “genius” (in Chinese, the word has both a positive and a satirical meaning of doing something unexpectedly or illogically) because they unexpectedly squeezed everything from desktops into laptops. He explained that there was no special tip: they just tried every possible way to squeeze the components, which became highly condensed, on the printed circuit boards of the laptops.

Quanta faced a few problems that they had to solve, such as electromagnetic interference, but Leung said that when the customers saw that their machine worked and was very cheap, they gave the orders to Quanta.

The inexpensive cost certainly resulted not from cheap assembly workers, but from engineering effort. The Quanta team used a specific way to make the machine cheaper.

²⁶ Leung (9/7/2010)..

There were two types of printed circuit boards, one that used SMT (surface mount technology), which directly mounted the components onto the surface of printed circuit boards with solder paste and then was conveyed into the reflow soldering oven to bond the components in their places. The other method used through-hole technology, which affixed components with wire inserted into holes in the printed circuit boards. Leung said SMT machines were used for high-density products with smaller components, but SMT lines were so expensive that few companies in Taiwan at that time had that device.²⁷ Thus, Quanta had no choice but to design the laptop with the cheaper but clumsy (with crowded wires) through-hole technology.

With the first working machine, Quanta received their first laptop order from Tulips, a famous Dutch company, and then later an order from the US company Packard-Bell. They were both ODM orders, since Quanta designed and made the laptops. Quanta shipped only a few thousand units in total for the first product, but the price of more than two thousand dollars per unit yielded a large profit margin, and so it was already a success for Quanta. Shortly afterwards, when making a second model, they modified the first model slightly and got even larger orders for that model. Upon reflection, Leung thought the first model was very critical to Quanta. “We made it muddle-headedly, and they bought it muddle-headedly.” It really needed some kind of luck. The machine actually was very heavy by today’s standards,

²⁷ Ibid.

weighing 7.5 kg, so when Lam carried it to sell around the world, it bruised his shoulders.

This initial success would not guarantee Quanta's survival. They kept looking around at other products and responded accordingly. In 1989, Compaq Computer launched one of the earliest A4-size portable computers (The Compaq LTE, was one of the first computers to be widely known as a "notebook computer.")²⁸ This time, Quanta strived to design one machine in a few months that was similar to Compaq's, again based on dismantling Compaq's machines, on team members' own experience, and on the cooperation with the components vendors. Consequently, Quanta became the one of the first companies in Taiwan to make such small size portables.

I showed how Quanta's engineers, in designing their laptops, endeavored to mobilize their limited resources, including technical documents, artifacts, and component supplier networks and to use a trial-and-error method based on their own experience with other products to design a workable laptop. There were few concerns about cheap labor or efficient assembly lines in the factory. Indeed, when a laptop product had only tens of thousands of units marketed over months, there was no need to worry much about mass production and efficiency issues.

²⁸ Just like there are always disputes about which computer was the first portable computer, it was similar in the first A4-sized notebook computer. *PC Magazine* featured the UltraLite of NEC on its cover in November 1988 and later media began referring to the A4-sized computer as a "notebook" to distinguish it from the laptops of the time. But in my interviews, interviewees tended to regard Compaq's product as a hit to them on the market.

Acer/Wistron:²⁹ Learning through Outside Partnership

Compared to Quanta's humble start, Acer's entry into the laptop business seemed to overpower Quanta in several ways. According to Fred Lin,³⁰ one of the co-founders of Acer Computer, when Acer saw the impressive product of Compaq's notebook computer (Compaq LTE, launched in late 1989), they seriously considered entering the market. Acer was founded in 1976, much earlier than Quanta, by Stan Shih, his wife Tsu-Hua Yeah, and five other partners. Most of them were engineers, with little wealth in their background. Therefore, Acer also had a very humble beginning in its early years, beginning as a company that sold some foreign computer-related products, taught people about microprocessor technology, and promoted computer usage in everyday life in Taiwan.³¹ But in 1988 when Quanta was founded, Acer had been very successful with desktop computers, and had already been a star company in Taiwan when their stock became publically available. Compared with Quanta, however, they were a bit late in developing the laptop business at that time. Fred Lin, one of Acer's founders, said that the technological challenge of laptops was very high, but another difficulty was "starting a new business with the company (inner start-up)," because usually other departments would question the resource usage of the new department. One reason

²⁹ Acer was separated into two companies in 2001. One kept the brand-name business; the other was spun off and renamed Wistron, which kept the design and manufacturing services.

³⁰ Author's interview with Fred Lin (3/8/2010).

³¹ See "about acer" on Acer's website: http://www.acer-group.com/public/The_Group/milestones.htm. Acer split off its manufacturing business unit as Wistron in 2001. The lower case "acer" is Acer's brand name.

that Leonard Liu, the then-CEO of Acer, assigned Fred Lin as the head of the new group was to avoid possible quarrels among different units.

Acer contacted a famous laptop designer Kazuhiro Miyashita (宮下和博) from NEC in Japan, who was introduced by an Acer manager's friend. Miyashita, who was responsible for designing NEC's first laptop UltraLite (launched in 1989), had left NEC for personal reasons. Acer then decided to form a joint-venture company, Long Chi (龍基), with Miyashita as the general manager of Long-Chi. Lin said they formed a new company because, if they did everything internally it might take a longer time. Also, Acer was too large an operation to accept Miyashita's technological share (using his technological capability rather than money as an investment and receiving a certain percentage of stock shares). The division of labor between Acer and Long-Chi was that Long Chi completed the major design, and Acer was tasked with detailed design.

Acer valued this project highly, and they dispatched important engineers/managers to this new project. Within Acer, Lin asked a director of quality control in the factory, Dr. Shung-Hui Chang, to be the notebook factory director. He was a person who received a Ph.D. degree in the US and had worked at America's GE as head of sales and marketing. Lin then also assigned Kung-Ming Lee, another doctor from National Taiwan University who had joined Acer in 1978, to be the head of research and development.

Before Acer constructed their own laptops, another co-founder Kenneth Tai

suggested that they should first try the market. As a result, they sourced some laptops from Quanta. Acer's made-by-Quanta machines were selling well, which made Acer more determined to enter the laptop business.³²

Acer's internal target was to design and produce a notebook within one, to one and a half years that would be similar to Compaq's LTE product. When asked if they also dismantled Compaq's machine, Lin answered, "of course we dismantled it, even Miyashita dismantled it." This statement shows that referring to the product of an earlier comer or a competitor was a common practice at that time in Taiwan and Japan, and in fact, in many other places. One difficulty of developing early products was the component supply, since most of the parts and components were still designed for desktop use only. For example, Acer had to use Intel's CPU for desktops. Therefore, Acer faced various challenges, including heat dispersion, internal structure, reliability, electromagnetic interference shielding, and sturdiness after dropping.³³

The model by Acer, *Anywhere*, was delayed for seven to eight months due to different challenges, and it did not sell well after Acer finally put it on the market. The technology was evolving so quickly that their new model was obsolete. After investing more than one million US dollars, because the new company kept "burning money" and did not run smoothly, Acer

³² From the interview with Fred Lin (ibid). But Quanta had a different interpretation on the laptop order from Acer. In their 10th anniversary internal magazine *Quanta's* (1998), the author (a senior manager) of the history of Quanta's products said that the "A company" was trying to learn their know-how by giving them the order.

³³ Lin (ibid.)

finally stopped investing in Long-Chi. But they had gained valuable experience from this cooperation: how to define a question, how to plan a system's architecture, how to manage quality, and how to solve a problem.³⁴

Lin said that it was not expensive to design a prototype or a sample machine, costing about twenty million New Taiwan Dollars (about 0.8 million USD at that time), but the investment for mass production was significant. Therefore, like Quanta, design capability, especially design engineering capability, was more of a salient feature of the company than that of a robust factory in the initial years.

Acer and Quanta's early laptop development projects displays a contrast. In their initial years, Quanta devoted few people and limited resources. They implemented a trial-and-error method to commercialize their first laptops by squeezing components and parts from desktops into a laptop design. By contrast, Acer failed with its first product, even though they drew upon on a more formal organizational effort. They invited a laptop expert from Japan, recruited people with Ph.D. degrees, and invested a great deal of money into the project. As a late-comer, Acer asked for an advanced machine and set high standards for it. By contrast, Quanta just wanted their first product to work, so that it could be sold. In many ways, the star company Acer should have superseded Quanta in their first laptop projects, but they did not. Within a decade, Quanta established their foundation and climbed to the top

³⁴ Interview with "Yonathan" (5/25/2010). He said Acer lost for four years in the laptop business, it wasn't until the fifth year that they began to be profitable.

position in Taiwan and in the world, although at this early point, none of these companies could be sure whether they would continue to succeed, let alone know that they would become future global laptop producers.

The Notebook Alliance: Sharing Jobs, Knowledge, and Technical Objects across Company Boundaries

It was not long after Quanta produced its first laptop in 1988 that the government began to value the potentiality of the laptop industry. Consequently, in 1990, the Notebook Alliance, convened by CCL (Computer and Communication Research Laboratories) of ITRI (Industrial Technology Research Institute) was initiated to help more companies join this high-growth industry. This was the second major initiative of ITRI that aimed to boost the computer industry. In 1984, they successfully developed a basic input-output system (BIOS) that was compatible with IBM PCs, and licensed it to several PC companies, which partially helped fuel the booming PC industry in Taiwan.³⁵

This time, due to demand from the local companies, ITRI decided to form an alliance to help more firms enter the notebook business. According to a document produced by ITRI about this alliance,³⁶ the goals of this project include: to increase the competence of national notebook industry; to push collaboration within companies, just as in the PC industry; to save the repeated modeling development fees, and to make the components standardized. Peter

³⁵ Author's interview with Peter Wang (10/28/2010). Wang is a senior manager in ITRI.

³⁶ *IT Information* (Chinese), Aug. 1990.

Wang, a senior manager in ITRI who has been familiar with computer projects at ITRI, recalled that, based on their experience of desktops, they regarded the standardization of laptops and the horizontal division of labor as crucial, because this strategy would enable them to make the various small and medium enterprises in Taiwan “become a company”, in order to “fight together with others.” The alliance indeed attracted many companies to join. As long as they spent a share of investment and joined the division of labor, they would get a “public motherboard” from the collaborative project.

According to the alliance manager from CCL, Sid Wang,³⁷ the development fee for such a project was about \$400,000 to \$800,000 (US dollars), but when they shared the fee, the companies could save a lot of money. In February 1990, they planned to let five companies join, but for various reasons, they changed the plan in April to let 15-35 companies join, so that each company would only pay around \$50,000 if they joined the Common Product Alliance. But more than 200 companies came to the first meeting, and finally 46 companies joined with a total investment of 2.1 million USD for this development project. They signed the alliance contract in July 1990, and then spent only four months finishing a prototype machine in order to attend the ComdexFall Exhibition, a large international computer trade show held annually in November in the United States. The company members then divided into groups focusing on motherboard, mechanical

³⁷ See Sid Wang 1991.

engineering and keyboard, power, testing, and electromagnetic interference etc. to co-develop the product.

The company composition of the alliance was complex: from PC and notebook companies to components, consumer electronics, and trade companies, and brand new companies.³⁸ Some famous companies in consumer electronics in Taiwan such as Tatung and TECO joined the project, but major computer companies like Quanta, Compal, and Acer did not. C.C. Leung from Quanta in the interview said that, because they already had developed workable machines, there was no reason that they should join, especially since other companies might learn Quanta's know-how through the alliance.³⁹ Overall, the major computer companies thought this alliance was a disaster because all kinds of companies could attend it without any control over their qualifications. Trade companies or three-people companies, as long as they had the money, could join it. The result was even more disastrous because by the time the "common board" was finished, there were twenty-one Taiwanese companies demonstrating their machines based on the common board at Comdex in 1990. The only thing that resulted from the alliance was a price war, because price became the only way to distinguish among the companies.

Regarding the dispute of whether ITRI should become involved in the development of commercial products, the notebook alliance manager Sid Wang pointed out that the main

³⁸ Ibid, p52.

³⁹ Leung (9/7/2010).

complaint from these big companies was that they thought CCL was “helping the weak to defeat the strong”, and as a semi-governmental organization, what CCL should do was to focus on developing core technologies rather than a commercial product.⁴⁰ But Sid Wang justified the plan and refuted the argument that Taiwan was doing well in the notebook industry at that time; he said that there was a huge demand from the private sector that encouraged ITRI to form an alliance to seize the great new opportunity. Also, when he proposed the project, he believed that no company in Taiwan was advanced in the notebook industry. Even for Quanta, he asked, “[w]ere their specs more advanced than ours?” He explained that what he observed was that Japanese companies such as Toshiba had advanced notebook products, but none were from Taiwan, therefore, ITRI would prefer to push for a common product.⁴¹

It was argued that the alliance at least had the benefit of training many people for the laptop industry.⁴² Also, the effect on the standardization of components and parts for laptops should not be neglected, as Peter Wang mentioned above. A final contribution of the notebook alliance was that the Comdex event helped Taiwan gain a reputation for being good at making notebooks.

Facing the critique of allowing too many companies to join the alliance, Sid Wang

⁴⁰ Ibid, p.72

⁴¹ Sid Wang (1/26/2011).

⁴² Interview with a senior Quanta manager, “Taiwanese Laborer” (11/17/2010), a pseudonym he wanted me to use for him.

said that forty-six companies in the alliance might have been “too few” because according to statistics, there were thousands of companies in the PC industry in Taiwan at that time. Since many of them wanted to enter the laptop industry, forty-six was not too many. Indeed, the concentration of global shipments to only a few major Taiwanese players since the late 1990s (as shown in the beginning of the chapter) contrasts to the earlier situation—there were more than 100 notebook system providers in Taiwan in the early 1990s. It was similar to an early gold-rush-like pursuit in the motherboard market (for desktops) that attracted more than 200 players in Taiwan, resulting in severe competition and price wars.⁴³ The numbers also give us a sense that start-ups and small-medium enterprises were active in Taiwan in the golden era of the PC’s high growth.

This notebook alliance illustrates a third way of designing and manufacturing the initial laptops in Taiwan—forming a horizontal alliance across company boundaries in order to quickly and inexpensively obtain a sellable machine and to push for a standardization of laptop components. If Taiwan’s companies could not compete with foreign computer firms in size or finance, they could at least do it collectively and collaboratively -- share jobs, resources, risks, knowledge, and even the finished artifact itself. This notebook alliance also displayed an effort to design a laptop rather than draw on assembly, mass production, or cheap labor.

⁴³ From the interview of the chairman of Compal, Sheng-Hsiung Hsu on 6/8/2010 in *Global Entrepreneur* (Chinese).

Emerging Through Design Engineering

The development of those three of the earliest laptops in Taiwan demonstrates that Taiwan emerged in the industry primarily through capable design engineering. Overall, Taiwan's strong design engineering resulted from both the educational and industrial sectors. Successful universal education in Taiwan created large groups of engineering students. The early foreign electronics companies in Taiwan also helped train those people into experienced engineers. These newly graduated or experienced engineers later began to star up their own business. Overall, Taiwan in the 1970s already had an excellent pool of engineers, especially in the areas of electrical engineering, electric engineering, mechanical engineering, which were crucial to produce workable machines such as computers.

In addition to the three first laptops I presented, other important laptop players such as Twinhead Computer and Inventec Corporation, also gained laptop contract orders from the US's brand-name companies based on their design engineering, Twinhead's co-founder Yi-Cheng Chen was a famous computer designer. The company designed and produced computers and had their own solid brand-name business in Taiwan in the 1990s. Inventec was selected by Dell in 1992 when Dell first sourced from Taiwan for notebooks due to Inventec's impressive capability in both design and manufacturing, although this relationship did not last long.⁴⁴ Richard Lee, now the Chairman of Inventec, commented that it was a time

⁴⁴ Author's interview with Richard Lee (9/30/2010). The relation between Dell and Inventec did not last

when Inventec's calculator and telephone set factories moved to Malaysia and Inventec's hundreds of engineers were left in Taiwan. Therefore, Inventec decided to move into the notebook business for these employees, which they considered to require intensive engineering capability.⁴⁵

Acer's main founder, Stan Shih, asserted that Taiwan's computer and laptop industry was established mainly on design capability. For example, the design capability of Taiwan's companies with PC motherboards was especially strong: Acer even once outpaced that of IBM and Compaq in the mid-1980s. Shih expressed that Taiwan never simply "transferred" foreign technology to its domestic computer industry and he was proud of Taiwan's engineering and design capacity.⁴⁶

Shih: So there were people visiting Taiwan for ODM. It was ODM, not OEM.⁴⁷ Taiwan had no opportunity to do OEM [first]. OEM was not the reason we made computers. Quanta did well on notebook [business] because they designed a good product, not [because of] providing only manufacturing.

Author: Okay, so you meant that notebook was involved in ODM from the very beginning,

Shih: Yes, ... because we need to concentrate. So their (Quanta) first move was to conduct design. Just like HTC,⁴⁸ they also designed products first.

Author: that's right.

long, though. Instead, Inventec and Compaq later formed a robust partnership in the laptop business until Compaq was bought by Hewlett-Packard in 2002.

⁴⁵ Author's interview with Richard Lee (9/30/2010).

⁴⁶ Author's phone interview with Stan Shih (07/02/2009).

⁴⁷ Again, as the discussion in the beginning of this chapter, ODM means providing both design and manufacturing services and OEM refers to providing manufacturing service only.

⁴⁸ Both Acer and HTC are brand-name multinationals headquartered in Taiwan. HTC is famous with its smart phone products.

Shih: If there is no design capability, there will be no contract manufacturing for Taiwan. How would Taiwan get product orders [if Taiwan didn't have design capability]? China could do that, or the nearby EMS companies⁴⁹ in the U.S would just take them [those orders]. ⁵⁰

Also, Max Fang, the former general manager of Dell Computer's international purchase office in the Asian Pacific region, commented that, "The [brand-name] clients only talked, but Taiwan really acted [for producing a laptop]." Fang added that the foreign companies relied heavily on Taiwan's design capability for laptops from the beginning, and that the first notebook order Dell gave to Taiwan in 1989-1990 was a joint-development project.⁵¹

These examples further support my claim that these Taiwan's laptop companies won their pioneer laptop orders based primarily on their design engineering, rather than on enticing manufacturing capability or cheap labor.

Road to Expansion: Key Orders and Early Learning Experiences

Earlier in this chapter, I show that several Taiwanese actors drew on different approaches and mobilized various practices/resources to design and make their first laptops. But all of them had a common focus: the initial laptop efforts of Quanta, Acer (later Wistron), and the Notebook Alliance focused only on the product itself. But it is important to know that

⁴⁹ EMS refers to electronics manufacturing services, which also provides only manufacturing services.

⁵⁰ Author's interview with Shih (7/2/2009), p.6.

⁵¹ Author's interview with Max Fang (07/02/2009). He said that when Dell gave contract manufacturing orders to Taiwan's companies, all of them included design services, although earlier they outsourced to Hong Kong's Wang Company to manufacture a laptop which was designed by Dell itself.

product-level innovation was just one piece of the puzzle of establishing the soon-to-thrive industry. Another crucial part involved the level of process innovation. “Process” here is an abbreviated term for “product development process,” which is the systematic dynamic that connects all of the elements on the spectrum from design to manufacturing (D-M in short). This enhancement in the process means the CMs had to grow both their manufacturing techniques and the interactiveness between design and manufacturing, in addition to their capable design engineering. In other words, there is a framework of procedures or mechanisms CMs implemented for making a machine, and it is the process-level learning from early collaboration with major brand-name companies that will be the focus of this section.

In the early years after 1988, Quanta and other laptop companies began to receive a few small and sparse laptop orders from European and US computer companies. Usually, it was a one-time exchange and a simple model of “buy and sell.” That is, the foreign brand-name companies would select components of Taiwanese production, and then simply attach their own brand logos to the machine. As the market needs and momentum grew, their business partnerships also changed to a more long-term and systematic form of collaboration. They then formed long-term contractual relations. I argue that for Taiwanese laptop enterprises, running a contract manufacturing business entailed learning about professionalizing the whole process of making laptops (the process level), rather than just about designing a workable laptop (the product level), although the two were related. This was especially true for the newly-established small

company, Quanta Computer.

In the early 1990s, most of the famous computer brand names in the U.S. still formed partnerships with Japan in laptop productions, partially due to the fact that Japan controlled many key components of laptops, such as the lithium battery, and liquid crystal displays. Dell worked with Sony, Gateway cooperated with Sanyo, and Compaq united with Citizen Watch. Due in part to the high cost of production in Japan as well as an increasingly direct competition, the U.S. companies gradually shifted their contract orders to Taiwan when discovered Taiwan's capability to produce computer products for them. For example, HP began to source its Omnibook series from Taiwan's Twinhead Computer in the model of OEM (which involves manufacturing services); Apple sourced from Acer also in the model of OEM first, then sometimes partial ODM from Quanta; Dell from Inventec first then from Quanta, both in the model of ODM (which involves both design and manufacturing), and then Compaq sourced from Inventec, first in the model of OEM, then in ODM.⁵²

I will discuss some major laptop projects from major US brands, and how they learned a systematic way of making laptops through these big projects. Although the Taiwanese producers learned from their brand-name clients, they learned (the process) in their own ways and combined the different learning experiences, adding their own

⁵² From Chapter two of Addison, 2001, and multiple sources from my interviews with Dell's Max Fang, Inventec's Richard Lee, Wistron's "Bruce" and "Richard," Quanta's "Harrison" and "Taiwanese laborers." Fang was a retired senior manager in Asia-Pacific Dell, and Lee is now the chairman of Inventec. Fang said, in 1990-1991, Dell worked with Hong Kong's Wang's Electronics in the model of OEM, but when they sourced from Taiwan, the projects became ODM.

innovations to form their version of design and manufacturing practices.

Quanta and Apple's Orders: Industry-Changing Events for Taiwan?

In the mid-1990s, Quanta received a partial ODM project from Apple, from which Quanta gained insight about how to conduct project management rather than product design. According to retired R&D head, "Harrison,"⁵³ this was the most important learning experience in his years of making laptops in Quanta. For him, before this Apple project, everything in Quanta was "fragmented," but afterwards, Quanta began controlling the production process and their supply chain in a precise manner.

The Apple project, code-named "Epic," began in the middle of 1995, but Quanta did not ship products for Apple until the fourth quarter of 1996. This was not the first time that Apple had a system contract manufacturer in Taiwan. Before Apple gave Quanta the contract order, from 1993 to 1995, it was Acer who produced partial laptop products (Powerbooks) for Apple.⁵⁴ But in 1995, Acer won a large contract to produce desktops (and one to two years later, also laptops) for IBM, the number one PC seller in the world at the time. Acer declined to continue producing products for Apple due to its "lacking enough human resources," and it was also due to Apple's dramatic re-organization and turmoil which made Acer conclude that

⁵³ Interview by author with "Harrison" (6/23/2010).

⁵⁴ From "Bruce", a Wistron senior manager. Wistron was a part of Acer before 2000. Interview was conducted on 4/16/2010. Also from interview with Simon Lin, Wistron's current CEO (5/26/2010).

Apple's outsourcing strategy was disconnected from them.⁵⁵ In 1995, Microsoft launched Windows 95, its first GUI (graphical user interface)-based operating system, and gained huge success in the market. Apple, by contrast, was at a low ebb, as its PC market share fell further to only 4% that year.⁵⁶ As a result, this rejection from Acer was interpreted as "despising Apple," which caused Apple to bear a grudge against Acer. Consequently, they never gave orders to Acer again.⁵⁷ This, in part, changed the business ecology in Taiwan's laptop production.

Apple's vacillation of outsourcing strategies came from an important consideration about their own position in the industry. From August 1985 to December 1996, Apple's main founder, Steve Jobs, was ousted. During this time period, Apple wanted to change its proprietary system and adopt a more open structure like that of its foes IBM and Microsoft. Hence, it licensed its operating system to other companies, and outsourced some of its production to Taiwan. According to "Richard," a Wistron manager (previously a Quanta manager), it was Inventec who introduced the Apple business to Quanta. Inventec and Quanta had a special relationship: several top managers at Inventec invested in Quanta when Quanta was founded and had been important shareholders. Inventec was the system

⁵⁵ "Lacking enough resource" is from "Bruce" (4/16/2010), p.16; Wistron's current CEO, a top manager at that time, Simon Lin, said Apple was reorganizing and its outsourcing connection with Acer suddenly broke (5/26/2010).

⁵⁶ Apple's market share had fallen to 4% by 1996 from a 16% in the late 1980s, see Isaacson (2011: 296).

⁵⁷ Author's interview with "Richard" (7/28/2010). He is a senior manager who work in Wistron, but also worked in Quanta in the past. Also, this "Acer rejected Apple" incident was well known among several of my interviewees.

production partner of Apple's PDA (personal digital assistant), and had not yet been involved in the mainstream notebook product as it later would be.

A Design Project for Apple

It should be pointed out that this was a project that required Quanta's product design capability. At first Acer's contribution to Apple concerned only "pure" manufacturing,⁵⁸ but Quanta went beyond manufacturing. While Apple was responsible for the industrial design (design for aesthetic and user-interface of products) and provided its electronic circuits reference to Quanta, Quanta was responsible for other work, such as electrical engineering (e.g., EMI, thermal dissipation) and mechanical engineering. That is, Quanta did most of the physical design of the product. "Richard" also indicated that Epic was a "joint-development project" between Apple and Quanta. Actually, Apple did not provide any engineering support to this first project. Apple had already had a similar machine produced in its own factory. In "Richard's" mind, Epic was just a trial-type order to Quanta because Apple had recently lost the manufacturing partner, Acer. As discussed, in the early period of the laptop industry, the types of ICs that were specifically designed for laptops were incomplete, and that was why they could have many innovations in physically designing a laptop.

The project was important to Quanta and Taiwan's electronics industry in several

⁵⁸ Quanta's retired R&D manager "Harrison" (6/23/2010), Simon Lin (5/26/2010) and R&D manager "Bruce" (4/26/2010) said so.

aspects. “Harrison” described this project as “the fate-changing battle” of the Taiwanese laptop industry (p4), because they shipped 370,000 units in total for the single product, which was a record in Quanta’s and also in Taiwan’s laptop history. When the product was shipped in the fourth quarter (Q4) of 1996, it boosted the revenue of Quanta from 1 Billion in Q1 to 9.9 Billion Taiwan Dollars in Q4 for the single quarter. After that, as mentioned earlier, from the production line to the supplier chain, things became orderly and on track at Quanta. “Richard” also agreed that the Epic project was crucial, and he added that it not only caused Quanta to flourish but also Hon Hai Precision (later Foxconn Group, the largest manufacturing company in Taiwan since 2002, and the largest 3C electronic manufacturing service company globally since 2004)⁵⁹ and other local component suppliers such as Yageo Corporation to flourish. The latter companies flourished, in part, because whenever possible, Quanta would change the component suppliers to local ones. According to “Richard,” Apple had their own vendor list for Quanta to choose from, but for not-so-crucial passive and inexpensive parts, Quanta had some freedom to change. The reason that Quanta would rather choose Taiwanese rather than Japanese companies was not so much about price, but about “relationship.”⁶⁰ Quanta liked to build close relationships with their suppliers. Hon Hai was the supplier who approached Apple together with Quanta and was new in the laptop connector business. After

⁵⁹ From Hon Hai’s company website, “company milestones.” http://www.honhai.com.tw/GroupProfile_En/CompanyMilestones.html.

⁶⁰ Author’s interview with “Richard” (7/28/2010).

numerous co-experiments and trials with Quanta, Hon Hai successfully developed components that Apple accepted, and later in the second and third Apple projects with Quanta, it remained the connector supplier. This partially helped Hon Hai surpass the world's largest connector suppliers AMP and Molex, both from Japan, at that time. No one would know that Hon Hai (Foxconn), the component giant in Taiwan would also enter the laptop and pad-like computer assembly market in late 2000s. This Apple order shuffled the whole industry and benefitted Taiwan's system and components companies.

Although Quanta had already had some customers such as AST and Philips, a retired R&D manager, "Harrison," thought previous machines were made in a fragmented and disconnected way (it was unknown to the managers at what time the machine could be sent to the production line and at what time the finished products could be shipped). Meanwhile, the parts from suppliers were not regularly delivered on time, the testing was not thorough, and the fundamentals of R&D were not good, so when there was something wrong, the machine would be sent back to be re-checked.

But how did this project proceed and become ordered? "Harrison" said it was at that time that they began to have condensed and daily meetings on the project. Every day at 5 pm, R&D, production, testing engineers, and even suppliers all needed to come to the daily meeting to solve different kinds of problems. Because both Apple and "Harrison" were rigid and wanted perfection, the project was delayed by about 4-6 months. "Harrison" said the

main problem was that it could not pass the FCC (Federal Communications Commission) regulations because of an electromagnetic interference (EMI) problem, so they invested time trying to figure out how to solve the problem. Richard said that they solved the EMI problem by flying to Apple in the US and staying 2-3 weeks to have face-to-face communication. From this encounter, Richard did not feel that he learned advanced technical skills from Apple, but was confident that Apple would trust Quanta more after they understood each other's capability. What he remembered was that he experienced a little culture shock because Apple's company culture was so different - Apple employees wore shorts and slippers to work, and could "lie on the table."

In contrast to "Harrison", "Richard" mentioned that the EMI problem was not the most important reason for the delay - the human factor was the major problem. "Richard" said Apple was kind of testing Quanta. As a result, Apple initially dispatched only a part-time non-inexperienced person to bridge their project. This person, who was from Taiwan but received a Ph.D. in the US, seemed unhelpful at all in his mind. But the situation changed dramatically after a new bridge person, Bill Schonfield, came in. In different interviews, both "Harrison" and "Richard" regarded Schonfield as a crucial figure for Quanta's growth ("Richard" even described Schonfield as "Quanta's biggest benefactor"), because as a bridge person between the two parties, he not only was willing to help Quanta and was responsive to Quanta's requests, but he also greatly strengthened Quanta's relationship to Apple.

Schonfield, was involved in Quanta's weekly, sometimes daily operations.⁶¹ For example, when a product was in the production trial stage, there would be daily involvement. Apple's electrical, software, and mechanical engineers also came in to Quanta. Most of them were Americans, but later also included Singaporeans. The important thing "Harrison" thought that Quanta learned from the Epic project was that everything should be based on numbers, data, procedures, and logic, which was the Americans' attitude he appreciated.

"Harrison" indicated that Apple did not mean to "teach" Quanta, but when Quanta was "tortured" by Apple, they would learn a lot by themselves. In the beginning, he even had verbal fights with Schonfield on several issues, but later they became good friends.

"Richard's" account of the Apple project, however, is that they learned more from the Second Apple project (code name: the 101 Project – 101 is a major highway number in California) rather than the first project. His idea is that in the first project it was more about Quanta's internal project management, but it was in the second project that Quanta not only had more interaction with Apple, but also Quanta's back-end management connected with the system from Apple, including schedule management and future production management. They learned a great deal about managing and locating materials.⁶²

It was from the 101 project that Quanta established the idea of "design for manufacturing" (DfM). This happened when Apple sent people to Quanta to administer the

⁶¹ Harrison (ibid).

⁶² "Richard" (7/28/2010).

design guideline. Later, when working with Dell's projects, Quanta learned a great deal about "DfX" (which means: design for other different considerations, such as design for cost, design for stability). After that, they increasingly considered DfX criteria to be important for shaping their knowledge production and practices,⁶³ which I will discuss in the next chapter.

Acer/Wistron and IBM's Quality Control

Unlike Quanta, Acer learned how to improve quality control from their projects with IBM Japan's Yamato Lab. They also learned logistical strategies from HP (Hewlett-Packard) and efficiency from Dell, but one main senior engineer-manager thought that they learned the most from IBM early in their laptop business.⁶⁴ However, this did not mean that Acer was a follower: they had their own agenda to select what they wanted and what they did not want. At least, they showed a resistance to the stringent attitude toward quality control promoted by IBM Japan years later.

Quality control involves many aspects from design to manufacturing, rather than just testing the final results of finished products. Every procedure in the D-M process might contribute to the final quality of a product, thus it can be viewed both as a process-level and a product-level issue. But my Acer/Wistron interviewee seemed to stress the product-level more, which helped to deepen their expertise in the product itself. This was different from

⁶³ Ibid, p. 26-27 in the transcription.

⁶⁴ Author's interviews with "Bruce." (4/16/2010 and 8/4/2010).

Quanta's learning experience from Apple—Quanta's interviewees focused more on perfecting their abilities at the process level. That is, one case (Acer/Wistron) concerned the depth of the product design, and the other concerned the breadth of the process, or connecting the dots across the D-M spectrum.

Maybe these different learning experiences occurred because Acer and Quanta were in different stages as companies, as the former had been an established enterprise and already had a more systematic way of manufacturing computer products. As discussed, Acer was established in 1976, and by 1987, Acer had already had its manufacturing operations going for several years and was a star high-tech company. In many ways, Acer in the early 1990s was a much bigger and more famous computer company than the newer and smaller Quanta. "Richard" said that, at that time, it was so hard for Quanta to find employees: at one time he received not a single resume after two weeks of running newspaper ads. He even called an old friend in Acer to send over resumes of people who had applied for jobs in Acer, but whom Acer did not hire.

In the laptops field, Acer appeared on the scene later than Quanta. Acer aggressively approached Apple in 1991, and as discussed earlier, they received Apple's contract manufacturing order between 1993-1995,⁶⁵ and later received the contract for IBM's desktop

⁶⁵ Author's interview with "Bruce" (7/9/2010).

and then IBM's notebook orders.⁶⁶ Significant orders from IBM led to the decline of making Apple's notebooks from Acer after 1995, so Apple switched to a new partner, Quanta. In fact, IBM would be Acer's number one brand-name client for several years until the blue giant sold its personal computer business to China's Lenovo in 2005. Even after the selling off, Acer was still a loyal partner of the IBM-PC buyer, Lenovo.

IBM had its major R&D center for notebooks in Yamato (Yamato City is located near Tokyo).⁶⁷ The cooperation between the Yamato Lab and Acer began in 1997. Acer learned a great deal from them about the well-known Thinkpad notebook series. In particular, Acer learned about quality control from its cooperation with IBM Japan. "Bruce" explained,

"The group of people at Yamato was the most experienced in the notebook area ... no matter if it is the design capability, quality, how to gate-keep, how to test, and how to request, these are the biggest values they brought to us."⁶⁸

Although Acer employees sometimes travelled to Yamato, it was not for systematic or purposeful training. Usually, it was the Japanese who went to Taiwan to monitor what Acer did.⁶⁹ Excellent quality management has been a characteristic of Japan's companies for decades. Since the 1950s, Japan gradually shifted the image of made-in-Japan as shoddy and cheap to an opposite image of quality and expensive products. American statistician W.

⁶⁶ Author's interview with "Jaxon" (5/25/2010).

⁶⁷ IBM Yamato Facility located in the city of Yamato, Kanagawa Prefecture, Japan. It is basically a R&D base. In 2005, IBM sold its PC, including the notebook division to Lenovo, but IBM's other R&D resources still remained there until July, 2012, when all IBM research and development functions moved to IBM Toyosu Facility, Tokyo (the office relocation is from IBM's news release). Lenovo's Yamato Lab is still in the City of Yamato.

⁶⁸ P.8. Interview with "Bruce" (4/16/2010).

⁶⁹ *ibid.*

Edwards Deming is viewed as a main figure who brought to Japanese industries new principles of management and who revolutionized their ideas about quality and productivity.⁷⁰

Simon Lin, Wistron's current CEO, and a top manager in Acer at that time, indicated that both the earliest IBM and Apple orders given to Acer were only about manufacturing with no design requirements, but the company still conducted design for Acer's own brand and for other second-tier brands. However, the Apple and IBM orders were crucial in helping them to switch from structurally bulky machines to slim types of machines, which meant they needed to improve the combination of different new elements and new materials.⁷¹ It was through such back and forth interactions that Acer's design capability further progressed, and Lin considered that after 1998, the design capability of Taiwan's notebook industry was almost parallel to that of the US and Japan, but at better prices.⁷²

Acer indeed gained knowledge from IBM Japan, but in recent years, Acer has held a different attitude towards IBM's ways of quality controls. In the mind of "Bruce," it seemed that (the) Yamato Lab did not change over time. Their "problem" was that they were "too persistent," or, in other words, not flexible. Years ago, the development time for a notebook was about 18-24 months, but by around 2010, the production time had shrunk to about 4-6 months, so Acer regarded that procedures and processes had to change. Bruce said that IBM

⁷⁰ "About the Author" in Deming (1982).

⁷¹ Simon Lin (5/26/2010), p.6.

⁷² Ibid, p. 6.

continued to require Acer to test all items accumulated over the years. He believed that IBM failed to take account of the market and the progress of components. They still tested for the same quality problems that they had ten years previously, but which rarely happened anymore. Wistron suggested reducing the test steps and types of testing machines, but IBM did not agree with Wistron. "Bruce" said, "The biggest weakness of them (IBM) is that they trust only themselves on quality." By contrast, Wistron trusted the quality of the components furnished by their suppliers.⁷³

The degree of tolerance for defects seemed to differ between Taiwan's and Japan's industrial cultures. Stan Shih, the main founder of the Acer group, said that Japan requested the best quality in personal computers (PCs), but the problem was that the PC industry required speed. The Japanese did not want any defects, but the whole historical development journey of PCs had "tons of defects," which they had to debug all the way.⁷⁴

The Yamato Lab had its own rationales for keeping their methods of production. Arimasa Naitoh, who is called the "father of the ThinkPad" and who has been the head of IBM/Lenova's notebook business for two decades, responded to my question in an interview about simplifying tests, saying that, "of course we were hoping to make it simple. We are testing details not because we like to test. We are testing because we have to."⁷⁵ Naitoh

⁷³ P. 10 on the interview transcription of him.

⁷⁴ Interview conducted on 9/14/2010, p2-3.

⁷⁵ P. 22 on the interview transcription.

believed that users stayed loyal to a brand like ThinkPad because they expected the same high performance. So they should keep consumers' trust in the brand. For Naitoh, trust in a good brand might be broken overnight due to a small issue, even though that trust took years to accumulate. Therefore, the quality of the ThinkPad could not be compromised.⁷⁶ This dispute between the two partners show they have different philosophy toward the idea of how to develop a laptop for today's market.

Connecting the Dots through Collaborative Projects with Brand Names

For laptop contract manufacturers, it was crucial to secure their orders and expand their influence from deepening their knowledge of product quality control and mastering the entire design and manufacturing process. The main idea is that their focus was not merely on assembling a workable machine, but also on expanding their value at both the product and process levels. In addition to providing more value at each point (product), it is important to grasp the whole process on the D-M spectrum and to form a line that connects all the individual dots, an effort that I will further explore in the next chapter. Furthermore, they were not satisfied with only integrating the product development process internally. They went externally to reach other possible partners, mainly components suppliers and brand-name companies, in order to connect the lines to form an extensive plane of knowledge.

A Paradoxical Effect? Owning Design Capability to Attract Manufacturing Orders

⁷⁶ Author's interview with Naitoh (8/27/2010).

In the first half the chapter, I have shown the ways in which Taiwanese producers strived to design their own laptops. Although by divergent paths in constructing their first products, none of them stressed that their manufacturing capability or factories were excellent. No producer waited passively for foreign companies to give them product design diagrams in order to manufacture a product by following the clients' ideas. On the contrary, they designed and made products to attract foreigner buyers, who could buy and sell a ready product by attaching a logo of their own brands. Compared to the Taiwanese producers' small scale and plain production facilities in the initial period (for example, Quanta's early awkward factory was criticized by Apple, Dell, and even its own employees),⁷⁷ their product design engineering capability was a more salient feature.

In the second half about the collaboration between the Taiwanese CMs and well-know brand-name companies, I further showed how these Taiwanese companies' manufacturing capability, process management (from design to manufacturing), and quality control were fragmented and immature in the early period. The Taiwanese producers learned this most from their major early orders, but none thought that they directly learned how to design an advanced product from their foreign partners.⁷⁸ This implies that the laptop producers' process management

⁷⁷ One Apple's former managers who came to Quanta's factory said that the factory was horrible that it did not even have a restroom, so they needed to go outside to solve the related issue ("Louis," 10/01/2011); Max Fang, a former Dell purchase general manager in Asia Pacific said Quanta's old factory was like a second or third-tier one when Dell first went to visit Quanta (3/19/2010); A later Quanta factory manager said that when he was interviewed by Quanta's manager for a job in Quanta, the factory's roof was broken and leaking ("Christopher," 7/19/2012).

⁷⁸ Product design can involve different levels of considerations. It can be as narrow as considering only the

and manufacturing excellence might not be parallel to that of their product design engineering in the first few years of making laptops. It was not until the mid-1990s that a few companies' manufacturing and process management began to reach a world-class level.

This evidence contradicts against the discourse that Taiwan's laptop industry was gradually progressing from initial owning of manufacturing capability first, then to developing its design capability. On the contrary, their product design capability was from the beginning their most important advantage. I argue that the Taiwanese laptop used their design engineering capability in the beginning to successfully receive the manufacturing contract. Namely, instead of offering merely a complimentary function, it is crucial to also offer overlapping (and thus bridging) functions to a partner when forming a contract alliance.

A possible policy implication is this: a group of excellent engineers in a shabby office might be more helpful than a large group of workers in a modern large-sized factory when a company wants to earn even merely an OEM (manufacturing service) project. It seems paradoxical: since an OEM contract requires the producer partner primarily to manufacture products, so isn't the manufacturing strength more an important issue than the design capability for a brand-name company to choose their manufacturer partners? But why is this not the case in the development of Taiwan's laptop industry?

desired functions of the machine, or as open as to consider different departments' needs: design for a workable machine, design for functions, design for advanced features, design for user-friendliness, or design for cost, for design for serviceability. To a broader way, a company's, and even its client's, various considerations and priorities can be embedded in even merely a product design. In broader sense, the product design can connect to the issue of the process)

According to several of my interviewees, Taiwan's laptop companies were chosen for their design engineering capability. For example, in the first laptop sourcing visit to Taiwan in 1991, Dell's team was impressed that Taiwan's computer companies were more advanced than expected. Nearly all the laptop companies they visited could show workable machines.⁷⁹ Although working with Hong Kong's Wang's electronics in the model of OEM (which provides only manufacturing service), when Dell came to source from Taiwan, they changed to use the ODM model (which provides both design and manufacturing services); that is, the Taiwan's partners would both design and produce the product for them.⁸⁰ However, HP, Compaq, and some other brands did not give ODM orders in the very beginning, although they changed to the other model (almost all were ODM orders) not long after. Different reasons could explain this early situation: the brand names did not trust Taiwan companies' design capability yet, especially it was still the early years of laptop development, many elements including the components were not reliable or stable yet. It was understandable that the brand names chose a safe model (OEM) first for the partnership with Taiwan's companies; and, importantly, the brand-name firms still had their own design teams internally. Therefore, even if some might trust Taiwan's producers in designing a laptop for them, sourcing ODM services would affect their own employees' jobs.

Capable Design Engineering Mediating to Assure Manufacturing Success

⁷⁹ Max Fang (3/19/2010).

⁸⁰ Ibid.

How do we explain the seemingly paradoxical phenomenon that these US branded companies were sourcing manufacturing services from Taiwanese companies which had better design capability than manufacturing techniques? If contract manufacturing or assembly was so simple and required low-skilled workers, why did brand-name companies not choose those manufacturing partners from other countries that had even cheaper labor and overall costs? The phenomenon of brand-name companies selecting manufacturers by considering the partner's design capability demonstrates that solid linkage between design and manufacturing is crucial. The chosen partners might not have established excellent manufacturing capability, but *they need to have a solid team in design engineering whose functions overlap with that of brand names' own core teams*, so as to ensure the two parties can connect smoothly. Design engineering then becomes an important linking mechanism to assure successful manufacturing, the purpose of the brand-name firms. This design-manufacturing integration argument will be persistent in the later chapters. One special linkage mechanism between these different organizational actors will be "engineering contact layer," which I will elaborate in Chapter 5.

The direction of the linkage is not arbitrary, however. For example, in my case, brand-name firms did not choose an OEM partner from those who had an excellent marketing capability because this functional linkage was not toward to the brand's purpose of integrating design with manufacturing.

Conclusion

In the first half of this chapter, I address several issues in order to explain the origins of the laptop industry in Taiwan. It was rooted in the rise of electronics and the supplier network in the 1960s and then the calculator and PC industries in the 1970s. The contract manufacturing model had been well developed in the calculator and desktop industries, and showed continuity in the laptop industry. Taiwan, as a material mediator, mobilized and leveraged available domestic and international resources to facilitate their industrial development. These factors combined with high growth in the global information technology industry, high value placed by Taiwanese society on education and engineers, entrepreneurship and small-and-medium business culture in Taiwan, as well as the Wintel-IBM PC standard, all contributed to the steep rise of laptop CMs in Taiwan.

Next, I explore the early history of two laptop companies (Quanta and Acer/Wistron) and their distinct approaches to developing their first laptops. I also examine a third path of making laptops by the Notebook Alliance. Although the product design process involved certain degree of reverse engineering and partial references to existing products, few of the major moves were directly copied or transferred from technological designs that the U.S. or Japanese had developed. By contrast, they wanted to make their own machines based on what technologies and resources were available to them. I argue that Taiwan earned their initial laptop orders not based solely upon low-cost labor or on direct technology transfer from foreign countries,

but instead based significantly on their own established engineering capability (even reverse engineering involves engineering capability). Quanta used a trial-and-error engineering method; Acer partially drew on experience from Japan but went on to develop their own advanced machines, on top of considerable human resource and financial investment. Additionally, ITRI's notebook alliance was a showcase of the collective power of both the engineer community and small and medium sized enterprises in Taiwan.

The second half of the chapter explores a few early major product order projects that were crucial in these producers' learning experiences, which extended their expertise to integrate the product developmental process and deepened their knowledge of manufacturing management and product quality control. These learning opportunities were influential for the CMs' later success in global production. The Taiwanese laptop road to success involved learning by mastering the whole process (from design to manufacturing), and re-inventing the D-M process continuously in their daily practices. But no matter whether it was the product level or the process level, I argue that the Taiwanese laptop industry was winning the race through design engineering, rather than through low-cost assembly or manufacturing techniques.

Overall, a popular historical discourse of progressing from a primarily manufacturing capability to design capability can be doubly problematic for describing the development of Taiwan laptop industry. It not only assumes that manufacturing is "simpler," but also implies that the capability of these contract manufacturers "progressed" to design from the foundation

of manufacturing. I argue that Taiwan's laptop companies' product design capability was their most salient feature in even the very beginning of the industry. The linear discourse is misleading and neglects the design-manufacturing bridging mechanism that I just discussed.

Following this line of examination on the dynamics of design-manufacturing activities, I will problematize and shed light upon the complexities and the closeness of the relations between design and manufacturing in the next chapter.

CHAPTER 2

FLOATING BOUNDARIES AND INTERTWINING RELATIONS BETWEEN DESIGN AND MANUFACTURING

“Designed by Apple in California, Assembled in China”

The above statement is printed on the back of Apple’s tablet computer iPad2, produced in 2011. Upon consideration, this statement can trigger different interpretations. One interpretation is that, while some competitors’ products are both designed and assembled in other countries, Apple’s products are not. A second interpretation is that the company wants to highlight that the higher value and more innovative work (“design”) is produced by the company itself in California in the US, while the lower value work (“assembly”) is completed in China. But most importantly, the statement emphasizes that there is a clearly defined component (design), which is completed in California, and then sent to another place, China, for assembly or for the implementation of designs.

The separation of “design” and “assembly” or of “design” and “manufacturing” is a common distinction in popular and industrial usage. This separation involves industrial politics and represents a myth of how things are made: it follows the clear sequence of concepts, design, and then production. Furthermore, in product innovation narratives, the place of manufacturing artifacts is seldom regarded as a major site of knowledge production. Manufacture teams are often thought to play only the role of implementing design plans. But

is this really so? At least, in the laptop industry, it is not.

In Chapter 1, I show that Taiwanese laptop producers emerged initially and primarily due to their design engineering capability rather than from a manufacturing capability. However, this does not mean that manufacturing is easier or less important than design. It only means that in the early years, the importance of design capability seemed to outweigh manufacturing capability. In fact, in the same chapter, I show the increasing importance of manufacturing capability after the reception of larger product orders by CMs from well-known brands. Also, in Chapter 5, I will argue that knowledge from factory and manufacturing is very crucial for the Taiwanese actors to maintain their competitiveness. Over the past two decades, the CMs' expertise on both design and manufacturing grew, thus manufacturing expertise emerged as being as important as design and this deserves researchers' attention. In particular, when we evaluate the activities of design and of manufacturing, we should be sure to place them into their historical context, rather than argue that "design is absolutely more important than manufacturing capability" in a social and historical vacuum.

In this vein of analyzing design and manufacturing, I make four main arguments in this chapter:

First, the range of manufacturing is much more extensive than many outsiders might have imagined as it encompasses many important procedures well before the final assembly stage. Although the laptop actors separate design teams from manufacturing teams and

separate the design phase from manufacturing phase, the two major teams frequently work together in the process of producing a laptop, and this necessitates consideration of respective phase needs. This is why to certain degree, we can blur the boundary between design and manufacturing, and use “design-manufacturing” to better describe the machine making process by the contract manufacturers.

Second, the levels of design are also multiple and their relations complex. Even within the contract manufacturing itself, the ideas of R&D (research and development), design, and engineering overlap and are open to different interpretations. This further shows the politics of the boundary problem or high-low engineering culture in the middle of the design-manufacturing spectrum.

Third, technology and knowledge involved in manufacturing or factories is not simple. While I will further demonstrate this argument in Chapter 5 by exploring their precise calculation with the material arrangement and workers’ skills and tempo, in this chapter, I will show that the factory teams have to integrate information and knowledge from the design teams and component supplier partners in order to maximize efficient production.

Fourth, I will also show how different power relations or company priorities between design and factory divisions generate different knowledge and practices. This examination will deepen our understanding of the relations between the epistemic culture and power structure in the industry.

Before entering the next section, especially for the discussion of the boundary between design and manufacturing, I want to clarify the terms I use. I prefer to use design-manufacturing (D-M, as an analyst's term) to denote CMs activities, since the term shows a continuum and connotes a non-hierarchical and non-dualist meaning. This does not mean that the division between design and manufacturing is totally inaccurate or illusory. For organizational and practical purposes, it is certain that employees can be divided into a design team or factory team. Companies can also define what stage qualifies as the design stage, and what counts as the mass production stage. These are established social and actors' categories that are nearly unavoidable (unless we can invent a new term to replace them). For example, I still have to use "design teams" or "design capability" to categorize people and their core capability. But there are certain moments and occasions that we should pay more attention to the division. Is there special politics of the division? How might the great division between design and manufacturing be used to assign credit, value, responsibility, and discipline? Is the division meant to overvalue design and undervalue manufacturing?

Design, Engineering, and Manufacturing

Before delving into the discussion of the relations between design and manufacturing in the laptop industry, it is useful to consider the broader picture. In technology studies, many analyses are design-centered. The relationship between design and manufacturing is usually

presented implicitly as though there was a hierarchy with design located above that of manufacturing. Design-centered discourse implies that knowledge of design is more valuable than knowledge of production, or that a “good” engineering design will guarantee a good product under the assumption that manufacturing involves merely the fulfillment of design plans.

This hierarchical relation between design and production can then be tied to the traditional belief that “action will follow rules.” However, many scholars have shown that “action does not simply follow rules.” One of the most famous examples for action not following rules is Ludwig Wittgenstein’s number sequence. When trying to continue a number series by following a rule, we find that the sequence itself is influenced by culture and social conventions, but is not automatically produced by a universal law (Bloor, 1973; Collins 1985; Lynch 1993). If our actions are similar, that is because we share “forms of life” or ways of “going on” (Collins 1985, p133). Thus, the relation between rules and action is not a relation of cause and effect, as there can be various interpretations of which actions are in accord with a given rule.⁸¹

Likewise, the notion of “situated actions” comes from the insufficiency of plans or rules (Suchman 1987 & 2007).⁸² As actions are always situated in different local contexts, it

⁸¹ Scholars use the example in mathematics from Wittgenstein to show that, if mathematics, one of the most exact or most rigidly rule-governed activities is influenced by culture and social conventions, then other scientific activities are certainly shaped by social elements.

⁸² Suchman 1987, 2007.

is important to know the limitation of plans or underlying conceptions that try to guide actions.

It is suggested that the status of plans should shift “from cognitive control structures that universally precede and determine actions to cultural resources produced and used within the course of certain forms of human activity”; in this way, planning is itself “a form of situated activity” that results in projections that bear some interesting relation to the actions that they project (Suchman 2007: 13).

A line to understand design is to explore the relationship between science and engineering since “design” becomes an important category in this line of discussion. In his eminent 1976 article “American ideologies of science and engineering,” Edwin T. Layton argues that there are three ideologies for engineering in the United States: *basic science*, *engineering science*, and *design*. He argues that basic science comes from the line of Vannevar Bush’s thought (1945), and engineering science is science oriented toward practical matters but with its own distinctiveness. The first two ideologies are related to science, and though most engineers are willing to accept the identification as “applied scientists,” a further type of engineering ideology concerns “design”. According to Layton, McClellan says there are three basic types of engineers: the applied scientist, the mechanic, and the designer, and McClellan called the designer the “real engineer,” as the “ability to design” is fundamental for engineers.

Layton goes on to argue that, “from the point of view of modern science, design is

nothing, but from the point of view of engineering, design is everything,” because it represents the purposive adaption of means to ends, the very essence of engineering (p. 696). He claims, “the scientific parts of engineering are entirely auxiliary, since the end of technology is not knowledge.” He opposes the reductionist view of basic science, engineering science, and design because it presumes a hierarchy of progressive abstraction. Layton also proposes, “[w]e may view technology as a spectrum, with ideas at one end and techniques and things at the other, with design as a middle term” (pp. 37-38), and “the designs for the final products of technology do not exist in isolation. They are intimately associated with production and management” (p. 38). Without implementation, design would be in vain. Here Layton tries to reverse or flatten the hierarchical relations between science and technology and between design and production. But for the latter relation, he only mentions that there are two ends (ideas, production) and one middle part (design). From his article, it is not very clear what their more nuanced relations might be. Hence, Layton offers a thorough analysis of the relationship between science and technology/engineering, and extends this to “design”, which is an important feature of engineering, but he seems to stop before providing insight into the deeper relationship between design and production.

In this chapter, I will problematize and illuminate the complex process of design-manufacturing (“D-M” in short) to show not only that the relations between design and manufacturing can be far from hierarchical, but also that there are much richer dimensions

and gray areas in the process of transforming ideas into objects. In other words, the boundaries between design and manufacturing in the laptop industry are far from clear since they form a continuum.

In this chapter, specifically, I frame the discussions into three inter-related subjects:

The first theme opens up the black-box process of turning concepts into physical objects. The process involves complex mechanisms and many levels of interaction among different groups of people.

The second theme stresses the different interpretations of the meanings of design, focusing on the gray areas and activity-centered aspects of design, R&D, development, and engineering, as viewed by different laptop actors. The interpretative flexibility indicates that the boundaries between the activities within the design-manufacturing spectrum are far from clear and also shows how a traditional hierarchical view of design and manufacturing is challenged.

The third theme explores the relation between knowledge production and the epistemic and political tensions that occur between design and manufacturing divisions. Different principles, such as **MfD** (manufacturing for design) and **DfM** (design for manufacturing), influence these actors' knowledge-making and engineering practices: for example, the generation of the DfM design guidelines from the factory for the design team. Tools such as fixtures are also used to bridge design and manufacturing.

I. Mapping the Extensive Developmental Process from Ideas to Things

The dramatization of Steve Jobs' product-launching events were attractive and sensational.⁸³ Jobs was a great marketer who could creatively maximize the effect of Apple's new products—not only with their innovative functions or cool designs, but also by keeping the whole process of creating the product secretive. The image of the product-launch likened Jobs to a magician, and suddenly, amazing new products were conjured up. Or the image was that a new product was simply born in the minds of Jobs and a few top designers at Apple. But the fact is that each product had gone through a long-chain of effort which involved industrial designers, different levels of engineers, numerous parts suppliers, and finally, Chinese workers. Even each of Jobs' presentations was a thoroughly rehearsed calculation involving the hard work of numerous people.⁸⁴ The entire process, a carefully orchestrated event, was the culmination of many mundane individual practices. Nothing happened by magic. The distant and hidden actors were merely not considered worth mentioning in the dramatization, which further reinforced a stereotyped image of high culture genius (Apple engineers) and unacknowledged low culture employees (Taiwanese engineers and Chinese

⁸³ For example, "The event, in typical Apple style, was tightly scripted and heavy on theatrics and hyperbole," New York Times, 1/27/2010, in "With Its Tablet, Apple Blurs Line Between Devices." For an analysis of the "theater" of product launch in high-tech corporations, see Simakova (2010).

⁸⁴ "The launch of a new product at Apple is often called 'the death march' because of the very intense work that is demanded of everybody involved, not only engineers, but also marketing and logistics people, to meet deadlines." A quote from Roman Moisescot, "Steve on Stage," available at: <http://allaboutstevejobs.com/persona/steveonstage.php> (accessed 6/6/2014).

workers).

As discussed in the introductory chapter, the “invisibility” of contract manufacturers (CMs) in modern times is similar to that of the technicians in eighteenth-century Britain.⁸⁵ Fundamentally, CMs’ invisibility to outsiders partially results from their “lower status” in the industry, rather than from the activities they engage in. But what efforts are involved in the so-called contract manufacturing in Taiwan’s laptop companies? Instead of the simple picture of workers assembling computers in huge plants, there are different and complex stages of procedure and practice. And the complexity itself is also an evolving process. In Chapter 1 on Quanta’s early history), I showed that the procedures for making a machine were primitive and unitary in the beginning of their laptop business, and now I will show how they gradually became complicated and professionalized.

From Concepts to Mass Production: “Ten Thousand Miles along the Yangtze River” in ITRI

Before the development of Taiwan’s laptop industry in the late 1980s, based on the earlier desktop industry, complex reference guides for developing computer products existed in Taiwan, which originated from the “product development procedure manual/handbook” that ITRI (Industrial Technology Research Institute) developed in August 1982. The manual soon became a widely-adopted product development tool for the laptop industry in Taiwan. The

handbook consists of a forty-one-page document in Mandarin Chinese, mixed with many English terms and abbreviations.⁸⁶ Although not completely public, ITRI would distribute the manual if people requested it.⁸⁷ Based on the domestic resources and the learning experiences gained from collaborating with major brand-name companies (as discussed in Chapter 1), Taiwanese laptop producers became skilled at integrating and manipulating the process from design to manufacturing.

This product development process manual in ITRI was a result of the Taiwanese government's effort to develop the computer industry. In 1979, the government entrusted ITRI to carry out the Computer Project initiated by the government. The director of the Computer Project, Ding-Yuan Yang, initiated several important plans for the project, and he considered that one important contribution from the project was that ITRI created the product development process manual. He said that he made great efforts to accumulate the development processes of various products from their friends in many American companies, including HP and DEC (Digital Equipment Corporation), two well-known computer firms at that time. ITRI members spent about a year organizing and digesting them, and finally created their own manual.⁸⁸

Peter Wang, one of the engineers of the ITRI Computer Project (now a senior

⁸⁶ Courtesy of ITRI's Peter Wang.

⁸⁷ The Oral History on Taiwanese IT Pioneers: D.Y. (Ding-Yuan) Yang. Interviewed by Ling-Fei Lin on February 23, 2011 in Taiwan. CHM Reference number: X6290.2012. CHM is Computer History Museum in Mountain View, CA. p.15

⁸⁸ *ibid.*

manager at ERSO, ITRI) said that the manual was nicknamed “Chang-Jian Wanli Tu” (“長江萬里圖,” or *Ten Thousand Miles along the Yangtze River*) by ITRI’s members because it was very long and as full of detail as the famous Chinese scroll paintings from which they took the name.⁸⁹

⁸⁹ There are several famous artists who made their paintings based on the same theme and same name; for example, Hsia Guei, a famous court painter in the Southern Sung Dynasty for emperor Ning-tsung (1195-1224), although there are disputes about the real author(s) and date. Contemporarily, the well-known painter in Taiwan, Chang Dai-chien (1899-1983), completed another, which attracted a great deal of media’s reports and numerous people to view it when it was displayed in 1968 in the National Museum of Taiwan History (Source: National Palace Museum in Taipei, Taiwan, <http://chinapen.tripod.com/guide/p02.html>, and <http://cart.ntua.edu.tw/upload/vercatalog/ver.012/ver.01208.pdf>). Other famous works are by Wu Chuan (1459-1508) in Ming Dynasty and the work by Wu Guanzhong (1919-2010) in contemporary China.

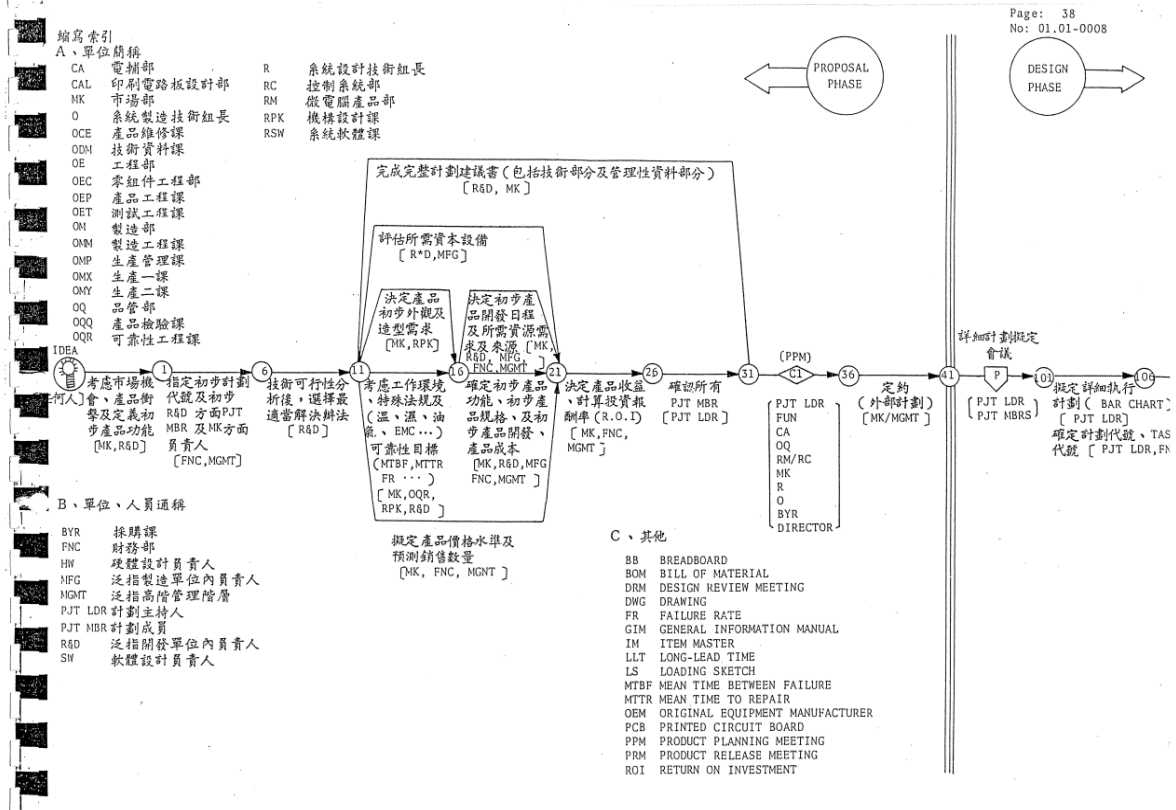


Figure 2.1

ITRI's Product Development Procedures Manual. The 1st page (proposal phase). The four pages can be connected together like a long scroll to represent the whole process from idea

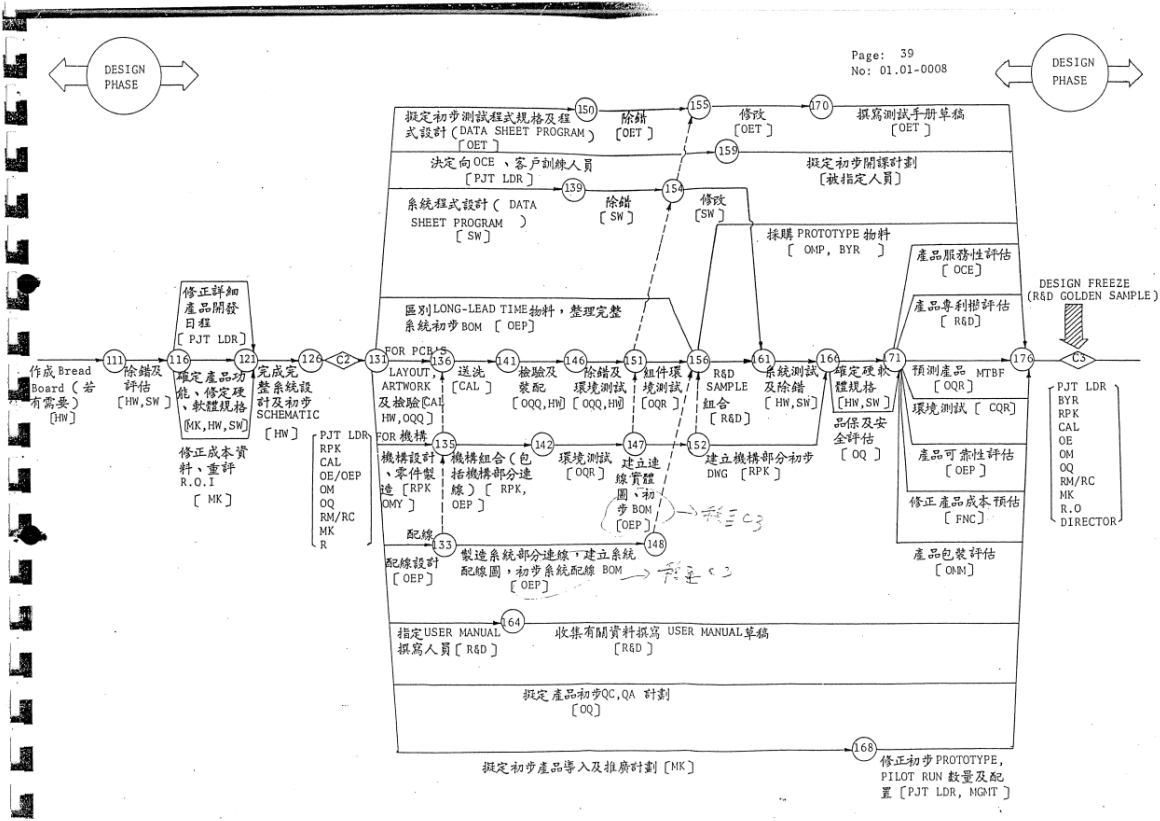


Figure 2.2

ITRI's Product Development Procedures Manual. The 2nd page (design phase).

(Courtesy of Peter Wang from ITRI).

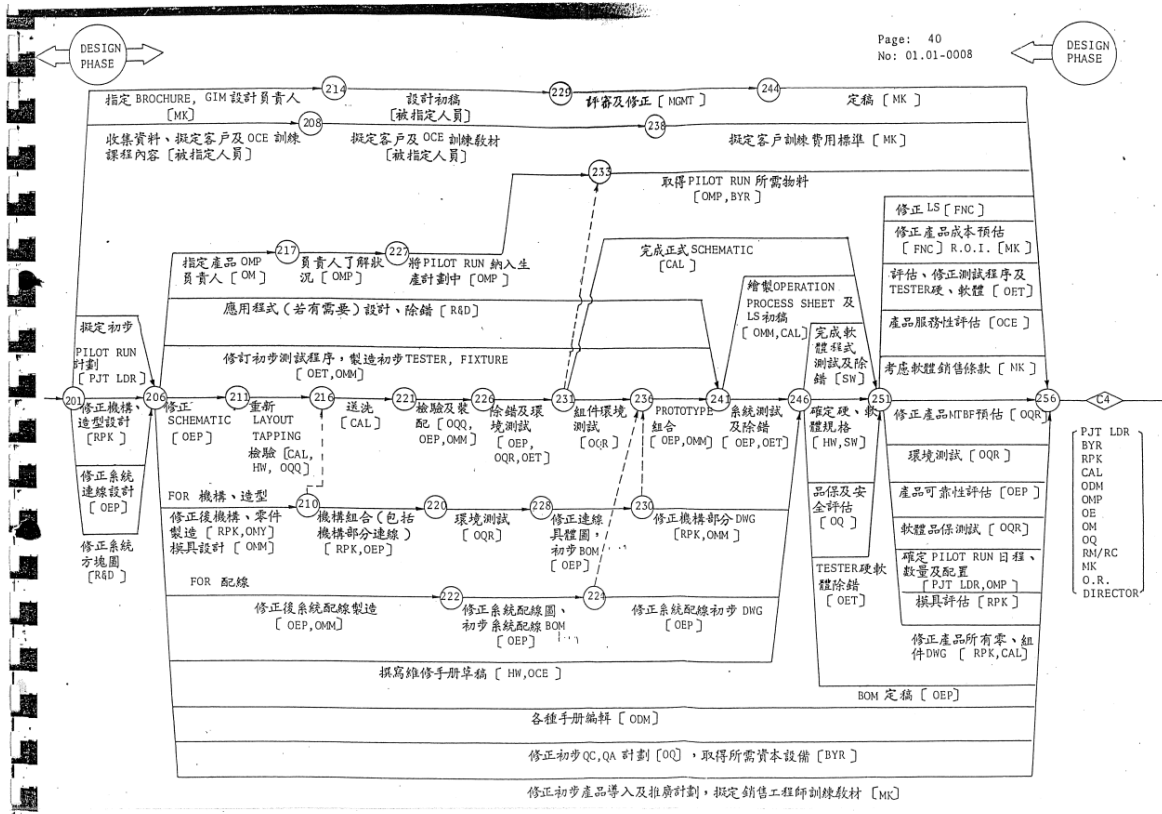


Figure 2.3

ITRI's Product Development Procedures Manual. The 3rd page (also design phase).
(Courtesy of Peter Wag from ITRI).

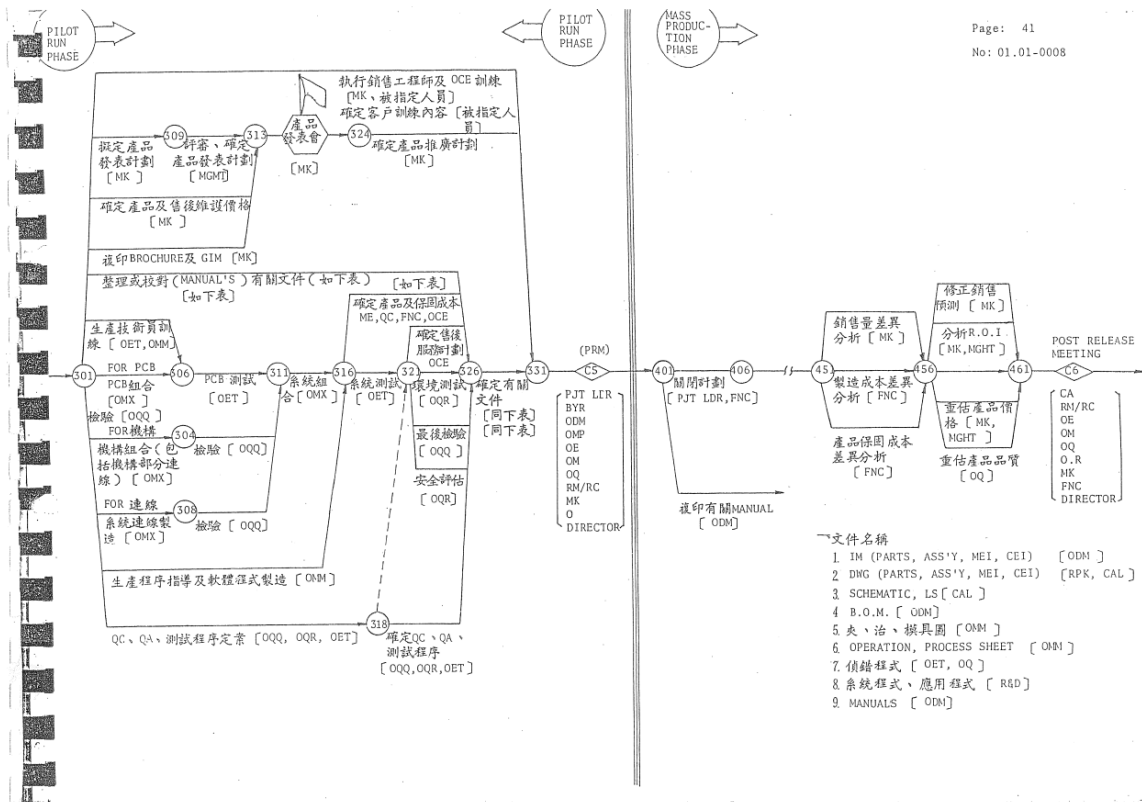


Figure 2.4

ITRI's Product Development Procedures Manual. The 4th page (pilot run phase and mass production phase). The four pages can be connected together like a long scroll to represent the whole process from idea to object (Courtesy of Peter Wang from ITRI).

The process manual from ITRI can be divided into four main phases—a proposal phase, design phase, pilot run phase, and mass production phase (see Figures 2.1-2.4). Each phase has sub-phases and tens of required jobs that involve multiple groups of people at every stage. Overall, there are many checkpoints, design review meetings and project progress meetings at different points of the process. For example, the “design phase,” one of the four main phases, and the longest phase in the manual, includes the following procedures (as well as others that are glossed with ellipses):

- A meeting to decide the detailed implementation plan
- Preparing a bread board for the hardware
- De-bugging and evaluation of the hardware and software --- Affirming the product functions and modifying the specs of hardware and software
- Modifying the detailed schedule for the product development
- Modifying the cost data and reviewing R.O.I.(return of investment)
- ...
- Mechanical designing and parts manufacturing
- ...
- Environmental testing of parts
- ...
- Quality assurance and security evaluation
-
- System testing and debugging
- ...
- Writing the manuscript for the testing manual
- ...
- Product serviceability evaluation
- Product intellectual rights evaluation
- Product reliability evaluation
- ...

Each single point (or activity) of these processes is usually based upon collaboration

among different groups of people. For example, one middle point of the design phase in the manual's diagram is called "Design Freeze, R&D Golden Sample," which requires eleven different specialized groups to be involved in the task. In other words, the entire development process involves complex webs of collaborations rather than a linear passage from design to a clear-cut assembly. Also, as the ITRI document highlights, "this set of procedures is only a generalized representative model, which cannot be applied to all standardized computer system products" (p.6). Even though the manual itself looks very complicated already, "Yao," a former top factory head from Quanta stresses that ITRI's process manual is merely a "skeleton without muscle," because it functions merely as an outline. He said the real work is even more complex and that, "each step of implementation is very hard."⁹⁰

Since then, major computer-related Taiwanese companies either copied, simplified, or modified this ITRI manual to organize their product development process. Fred Lin, one of the co-founders of Acer, mentioned that they drew on the process development idea from ITRI to create their own C-System (see Figure 2.5) for the PC industry. The C-System has been used by the Acer group and many other Taiwanese computer and electronics companies.⁹¹ The C-System looks simpler in its scheme than ITRIS's long manual, but the basic principles are still similar to ITRI's system, explaining where the check points are, at

⁹⁰ Author's interview with him (12/14/2010), p.3.

⁹¹ From Fred Lin's Interview (3/8/2010). Lin said he asked Bao-Yao Chang of Acer to write the C-system. Later it was revised by other pan-Acer group companies, and today Taiwan's companies also mix C-system with other types of new product development process based on their own needs.

which stages there should be meetings, which groups should join, and what documents should be produced and so forth.⁹²

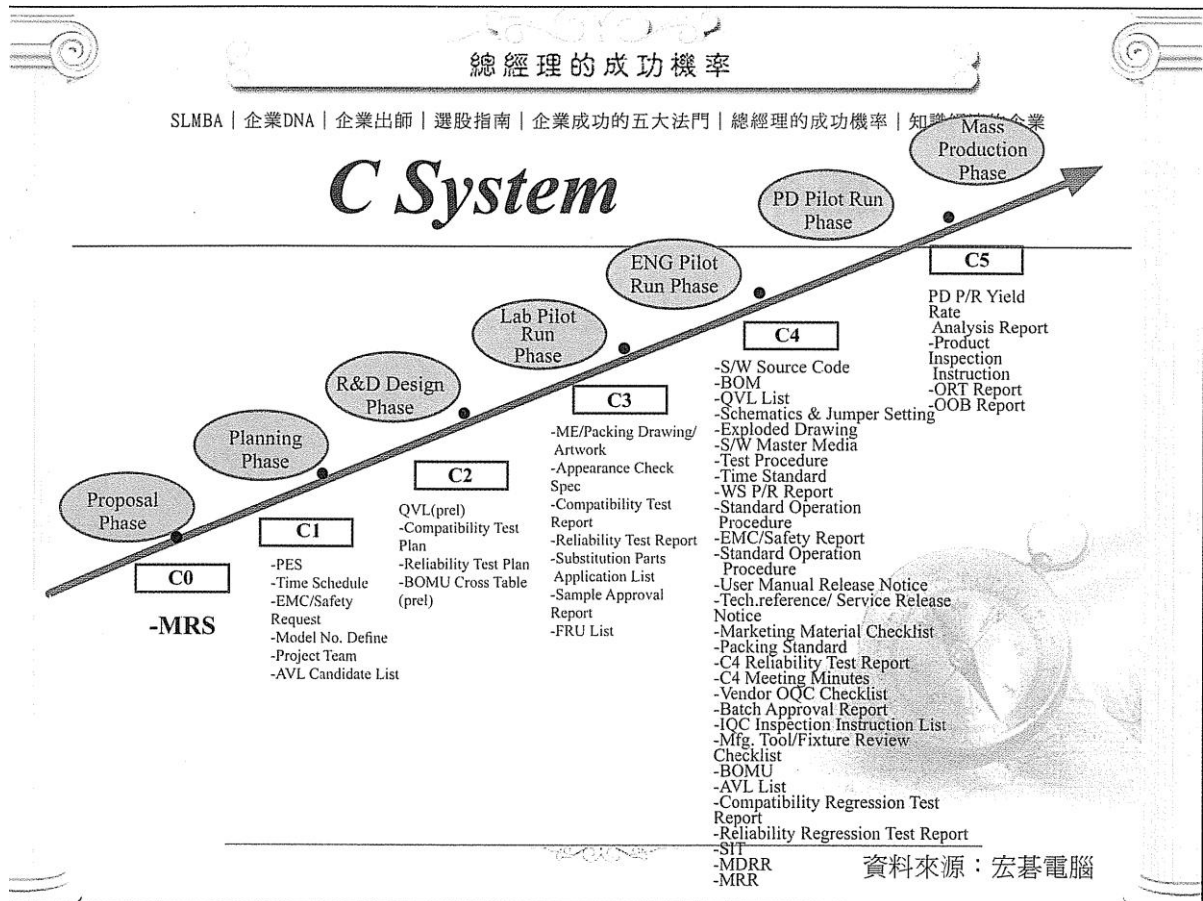


Figure 2.5
C-system diagram (Courtesy of Fred Lin from Acer)

As the C System diagram shows, there is a proposal phase (between C0 and C1), a planning phase (between C1 and C2), an R&D design phase (C2-C3), a lab pilot run phase (C3-C4), an engineering pilot run phase (C4-C5), a production pilot run phase (C5-C6), and

⁹² Ibid.

then a mass production phase (after C6). In the diagram, the engineering pilot run phase seems to involve the largest number of jobs. This is reasonable since engineering capability is the core advantage of the Taiwanese CMs.

I use the ITRI manual and the C-System to reveal the manifold and convoluted jobs involved in the product development process, to contrast with the simple dualistic division of design and assembly. However, in addition to complicating the design-manufacturing process, the question arises whether these images help change the fundamental hierarchical perception between design and manufacturing, since the two documents still look unidirectional? I want to highlight that showing the complication of the D-M process is only the first step to explore the relations among the various teams. By doing so, there is then the possibility to overturn their hierarchy in complex practice. Examining the two images is not meant to support the idea that producers merely “follow” the procedures shown in the manual or C-System, nor to claim that the team members’ jobs move unidirectionally from the left to the right. Instead, the two visualized objects are used as a starting point to problematize the dualist perception between design and manufacturing. These two diagrams, to a large degree, also represent the various jobs and the effort these Taiwanese CMs have made for more than two decades.

After examining the two diagrams, therefore, we know that the question of “how to design a notebook computer” is difficult to answer in the short term, because it is the work of

multiple teams in a complex web of procedures, just as the ITRI manual shows. When I asked the question “what are the procedures from design to manufacturing” in my interview, no one could answer it directly in just a few sentences, since those procedures included everything that the company was responsible for. When interviewees unpacked the procedures in more detail, they resemble the frame of the development process shown in the C-System or the ITRI manual.

One interviewee, a retired head R&D manager from Quanta, “Harrison,” who was trained as an electrical engineer, tried to explain how a laptop was developed. He spent a few hours in explaining the procedures. I simplify and re-organize his descriptions here:

A product demand is found. → 2. A proposal is generated, and a proposal meeting is convened, which is usually attended by a few electrical engineers, mechanical engineers, and software engineers, and is usually led by an electrical engineer; an initial computer simulation (called ideal simulation) is also involved. → 3. In addition to some paper drawings and 3D images on a computer, two versions of the mock-up are usually made, which have no real functions yet but are still expensive, and are the responsibility of mechanical engineers. → 4. If the product project is approved by the company, it is then divided into different jobs for the division of labor. These primary divisions are: electrical engineering, mechanical engineering, and software engineering, and in the process, the teams, especially the first two groups of people, will interact frequently to decide details, such as how thick and what size the machine will be, where to put what, and what new parts and components to use, and so on. But before the detailed division of labor begins, there will be usually be another simulation (called pre-simulation). → 5. Real product layouts and printed circuit boards are generated, mechanical and electrical elements are integrated together and checked to see if they work well, especially regarding the thermal and electromagnetic issues. → 6. If there are any issues that can be solved by the hardware itself, the software team is asked to write a program to resolve the

issues.⁹³ → 7. A post-simulation is conducted to compare the difference between the post-simulation and the measurement numbers from the real product in order to see what can be improved for the current model or for the future.⁹⁴

In each of the steps, there is always interaction and feedback among the teams, and when things go wrong, they need to go back to the previous procedures to fix the problems. Different reviews, validations, tests, and quality assurance are involved. They also have to have enough design margins, and should not overdesign or underdesign.⁹⁵ One special point is the use of simulation. In the early years, the design teams relied on experienced experts (“old masters”) to do what simulations do today. It was in about 2000 that Quanta began to use computer simulations, but in the earlier years of using simulations, since the software was immature, they still needed the help of the old masters’ judgment. Harrison considered himself an old master, but he was not fascinated with the old masters because they could only make very limited models and were not as reliable as machines,⁹⁶ although a former

⁹³ He said that software programs are usually hard to write, because there are accumulation effects from earlier programs, and you cannot check them all; and software programs will occupy the calculation capability of microprocessors, but it has the advantage of lower cost compared to using chips. Because you can write one software program to be used in millions of laptops, the cost is the same, but if you use three million chips for three million laptops, the cost will be multiples of that number.

⁹⁴ Interview by author (7/20/2010).

⁹⁵ The three concepts in the design fields are too complicated to explain here. I will just briefly mention that design margin means the safety margin or headroom on a specific design characteristic. For example, if one thing will occupy a length of 1 centimeter, but you design a 1.2 centimeter space for it, then the 0.2 centimeter space is a design margin. But it is not limited to physical margins, but also applies to safety margins for factors like thermal control. Overdesigning basically means the design is “too over” and underdesigning is the opposite. These are complicated ideas and are always relative and company- specific.

⁹⁶ He told me one story about how he thought about the appeal of “handmade.” He said that one time when he went to a watch store, looking at a luxurious Chopard watch and said “Oh, the strap on the two sides are asymmetric,” the store staff gave him a contemptuous look, replying, “Hey, this is handmade!” And he only thought, so what, handmade was equal to better or worse? And even experienced masters need to rely on tools to help themselves to make better things.

Quanta manager thought Harrison had blind faith in the expensive simulation.⁹⁷

A senior Wistron manager, "Charlie," who is by training a mechanical engineer, simplified the design flow of mechanical engineering jobs in the company: concept design → detail design → mock up → tooling → engineering pilot run → production pilot run → mass production. The work flow is a sketch similar to the C-System. Overall, Most interviewees are only familiar with their own specialties. They also have various missions, negotiations, and collaboration with other teams. The reality of contingent and complicated interactions and feedback loops are not represented in the two diagrams since even though the diagrams are more complicated than the dualist perception, they are still simplified versions of real practices.

As for the division of labor between a CM and a brand-name client, there are multiple combinations. If we simplify the procedures from the proposal phase to the mass production phase (I will later use design-manufacturing spectrum, or D-M spectrum to indicate this idea) to 100 steps, then the brand client can say they want to be responsible for the first 10 steps, and ask the CM to take care of the other 90 steps. The brand client can also ask for more involvement, for example, 60 steps, and give the CM 40 steps. But this is only a simplified explanation to help readers know their possible division of labor. In actual situations, even if they have divided the main jobs, there will always be communication and interface

⁹⁷ Interview by author (7/28/2010).

mechanisms between their different teams so that they can work together.

Although the top five laptop CMs in Taiwan are involved in all of these different phases, the degree of their involvement depends on how their customers choose their cooperative models for different product projects. Since the mid-1990s, Wintel camp companies (such as HP, Dell and earlier, Compaq) have often held Taiwanese CMs responsible for all phases of product development except for the proposal and planning phases. As a result, these CMs were far from being merely passive “assemblers” of laptops. In fact, one of their long-term practices is to prepare in advance at least several model-ready laptops (whose design and production work are all done by the CMs) to demonstrate to their clients and to let the clients choose any of the ready machines they desire. The client can ask them to re-design part of a machine, or have minor changes made in the industrial design for customization and then quickly sell the model on the market.

According to Arimasa Naitoh (内藤在正), “the father of the IBM Thinkpad,” there are multiple ways of collaborating between brand-name companies and ODM partners. He personally defines them into six types in the interview:

1. Type zero is no collaboration—that is, the brand-name company itself designs and manufactures the computers.
2. Type one is called “white design,” which means that the brand name designs everything and knows everything in detail, and then assigns manufacturers do the production. White design contrasts with black box design, in which the brand name does not specify how to manufacture the product.

3. Type two occurs when the brand name knows how to design the product, and gives a design reference to the partner. In this case the partner can modify the design to improve or lower the cost of the product.

4. Type three refers to the brand name giving its partner their product specs, industrial design drawings, and testing procedures for the product, but the partner completes the remaining aspects of design and production unspecified by those guidelines. The brand-name company also reviews the design and provides help when the partner has problems.

5. Type four occurs when the brand-name company only reviews results, products and problems: “Unless you have huge problems, don’t call me,” as Naitoh described.⁹⁸

6. Type five, which he calls “no touch,” refers to a brand-name company that does not do anything, rather it asks their partner to provide the product for them.⁹⁹

Naitoh explained that for the ThinkPad products of IBM/Lenovo, Yamato Lab used types one, two, and three. They had type zero (meaning that Lenovo designed and manufactured the product all by themselves) for high-end products until 2008. According to his understanding, many other laptop companies have been using type three. That is, the brand-name companies provide their production partners with only the product specs, the industrial design drawings, and the testing procedures. The partner will be responsible for much of the product production and the detailed design.

These diagrams and discussions reveal the complexity of a highly simplified version of separating design from assembly. In fact, the Taiwanese laptop CMs have been involved in

⁹⁸ Author’s interview with Arimasa Naitoh (8/27/2010), p.10 in the transcript.

⁹⁹ Author’s interview with Arimasa Naitoh (8/27/2010). He explained the six points in a detailed way, but I here I reorganize and simply them into more concise sentences.

industrial design, circuit design, mechanical design, firmware design, product testing, parts and components evaluation and purchasing, logistics, after-services and so forth. Depending on what services their brand-name clients want, different projects usually have different levels of collaboration. For the past two decades, these CMs have been mostly involved in design and other services. Hence, calling them “our assemblers” or “our manufacturing partners” provides only a small indication of what the actual work encompasses.

The polarized picture of design versus assembling reinforces other opposing couples such as innovator versus shop floor worker, West versus East, idea versus object, low skill and low value versus high skill and high value. The clear D-M boundary, therefore, does not come from a social vacuum. It is the product of value-laden, geography-laden, history-laden judgments which affect the jobs and lives of Asian designers, workers, and engineers. Asian CMs might be mistakenly labeled as “low-value” manufacturers to their detriment, even when they engage in innovative manufacturing and design work. This misconception perpetuates a new level of a collective “industrial class structure.”¹⁰⁰ Furthermore this discriminatory structure denies the fact that the form of production (contract manufacturing) of these Asian countries is an important conduit that is transforming our modern world. I consider that this D-M manual precisely represents Asia’s position and predicament in today’s science and technology world.

¹⁰⁰ This hidden class-like structure is also similar to the invisible and under-credited technicians in the seventeenth century laboratory, see Shapin (1989).

Specialization: A Dilemma between Disintegration and Integration

Within the laptop industry, there seems to be a dilemma between disintegration (more division of labor based on specialization) and integration. The complicated and elongated design-manufacturing procedures, as analyzed in the previous section, are especially ironic, given the pressure for speed in the computer industry. Moore's Law tells us that integrated circuits progress quickly, with their density doubling every twelve to eighteen months. It means if these computer companies do not sell their components and computers on time, they will lose money resulting from having inventories of outdated machines and components. It is thus unavoidable that this long chain between ideas and materials, after disintegration, needs to be quickly re-compressed to meet the goals of rapid innovation.

The ultimate mission of mediating among groups of industrial actors for the Taiwanese producers is to weave together fragmented elements into a computer system that can satisfy their brand-name clients or to receive significant product orders. In fact, in the industry, the computer producers are also called *system integrators* because they are the ones who construct the (computer) system, and make everything in the system compatible and work well. As integrators, they know each segment of the process well.

However, integrating the product is only one level of the story. In the design-manufacturing world, there are two main levels of consideration-- product-centered and process-centered innovations. Although they are related to each other, there is a major

difference in their orientations. On the one hand, engineers, depending on their positions and jobs, can focus on the machine itself, concentrating on product innovation and treating the machine as the locus of their calculations. They then project the requirements and resources for producing the machine back into the design-manufacturing process, in the hope that others can accommodate the needs of their machine. On the other hand, engineers can also focus on process innovation. Their universe is not the machine itself, but the process. The machine is still an important reference, but what they need to do is to balance and arrange different resources from all departments to produce the machine, which is potentially changeable and adaptable in its design.

Thus, as Taiwanese laptop CMs proceeded over the years, they learned both how to deepen the knowledge of each section of the D-M spectrum through professionalization and more disintegration and how to integrate sections of the whole process in order to extract increased value from the so-called value chain (although, ironically, it became a “de-value chain” later, which I will discuss in Chapter 3). For example, in their first year, Quanta employed fewer than ten engineers to co-design their product and only a few factory workers to assemble the computer. Today, the same process involves many more employees with different specializations. It also involves more disciplines at each stage. The dilemma is that these producers have increasingly shorter cycles in which to design and produce a computer product. Since the process is broken down by specialization, producers must compensate for

these specializations by integrating and facilitating the developmental process.

In other words, the ironic reality is that as you divide things up, you need to try to (quickly) put them back together again. This is also why professionalizing knowledge/practices of each part of the design-manufacturing (D-M) spectrum is not sufficient; the time pressure requires CMs to have integrated design-manufacturing knowledge that can connect all the dots smoothly and efficiently.¹⁰¹

II. The Floating Boundaries between Design and Manufacturing: Interpretive flexibility regarding Design, Development, R&D, and Engineering

The second theme will further demonstrate the complexities of product development by exploring the boundaries between design and manufacturing. Since every step prior to assembly involves different degrees of mental work, it is theoretically possible to call everything preceding that assembly stage as “design”. On the other hand, although early design for a product might only involve paperwork, it can be categorized as a step towards manufacturing since it has a product goal. A senior project manager from Quanta said it was difficult to distinguish design from manufacturing, as they were in a continuous spectrum. He considered that “manufacturing is one part of engineering.”¹⁰² Another example can be seen

¹⁰¹ The discussion of the CM’s “field knowledge” later in Chapter 3 will involve expanding not only dots into lines (the internal design-manufacturing cooperation), but also lines into planes (co-working with outside partners).

¹⁰² Author’s interview with “Taiwanese Laborer” (11/17/2010), p.9. “Taiwanese Laborer” is what the interviewee wants his pseudonym to be.

in the C-System, between the lab pilot run phase and the mass production phase-- both engineering pilot run and production pilot run phases exist separately, but are they considered as design or manufacturing? Both categories seem to make sense, so the boundary between design and manufacturing can be ambiguous, and it can fluctuate. Therefore, to some extent these labels can be arbitrary and involve the ideology of demarcation and boundary work (Gieryn 1983).

Interpretations of Contract Manufacturers' R&D

Another pair of concepts that is hard to separate is the so-called R&D (research and development). These designations were initially used separately, but by the late 1920s, Du Pont's research directors had begun to use "research and development" as if they were a single concept, since it is very difficult to differentiate the two activities.¹⁰³ The term was later shortened to "R&D." Although they raise different questions, many policy makers and professionals still believe that science is epistemologically more fundamental than technology. Therefore, it is important for a country to develop R&D (representing science). The origin of the R&D division in the industry has historical specificity,¹⁰⁴ and it can trace back to the

¹⁰³ See Hounshell (1988). In the book, he mentions the inseparability of the two activities, although "research is usually seen as literally searching for something, and successful research culminates in an invention which appears in incomplete form, existing more as a promise than a reality. Development consists of adjusting, altering, and adapting this idealized concept into a product that can compete successfully in the outside technological and commercial environment" (p.249).

¹⁰⁴ For example, Hounshell & Smith (1988) explores the historical development and changes of R&D in Du Pont.

disputable relations between science and technology, or a linear model between basic research, applied research, and development (Godin 2005 & 2006). However, today R&D in general is understood as a “basic” component in most large firms. What “R&D” means may in fact be very vague and unstable.

In this section, I argue that R&D should not be imagined as a decontextualized category, but can have different local interpretations. Specifically, in Taiwan’s laptop industry, the term R&D has had its own unique meanings, which are different from those of its major US partners.

Quanta and several other major laptop CMs in Taiwan tend to divide their product employees into the “design division” (or the R&D division) and the “factory division” But their term “R&D” seldom referred to basic research, rather it referred to design, engineering, or development, depending on contextual differences and the relative positions in which they were situated.

Although Taiwanese partners had their own so-called R&D teams, in the eyes of US brands, these R&D teams might not be “true” R&D because Taiwanese companies before 2000 were seldom involved the basic science and advanced technology necessary for their market goals.¹⁰⁵ From an outside perspective, Taiwanese partners were simply

¹⁰⁵ After 2001, as the largest laptop CMs have grown up to have multi-billion (in U.S dollars) annual revenue, and as they began to move factories to China, companies such as Quanta started to invest and extend their R&D to more fundamental research.

manufacturers, or even assembly-oriented workers, and most of the exciting and “high-end” work was conducted by the brand-name firms themselves.

This hierarchal stereotype popularizes a myth about contract manufacturers, which is that they have no, or have only very limited “R&D” capabilities, since they focus merely on “manufacturing”. This results in a “low” value perception in the industry. If this is so, why would CMs invest money in R&D? However, the annual report of these Taiwanese contract manufacturers shows that every company has their R&D divisions, and every year they spend a certain proportion of their revenues on R&D.¹⁰⁶ Even though some of them do not directly associate R&D with their computer system product (a computer is a system, rather than a component), they do have “R&D capabilities” in some other aspects. For example, Foxconn is an EMS (electronics manufacturing services) provider, and although it does not provide product design services, this does not mean that they have no R&D capabilities. On the contrary, they invest huge resources in R&D or technological capabilities in numerous aspects such as assembling technology, electroplating technology, punching technology, and tooling development. In fact, Foxconn has been very aggressive in developing its own patent rights. The accumulated number of their patents worldwide was 17,250 in 2006,¹⁰⁷ which was

¹⁰⁶ The percentages usually are between 1% to 2% for Taiwan’s laptop CMs. Top players’ annual revenues were very high in the recent decade, so the investment in R&D was quite high in absolute numbers. In Taiwan’s regulations about public companies, there are definitions for what counts as R&D, which involve a complex framing (e.g., expenses researching a new product, improving the existing production procedures, or developing new materials and components) which I will not elaborate here.

¹⁰⁷ In Xu, 2008. Section III. As a component giant who paid special attention to patents and intellectual property rights, Foxconn hired over four hundreds of patent engineers and lawyers to file, buy, and

top-ranked among Taiwan's high-tech companies.

After the lifting of industrial ban on investing in China from the Taiwanese government in 2001, the Taiwanese headquarters needed to "upgrade" the industry at home. As a result, the interpretations of R&D in Quanta and other Taiwanese companies shifted accordingly. Within a few years, almost all laptop production lines in Taiwan were moved to China, especially to the Greater Shanghai Region. However, not only were all these Chinese factories Taiwanese subsidiaries, but also most design and engineering jobs remained in Taiwan.

Facing a "hollowing out" concern due to the large scale of factory exodus, both the private sectors and the Taiwanese government searched for an "upgrading" solution. In 2002 Quanta announced that it would build a research institute that distinguished it from the regular design team. The new and advanced research institute would recruit five thousand engineers within a few years and would focus on researching new ideas and new technologies aiming for the production of new products.. However, their new aims reproduce the problematic and stereotyped value system held earlier by their US partners. In the imaginings of Taiwanese laptop producers, China was only a "manufacturing" base that would not threaten Taiwanese design capabilities. Within a decade, however, they had hired more than a thousand

manage its related issues, according to a 2004 media report. In 2003, within the approved patent numbers of Taiwan's firms in the U.S. Foxconn ranked number one, with a patent number of 483 in that year. Overall, Taiwanese companies was ranked number four in the US patent approval case that year, next only to the U.S., Japanese, and German firms. See http://www.gvm.com.tw/Boardcontent_10310.html (Chinese).

engineers in China, including a vast “Extended R&D” center and a smaller “R&D” division there.¹⁰⁸

The spectrum from R&D to production can be considered in alternative ways. Usually, when policy makers and even industrial actors present a general picture of the global value chain, they tend to divide it in a geographically convenient way, such as R&D in the US, and manufacturing in China. But this picture is too simplistic. Each local entity strives to gain its own “R&D” capabilities, regardless of what labels (such as “manufacturing partners”) are given. There is a desire and a requirement for “R&D” to grow in every locality, especially in those areas that they think will enhance their expertise and consequently their value. Every place can develop its own versions of “R&D,” which means the concept of R&D can be invested with different meanings. In the CMs I studied, part of their R&D functions might replicate or overlap with those of their foreign brand-name partners, but the CMs’ R&D had its own unique features, usually an intensification of expertise surrounding CMs’ own core of services: design, assembly, component supplies and so forth. The value chain picture is more than a simple and separate distribution of R&D and manufacturing within the global geography, as it can also expand to include possibilities of different local versions of “R&D.” Thus the R&D elements evolve distinctly at every node in the entire network of production.

¹⁰⁸ Author’s interview with “Christopher” (7/19/2012).

The Gray Area: Design, Engineering, and Development

Any fixed boundary between design and manufacturing can be highly problematic. This is not, however, to say that design engineers will regard themselves as assembly operators, nor vice versa. Their respective job responsibilities have a core that distinguishes it from others, especially those that are distant from it in the chain. But, if we imagine enlarging the spectrum between design and assembly and focus on the middle part of the spectrum, we can find overlapping boundaries and gray areas. These are especially evident in the frequently-mixed references to design, R&D, and engineering from my interviewees. Furthermore, this gray area and ambiguity will influence actors' ways of acting or thinking, and can be used to classify people's work and lives.

As I mentioned earlier, when Taiwanese CMs divide workers into two groups in their companies, the most common expression they use for the upper stream is "R&D." Yet very often, they also replace "R&D" with "design", "development," or "engineering." In their usage, they seem to infuse the label "D" with several meanings --- "D" can be for design, for development, or for engineering. In fact, laptop engineering is often called "design" in Taiwan, because in the context of Taiwanese laptop manufacturing, the major design work is related with engineering efforts. Furthermore, different employees and different companies, in different historical periods, seem to have different interpretations of design, development, and engineering. I received complex versions of them from interviewees:

A retired HP head manager of the PC division Ed Yang said that, for him,

“Design is about innovation... Taiwan was once only strong in development, but their design also becomes strong now... Design can refer to system design, product specs, or industrial design, software design, and interface design etcetera. Only when design is completed, then development is initiated. Development is not so much about innovation, but more about discipline.”¹⁰⁹

Thus, according to Yang’s interpretation, design is a matter of engaging with innovation, while development is not.

Barry Lam, the founder of Quanta offers another view in an oral history interview. He said that research aims for things to be made three years later; development defines products according to the market needs, in relation to possible technological capabilities, and considerations of cost. Usually for technology it takes from eighteen months to two years. According to Lam, engineering is the making of a product after its product specs have been established, and it usually refers to molding, layout of motherboards, and testing. He explained,

”In Taiwan, engineering is also considered as the R&D capability because products have already been defined by Microsoft and Intel, so there is nothing else to add to the design, the rest of it is only engineering.”¹¹⁰

The later part of his comment indicates that there is a conditioning force on the R&D in the PC industry, which makes the R&D in Taiwan a special sort of it -- engineering.

¹⁰⁹ Author’s interview with Ed Yang (9/30/2011, Santa Clara, California).

¹¹⁰ Taiwan IT Pioneers: Barry Lam, The Oral History collections in the Computer History Museum, Mountain View, CA. The oral history was conducted on March 2nd, 2011. CHM reference number: X6260.2012.

"Harrison," a retired R&D head of Quanta has a different interpretation:

"Design is a word that can be applied to much broader range. Basically when you come up with some realistic idea it can be called a design. It can be generated in a purely concept stage, in a development stage, in an implementation stage, or whenever. Development is after you have a target or a goal, and you then start to think about more details. Engineering is to use knowledge in various engineering fields to get things done."¹¹¹

Another idea is from "Yao," a retired factory head in Quanta:

"Design is just an implement for a well defined product, say, [when one] makes a design specification to realize a workable unit. Development includes more advance[d] [work] and gets an idea to be a specified marketing spec, or product spec, then it results in an engineering spec. Development can be more creativity-orientated, more from ground zero; [it] can be a brand new idea, a new working method or a kind of work force. Engineering involves a wide range of works, say a process improvement. ... Basically, just do something to make things better, or make it happen. This is why a re-engineering is so important for industries."¹¹²

In his interpretation, design seems less relevant to innovation, but more relevant to development and engineering.

"Louis," an industrial designer who has been working at different famous computer and Internet companies in the US considered that R&D means when there are several ways of doing things, you study and decide to choose one of them; engineering is getting into the details for the selected version, and design is about initiating ideas.¹¹³ After I mentioned that different people seemed to invest different meanings on those terms, he admitted the

¹¹¹ Author's email correspondences with "Harrison" (10/07-10/11/2011).

¹¹² From author's email interview with Yao (10/23/2011).

¹¹³ Interview by author (10/01/2011).

ambiguity of these terms. He remembered, one time he was sent to work in Taiwan as an Apple manager in the 1990s, when a Taiwanese employee of that company's CM partner asked him "when will the design be done?" "Louis" found this strange, and answered "it's done!" In his perspective, design meant "idea", but the other party was referring to engineering details. "Louis" added that, depending on the context and who was asking the question, the interpretations would be different.¹¹⁴

For now, I have presented different interpretations on R&D, design, development, and engineering from my interviewees to challenge the boundaries imposed upon the design-manufacturing spectrum. These classifications are evidence of boundary work, and realizing this is important to understand how actors view themselves and others in different ways, and how they implicitly give different value judgments to different jobs. In the list of the above "definitions", it seems that the former top manager from HP, Yang, regards design as innovative, but denies this for development. By contrast, the retired factory head of Quanta, "Yao," does not view design as "innovative." Also, although disciplines in general are regarded as connecting more to factory activities, the retired R&D head of Quanta, "Harrison" supports imposing more discipline on his fellow designer-engineers.

Concertos, rather than Solos: Entanglement of Design and Manufacturing

¹¹⁴ For example, when his boss asks, "When will the design be done?" he is asking when it can be sold to the carriers. When engineers ask the same question, it can refer, for example, to "When will the mock-up be done?" or "When will the appearance model be done?" depending on whom they are talking to. Interview by author (10/01/2011).

The above discussions focus on uncovering nuances in the spectrum of design-manufacturing, in order to understand CMs' work in an alternative way to the popular dichotomous categories of design and manufacturing. Nevertheless, there is yet another way to look at CMs' activities: analyzing them from the angle of a time horizon rather than from that of job functions in a division of labor. Especially, if we consider the tasks they engage with at any moment, this D-M spectrum image can be quite static. The real laptop CMs' daily activities were not just conducted by one group of people at a time, but rather by a combination of different simultaneous groups.

Figure 2.6 shows the jobs of design and manufacturing teams in laptop CMs at different points of time in the process of making products. This diagram is based on a hand drawing from "Yao."¹¹⁵ It shows the general and common distribution of overlapping work from design and from factory employees. At a very early stage, only the design team is involved, but the factory team joins in the process much earlier than might be expected: they do not come in merely at the stage of mass production. Just as factory teams attend many meetings and give ideas and suggestions at the "design" stage, design teams do not remain outside of factories. They are involved with manufacture at the mass production stage. If we draw vertical lines to represent different moments, we can see that at most time points, both groups work together. "Yao" said that the two waves (of design and of factory shown on

¹¹⁵ Author's interview with "Yao" (10/20/2010).

Figure 2.6) have become more proximal in recent years. Thus, the overlapping area occupied by design and factory teams becomes even larger. As a result, the laptop product developmental process involves more cross-departmental collaboration rather than finished tasks being handed from one department to the next.

At Quanta, there is still another group of people who belong to the QA (quality assurance) department (see Figure 2.6). The set-up of the QA engineers is to enhance and ensure product quality, but they also bridge and negotiate the design employees and factory employees in many ways based upon the principle of offering quality productions. In Wistron or Compal, they have different strategies that aim to bridge design and factory teams. For example, they have the so-called NPI (new product introduction) phase. NPI is not a fixed organization like Quanta's QA division, but rather it is a working procedure involving a temporary team formed by people from both design and factory divisions to ensure a smooth transition toward mass production.

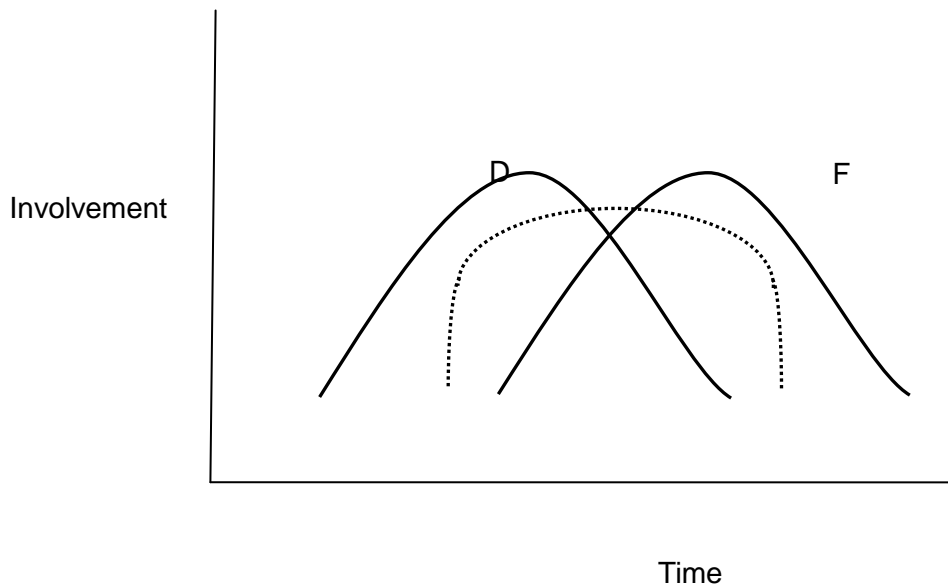


Figure 2.6

The design-factory "concerto". Recreated based on the hand drawing of "Yao." (10/20/2010)

In the product developmental process, as time proceeds, the activities at each single time point will look like D-DM-DM-DM-MD-MD-MD-M (D or M means the design team or the factory team is active at a given point in the above diagram, when the QA team, which is specific at Quanta, is not considered. In the general daily practice at a CM, design or factory teams do not play their functional roles individually or *solo*, but as a group, in *concerto*. This image of collaboration in turn can describe the rich levels of the gray area and the continuity on the D-M spectrum I discussed earlier. It is less problematic to say a person belongs to a design team or to say a stage is the "mass production" stage than it would be to assign a

distinctive feature to the complex combination of people, stages, and activities.¹¹⁶ The image of “design by (one single party), assembled in (one single place)” not only reduces rich levels and complexity to two simple poles, but also hide the various interactions in the whole process.

III. Relations between Design and Manufacturing Teams: Design for Manufacturing, or Manufacturing for Design?

After discussing the unstable boundary between design and manufacturing activities, this section explores the relations between design and manufacturing teams. With no clear boundary between design and manufacturing, it may seem contradictory to say there are relations “between” the two. To clarify, this section concerns the power and knowledge-production relations between design and factory departments, two long-existing organizations of the CMs, rather than those between the far more unclear demarcation between design activities and manufacturing activities involving different groups of people.

As discussed, there is a popular hierarchical image of the relations between design and manufacturing. In contrast with that image, some studies show that manufacturing could

¹¹⁶ People tend to assign manufacturing functions to job descriptions of workers and operators in the factory (usually with a passive and oppressed representation), and assign design functions to those technical planning and engineering activities prior to final assembly or execution of those plans (usually with a more active and privileged atmosphere). Exploring these further, we will find inconsistency and unevenness in the “assignments”. It is far from clear what counts as the beginning and end of design activities, and what counts as the beginning and end of manufacturing activities. The boundary between them seems quite flexible and even arbitrary.

shape the direction of design. For example, in the history of computing, the semiconductor industry has been an academic focus with regard to knowledge creation in manufacturing. The difficulties with manufacturing semiconductor products are so significant that they often reshape the direction of design (Choi, 2007, Bassett. 2002, and Lécuyer 2006). One historical actor even complained that “[researchers often assume that a process that works well in the laboratory will automatically work well in the factory. It’s not that easy at all. In fact, it takes about ten times as much work to introduce a new process to a manufacturing line as it does to demonstrate that it works on a small, carefully controlled experiment in the laboratory”.¹¹⁷ One of my interviewees, “Richard,” also said that,

“Merely being able to produce products and mass production involve completely different skills.”¹¹⁸

These distinctions show that design does not necessarily have the priority in directing what to do with manufacturing. In addition, the close interaction and integration of design and manufacturing also comes from the fast-changing industry-- there is less freedom and luxury to distance design from manufacturing.

This section explores how the power relations between design and manufacturing divisions and how different principles such as “design for manufacturing” and “manufacture for design” in laptops CMs affect the knowledge-making of both teams, and how CMs created

¹¹⁷ Quoted in Choi, p.780.

¹¹⁸ “Richard” is a senior manager in Wistron’s quality assurance department. Interview by author (8/4/2010).

different bridging tools and interfaces to facilitate the back and forth interactions and negotiations between design and manufacturing. In what follows I present views from both members of the design team and the factory team. The first part of the discussion shows how a powerful factory team at Quanta reset the practices of the R&D team by highlighting the idea that good yield rates in the factory came from upstream divisions' full consideration of manufacturability. The second part of the discussion explores the different power relations between design and factory teams, and how the relations influenced the actors' knowledge production.

A Strong Factory Power: Quanta Factory Fought with the Design Division, 1992-1998

Despite increasing product demands since 1989, Quanta was still struggling to establish a more systematic way of engineering and manufacturing laptops until "Yao" initiated dramatic changes to the Quanta factory. Initially, Quanta was a very design- or engineer-centered company. As "Taiwanese Laborer" explained, in the early years, to successfully design a laptop was most crucial. Manufacturing was not a big issue. Since the quantity of demand was not large, they could even assemble the machines one by one. But when the industry entered the stage of global mass production and company survival depended upon yield rate and cost, the power of factory production then became stronger.¹¹⁹

¹¹⁹ Author's interview with "Taiwanese Laborer" (11/17/2010).

When Yao changed his position to factory manager in 1993, he decided to reform the Quanta factory as well. On one occasion, Yao discovered that there was a defect in the laptops being assembled, and, he decided to stop all the assembly work in order to identify the cause of the problem. He describes how time passed, and money was wasted. Customers were nervous, and so were some of the managers in Quanta. One manager finally called Barry Lam, the founder and the general manager of Quanta Computer, asking him if he could persuade Yao to release at least a few products, but Yao refused. This was his philosophy of doing things: in order to avoid later and larger losses, he would systematically solve a problem before products were shipped to customers.

Confronting the popular view of design as higher status work, Yao dared to fight with the design or the so-called R&D (research and development)¹²⁰ division in Quanta. He would return the designs to them and ask them to redesign them when the product was flawed or was too difficult to mass- produce. This was his style. He was a quality assurance (QA) head in Quanta when he joined the company in 1989, the year after the company was founded. Initially he was assigned to take charge of different jobs such as documentation, MIS, and field service until he acquired responsibility for a production line for a US customer in 1993 at

¹²⁰ Again, I am using “research and development” (“R&D” or just “RD”) here as most Taiwanese laptop actors use it. They generally distinguish two kinds of work during the production process—R&D and manufacturing. The “R” here does not necessarily (and usually does not) refer to basic research as it might be meant to be. In the Taiwanese context, their R&D refers more to electronics engineering, mechanical engineering, and software design, the three most important contributions the Taiwanese perform in the laptop supply chain.

Quanta. After that, he took charge of the whole system of production lines in Quanta in 1995.

Before he joined Quanta, Yao had worked for a US company, Qume, which was under the ITT group for quite a long time.

Yao had had a strong personality before he joined Quanta. One reason he left the US company was that he thought he did not receive enough respect from headquarters. He had been the Taiwanese manager for quite a few years, but every time he travelled to the headquarters, and joined managerial meetings, he believed that they viewed him as nothing more than a country manager. He finally left Qume thinking there was no hope of getting anywhere from the position he was in. In 1989, Barry Lam, the top manager of an ex-supplier of Qume, now the founder of Quanta, called Yao, then visited him and took his daughter to McDonalds (which was then a high-priced fast food restaurant in Taiwan) before persuading him to join Quanta. He accepted the offer after Lam and another co-founder, C.C. Leung, meeting with him several times. An attractive proposition in the offer for Yao was that he could do anything he wanted to do in Quanta. In a word, Lam was not so much his “boss”, but rather a parallel partner.

After joining Quanta, Yao played a key role in shaping the manufacturing-oriented culture in Quanta. In his observation, the R&D members in Taiwan always assigned themselves a high status and thought “coming down to production line” was a disgrace. Thus, the devaluation on factories seemed to not only come from the outside brand-name partners,

but also from the internal division. Yao changed this culture by pushing R&D employees to “come down” to the production line to find out what factory employees were doing. In his interview with me, he very disagreed with the culture that R&D employees thought highly about themselves, in fact, a lot of them even could not finish a decent product. For him, successful manufacturing could be harder than the R&D job. But the strong power from factory also made the R&D members feel wronged. A former team member of the factory “Frank” commented that R&D employees in Quanta were devalued, especially compared with R&D employees in companies such as Acer and Asus which viewed R&D members as treasures.¹²¹

Every day, Yao would convene a meeting to review any problem they encountered. If a team head in the factory could not explain in a rational way why there was such a problem, Yao would forgive him only once. The second time the head could not give a reasonable explanation or at least a good observation of the problem, they would have to stand until the meeting ended. Sometimes, group heads would even be punished, sitting on a high chair to observe the production line from a higher and perhaps clearer position, in order to learn what was going on in the factory. And whenever a manager sat in the isolated chair, all the employees, including shop floor workers knew that he was being punished (This is the

¹²¹ Author’s interview with “Frank” on Skype phone (07/23/2011).

opposite of panopticon observation,¹²² since the gaze was from the workers to the supervisor). Yao recalled, most people in the factory were so afraid of him, thinking of him as a rigid and demanding person, that the hallway would become empty when he appeared.¹²³ His discipline of factory managers, and even design teams was more famous than his discipline on factory shop floor workers because he regarded that design employees were the people who needed to be re-educated and to be actually integrated to design-manufacturing collaboration in the laptop industry.¹²⁴

In the past, the general practice in Quanta factories, just as in many other factories in Taiwan at that time, was to increase the output as much as possible. It was a culture that Yao could not agree with, and he changed it dramatically by insisting upon the factory's rights to return faulty designs to design teams, and to halt the production line until the problem was recognized and solved. He even once cancelled a whole project due to bad mass production performance. He had a power that most laptop factory managers in Taiwan could not think of having.

"Harrison," a senior retired R&D engineer-manager of Quanta said,

¹²² Panopticon is a concept from Foucault 1979, which he uses to show a way how prisoners are easily monitored and watched, and thus disciplined, through a particular design and arrangement on space.

¹²³ The discussions for "Yao" in this section were digested from Yao himself and two other interviewees including "Richard" (07/28/2010) and "Harrison" (06/23/2010). "Yao" is now retired, and the other two people left Quanta and joined other companies.

¹²⁴ This idea of discipline resembles Foucault's, although Yao's power demonstration seemed to be direct rather than subtle, his idea of design should serve manufacturing, and everyone should insist to get things done is a best way was quite influential and omnipresent in shaping Quanta's culture and the collaboration between design and factory teams.

“I think he (“Yao”) had done it right. R&D employees in Taiwan have been spoiled too much ... quality and time to market are the key to success. And these need a lot of discipline. But many engineers do not like to hear about discipline. He (“Yao”) is the guy to put discipline in front of them.”¹²⁵

Imposing discipline on R&D teams was not unique in Quanta. Foxconn, the major manufacturing partner of Apple’s iPods, iPhones, and iPads, had already done this for a long time. “When you walk out of laboratories, there will be no high tech, but only discipline,” although in fact Foxconn also exerted clear discipline even in their laboratories. When people said that R&D could not merge into Foxconn’s culture, the founder and CEO of Foxconn Terry Kuo would say that those people did not really understand high-tech. In his opinion, R&D not only requires discipline, but must also value discipline more than other divisions. Furthermore, Kuo considers that discipline should be imposed at every step, and with every analysis, every problem, and every verification of the research and experiment process.¹²⁶

The stress on discipline presents a special image of R&D’s work in the laptop industry.

Power Relations between Design and Factory Teams

While Quanta had a very influential factory due to “Yao’s” special status and effort after 1992, other laptop CMs in Taiwan in general had no such powerful manufacturing team. One senior manager in Compal, “Stewart,” who has been in the industry for over thirty years,

¹²⁵ In an author’s email interview with “Harrison” (10/25/2011).

¹²⁶ In Xu, p.405. This sort of permeating and invisible discipline also reminds us of Foucault’s (1979) idea on discipline.

pointed out that the power distribution between R&D and factory divisions was different in different Taiwanese companies. If Compal had a 50% vs. 50% distribution, Quanta would be a 60% (for factory) vs. 40% (for R&D) distribution, and Acer/Wistron was a 40% (for factory) vs 60% (for R&D) ratio. “Frank,” a quality engineering manager who once worked for Pegatron (another top five laptop CM), Wistron, and Quanta also mentioned that, while Quanta was a manufacturing-oriented company, Pegatron and Wistron were both R&D-centered.¹²⁷

James Chou, General Manager of Wistron Kunshan,¹²⁸ agreed that, compared to Quanta’s factory, Wistron’s factory power was weaker. When there was a dispute (which was not uncommon, at least once every one or two months), the factory team would usually need to compromise. He said, “If it is hard to assemble, we will just tolerate it.”

The factory team would tell the R&D team the price of not changing the design.¹²⁹ Sometimes the R&D would change it, but at other times they would not. Another Wistron senior manager “Richard”, who worked for Wistron and Quanta, complicated the power relations by adding more divisions: in Wistron, the sales department was more powerful than procurement. Next in terms of power was R&D, and then finally the factory. But in Quanta, the factory was the most powerful, followed by R&D, and then the procurement division. The

¹²⁷ Author’s interview with “Frank” on Skype phone (07/23/2011).

¹²⁸ Kunshan is a city near Shanghai, where is Quanta’s factory base in eastern China. Interview by author (7/16/2012).

¹²⁹ In Wistron’s factory, Chou said that it was less likely that the factory would check the electrical engineering design than the design of mechanical engineering part.

least powerful division was sales.¹³⁰ In Compal, the power struggle was mainly between the R&D and procurement divisions.¹³¹ Although these are rough and static pictures of the different tensions between R&D and factories at various CMs, they illustrate crucial differences in their organizational cultures.

Different power structure cultures at these companies can be attributed to their organizational heritage. As discussed in Chapter 1, on the early history, two main players who joined the laptop industry were from the calculator and the desktop camps. Quanta and Compal were from the calculator camp, and Wistron and Pegatron were from the desktop camp. "Stuart" from Compal said that there was a different degree of integration between notebooks and desktops. Notebooks were much smaller and were used for mobility, so they required much more integration and posed a greater challenge for mechanical design and production. Although the desktop camp knew more about computers, the calculator camp had more experience with tooling and system integration. Calculator companies initially paid more attention to factors such as battery and mechanical design, and they needed to consider manufacturability for the small-sized product as well. Desktop companies, however, usually did not pay as much attention to the mass production problem in the factory as the calculator companies did. Instead, desktop companies could simply design a good motherboard, and then the mass production followed smoothly. That is, desktop companies

¹³⁰ Author's interview with "Richard" (8/4/2010).

¹³¹ Author's interview with "Eli" (12/7/2010).

had a looser relationship between their design and manufacturing operations, and here design teams were at the center of the company. It took more time for the desktop camp to learn to integrate design and factory teams when they joined the notebook field. For “Stuart,” the original desktop companies were very hardware-oriented, but the later notebook companies required them to be system integrators.¹³² Therefore, the relations and power distribution between design and manufacture in each notebook company was influenced by their earlier path.

Design for Manufacturing (DfM): How Knowledge Production and Practices were Influenced by DfM

But what did it mean to have a greater concentration of power in the factory than in the R&D division? How did the different power distributions affect CM’s knowledge production and practices? Design occurs earlier in the time sequence of making a computer, thus design teams are often required to orient their work to other divisions’ needs. Simon Lin, the CEO of Wistron, said that the design team had needed to work with the factory sector for a long time. Originally, the purpose of coordination was primarily to debug manufacturing issues and smooth production, but later the design team came to factories, supply chains, and even the end-market in order to incorporate ideas into their design. As a result, the design process

¹³² Author’s interview with “Stuart” (7/21/2010).

itself became more dynamic.¹³³

There is a widely used acronym in the industry called “DfX” (design for X, X can be anything the company prefers), which could be “design for manufacturing/manufacturability (DfM)”, “design for quality”, and “design for services” and so on. This represents the idea that designers need to pre-consider the other party’s requirements and remain open to their feedback. For example, to facilitate DfM, Dell Computer asked the factories of Compal in China to report anything that was NUDD: new, unique, different, and difficult from production, in order to take action or communicate findings to the design teams.¹³⁴ But the question remains: to what extent would CMs’ design teams accommodate factory and production needs?

The laptop design teams consist of members from brand-name companies and members from CMs themselves. But in this section, I will focus on only internal relations between the design team of a CM and the factory team of the CM. I will discuss the external relation between brand-names’ design teams and CMs’ factories in Chapter 4 on contained innovations.

In Quanta, the philosophy of “design for manufacturing” (DfM) was realized to a high standard for many years, especially after “Yao’s” pushing. In most years before their factories

¹³³ Author’s interview with Simon Lin (5/26/2010).

¹³⁴ Discussed with several factory managers in Compal when I visited their factory in Kunshan (7/16/2012).

were moved to China, their design offices and the main factories were geographically proximal to each other in Taoyuan County. Hence, the R&D employees visited the factories frequently whenever any issues with production arose in order to debug an issue or modify their design. By contrast, Acer/Wistron's R&D teams were in Taipei while their factories were in Hsinchu. Although the distance between the two sites is only 100 kilometers, the R&D teams showed reluctance to go to the factories.¹³⁵ Roger Huang, a senior R&D manager in Quanta, said that the close interaction between design and factory was originally a characteristic of Quanta, but later when they moved factories to China, it became more of a burden to the R&D team because they needed to travel often to China. On the other hand, although other companies had looser relations between design and factory and were originally at a disadvantage compared to Quanta, after the collective factory relocation to China, the competitors possessed better transfer mechanisms from design to factory than Quanta did.¹³⁶

Undoubtedly, the principle of *design for manufacturing* (DfM) involves more than the physical contact of the two divisions when the product enters the factory. It concerns the mentality that when designing a product, engineers should consider how to make mass

¹³⁵ Author's interview with "Richard" (8/4/2010). He was a senior manager who worked many years in both Acer/Wistron and Quanta.

¹³⁶ Author's interview with Roger Huang (12/31/2010). "Bruce" from Wistron had the same argument with Roger about the D-M integration was a disadvantage to Wistron earlier, but later became an advantage after their factories moved to China, because Wistron had gotten used to remote management.

manufacturing more feasible, simpler, and more efficient. Furthermore, it was important to engage the factory team in the design phase to prevent endless disagreements between design and factory over production issues afterwards.¹³⁷ It was best to engage factory team members right after the completion of a design concept. “Taiwanese Laborer” said that in the past, it was not unusual to have quarrels in Quanta, but later the situation improved due to the practices of DfM.¹³⁸ “Richard” also said that Quanta’s culture combined “conflict management” with a Japanese style of self-management, hence, every team could insist on what they wanted to do, and no one would blindly follow the ideas of other teams.¹³⁹ Both of them mentioned that it was common in Quanta to have daily quarrels and even table-pounding.

Although Quanta’s factory “won” the battle in the D-M relationship after the early 1990s, the victory was not stable. Because of the tendency to turn back to an R&D-centered culture in Taiwan’s high-tech companies and in Quanta, it was important to find a systematic way to retain power in the factory. Trained as an electrical engineer, “Yao” knew that he had to hire excellent production engineers (PEs) who understood both design and manufacturing know-how; otherwise, the manufacturing division could be “cheated” by the RD division.¹⁴⁰

Another solution involved having necessary equipment and bridging organizations within the

¹³⁷ Author’s interview with “Taiwanese Laborer” (11/17/2010)

¹³⁸ Ibid.

¹³⁹ Author’s interview with “Richard” (8/4/2010).

¹⁴⁰ The discussion of grasping the technological core is from the interview of a former-manager in the Quanta factory, “Frank” (7/23/2011).

factory. Quanta had a QA (quality assurance) division, which did not belong to the R&D team and acted as a judge in qualifying designs and deciding which party should solve product problems.¹⁴¹ If the product did not yet qualify for mass production, it would basically be returned to the design team for modification, but once the product passed QA's examination, it would be the PEs in the factory who would be held responsible for any subsequent problems. Quanta's PEs even had the rights to change product designs for solving mass production problems, as long as they acknowledged the R&D team.¹⁴²

"Yao" was very proud of his factories' capabilities: the engineers in the factories "had R&D capabilities"; also the experimental equipment in QA was as good as that in the R&D teams of Quanta and was even better than ITRI's. He said, "Power is not what the boss gives you. Once we have a QA lab that can prove that a design is having problems, is it possible that you (the design team) don't modify your design?" He believed that when the R&D team knew that the factory could do experiments and tests to disapprove specific designs, the design teams had to be convinced of the results.¹⁴³ Therefore, it was not only the subtle battle about who had more political power, but also about who could convince others that they possessed legitimate power from their own knowledge production.

¹⁴¹ According to "Yao" and "Frank," at different times, Quanta had different organizations for this division, but it was basically a neutral department. "Frank" said that QA can be divided into QE (quality engineering or quality enhancement). QE requires engineering capability, and QC was responsible for only examination of products. QE in Quanta now is called SDA (system design assurance).

¹⁴² Author's interview with "Frank" on Skype phone (07/23/2011). But Frank said this was confined to the electrical engineering. For mechanical engineering, it was not so possible to modify the design since there would be only one set of tools (mold making was expensive and time-consuming).

¹⁴³ Author's interview with "Yao" (12/14/2010). p.8.

Producing Design Rules to Tame the Design Team

To meet the aims of DfM, Quanta's factory team generated the DfM guidelines, requesting the design team to follow basic rules from the factory. These documents included "musts" (for example, there must be a certain distance between a screw and a part) and "must-nots" (for example, certain kinds of materials should not be used). The guidelines were a result of a long-term accumulation of experience and reflected important practical know-how as well as a database in Quanta, according to "Taiwanese Laborer." When I asked if I could take a look at the documents, he said it was not possible, because it was one of their competitive resources. He said,

"Although it concerns only 'small knowledge,' the collection of small knowledge is a company's competitiveness."¹⁴⁴

It is interesting that it was the factory team members who generated important rules for the designers, rather than the other way round. Due to mass production being at a later stage in making products, the CMs believed that instead of getting endless feedback and arguments from the factory later that would delay the time of shipment, it was better to initially inform and tame the design team. Factory engineers, team leaders, and shop floor workers accumulated information and experience which were then encapsulated in the guidelines to the design teams. This practice further demonstrates that these factory actors were nothing

¹⁴⁴ Author's interview with "Taiwanese Laborer" (11/17/2010,), p.10.

like passive followers.

Besides factory-initiated rules for designers, Quanta had a special center called PDC (product design center) that was responsible for maintaining and monitoring different documents. For example, in addition to the DfM guidelines from the factory team, the design engineers also generated product design guidelines for their own members, informing engineers of how to create better designs based on past experiences. As a “Taiwanese Laborer” highlighted, however, it was not possible to describe all design experiences in written form, so in addition to documentation, they needed the master-apprentice mechanism to allow less-experienced engineers to stay by the side of senior ones to learn the know-how and skills of handling different issues.

After 1989, Yau also initiated accurate and comprehensive documentation. “Yao” said all documents and engineering drawings would be put into the document center after review approval, and the document would then be stored, organized, maintained, updated, monitored, and released to people who needed it. Each of the steps of documentation was not cheap. It was a huge project for Quanta.¹⁴⁵ While documentation partially contributed to the success of Quanta, some people doubted its effectiveness. “Rob” did not think the mode of documentation would work all the time. He said the very idea of documentation was resisted by some R&D team members, and some factory employees said that they would not

¹⁴⁵ Author’s interview with “Yao” (10/20/2010).

read documents. The main obstacle came from problems of efficiency. The industry changed so fast, and simultaneously it took time to organize what they learned and put into writing or action. For “Rob,” although there were some general rules, the degree of using the documents might not be so high.¹⁴⁶ Thus, there was a deliberation inside the firm on how to measure and balance the advantages and disadvantages that explicit documentation brought about.

Creating Fixtures to Free the Design Team

DfM seemed to be a beneficial support to the factory team since it meant that the design team took full consideration of practical mass production in the factory, but was it always so? And was there a better way to benefit both parties? A senior Wistron manager “Richard,” who once worked in Quanta, said that DfM was not always good for factories, since it might limit factories’ own possibilities. For example, EMS (electronic manufacturing services, which involves no design work for the clients) companies can produce almost everything that their clients need and want. Wasn’t accepting the challenge from the design team also a good way to train the factory’s capability? Also, would the design team’s creativity be limited due to various requirements from factory and other teams? How far upstream can the power of mass production influence the design stage? Robert Huang, President and COO

¹⁴⁶ Author’s interview with “Rob” (1/17/2011).

(Chief Operations Officer) of Wistron, who was himself an industrial designer for many years, said that the notion that “form follows function” was still an important belief for designers, therefore they always need to consider practical functions. That is, it was inevitable that “ID (industrial design) will be pulled by manufacturing, because we can’t design stuff that can’t be manufactured,” but it was also important that the company needed to keep the uniqueness of ID. Fortunately, the idea of DfM only reached the levels of electrical engineering, mechanical engineering, and supply chain, but not yet to that of industrial design. The company still wanted to preserve room for creative ideas of industrial design.¹⁴⁷

Similarly, in “Richard’s” opinion, there should be DfX, but if the items of DfX continued to increase, they might signal retrogression rather than progress. For him, a compromised way to balance the relative weight placed on design versus manufacturing was to develop fixtures for production lines’ workers. He considered that in the first place, it was necessary for the factory team to ask the design team to design easy-to-assemble products, but at the same time the company needed to think of a way not to restrict the design team too much, and to allow more room for the design team to create more value.¹⁴⁸ The creation and usage of fixtures was one way to solve the problem.

Fixtures are special tools that are designed by experienced engineers that can help production-line workers or machines to affix the object they are assembling or disassembling

¹⁴⁷ Author’s interview with Robert Huang (7/22/2010).

¹⁴⁸ Author’s interviews with “Richard” (08/04/2010).

and as a result to perform a precise and efficient action. “Richard” said that when he had the opportunity to visit others’ plants, he did not observe their factory layouts or equipment because that information was easy to get from equipment vendors.

Author: So these fixtures are all very popular here now?

Richard: Yes, very popular. So, right now when we visit others’ factories we won’t observe their production lines, but look at the small fixtures on the desks.

Author: Oh?

Richard: That’s right. Because when you have a fixture at that place, that means you want to solve a problem. So when you see what fixtures are in a position [being worked on] , you know you have some problems in the production...

Author: You said that when you visited others’ factories, you don’t observe other things but only fixtures?

Richard: Right. Because when I walk by, I will see what tools are on the desks.

Author: But don’t you watch their [factory] layout? Isn’t layout different?

Richard: Those are not so different, and I can know about layout just by asking the equipment providers. I can observe the brand names on the equipment, then that [equipment] vendor can tell me.¹⁴⁹

Instead, he observed what fixtures they were using because that would imply:

“What problems they attempted to solve, what stuff they wanted to release, and what things they want to make the other department to have more creativity.”¹⁵⁰

Or, in other words, what difficulties the production had and how that company could conquer them. For example, if the workers were trying to put in a keyboard wire, but the

¹⁴⁹ Author’s interviews with Richard (7/28/2010), p.48.

¹⁵⁰ Author’s interview with Richard (8/4/2010), p. 35. Richard discussed the idea of fixtures extensively in two Interviews with me (7/28/2010 and 8/4/2010).

space was too small for their hands to operate, they had to design and manufacture a special fixture to help perform the motion. “Richard” said that fixtures aimed to “transform humans into machines” because they helped the fixation of people’s motions, and the two main principles of fixtures were enhancing the production efficiency (shorten the time of the motion) and avoiding human errors.¹⁵¹ He said, “Whether the capability of your factory is strong or not depends on if you value fixtures.”¹⁵²

Although some of the fixtures could be shared, producers still needed to design different types of fixtures for different notebooks because each model had different designs, sizes, and components.¹⁵³ They are designed by experienced engineers in the factory of CMs or from the brand-name clients, and co-designed and produced by outside fixture vendors. Fixtures could be used in different production procedures, usually the types of fixtures in the SMT (surface mount technology) were more numerous than those in the final assembly line. While most brand-name clients hired only a few people to maintain their fixtures in Quanta Shanghai, Apple dispatched one to two hundred people to maintain their fixture rooms there. That was because Apple’s products were quite different from others, and most of their components were small and customized.¹⁵⁴ Also, very importantly, Apple is

¹⁵¹ Author’s interview with Richard (8/4/2010), pp. 35-36.

¹⁵² Ibid.

¹⁵³ “Leo” indicated that for most notebooks, about 70% of fixtures would be used continuously. It is important to continue the same assembly skills. “Leo” was a factory manager in Quanta Shanghai. Interview conducted on 7/23/2012.

¹⁵⁴ Author’s interview with “Christopher” (7/23/2012).

relatively a design-centered company. That is, it leans toward a principle of MfD (manufacturing for design). Apple's products are notoriously difficult to assemble, so its new products' initial yield rates are usually lower, but it could thus enhance the knowledge and capability of the factories and the manufacturing teams.¹⁵⁵

In addition to fixtures, there were still other ways to bridge the design and the factory teams: for example, through the QA department, through D-M knowledgeable production managers (as I briefly discussed earlier), through simulation, and through processes such as NPI (new product introduction).

In this section, I examined the interactions between the design and factory team with a focus on the principles of design for manufacturing (DfM) and manufacturing for design (MfD). Different principles originated from different relations between design and manufacturing, and generated different knowledge and practices for both design and factory teams. However, adopting a single principle will not determine the degree of a given department's capability. In a company that stresses a strong DfM principle, the factory team's capability could thus become weak in handling complex issues by itself if the factory demands others to solve problems. But it is also possible for the factory to increase their own expertise by transforming their experience into guidelines or rules for the design team to follow, which enhances the factory's capability when they have to keep necessary design and

¹⁵⁵ Author's interview with "Richard," *ibid.*

engineering knowledge within the factory in order to sustain legitimacy during tricky D-M interactions. Under the principle of DfM, the design team can become very restricted by the numerous rules from the factory team, but the design team can also employ innovative strategies to buffer the negative impact from those requirements.

In a slow-changing or less time-critical industry, the separation of D-M is feasible, but in a fast-changing industry such as the laptop industry, the intertwining of the design team with the factory team is necessary. This is especially so, because laptop actors are not working with unchanging parts and components. They continue dealing with various unstable parts, components, and software technologies, so the interactions between design and manufacturing need to be frequent, and the relations between them are also open to change.

Conclusion

Overall, this chapter aims to disclose the dynamics of design-manufacturing laptops and recognize the importance of both design and manufacturing capability in the industry. In particular, the range or influence that manufacturing or factory teams exert can reach upward to the product proposal stage and thus dissolve the hierarchy between design and manufacturing.

I first show the complicated process from ideas to artifacts based upon C-System and the so-called “Ten Thousand Miles along the Yangtze River” product development manual. In

that section, I show that Taiwanese companies contributed much more than assembly and were important providers of engineering efforts and innovation.

Calling attention to the ambiguities among design, development, and engineering sectors, I secondly reveal the undefined boundaries within the design-manufacturing relationship continuity. I argue that the ambiguous middle region within the D-M spectrum can be manipulated to have a strong value-laden effect: The value of the “activities” that fall in the gray area of the spectrum is thus contingent to certain degree. Likewise, the meaning of R&D in the industry is not universal; rather, the term acquires different interpretations and adaptations according to the needs of local laptop enterprises that usually strove to develop their own R&D versions. The knowledge and practices of each sector over the D-M spectrum influence and are influenced by others. Even for scholars who focus on solving poor labor conditions, it is crucial to understand the complex process from ideas to objects holistically rather than to conceptualize the material production dualistically as “capitalists/managers vs. laborers” or “design vs. manufacturing.” The D-M boundaries and their interpretative flexibilities are the product of value-laden, geography-laden, and history-laden judgments.

Lastly, I illustrate the ways in which different (power) relations between the design team and the factory team generate different sorts of knowledge and practices. Specifically, it is possible to have factories with significant power in the laptop producers. They are not always subordinated to their design counterparts. The principle of DfX or DfM helped to tame

and integrate the upstream design team to put those factors into major considerations. I also show how the knowledge relation between design and factory teams is very dynamic and can be mediated by tools such as fixtures.

In sum, this chapter shows that the equation “CMs= Who do Manufacture = Factories = Assembly Lines= Dummy Jobs” are problematic. The computer outsourcing process extends far beyond separating a “low-value,” “low-knowledge content” assembly from “high-value” design. This dualist misconception perpetuates an industrial class structure between the U.S, Japan, China, and Taiwan amongst others that denies the fact that these countries’ important form of production (contract manufacturing) is an important intermediary mechanism transforming our world.

Although I highlight that these CMs have design ability, I do not mean to downplay the importance of factory, manufacturing, or assembly jobs. As I discussed in chapter 1, relying primarily on manufacturing or inexpensive labor for the initial development (a linear development perception) is a traditional myth toward Asia. Undervaluing or even disdaining manufacturing is another myth. We should note that one reason that Silicon Valley surpassed the East Coast of the US in the high-tech industry was because they engineered innovative manufacturing techniques. “The manufacturing capabilities made Silicon Valley,” as Christophe Lécuyer concluded.¹⁵⁶ In other words, we have no reasons to devalue either

¹⁵⁶ See Lécuyer: Making Silicon Valley, p.297.

Taiwan's design or manufacturing capability. In fact, much knowledge in the laptop industry is co-produced by the design teams and the factory teams. It is even more appropriate to regard these Taiwanese laptop producers as design-manufacturing knowledge integrators. *It is the dynamics and interactions between design and manufacturing teams that matter, not just design or just manufacturing matters, especially when they form a continuum.* In chapter 3, by exploring their practices focusing on cost reduction, I will further extend the idea of integrated D-M knowledge to that of a broader concept, field knowledge, which covers not only the internal D-M relations but also outreach interactions with multiple-sited and trans-organizational fields for production activity.

CHAPTER 3

CHEAP AND CHEAPENED INNOVATION:

FIELD KNOWLEDGE, AND THE GLOBAL DE-VALUE CHAIN

“‘Cost down, cost down, cost down,’ all the keywords I heard in the meeting of the board were ‘cost down,’” a board member from a Taiwanese laptop producer said.¹⁵⁷

The Chinese saying “turning soil into gold” describes the magical power dreamed of by ancient alchemists of instantly transforming low-value objects into treasures. Yet a senior Taiwanese laptop manager said that Taiwanese people have been good at “turning gold into soil,” meaning that the magic wand functions the opposite way. In other words, no matter what industry the Taiwanese companies joined, they would cause it to become both lower-priced and less profitable. For example, LCDs, laptops, and CD-ROMs all faced the same fate of devaluation.¹⁵⁸ D. Y. Yang, an important figure in Taiwan’s semiconductor and PC industries, even commented,

“Taiwan’s capability is the ability to turn high-tech products into a low-tech production method.”¹⁵⁹

Yang’s comment presents both a process and an image of the work of the Taiwanese

¹⁵⁷ Author’s interview with an anonymous interviewee who was a board member from 2007-2009 with a major Taiwanese laptop producer. Interview conducted on 10/27/2011.

¹⁵⁷ Author’s interview with “Bruce” (4/16/2010).

¹⁵⁸ Author’s interview with “Bruce” (4/16/2010).

¹⁵⁹ From the Taiwanese IT pioneer oral history collected by Computer History Museum (CHM, Mountain View, CA). Interviews with D. Y. Yang. CHM Reference number: X6290.2012 (Chinese transcript, p. 44).

companies. We know that many high-tech products need the so-called low-tech method and dirty work. They are presented as “high” partially because the middle process is hidden. Additionally, isn't expertise also illustrated by the ability to transform complex missions into operational and simple procedures? But once one is labeled with or works together with low-tech, his/her value will seemingly be automatically decreased -- a situation similar to what happened to the Taiwanese CMs.

There were various reasons for shrinking profits,¹⁶⁰ but the question here is, how did they achieve the goal of cost reduction through their engineering efforts? Did they receive credit because of their efforts? If not, why? In this chapter, first I will show the ever-decreasing profit margin of the Taiwanese laptop CMs, and then reveal the way in which they innovated laptop designs and manufacturing practices to reduce the cost of laptops. Reducing cost involves many invisible engineering innovations, either in the process of producing products or within the small computer black box. These innovations might not be very visible or easily sensed by users, but are usually embodied in “lower prices.” I then develop the concept of field-integrated knowledge to describe their various efforts in achieving such cost reductions. Finally, while producing cheap (meaning low-priced rather than poor quality) technology was a valuable contribution, ironically, it turned out to devalue the work of the engineers. The CMs’

¹⁶⁰ The devaluation of Taiwanese industry partially comes from the fact that the Taiwanese seldom join an industry in its infancy, when the potential for both risks and rewards is higher. Instead, they join those industries that will be approaching maturity soon or those that will have a big market in the near future. It also occurs because Taiwanese entrepreneurs are often swarming into the same industry together and are forced to cut prices due to severe and incessant competition.

innovations to achieve cost reduction did not result in higher profits for their companies; instead, they resulted in doubling the devaluation: these CMs created inexpensive technologies for others through engineering effort and innovation, but in the process of doing so, the CMs' engineering efforts also were cheapened.

Cheap and Cheapened Innovation

The knowledge and knowhow involved in reducing cost has been important. If is possible, most consumers want to obtain high-end and high-quality products at very low prices. There are at least two things that companies can do: the first is to produce counterfeits of expensive products, although the quality might be dubious. The second is to provide inexpensive but good-quality products through innovative design and manufacturing techniques that are invisible to most of the buying customers. This has happened in the fashion industry (e.g., Zara and Uniqlo represent the recent trend of the so-called "fast fashion" and popularly priced products in the apparel industry), and it can also be seen in the personal computer (PC) and laptop industries.

The interest in cutting costs partially led to US and European companies outsourcing production to Asia in the 1960s.¹⁶¹ When a product went wrong, very often blame was laid on the place that made it. In the earlier years, it was nothing new for the image of Asian

¹⁶¹ Although labor cost was mostly highlighted, the cost-saving factors were multiple, ranging from labor and engineer salaries, to land rents, utility fees, and tax incentives.

manufacturing to be associated with “low value,” and often, low quality. Even though, at different times, Japan, Hong Kong, Singapore, South Korea, and Taiwan seemed to gradually escape this sort of image, the low-value association with certain geographical regions has lingered. This historical continuity, together with the competitive logic of capitalism, is translated into a devalued image that these Asian producers did not wish to have.

The requirement for cost reduction was also one major attraction for world-famous brands in the 1990s to source from Taiwanese laptop producers. At this stage, the interest in producing cheap computers was driven mainly by the international (non-Taiwanese) computer companies at a time when Taiwanese laptop producers were concerned more with designing and producing workable machines. Taiwan also gradually became a center for producing relatively low-cost laptop computers. About a decade later, the same requirement for “cost down” continued; however, by this time the cost savings seemed to be no longer a blessing that brought prosperity to Taiwanese producers. Rather, they were more of an inescapable curse that trapped the producers when they found that while they continued making contributions to innovation, their engineering capabilities were also “cheapened” in a world that values brands and users rather than producers.

Taiwanese companies’ most significant contribution to the industry has been reducing costs of personal computers and helping with the diffusion of the PC as a household entity worldwide. For example, Stan Shih, the main founder of Acer, was elected by *Time* magazine

in 2006 as one of the “Asian Heroes” of the past 60 years because Shih helped turn Taiwan into a PC-manufacturing powerhouse, as well as a main provider of inexpensive technology for the world. Shih himself attributes the rapid popularization of the PC in the world to the incessant efforts of Taiwanese industry. He argues that if there had been no Taiwan to help reduce the product cost, the PC would not be as widespread and commonplace as it is today.¹⁶² Certainly, “cheap” is based on a relative comparison. People in poor countries might not be able to afford “cheap” products in the US. But when we see that the ASP (average selling price) for personal computers (PCs, including both laptops and desktops) dropped from above \$2000 in 1994 to around \$500 in 2011, we might want to know who helped to make the product much cheaper.

The Double Effect of Moore's Law: Both Better and Cheaper?

Since information technology continues to progress, it is reasonable or even natural for people to expect that computers should become cheaper, but this thought is somewhat misleading. One interviewee, Ed Yang, who was a retired Hewlett-Packard top manager of the PC division, stressed that the “wrong” expectation comes from Moore’s Law, proposed in 1965 by Intel’s Gordon Moore. Moore’s Law says that the density of transistors on integrated circuits doubles approximately every 12-18 months. That is, the performance of the

¹⁶² Interview by author (4/22/2010 and 6/02/2010).

technology will double after a year or one-and-a-half years. This “law” is based more on experience than on a physical theory. How the industry in recent decades has realized the self-fulfilling prophecy is a long story, which is beyond this chapter’s scope, but Moore’s Law¹⁶³ has had a significant impact on market expectation. People do not expect that the clothes and shoes they buy will be cheaper next year, but they expect this of computers. Even when the new computers’ general performance is better, they still expect to pay lower prices rather than the same price for the newer/better products. This phenomenon of decreasing prices for computers does indeed keep happening. However, it should be noted that, Wintel (Microsoft Windows +Intel),¹⁶⁴ the hegemon of the PC world, have kept almost the same prices for each generation of their new products.¹⁶⁵

For example, the price of Intel’s mainstream CPU in laptops has been around 100 to 110 US dollars. They did not lower it, or they lowered it only by an insignificant percent, nor did the major companies that produced other key component products lower their prices. For example, although the price per mega DRAM (dynamic random access memory) dropped, the new computers use more memory, so the total price for DRAMs is not necessarily lower in a new single computer system.

¹⁶³ In STS, MacKenzie and Wajcman (1999) commented that Moore’s Law, which is regarded as being close to a natural law, implies technological determinism.

¹⁶⁴ “Wintel” is a compound word representing Microsoft’s Windows operating system and Intel microprocessor technology; both have been dominating the PC market for decades.

¹⁶⁵ Author’s interview with Ed Yang (9/30/2011, Santa Clara, CA), he has worked in Silicon Valley for more than thirty years.

Moore's Law created a double effect: with each product generation, the technology is not only better, but also cheaper, as Ed Yang described, but when Intel and dominant key component players did not lower their average prices for the computer system, who absorbed the loss in the selling price? Yang observed that it was the Taiwanese companies who helped this happen. It was efforts from both the Taiwanese CMs and from their non-market-dominant and non-key component suppliers.

Who Profits from Innovation? A Meager Profit Era for Most, But Not for All

After 2000, a popular term, *meager profit (mini-profit) era*, appeared frequently in Taiwan's media and industrial discussions. They used it to describe the poor profit margin in Taiwan's computer-related industry in Taiwan. But does no one profit from the innovative computer industry at all? Is it only customers who benefit from low-priced products? Various scholarly works have explored who benefits most in the global value chains of computers and smart phone products.¹⁶⁶ Not surprisingly, the brand-name firms are the ones that capture the largest share of the profits. In the two cases below, HP received 28% of the profit from its notebook nc6230 in 2005 (see Figure 3.1), and Apple received 30% from its iPad in 2011 (Figure 3.2) (although some people tend to think that Apple gains its major profits from online services or applications, the hardware business is still their main source of company profit).¹⁶⁷

¹⁶⁶ Such as Dedrick et al. (2008) and Kraemer et al. (2011).

¹⁶⁷ See <http://investor.apple.com/secfiling.cfm?filingid=1193125-12-444068&cik=> for Apple's

In both cases, Taiwan got only 2% of the entire profit, and China's direct labor, received another 2% of the profit in the Apple case, though the amount is not clear in the first HP case. Dedrick et al. (2008) explain different reasons behind the profit monopoly, such as dominant design (less design heterogeneity), appropriability (such as standards and intellectual rights), complementarity (of functions), and industry architecture.

In another related work, the authors directly suggest that, "[a] key finding for policymakers is that there is little value in electronics assembly. Bring[ing] high-volume electronics assembly back to the U.S. is not the path to "good jobs" or economic growth."¹⁶⁸ However, we might need to further question whether these "assembly" jobs done in China and Taiwan are devalued for different reasons. That is, if brand-name vendors move these jobs back to the US, will the jobs still have the same value as they had in China and Taiwan? The fact is that many CMs do more than merely assembling products, and the devaluation of their activities applies to a broader array of design-manufacturing processes that are invisible to outsiders.

consolidated annual reports of 2010-2012. The hardware revenues (iPhone, iPad, Mac desktops and laptops, iPods etc) are still much higher than its software and services revenues.

¹⁶⁸ In the abstract of Kraemer et al. (2011).

HP nc6230 notebook

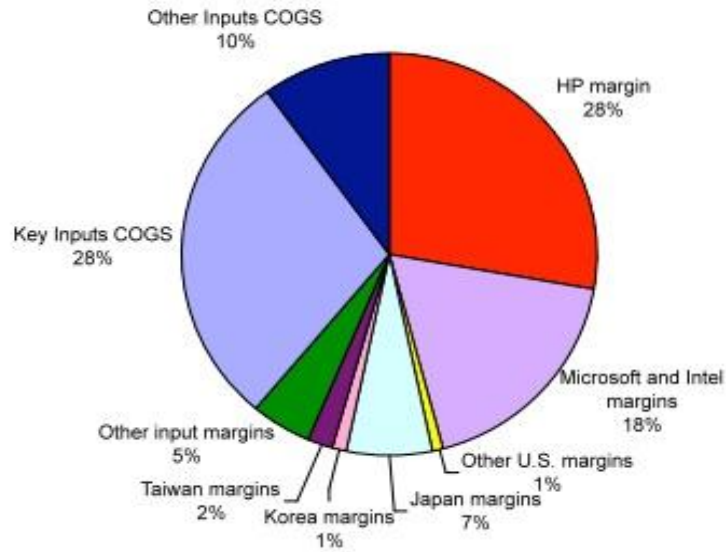


Figure 3.1.

Value capture in HP's nc6230 notebook as percent of wholesale price in 2005. COGS means cost of goods sold, including purchased input and direct labor. Source: Dedrick et al. (2008).

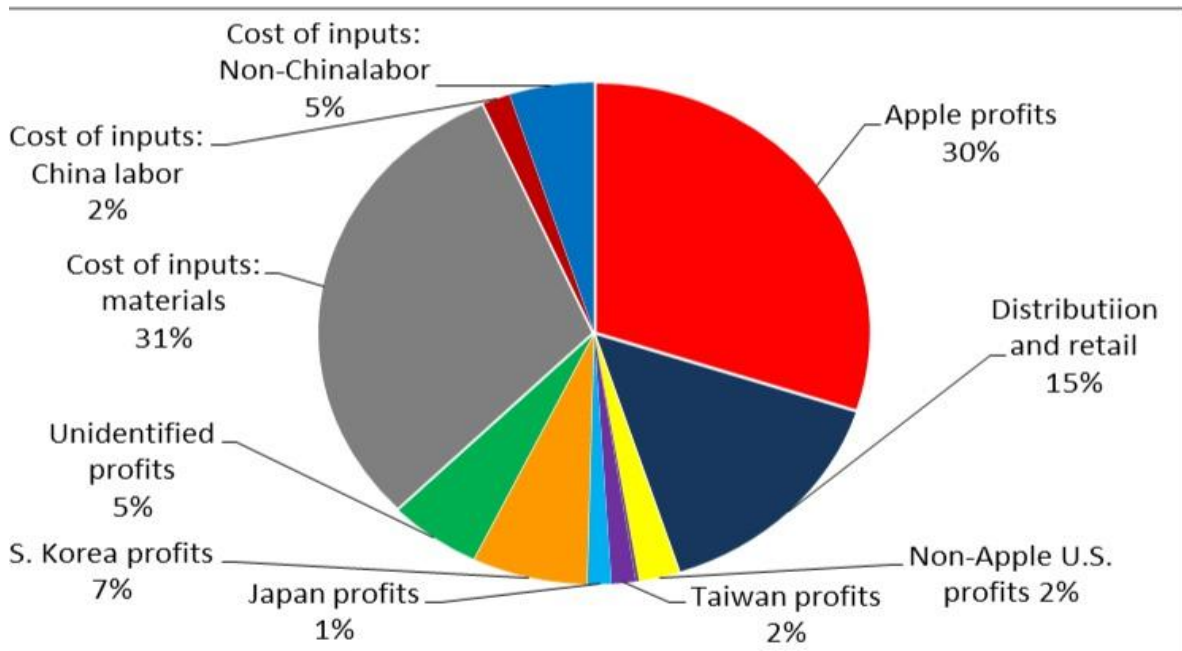


Figure 3.2.

Value captured in Apple's iPad in 2010, source: Kraemer et al. (2011).

By examining the margins of the world's largest laptop producer, Quanta, we observe that its gross margins dropped from the peak of 24% in 1998 to 11.5% in 2000, and to 2-4% in recent years. Similarly, their operating margins also decreased, from around 17.5% in 1998 to 8% in 2000, and to 1.5% in recent years (see Figure 3.3). This is not true for other leading players such as Intel and Microsoft. Their gross margins have ranged between 40% to 80%, and their operating margins have been between 25% to 50% from the mid-1990s to 2011, except for one or two bad years. The possible reason for this uneven profit distribution in the industry is Wintel's near-monopoly position. As for the re-emergent Apple, their gross margin in recent years also was at least 35%. Although Quanta, Compal, Wistron, and Inventec have occupied 60-70% of the worldwide market in contract manufacturing laptops for the last decade, none of them has achieved a dominant position like those of Intel or Microsoft. However, if we compare Quanta with another number-one player that lacks a monopolistic position, Hewlett Packard (HP, the world's number-one laptop brand since it merged with Compaq in 2001), it is clear that HP's margins were also declining. However, for most of the years from 1995-2011, their gross profit margins or operating profit margins were still several times that of Quanta.¹⁶⁹ That is, although some of the brand companies such as HP and Dell absorbed part of the reduced price, it seemed that the Taiwanese CMs "shared" more of the burden of low-cost technology, meaning that they were relatively more "cheapened" than

¹⁶⁹ The data about the margins of Taiwanese laptop producers are from Taiwanrate.net; the margins data of the US computer-related companies come from wikinvest.

others.

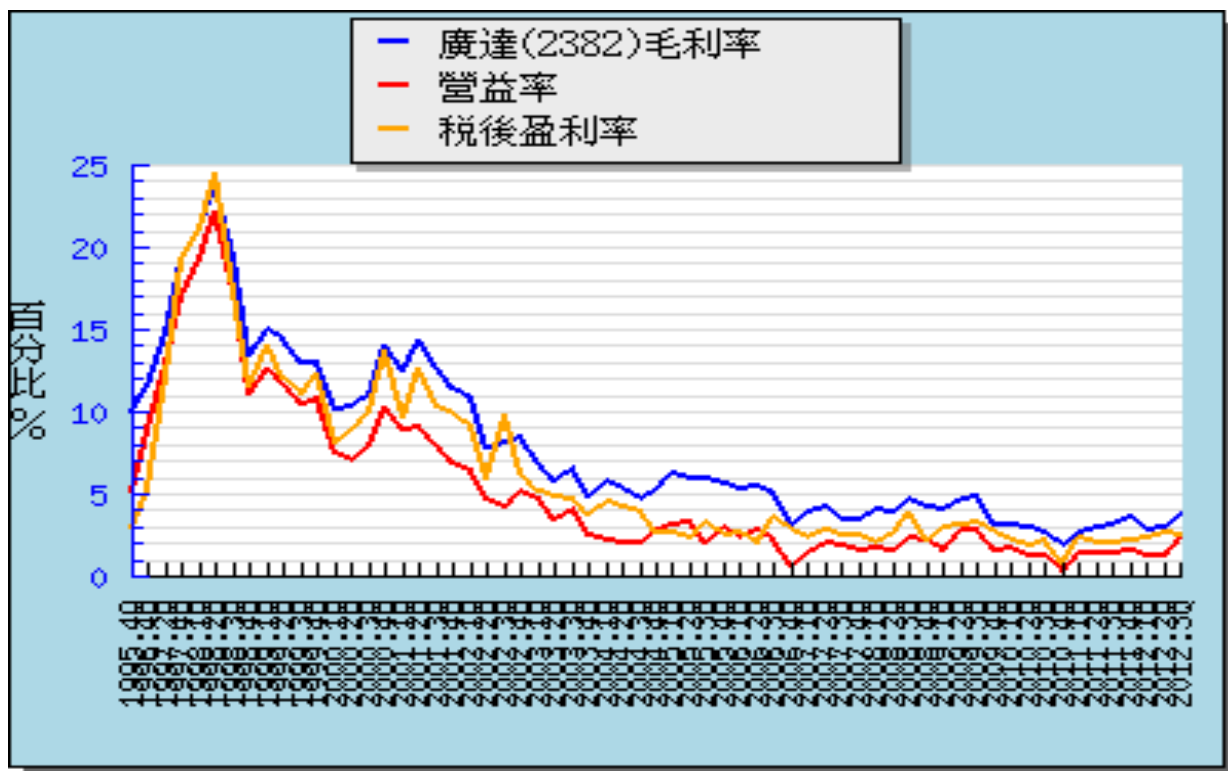


Figure 3.3.

Quanta's margins from the 4th Quarter of 1995 to the 3rd Quarter of 2011: The blue (the darkest) line represents gross profit margin; the red line, operating profit margin; and the orange (the lightest) line, net profit margin. All of them plummeted to less than 5% since around 2003 (Source: Taiwanrate.net).

If every player in the laptop industry were affected equally, complaints might not have occurred among the CMs' employees. Facing the thin-profit predicament, a senior and top engineer-manager in Quanta wanted me to use as his code name, "a Taiwanese laborer," to express what he felt about doing jobs for others with such a thin profit. He complained that their innovations were taken for granted and received no credit, and they were as devalued

as the foreign laborers who work in factories.¹⁷⁰ A similar sign came from Compal's senior manager. He said that they were just like a "Chang Gong" ("Chang Gong" in Chinese means a long term servant working for rich men, landlords, or big families) for brand-name firms.¹⁷¹ "Bruce" from Wistron, who was a senior laptop design manager, said that what they earned was really "blood and sweat money," because they worked so hard and the margin was so low. Bruce" indicated how hard they worked. He mentioned his average working hours were from 6:30am to after 8pm, but he said he was already better compared to others. Some people, for example, those who were in charge of China's factories had to work from 7am to 10pm or 11pm.

Bruce: And also, the flexibility of these employees. Can you tell me which country's employees can be dispatched to China for two months this time, and then to another place tomorrow. This is really a nationality.

Author: You meant that the Americans don't want to do that?

Bruce: Of course not. Are you kidding? Try to ask them to stay in China for two months. I don't mean those expatriate jobs. Some of them will agree to do those jobs, but most will not. [A business trip that is] over one week [for them] is rare. In particular, you are staying in the factory working, not there to have fun . If it's about visiting clients in different places, from one station to another station, it might be okay to them. But trying to stay in factory for one week? I don't think they can stand it...

Author: What else about the flexibility?

Bruce: Yes, we are desperately willing to work against time to finish the jobs. People will say yes even if they have to work for 24 hours.

¹⁷⁰ Interview by author (11/17/2010).

¹⁷¹ Author's interview with "Eli" (11/17/2010).

Author: Won't this be too inhumane?

Bruce: Yeah, that's why we are earning money from blood and sweat.

Author: A sweat shop?

Bruce: And the margin is so low. Definitely it is blood and sweat money.¹⁷²

"Charlie" from Wistron, a senior mechanical engineer-manager, also claimed that team members should be called "the [factory] operators of design" rather than "designers," as in the past. He said that, previously, each laptop mechanical engineer could be involved in almost every step of the D-M process, but later, in order to pursue ever-increasing speed to market, the design work was divided into smaller jobs, and each engineer was responsible for a small part, according to the new division of labor. For example, in the past, one member would be responsible for the entirety of the major four pieces of the mechanical structure of a laptop. Now four people divide those jobs.¹⁷³ These accounts derived from different individual interviews in which the interview was designed without leading questions,¹⁷⁴ but the interviewees revealed a similarity by comparing themselves to the working class. Thus, this seems to be an overarching and general discourse and thought within the CM design teams.

Although comparing themselves to the working class in the factory, these well-educated and well-paid engineer-managers certainly enjoy a much better middle-class

¹⁷² Author's interview with "Bruce" (4/16/2010), pp. 26-27.

¹⁷³ Interview by author (8/14/2012), p.12.

¹⁷⁴ These quoted interviews were conducted between 2010 and 2012.

life. Some of the top engineer-managers even received decent salaries and generous stock or cash bonuses, especially during years with high profit margin in the mid-to-late 1990s. Thus, the shop-floor workers are more likely to align these engineers and managers in the contract manufacturers more with the capitalists rather than with the laborers. Nevertheless, this self image from engineers and managers in the CMs partially reflect how they view themselves as being increasingly devalued (even as they become more skilled and experienced), compared to the much higher-status designers, engineers, and marketing employees in brand-name companies. These CM are drawn in near the terminal step of “low-value assembly” in order for the higher culture managers and engineers in the powerful brand-name firms and industrial leaders to keep profits and credits for themselves in an ever-lower cost era for high-tech products. It is a grievance of the class-like image between the high-culture designer of the West and the low-culture “manufacturer” of the East. This “industrial class” structure can have great influence on all the global division of labor.

It seems that the gap of value distribution in today’s high tech industry comes not so much from what work industrial actors engage in, but from the unequal power they have in the market. According to Wistron’s CEO Simon Lin, Taiwan’s laptop industry is a knowledge-based industry, and the Taiwanese have expert knowledge, but it cannot be simply divided into supply chain knowledge, design knowledge, or knowledge of materials. He considers that what the industry in Taiwan has is “interactive knowledge”, or “integrated knowledge,” which

is not easily duplicated. He pointed out,

“Our knowledge has [its] value, but [the question is that] we don’t have the right to serve the ball. We just have the right to reply to the ball.”¹⁷⁵

Therefore, it is not enough to have only knowledge, he argues. Lin is clearly concerned about the problem of power and market control. Knowledge does not necessarily lead to wealth; power does. The fact that market power determines wealth distribution has a serious global impact, both economically and socially. Paul Krugman, the Nobel Prize-winning economist, points out how the monopoly position in the market can create a “disconnection between profits and production,” which might be a factor in the prolonging of the slump of the U.S. economy that started in 2008.¹⁷⁶ For example, Apple’s monopoly rents are profits that do not represent returns on investment, but instead reflect the value of market dominance. To illustrate this, he compares the differences between General Motors in the 1950s and 1960s, and Apple today.

“Obviously, G.M. in its heyday had a lot of market power. Nonetheless, the company’s value came largely from its productive capacity: it owned hundreds of factories and employed around 1 percent of the total nonfarm work force. Apple, by contrast, seems barely tethered to the material world. Depending on the vagaries of its stock price, it’s either the highest-valued or the second-highest-valued company in America, but it employs less than 0.05 percent of our workers. To some extent, that’s because it has outsourced almost all its production overseas. But the truth is that the Chinese aren’t making that much money from Apple sales either. To a large extent, the price you pay for an

¹⁷⁵ Interview by author (5/26/2010).pp7-8.

¹⁷⁶ By Paul Krugman, “Profit Without Production,” in *New York Times*, 6/24/2013.

iWhatever is disconnected from the cost of producing the gadget.”¹⁷⁷

The result is, according to Krugman, “the old story about rising inequality, in which it was driven by a growing premium on skill, has lost whatever relevance it may have had,” because since around 2000, there has been a sharp shift in the distribution of income away from wages and toward profits. Companies such as Apple are hugely profitable, but they are sitting on a giant pile of cash, with no need to reinvest in many aspects of its business. As they have little incentive to invest, the U.S. demand is persistently depressed.¹⁷⁸ Therefore, the seemingly simple division of labor between branding and manufacturing in the high-tech industry has a much deeper social impact, domestically and internationally.

Price Killers

The uneven distribution of profit is also an issue in the laptop industry, although less so than in the past. Before 2000, especially in the mid-90s, when the laptop was relatively new and had high market growth, the profit in general was large for the biggest Taiwanese producers. It was still a high-margin business for leading brand-name firms, so they made few demands on how their associated CMs should reduce their costs. As a result, the various efforts of Taiwanese CMs to reduce cost resulted in a high profit margin for themselves,

¹⁷⁷ Ibid.

¹⁷⁸ According to Piketty (2014) and the economists who work with him, Anthony Atkinson and Emmanuel Saez, the gaps in wealth and income have increased after the 1980s in France, the U.K, and the U.S. To avoid further inequality of income and the collapse of capitalism, it is essential to raise the tax on the top earners.

although it primarily benefited their engineers and managers, because they enjoyed large tax-free stock bonuses, which provided a special incentive in Taiwan's high-tech industry. However, after 2000, as the high margin quickly "evaporated," the efforts to achieve ever-lower costs became a survival skill that these Taiwanese producers were forced to implement with every possible strategy. The thin profit margin, then, affected not only the production line laborers, but also the engineers and managers of these contract manufacturers.

Average bonuses decreased, many people relocated to China or resigned, and CMs faced social blame for their practices of "low-value" contract manufacturing and the "old thinking" that would affect the "upgrade" of Taiwan's economy.

Even though the profit margin was already low after 2000 due to the severe competition among the Taiwanese producers, major Taiwanese laptop producers have continued taking turns as "price killers" every year since 2006. In 2006 it was Wistron; in 2007 Compal; and in 2008 Quanta. The result was that the price killer always obtained larger orders from the big brand names.¹⁷⁹ However, these companies each took very different paths in how they reduced the product cost. A Compal manager recalled that when their team got the order from HP again in 2008, their boss, who led the team to get the bid, did not look happy, but was serious and grim, because the reason they got the order was that they would

¹⁷⁹ Author's interview with "Eli" (11/17/2011), a procurement department manager in Compal.

have to produce the client's laptops in the red (with a deficit). That is, they designed and manufactured the product with a loss rather than a profit in the beginning. It was only after many different attempts that they could turn the red into the black. Although they invested great effort into the process, their profit margin continued to decline. Even their ways of purchasing and manipulating various parts and components that resulted in hidden profits were no secret and were gradually taken over by brand-name companies.

It is also important to note how the profit decline in Taiwanese producers has also influenced suppliers of computer parts and components. Taiwanese laptop producers are usually not involved in purchasing key components, such as Intel's CPU, because the brand-name vendors themselves usually buy the key components directly from the main suppliers. Taiwanese OEMs, however, had bargaining power over lower-priced or non-key components and parts, which were usually purchased from the local and smaller partners. Since many Taiwanese component suppliers were also public companies, they could not afford to lose large orders, so they tended to accommodate the notebook producers' demands. As such, the structure of the industry might be described as a "food chain," in which the brand-name companies suppressed computer system manufacturers, and the latter suppressed their suppliers or vendors or even just their own factory operators. This has been happening almost every year; hence, these Taiwanese actors gave a name to it: the

“Autumn struggle” (*Chiutou*).¹⁸⁰ For example, the Huan Hsin Company, the number-two laptop casing provider worldwide (with a market share around 25% in recent years), kept losing money from 2008 to 2012. The general manager said, “We are the second-largest provider. If even we can’t make money, what is the meaning of everything?” In contrast, Huan Hsin’s joint venture with another Taiwanese company in a fried chicken chain store in China is very profitable. The title of a magazine article in which he was quoted is, “I have been making casings for my whole life, but now it is less worthy than selling fried chicken.”¹⁸¹ A head manager in Quanta’s factory, “Christopher,” also commented,

“The industry of notebook computers is sick. It is so capital-, labor-, and technology-intensive, but the profit is so low [for Taiwanese CMs].”¹⁸²

An interviewee from one CM said that they were aware of the cruelty of the economic environment, yet, “life will always find its way.” “Finding its way” here seems to imply numerous extreme efforts to reduce costs from every possible element in the Taiwanese computer producers as well as their long-term local component suppliers.

Cost reduction has been one of the important competitive advantages, and is now even the most fundamental survival skill to gain tiny profits. But how could the CMs achieve

¹⁸⁰ Author’s interview with Fred Lin (3/8/2010). *Chiutou* in Chinese means the *Autumn struggle*, which refers to the political struggle in which everyone wants to criticize and even eradicate each other for survival in an annual gathering. This term is usually used to describe the cruel struggle between people and between classes in the period of the Cultural Revolution in China.

¹⁸¹ In Mandarin Chinese, fried chicken is pronounced as “ji-pai,” and casing is pronounced as “ji-ke,” so the two terms have alliteration when put together.

¹⁸² Interview by author (2012/7/23).

their goal? It is far from enough to move factories to China or to cut unit prices of components, which many producers are capable of doing, without distinction. I argue that Taiwanese companies have exerted extreme managerial and engineering efforts to reduce cost for the personal computer industry and they have accumulated special expertise and practices in it. However, their efforts are often invisible and have not been adequately described. This forms the focus of the next section.

As I have discussed in the introductory chapter, scholars have explored the knowledge dimension in manufacturing, but they focus primarily on the issue of workers' skills and on the final knowledge translation from managers/engineers to laborers.¹⁸³ That is, their explorations of manufacturing are still very worker-centered. Instead, I shift to examining the various and integrated engineering efforts to reduce costs before the final assembly stage. I complicate the actors' categories of cost reduction through the lens of an analytical category of knowledge production and practice. Knowledge regarding cost reduction is not merely engineering science knowledge, skills, or tacit knowledge. Here I will refer to it as the notion of field knowledge, which I will discuss immediately in the next section.

¹⁸³ Scholars such as Braverman (1974) and Noble (1984) discuss the deskilling of workers from a Marxist tradition. Zuboff (1988) offers the contrary idea of "reskilling" of workers. MacKenzie (1984) argues that Marx himself never suggests that capital will seek maximum control over the labor process. There are also many studies about Taylorism. They explore the relation either between managers and workers, or between capitalists and laborers, and primarily focus on aspects of the workers.

Field Knowledge: Generated in Multiple-sited and Trans-organizational Exchange

Complex economic, social, and industrial factors have contributed to the consolidation of laptop production in the hands of Taiwanese firms since the mid-1990s, but it seems that we can find some commonalities and specific features from their knowledge production and practice that have made this concentration possible. One crucial characteristic that I found is their employees' ***constant visits and frequent communication with various partners, internally and externally***. In order to describe these exchanges, I develop the concept of *field knowledge*. It is a knowing practice that intensively relies on information and resources from the field. Field knowledge is primarily concerned with a process rather than with a static form of knowledge. I define field knowledge as the following:

Field knowledge is an integrated form of knowledge generated in a field that involves multiple-sited or trans-organizational exchange between actors who engage in complex interactions based on their own expertise, experience, social positions, and other relations. A field can be composed of specific geographic locales, regions or territories, expertise, market relations, or some other socially bounded domains. In a field full of calculations and purposiveness, field knowledge practitioners actively and frequently gather information or knowledge from heterogeneous origins and generate integrated knowledge to meet both their individual and collective interests.

One main idea in the definition is that it is concerned not with whether knowledge travels, but primarily with whether people travel to interact in order to generate necessary knowledge. Actors in the field, based on their own needs, expertise, and positions, see different things, and gather, extract, digest, and integrate information from diverse sources to

create new knowledge that might be useful for them to finish their missions. The multiple-sited or trans-organizational exchange is made possible primarily through face-to-face communication, and can be aided by communication tools. For example, it is a general practice that the members from different teams at different places in a laptop project will not only have constant conference calls, but also make frequent physical visits. Also, the people who visit and the people who are visited can both potentially benefit from the interaction, depending on the nature of their cooperation. For instance, when a large group of laptop design engineers from Taiwan constantly visits the company's and its suppliers' factories in China, not only can they gather information from the factory team and from the machine they are working with, but also the factory team can gain information from the design team to help them to improve the production. Overall, field knowledge stresses the idea of knowledge being produced from intensive interaction among actors from heterogeneous organizations who bear both individual and collective interests.

The Field

Fieldwork is fundamental to sciences or disciplines that are essentially field-based, such as geology, forestry, anthropology, and oceanography, which require the practitioners to travel to "real" or natural environments to observe and gather the information they need. Although they are not natural scientists or social scientists, certain groups of engineers and

managers in the laptop producers have been busy in fields that are outside of their particular specialties or workplaces. In addition to their own departments, they go to other departments, clients' meeting rooms, and parts and components suppliers' offices and factories. They can enhance their production, efficiency, or innovation by gathering and integrating information, ideas, or knowledge from different organizations or sites and therefore creating useful knowledge from the field.

The "field" has two levels of meaning. The first concerns a spatial meaning. In my research, a large group of engineers and managers need to go outside of their routine workplaces and to go to other departments or various components suppliers' offices. It is as though they are in fieldwork sites, just as anthropologists visit the field. In contrast to one's own organization, fields are areas that are not easily controllable by the actors and are full of unknown situations.

The second level of "field" goes beyond the spatial meaning, which refers to the relative position between the actor (or the actor's organization) and others. It can be different socially bounded domains, with a broader sense for the word "socially," which can mean culturally, economically, industrially, or politically. In my study, the field, in this sense, is composed of markets, competitive situations, industrial architectures, local contexts, and so forth.

This second implication of the term is partially borrowed from Bourdieu's (1990)

notions of *field* and *habitus* (but not confined to his definition). In *The Logic of Practice*, Bourdieu situates his own position between subjectivism and objectivism, and embraces both structure and agency by creating concepts including field and habitus. Bourdieu brings a “game” metaphor: the practical sense (the “habitus”) is like “the feel for the game” in sport, and hence the concept of fields is introduced (66). In a game, the field (the rules, the board on which the game is played, and so on) is clearly seen and arbitrarily made, and entry into the game takes the form of a quasi-contract; by contrast, in the *social fields* (which are the products of a long and slow process) one does not start the game consciously: “one is born into the game and with the game (67).¹⁸⁴ In a similar sense, I also use “field” to denote that it is important to know one’s own and others’ positions, and to take into account the power and other structuring relations that constitute various situations and relations to be dealt with. For example, when going to work in outside fields, the CMs’ employees have the social fields in mind, knowing what they can interact with and what they can utilize and integrate. Although the Taiwanese CMs are situated in fields that are full of more powerful actors, they are not passive receivers of structures and rules. They have their own agency and special knowledge and practices that enable them to compete in the field.

The first (physical space) and the second level (social space) of meaning of “field” are

¹⁸⁴ As for habitus, it is “constituted in practice and is always oriented towards practical functions” (52), and is an infinite capacity for generating products such as thoughts and expressions. But habitus is also limited by historical and social conditions (55). The conditioned and conditional freedom it provides is from neither pure subjectivism nor mechanical reproduction (55). The habitus is the immanent law inscribed in bodies by histories.

not contradictory to each other, since they are both concerned with either the difference or the relation between the internal and external. If we image a chess piece as an actor or the actor's organization, the whole chess board then is their field.

Knowledge in Action: Why Field Knowledge?

In the literature of science and technology studies, there are several analytical dichotomies for understanding the types of knowledge: explicit knowledge vs. tacit knowledge, knowledge that travels vs. local knowledge, and objective knowledge vs. situated knowledge (or as specified in standpoint theory). In my introductory chapter, I discussed their distinctions in more detail, but here I will elaborate why they are not sufficient to explain the distinctive characteristics of epistemic activities of the Taiwanese producers.

Why Not Articulated—Not Always Due to Difficulty in Codifying

Tacit knowledge (Polanyi 1958, Kuhn 1962, Collins 1992 & 2010, MacKenzie 1996) is described as a trained capacity that is extremely hard to codify or articulate. More importantly, it belongs to personal or local experience, so it is hard for tacit knowledge to travel.¹⁸⁵ Usually it requires physical practice or personal contact, such as learning by doing through apprenticeship, to effectively acquire the tacit component of knowledge. In my study, although

¹⁸⁵ Collins (2010) further classifies tacit knowledge into three types: relational, somatic, and collective tacit knowledge, which he considers as weak, medium, and strong tacit knowledge, respectively. Weak or strong is based on the degree of difficulty of making them into explicit knowledge.

there is an unarticulated part of knowledge or practices among these producers, much of non-articulation is due to reasons other than the fact that it is hard to express or codify. For example, the detailed technological changes in laptop engineering or production are just too fast or too specific to be worth writing down every time, especially when interpersonal communication or working around the object (e.g., a component, a laptop) itself is more effective than that. Also, the concept of field knowledge *does not exclude explicit knowledge*, as long as the actors make an effort to spell it out. For example, for common problem-solving principles that can be applied to other models of laptops, the employees might document them into their company databases. The range of field knowledge, in my study, can cover engineering science, talents, skills, supply chain management knowledge, and special personal experiences in design-manufacturing laptops. Field knowledge is essentially based on diversified personal experiences, cross-disciplinary knowledge, and integrative capabilities. Some of these experiences can be documented, while some other experiences fall into the category of tacit knowledge.

Local or Trans-Regional Knowledge?

Secondly, when considering the idea of local knowledge (Geertz 1983, Latour 1987, Wynne 1992), which is used to counter the misconception of universal knowledge, one main constraint is its strong connotation of the “fixing” of knowledge in a specific location. Local

knowledge usually means that a certain system of knowledge, perceptions, and practices is rarely found outside of a locality, and it is formed, practiced, inherited, and limited within a geographical range or a local community. One advantage of the concept of local knowledge is that it helps make a fundamental shift from explaining phenomena through a scientific cause-and-effect analysis to interpreting phenomena by bringing them back to the context of local areas and communities. Local knowledge can be hybrid knowledge. It is not necessarily entirely generated within a specific location or community without any exchange of knowledge with the outside world, but it must be locally distinctive.

In many ways, the idea of local knowledge is close to many characteristics of the Taiwanese CMs' knowledge activities. However, a few reasons prevent me from just adopting this concept. Yes, these CMs' certain knowledge and practice were "local" when the laptop production lines were consolidated only in Taiwan. They had shared ways of practices that could generate knowledge useful to the design-manufacture of laptops. However, after 2001, these makers collectively moved their factories to China. Although many engineering and design functions were still kept in Taiwan after 2001, since the Taiwanese engineers had to interact with mainland Chinese engineers and workers in the factories and would generate new knowledge and practices in new places and new communities, I hesitate to say that their practice and knowledge is still "local" or attached to only the location of Taiwan or to the Taiwanese community. One main issue is just how local, geographically, must local

knowledge be? Isn't all knowledge local or provincial to some degree? And what is the advantage in saying that it is local knowledge: do I aim to also find "universal" knowledge to be opposed to it? The answers are not clear to me. I consider local knowledge to be a highly potential candidate, but there can be a better way to describe my actors' activities, especially when thinking about those travelling engineers (see Chapter 4): they worked in Taiwan to talk with different R&D teams from both brand-name clients and parts suppliers and travelled very often to China to either the suppliers' factories or their own factories to negotiate production and design issues in different development phases. Consequently, the idea of local knowledge lacks sufficient characteristics of their specific dynamics of knowledge generation.

Not Just Situated, but also Interactive

If we use "field" to also denote how an actor is situated in the industry, it becomes essential to compare field knowledge with a concept in science and technology studies, which is situated knowledge. Situated knowledge (Haraway 1991) and standpoint theory (Harding 1987) are feminist theories of knowledge in society.¹⁸⁶ Both argue that there is no such thing as objective or universal knowledge, since such knowledge would be "from nowhere." According to standpoint theory, an individual's own perspectives are formed by

¹⁸⁶ The concept of situated knowledge is commonly associated with Donna Haraway and Sandra Harding in STS, but related concepts such as situated action, situated learning, and situated cognition precede it, and differ from it, in several aspects.

experiences in his/her social groups or social positioning. Standpoint theory supports the proposition that the perspectives of oppressed or marginalized people can help create diverse accounts of the world. The idea of situated knowledge, therefore, is a powerful concept to endorse a “privilege of partial perspective” (for example, women can see what men cannot see).

To some extent, my definition of field knowledge overlaps with situated knowledge as the actors are “situated” in a particular industrial position or field, which is important but not the only feature that we can find in certain actors’ epistemic dynamics. The concept of situated knowledge seems to stress the limitation or false conception of “objective” knowledge and on how marginalized groups can illuminate more possibilities than any single dominant account. In a different manner, my notion of field knowledge does not focus on how certain groups of people can have certain knowledge based on their position or context relative to others. The actors are not merely situated in a field. They frequently interact and communicate with people from various departments and organizations in order to reach certain goals, for example, to keep up with the rapid pace of the whole computer industry.¹⁸⁷

Field Knowledge Per Se is Crucial

¹⁸⁷ Furthermore, one major difference is that all knowledge can be said to be situated knowledge, but I do not argue that all knowledge is field knowledge unless its production depends upon a frequent interaction between the actors that come from multiple sites or different organizations.

When I refer to the interactive dynamics between the actor and the field, I want to differentiate it from the concept that Collins & Evans (2007) call *interactional expertise*. In classifying levels of expertise, Collins distinguishes *contributory expertise* from interactional expertise, for only the former can directly contribute to the core of expert knowledge, while the latter concerns “the ability to master the language of a specialist domain in the absence of practical competence” (14). Actors with interactional expertise can serve as integrators or communicators to connect different groups of people, but do not contribute to the core knowledge of that specialty. Indeed, field knowledge is characterized by its strong connection between the actor and its social fields; but there is a major difference between field knowledge and interactional expertise: field knowledge requires copious information from interaction or from the field to assure the actor’s success. The actor also needs to quickly adapt its practices or knowledge according to the changing field.¹⁸⁸ This field knowledge is not trivial or non-crucial. Without the knowledge from the field, they can totally lose the game. In other words, the concept of field knowledge does not exclude the possibility of the actor’s contribution to core theories or technologies. In the case of the Taiwanese laptop producers, the ones who have high levels of expertise are also the ones who interact with others to further deepen or supplement their own

¹⁸⁸ The concept of field knowledge partially overlaps with another concept, “situated actions” (Suchman 1987; 2007), in that they both stress that actions and practices are closely related to the circumstances, and hence need to adapt to particular environments. My project, however, concerns not only how the actors are “situated” or structured in a certain environment, and how they adapt themselves to the environment, but also how the actors actively derive resources from the environment to assist themselves.

knowledge. Knowledge from the heterogeneous field is always a constituent of their core expertise, but in Collins and Evans' idea, the two groups of actors are separated. Therefore, field knowledge and interactional expertise will be two concepts to be used for different groups of people or different knowledge activities.

Information Gathering from Heterogeneous Origins

A final characteristic of field knowledge that I want to highlight is concerned with how the actors actively gather information, ideas, or knowledge from the field to assist themselves to reach their individual and collective goals. In my study, going from a machine's design to its production is not just a transition from a paper world to a concrete world, but also from paperwork to still more paperwork, and similarly to what Latour says, "from one centre of calculation to another which gathers and handles more calculations of still more heterogeneous origins" (1987: 253).¹⁸⁹ The contract manufacturers can seldom complete the mission alone. They need extensive knowledge spanning the design-manufacturing spectrum, internally and externally, and horizontally and vertically, forming a complex web. Thus, it is crucial for the Taiwanese producers to bring things, information, and knowledge from the field to their core workplaces.

Their information-gathering and extraction capability from the field is especially

¹⁸⁹ However, the idea of Latour's center of calculation would be only partially applicable in the case of the CMs because of the power differential implication: the center is the most powerful. Facing the subsidiary factories in China, the Taiwanese CMs could be viewed as a center of calculation from the perspective of Chinese employees, yet in comparison to the large brand-name clients, the CMs are far from a powerful center (of calculation).

important based on the special ecology of Taiwan's computer and electronics industries. In Chapter 1, I mentioned that in the 1980s, more than 2,000 PC companies and 5,000 PC-related companies were located in Taiwan. These companies had many vertical (downstream or upstream) partners and horizontal competitors to work with or compete with. This made it essential for them to gain information and generate useful knowledge from important partners, such as various components suppliers.

For these reasons, tacit knowledge, local knowledge, situated knowledge, and interactional expertise can each represent only partially the knowledge practices of the actors in my research. They are all very powerful concepts, yet they do not seem to be the most adequate ones to explain and describe the CMCs' distinctive knowledge practices.

The concept of field knowledge is a better alternative, because it includes the exploration of location, social position, a tacit component in knowledge and practice, and more importantly, the intensive interaction of actors from heterogeneous backgrounds. It is essential to grasp who the actor is, what the field is, and what the interactions between them are in the creation and use of knowledge. Furthermore, the concept of field knowledge implies both a structured (situated in a social field) and structuring (going to the multiple-sited field to actively use the resource) characteristic that better describe the activities of my actors. In many ways, the practice of field knowledge is an essential element in today's competitive industrial climate. The counter-idea to this, or "non-field knowledge," assumes that only

knowledge from core people or core organizations is the most crucial and neglects the importance of the dialectic dynamics with relevant fields.

This concept emphasizes the intensively interactive, dynamic, and dialectical relationship between the actors in a heterogeneous field. This interactive model of field knowledge is especially essential to Taiwanese contract manufacturers, as they need to link and integrate various elements from others when playing the role of active intermediaries between brand-name corporations and consumer products, and between ideas and things.

Field knowledge entails a process and a dynamic, rather than referring to static knowledge content. It is generated through the actors' active interaction with and utilization of the field to further deepen or supplement their expertise. Field knowledge is not incommensurable with tacit, local, and situated knowledge, or interactional expertise. It can include both tacit and explicit knowledge, both local knowledge and knowledge that travels. But it is not simply their sum. There can be different ways to analyze knowledge. I believe that the idea of field knowledge can contribute an alternative image and analogy to the analysis of knowledge and practice.

The Range of the Field Knowledge of the CMs

The concept of field knowledge can be applied to many industrial actors, but the fields themselves and kinds of field knowledge can be very different. For example, computer

brand-name companies (such as Apple) produce field knowledge as well since they also actively make use of information and ideas from outside fields, intensively interact with the fields, and generate knowledge for their own use. Their fields, however, are strikingly different from those of the Taiwanese producers. While Apple's fields are relatively tied to the market of and needs of end-users, Taiwanese contract manufacturers' fields concentrate on the spectrum between design and assembly in the industry, and in particular, on their engineering mediating roles over the spectrum. For example, Apple owns numerous market researchers, marketing teams, industrial designers, and software and application programmers, but Taiwanese CMs rarely have large teams with those functions. Most of Apple's employees go to strikingly different fields from those of the CMs' employees.

Then what is the range of the CMs' field knowledge? This question brings us to ask first, what is their primary expertise? From the discussions on Ten Thousand Miles of the Yangtze River and on C-System, we know that their core expertise is located along the spectrum of turning ideas into objects, especially in product engineering, processing engineering, and manufacturing engineering. They can provide comprehensive services to their brand-name customers, regardless of design, development, testing, final assembly, logistics, repair, and maintenance. Most of the services are based on efficient and skillful engineering. Many people in the CMs whom I interviewed indicated that their main effort or functions in engineering were electrical engineering (EE), mechanical engineering (ME), and

software development. The first two types are particularly important. Neither of them belongs to merely a single department. They are everywhere: from design, quality, and procurement, to factory divisions. For example, if Anna is an electrical engineer on the product design team. Internally, she will need to collaborate with some electrical engineers in the quality assurance department, and with some in the procurement department, and with others in the factory. Externally, Anna has to work with the electrical engineers from brand-name customers and also numerous suppliers. Therefore, for Anna, in addition to her internal learning experience with her EE colleagues and the ME and software teams to collaboratively make a complete product, her primary field knowledge will also come from visiting and interacting with other electrical engineers, who have their own expertise in their own concentration or products (e.g., certain parts or materials). However, if she is a more experienced engineer or a higher-rank engineer-manager, she can more systematically observe information and practices other than electrical engineering knowledge, and then transform them into her own knowledge.

To summarize, field knowledge can be used in many industrial or social projects; however, there can be sub-types. For example, if we want to classify or distinguish these CMs' field knowledge from that of companies such as Apple or HP, we can specifically call it design-manufacturing field knowledge, or engineering field knowledge. But field knowledge alone is already a more precise concept and a useful shorthand for describing the knowledge activities of the Taiwanese CMs and, in their case, is better than alternatives such as local

knowledge, situated knowledge, or tacit knowledge.

In the following section, I explore two examples of cost reduction as field knowledge.

The first one concerns the design team's effort to delve into and integrate knowledge from their supply chain. The second primarily analyzes a factory team's mediating practice of lowering the failure rate on the production line.

I. Field Knowledge from Penetrating into Small Components: Supply Chain and Cost Reduction Efforts from the Design Team

For a design team in a Taiwanese CM, there are at least three dimensions of identified fields that can be explored and utilized to create their field knowledge (the reader can think of these as three-dimensional axes). First, internally, the field of factory teams and other design teams in their own company; second, externally, the field of their brand-name clients; and third, also an external relation, the field of the CM's suppliers. There are also other fields that can be added, such as those of competitors, markets, or potential partners. These fields involve both multiple-sited and trans-organizational interaction. In Chapter 1, I have discussed how CMs learned from their brand-name clients through collaborative projects in the early years. This section will focus specifically on how they constantly drew on information and ideas from their suppliers.

The CMs' deep involvement with parts and components suppliers has been an

important source of innovation and cost reduction for Taiwanese laptop CMs. As mediators between ideas and things, they have at least two different choices on the degree of involvement. One is to use the existing parts and components for their machines, the other is to aggressively study those parts and components and make innovative integration of them into their own products. As constrained contract manufacturers, the Taiwanese producers have to make an effort to find space and gain more profit by cooperating with their numerous suppliers. Compared to brand-name companies, who study users and users' needs to plan their new products, the CMs work more with the material world. But this is only a superficial comparison. Without touching the dispute of non-human agency or materiality (Callon 1986, Callon & Latour 1992, Collins and Yearley 1992), by examining the importance of the supply chain in creating the industrial ecology, we can grasp how active the material world is. The laptop industry is not an industry with a slow pace or with stable parts and components that stay the same for years. Many ever-progressing or lower-priced small parts or components are the manifestation of the aggressive effort of the numerous small- and medium-sized companies in the supply chain, who need to adopt a fast and innovative product strategy to keep themselves competitive. As a result, the CMs' employees have to work hard closely with them to know about the ever-changing materials.



Figure 3.4

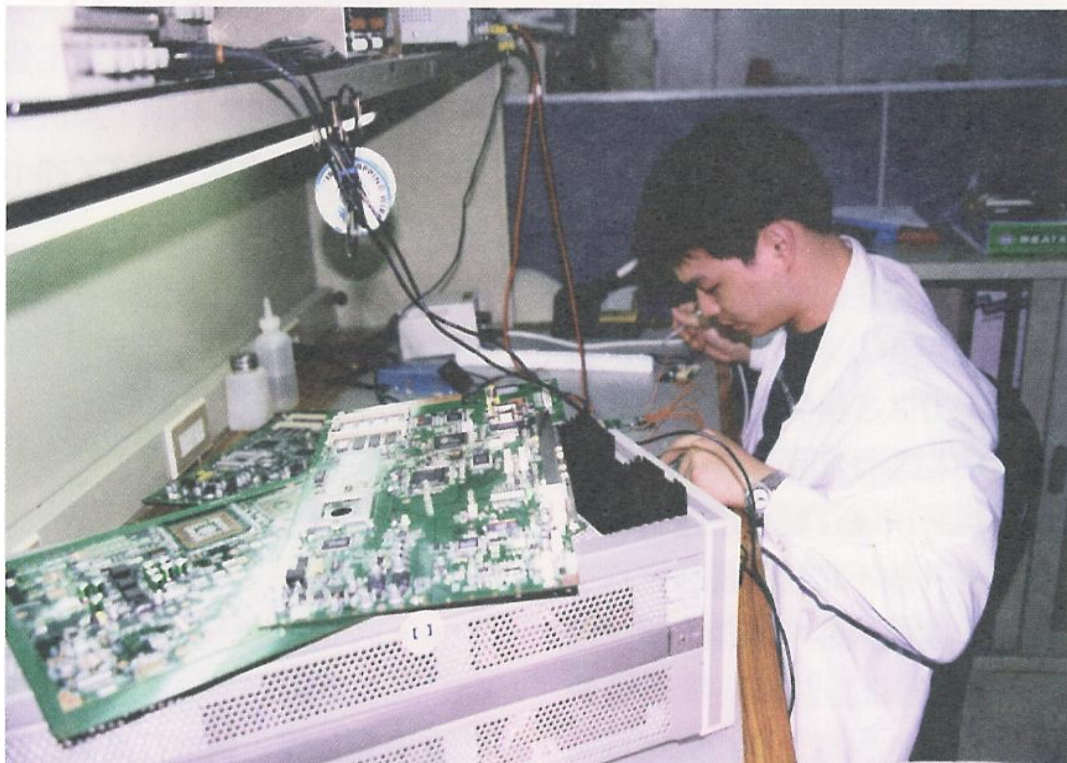


Figure 3.5

Quanta's engineers were busy at manipulating the parts and components of laptops. Figure 3.4 was the Materials division, and Figure 3.5 was the R&D division (Source: Quanta's, December 1998, p.28). and p.39)

As discussed in Chapter 1, the clustering of computer and electronics component suppliers in Taiwan was one major factor that contributed to the consolidation of laptop production in Taiwan. Stan Shih argued that the real advantage of Taiwan's computer industry was based on its component capability.¹⁹⁰ He considered that technological improvement and cost reduction were two of the main features in Taiwan's laptop industry. First, Taiwanese firms usually dared to use the most updated components and technologies for making computers; second, the overall product cost in Taiwan was relative low, which also resulted from the fact that Taiwan had many local parts and components suppliers who could provide state-of-the-art but inexpensive products. The relatively comprehensive supply of components and parts of laptop products in Taiwan is a structural continuity of the former legacy from the electronics industry beginning in the 1960s, but it still took effort to make the connection to the laptop era. For example, a Quanta senior manager claimed that Quanta was the first company that trained the local supply chain of desktops to transform them into that of laptops, and other competitors just received the supply chain that Quanta had trained, later.¹⁹¹ Therefore, the laptop CMs had been co-working with suppliers for years to make appropriate components and parts for the fast-changing laptop industry.

¹⁹⁰ Interview by author (9/14/2010). He supports his argument by evidencing the export amount of Taiwan's computer and electronics industry today. One half of its profits is from end products, while the other half comes from components. "But sorry, 70% of the end products revenues come from components again."

¹⁹¹ "Jon's" interview by author (6/18/2010). He said, for example, regarding the hinge of the cover of displays, it was Quanta who sent people to learn a better technology from Japan, and then taught Taiwan's local suppliers the new technology, which later would be leveraged to other laptop CMs.

Controlling the Deeper Material World

Wistron's President, Simon Lin, whose early career was in the procurement division of Acer, emphasized the importance of supply chain management. He explained,

“The biggest problem in the industry is located in the industrial supply chain. There are so many entangling and interactive factors... In all of the supply chain management, it is usually very tedious, and involves the communication among multiple parties... [For] our interaction with the supply chain, the interaction is always daily...”¹⁹²

Lin said that before their designers went to their own factories to learn the factory team's needs, they first considered materials.

“Most designers in the design stage have to go to suppliers to understand their materials and devices” (p.15).

Wistron also hired experts to take care of several crucial items of parts and components for making master plans regarding materials. For example, if there were 800 parts for a laptop model, when should they be purchased, and how many of them should be purchased? What parts could be commonly used in different models and what could not? Because the scale of purchase was vast and the cost involved was significant, all these decisions were tasks. Lin did not advocate using only ERP (enterprise resource planning, a corporate software system that includes internal and external management information such as manufacturing, finance, sales and service and so on) to manage the supply chain. He

¹⁹² Interview by author (5/26/2010), p.12.

pointed out that what ERP produced was just raw data; it still needed people with skills, patience, and care to effectively make the judgment, in a 24-hour time frame, although the process sometimes involved characteristics like gambling. He said,

“Success, failure, or win or lose is all based on this [experts’ judgment].” (p. 9).

The importance of the materials for the CMs cannot be overemphasized. From Lin’s description, we know that the CMs have to gather information from different fields and generate knowledge for them to make a better decision.

But how complex can the supplier world be? The components and parts used in laptops can be divided into three groups. The first group includes microprocessors, hard disk drives, DRAMs batteries, chipsets, and LCDs, which are usually called key components and which are relative expensive. The second group is comprised of electric components, such as printed circuit boards, connectors, capacitors, resistors, transistors, inductors, filters, and oscillators. The third group is mechanical parts, such as cases, keyboards, cables, and metal or plastic parts. Overall, Taiwan has been strong in the supply of non-key components (i.e., the above second and third groups of parts) rather than the key components (except for LCDs and some chipsets).¹⁹³ Non-key-components are much cheaper when compared to key components used in a laptop, yet in terms of types and varieties, they are much more

¹⁹³ According to Wistron’s President, Simon Lin (interview by author on 5/26/2010), 90% of items today can be sourced locally, but in terms of value, this is only about 30% to 60%, depending on whether or not the laptop uses local LCD panels.

numerous, and hence require various efforts to source and integrate into laptops.

Another classification of their components and parts is based on the “distance” to the CMs’ final product (laptop). The number of parts used in a laptop is between eight hundred and two thousand,¹⁹⁴ and they are classified according to their relations to the final product. According to a Quanta procurement member, “Craig,”¹⁹⁵ there are at least four tiers of materials in the BOM (bill of materials) chart in Quanta. Tier 1 refers to the end product itself, that is, a notebook computer. Tier 2 refers to the direct components and parts that are required for assembling the notebook system, such as the hard disk drive, display device, and motherboard. The items in tier 3 are the materials that comprise those of tier 2. The lower the tier, the closer it is to the level of raw materials. For example, resistors and capacitors are tier 3 items, because one of the tier 2 items, motherboard, is composed of them and other components. “Craig” said that if they buy merely tier 2 materials, first, their own value would be decreased, and second, there would be few technologies for the company to control. By contrast, Quanta and other laptop producers actually buy many raw materials, and design and make the motherboard themselves, since if they sourced the motherboard from others, their circuit experience would be learned and copied. As the laptop CMs’ profits decreased, Quanta began to establish their own components and parts companies. For example, they

¹⁹⁴ According to James Chou, General Manager of Wistron Kunshan. Interview by author (7/16/2012).

¹⁹⁵ Interview by author (6/18/2010).

built a slim optical disk drive company in 1999, a liquid crystal display firm in 1999,¹⁹⁶ and a top and base cover company in 2005.

In addition to investing and controlling certain parts and components, *to increase their values as much as possible*, Quanta's employees needed to further understand materials and manufacturing processes through the tier 3 and tier 4 levels.

Another important reason for delving into the deeper tiers of materials is that Quanta *could handle the cost of those materials to the third, or even the fourth digit after the decimal*, although initially they did not have to be so cautious. In 1999 (after eleven years of its establishment), the newly-listed Quanta was called "the king of the stock" in Taiwan, because it had the highest-listed price in Taiwan's stock market at that time, which came primarily from its high margins. After going public, financial information about Quanta needed to be disclosed and kept transparent, so the secrets of their high profits were gradually exposed. When the U.S. brand customers learned that one important source of Quanta's profit came from the handling of components and parts, tensions over procurement rights began, which I will discuss further in Chapter 4.

Design Innovation and Cost-Saving: Parts, Suppliers, and Field Knowledge

It is crucial to be concerned with small sums of money from small parts because a

¹⁹⁶ But the display company had already merged with AU Optics in 2006.

contract manufacturer can control very little in terms of price (although laptops seem to be high-priced electronic devices). Around the year 2000, the average post-factory price for laptops was \$1,000. What a laptop CM could control was slightly more than 20% of that number: around 200 dollars. But a decade later, the average post-factory price for laptops was only \$400. What a laptop CM could control was merely around 15% of that price: that is, they received only \$60 for designing and manufacturing a laptop; this money was to be used for purchasing non-key components and parts and paying for indirect and direct labor (of that \$60, only a few dollars were allocated to manufacturing costs in the factory). Therefore, the way they could profit was by saving all possible cents from the sixty dollars.¹⁹⁷ James Chou, General Manager of Wistron Kunshan, indicated that about 90% of the manufacturing cost of a laptop was its material costs; therefore, they had to reduce the material cost from the effort of the design.¹⁹⁸

Designing a workable machine is seldom a challenge for the experienced Taiwanese producers. The relative difficulty depends on the ability to provide advanced, reliable, yet inexpensive laptops. Facing the thin profit margin, in addition to the Autumn Struggle (cutting down unit prices of parts from suppliers every year), it is essential for them to examine in detail every component of the engineering effort. Quanta's "Taiwanese Laborer"¹⁹⁹ said that one way to save money was to employ methods like those of housewives: that is, be

¹⁹⁷ Author's interview with "Jonathan" (12/1/2010).

¹⁹⁸ Kunshan is a city near Shanghai, where Quanta's factory base is in eastern China. Interview by author (7/16/2012).

¹⁹⁹ Interview by author (11/17/2010).

conscious of every penny spent. He said, “Just like a housewife, when you buy vegetables, if you can get a green onion [for free], you will take it first.”²⁰⁰ He continued, “You can’t say a thing like this isn’t worth much, so forget it, and that isn’t worth much, so also forget it,...I consider cost saving to be examining everything. Every small component, [and] every small design should be looked at. See if they can be saved.” Therefore, the CMs looked at the price of every part, especially for those high-priced components, to try to save money from them. Saving cost is not always perceived to be a good thing, as some people believe that it harms product quality, but to “Taiwanese Laborer” the main concern is not product quality at all; it is that the cost reduction effort sometimes only benefits their brand-name clients rather than Quanta itself. The money Quanta saved from their own innovations was put into the pockets of their brand-name partners rather than their own; thus, it made no sense to him. This is one reason he wanted me to code him in this research as “Taiwanese Laborer,” because especially in recent years, their innovation and hard work were treated similarly to those of part-time workers with little value.

Manipulating parts and components can be a crucial strategy for Taiwanese CMs. In 2003, suffering from the separation from Acer (which became a pure brand-name company and then gave part of its laptop orders to Quanta and other producers),²⁰¹ Wistron’s design

²⁰⁰ In the traditional Taiwanese food market, a common practice when buying vegetables from a vendor is asking the vendor for some green onions or ginger, two cheap but must-have vegetables in Taiwan, for free as a kind of favor for buying vegetables there.

²⁰¹ Wistron was originally one part of Acer, which was founded in 1976 by Stan Shih and six other

teams crafted new ways to decrease the parts count to save both time and money. They

filtered parts into different groups, and managed to replace and decrease the parts count.

Bruce: Everything is considering cost down now, so the modularization of double E (i.e. electrical engineering related parts) is crucial. Every IC (i.e. integrated circuit) design company will give you the so-called reference circuits. If you use all of the reference, of course you have less of a quality problem. But that will make costs very high. So our function is to take every IC reference circuits[into consideration], then integrate them and simplify them. How to save cost through simplification without causing any bad result? [If it reaches the goal,] it will become our module.

....

Author: So how did you push the simplification?

Bruce: Initially, most of the time is [by using] trial and error. Generally, we removed the part, and tested it to see if it will cause any problems. Gradually, we became more and more experienced. For those very critical components, those that must not be moved, we won't touch them, and then some guidelines will be generated...

Daniel: There is some know-how which in fact is simple.

Bruce: For example, for those high-frequency components, don't take too many risks.

Daniel: Inside the circuits, there are many components are just like vitamins.

Bruce: When you put them in, there is no harm.

Daniel: But after you take them (take the vitamins), you don't know if it's

co-founders. As one of the earliest computer companies in Taiwan, Acer/Wistron not only succeeded in contract manufacturing, but also in the brand-name business. Acer was separated into two companies in 2001—the new Acer was the old Acer's "Acer brand operations" (ABO), and Wistron was the old Acer's "design, manufacturing and services unit" (DMS). During that time, not only was the high-tech industry as a whole affected by the dot-com bubble crash in Silicon Valley as well as in Taiwan, but also the brand-name clients and potential clients of Acer's contract manufacturing division could not tolerate the fact that Acer's own brand business was big enough to threaten even the brand-name customers' market. In addition, severe internal conflicts occurred around resource requests and management inside Acer. Therefore, Stan Shih and other top managers decided to separate the two business units into two independent companies and announced this at the end of 2000. This separation of Acer was covered by many Taiwanese newspapers and magazines during that time.

effective to your body or not...so if they are unnecessary, just cut them off.²⁰²

According to the two engineer-managers, sometimes those parts were kept only because they had been there for a long time. Few people knew what their functions were or the reason why they were there. However, if they wanted to get rid of them, it meant taking a risk on the new result. On the other hand, if they preserved the old things and continued to add new things, it might become a huge burden in the long run.

After a few years of effort, the parts count in their laptops decreased dramatically to only half of the original numbers. Even when one machine saved only \$0.01 from parts reductions, as the economy of scale went up to tens of millions laptops a year, the total cost saving was substantial. By contrast, for a newcomer with only a very small scale of production, it would make little sense to innovate in such a parts count reduction. Furthermore, the reduction of the parts count not only meant that the cost would be reduced, it also meant that in general, the production efficiency and total quality would improve, since many fewer parts were required, and much less interaction or inspection was needed.²⁰³

“People thought we did not get profits in the 2006 price-killing war after we got the major order. We in fact did. The secret was that we hugely reduced the parts count in our products. Thus our cost was much lower than for our competitors,” said Daniel.²⁰⁴

The interviewee, who himself was an experienced electrical engineer and owned

²⁰² Author’s interview with “Daniel” and “Bruce” (7/9/2010), p.18-19.

²⁰³ Author’s interview with “Daniel” and “Bruce” (7/9/2010).

²⁰⁴ interview with “Daniel” (7/9/2010).

several patents in Taiwan, refused to disclose further details about what the secret was, only adding that they evaluated and examined various ways to replace certain parts with fewer parts or integrated circuits. For example, to prevent electromagnetic interference, the previous way was to include many protective circuits, but they found a way to use just a mechanical engineering method, such as putting in an iron metal, so that the electromagnetic interference problem could be solved.²⁰⁵ This sort of effort required knowledge from both electrical and mechanical engineering and the acquisition of knowledge and information from their suppliers to create new knowledge for them to re-design the product. However, this material “secret” never keeps long. It was partially imitated by competitors later, as laptops were continually disassembled and read by each company. Although their engineering paths were different, the competitors knew that they could make an effort to reach similar goals.

The deep involvement with the parts and components from Taiwan’s laptop producers illustrates the practice of field knowledge. The CMs could have merely followed their brand-customer’s proposals or their previous experience of product design, without the new arrangements of parts, and focused on their in-house production, but they went on to create a new path by interacting with numerous supplies instead. Each component, part, or material corresponds to a possible resource from an outside field, and this opened the opportunity for the producers to gather information and draw on information from the

²⁰⁵ Ibid.

heterogeneous and trans-organizational field to innovate and enhance their own values.

II. Process Integration for Reducing the Factory Defect Rate

The above discussion concerns the innovation on the product level with the design team's effort projecting out into the field of the companies' suppliers. In this section, I will focus on the process level from mainly the factory team's integration effort by referring to information from other companies. Furthermore, the previous discussion explores the reduction of cost directly from tangible materials, but this section pays attention to the reduction of cost from intangible processes. In the fast-changing computer industry, saving time usually equals saving cost; thus, as long as the whole process from design to final assembly can be effectively smoothed out and shortened, the cost it reduces can be substantial. The factory manager and engineer team have another important field that they have to engage with, which is composed of the shop floor workers, and this will be discussed in Chapter 5.

In factory mass production, control of the failure rate is crucial because it not only ensures quality, but also cuts losses from the waste of time and materials. Quanta is no different, in this aspect. Although reducing the failure rate is a continuous effort, the most dramatic drop in the failure rate in Quanta occurred in the first half of the 1990s. The huge improvement in reducing the failure rate in many ways represents the practices of field

knowledge from the factory team.

In 1992, the laptop industry, no matter whether in Taiwan or in the world, was still very new. Only a few million laptops were shipped worldwide the previous year. As discussed in Chapter 1, the main large orders in these early years for Quanta were from European brands such as Tulips. As a result, Quanta had not yet formed long-term partnerships with any major American brands, so they had not yet systematically learned much from their partners. Very often, they needed to fumble or learn by themselves, or get different ideas from some experienced people in the company.

In Chapter 2, I discussed how “Yao” empowered Quanta’s factory team, and in this chapter, I will further show his and his factory team’s effort in reducing the product defect rate and thus the manufacturing, repair, and maintenance costs. In 1992, “Yao,” the newly assigned factory head manger,²⁰⁶ set a goal to reduce the failure rate on the production line. At that time, Quanta's total defect rate on the production line was around 18-20%, better than the average number in the industry, which was around 20-25%.

There were reasons contributing to the not-insignificant failure rate in the industry. According to “Yao,” in the past, the general practice in Quanta factories, just as in many factories in Taiwan, was to increase the output as much as possible, since output was the

²⁰⁶ This section about Yao’s effort in reducing the defect rate is selected from multiple interviews with “Yao,” unless specified. Author’s interviews with “Yao” (09/17/2010, 10/20/2010, 12/14/2010), with further confirmation on numbers and years over emails on 12/15/2010 and 10/23/2011.

major criterion for measuring the performance of a factory. At Quanta, from Monday to Thursday, all the computers were produced as quickly as possible. During the assembly process, any defective machines would be dragged off the production line and piled up in the factory. On Fridays, no new assembly would occur, and that day was reserved as the repair day to fix the defective computers that had been piled up during the week. In the industry, it was an open secret that if one's customer wanted 400 machines a day, but the contract manufacturer produced only 395 defect-free machines, the CM would randomly pull out five more from the pile of defective ones. The customer would find the defective machines later. Meeting the customer's needs was always the priority.

The problem with the factories of Quanta and other Taiwanese laptop firms, according to "Yao," resulted from the "mindset" that they did not know things could be better. He considered that "your mindset should be that you want to make things perfect, rather just finish a job assigned, and it would be even better to just do everything right the first time." He indicated that even more recently (2010), at least 10% of the money in the industry as a whole was still dumped into the water because people were not doing the right thing for their own job in the D-M process.

Trained as an electrical engineer, "Yao" knew that industrial engineering was just one of the ways to assure efficient production.²⁰⁷ In fact, from the quality of the material and

²⁰⁷ This is as the idea from Taylorism, which pays attention to the last linkage between industrial

components, to the quality of the design, all those aspects could greatly influence the yield rate in the factory. Therefore, it became necessary to take an upstream orientation to urge their design team and suppliers to perfect their own jobs. That was why he would simply return the design to the design team if the problem apparently came from design, as discussed in Chapter 2.²⁰⁸

After six to nine months' effort on every possible step that "Yao" could recognize from design to assembly, Quanta reduced the production failure rate to as low as 3-4%, a number they were proud to compare with the rates from all other Taiwanese competitors, although this pride would be dimmed soon afterwards, when "Yao" visited an NEC desktop factory in Japan, which had a failure rate as low as 0.1-0.2%.

Before joining Quanta, Yao's major work experience was with ITT Taiwan. At that time, with an interest in improving procurement and outsourcing, he visited around 300 companies in Asia. Most of them were computer and computer peripheral companies. With this constant trans-organizational and multiple-sited observation and experience, he accumulated valuable knowledge about factory operations and about how much better a factory could be. After he joined Quanta, they once attempted to get laptop orders from NEC

engineers and floor shop workers. It is important for Taylorists to make workers' bodily motions correspond to standards of high efficiency, as calculated and defined by industrial engineers and managers.

²⁰⁸ Although a total re-design would not be the most common situation, since usually, the intermediate team between design and factory, QA (quality assurance—an intermediary layer between design and manufacturing teams), would help identify any problem from the design before the machines were put into mass production.

(although the attempt later failed), and they got a chance to visit NEC's desktop factory in Japan in 1996. The first impression "Yao" got when he visited that plant was that everything was so slow. He said,

"We found that their plant had very few people. Also, the machines didn't move quickly. I felt that it was so old, so slow, and without energy at all; nothing like the energy in our factories."²⁰⁹

But when he looked at the chart on the wall, he was astonished. He saw the defect rate for NEC desktops was 0.1-0.2%, which was an unbelievable number, since even the defect rate from components and parts alone was higher than that number. Even though the desktop product's failure rate was lower than the rate for laptops, the difference was not supposed to be so large. He checked with the Japanese factory manager to verify if the number he saw was the "total" failure rate rather than just that of one station on the production line. The Japanese manager's answer was "Yes."

After flying back to Taiwan, "Yao" thought over this issue. He then began to believe that having a lower failure rate was possible for Quanta, since the Japanese company was able to achieve that incredible number. As a result, he focused all of his efforts on reducing the number in his factories to as low as 0.3% within the next two years. This was another record for Taiwan's laptop industry. When asked how they achieved this number, he, responded similarly to several of my interviewees, saying that there was no single trick for the

²⁰⁹ Interview by author (10/20/2010), p.44.

improvement. He emphasized that every step from design to assembly required re-examination and improvement. In 1994, he had required the R&D team at Quanta to visit the factory regularly, but after the NEC visit in 1996, he also drove the component supplier to provide them with components with nearly zero-defect rates. This meant that instead of Quanta checking the quality of the parts and components, the vendors had to examine their own products thoroughly before they shipped them to Quanta. Another important practice that he insisted on, for seven consecutive years, was holding daily meetings, asking all group leaders what problems they found each day, and requesting that they identify the causes of the problems, as well as provide possible solutions. This daily meeting practice offered an opportunity for examining and learning about different issues from various functional teams, and thus promoted a more comprehensive and integrated view for each party involved. It was this detailed and cross-departmental examination of steps and issues that contributed to the reduction of the failure rate in the factory.

In addition to visiting numerous factories, “Yao’s” hobby was to closely read technological documents from foreign electronics companies he had worked for (before coming to Quanta). He appreciated the valuable insights that the documents gave him, so he initiated documentation projects in Quanta later, with the hope that those documents could be drawn upon by other team members, departments, and employees in the future. Before managing the factories at Quanta, “Yao” had also worked in quality management,

documentation, management information system, and field service departments; therefore, he had diverse knowledge across different functions in the computer industry. His diverse work experience, his unusual power to integrate design teams to production lines, his insistence on daily problem-solving meetings, and his observations in hundreds of factory operations and in the NEC plant's low defect rate represented the very practice of field knowledge.

Field knowledge practitioners like “Yao” did not confine themselves to only what their departments requested of them. They usually extended beyond the organizational restrictions and brought back valuable experience and information from outside fields to further improve the expanded process from design to manufacturing. “Richard,” who worked in Quanta and later in Wistron, was another field knowledge practitioner. His multiple experiences and active learning habits across R&D and factory departments made him an effective mediator, encouraging cross-department adaptations, such as releasing design team creativity by using more fixtures in factories (as discussed in Chapter 2). Similar to “Yao”, “Richard” mentioned that he liked to visit heterogeneous factories and observe their use of fixtures to gain knowledge from other industries.²¹⁰

Hidden Innovations

²¹⁰ Interview by author (7/28/2010).

Cross-disciplinary knowledge and mediating practice, however, is neither individual nor sparse efforts. Quanta, Wistron, and Compal gradually have developed systematic mechanisms to exchange experience and to encourage cross-departmental learning. For example, in Wistron, different factories (which usually produce products for different brand-name clients) meet regularly in order to exchange what each team has learned from their own project or customer. Since 2008, the design teams have also held monthly “R&D master forums” that are designed to share experiences (such as so-called “best practices” or “lesson learned”) and knowledge from different business units (a business unit refers to the team serving a major brand-name client). The R&D master forum is for senior members to attend and share their important experiences and ideas regularly, but non-senior members in each functional group (such as mechanical engineering),²¹¹ also have regular meetings with staff from different business units to exchange information and experiences. Active learning from other departments and other projects is very routine practice for these Taiwanese producers, which nurtures a culture of facilitating the practice of field knowledge.

Overall, the Taiwanese CMs are situated in a restricted zone or space.²¹² Within their own zone, however, these CMs became very aggressive. They actively maintained their zone, and expanded the zone to where they could maintain control (e.g., parts supply). In the CMs’

²¹¹ Author’s interview with “Charlie” (8/14/2012).

²¹² The CMs are in a middle position with constraints mostly from powerful brand-name firms and from Wintel or Apple, including limits on marketing and branding, or limits on the use of technological platforms, which I will elaborate on in chapter 4. Sometimes the CMs set restrictions on themselves because certain areas (such as branding) were simply too risky.

own zone, they often made modest outside function innovations, since they could not go beyond the product definition from leading brand-name companies. This kind of active involvement, however, rarely resulted in the CMs getting credit for their innovation (unknown to users); or if the CMs are not free to alter the outer functions of the computer, they could “tinker” or innovate in the material world inside the black box itself or improve the process of making the machine. In this situation, the technology is to some degree “stabilized” in the function part (as the SCOT, social construction of technology, approach suggests).²¹³ Thus, the inside innovations are invisible to users. The key relationship, therefore, is not between innovators and users. Instead, innovations are “translated” into lower cost, and are of interest to brand-name vendors.

Field knowledge facilitates many of the CMs’ inner-world innovations, which were tasks that were hidden from users or consumer markets. In the above section, I explored the efforts that Wistron made in innovating to decrease the parts counts and also Quanta’s process integration concerning reducing defect rates, both involves the production of field knowledge. Wistron, for example, also worked on simplifying tests, synchronizing design jobs, and accelerating review processes by LKK teams (Lou-Ko-Ko means “very old” in Taiwanese) formed by experienced engineers and managers, who possessed a great deal of field knowledge. The largest laptop makers in Taiwan were in fierce competition, with none

²¹³ See Bijker, Hughes, and Pinch (eds.) (1987), p.17-50; Kline and Pinch (1996).

achieving an apparent domination and each actor striving to compete with one another by scanning and pinpointing any possible solutions from others. They invested the entirety of their energy in the small, inner world of the laptop in order to maintain this niche.

The invisible innovation was especially feasible when Taiwan had a large pool of engineers who had a great deal of expertise in designing and making computer machines. In addition, the cluster of many local parts and components suppliers was very crucial, whom the CMs could work with to gather and generate knowledge from heterogeneous sources and to effectively manipulate the inner world of computers with the materials and components.

Criticism on CMs and the Global De-value Chain

Facing an ever-decreasing profit margin (which contrasts sharply with the large amount of capital and human resources spent in the industry), many reflective voices within Taiwan began to criticize the pursuit of contract manufacturing of high-tech products after several decades of economic growth. A scholar used the term, “*Karo* (over-fatigued, overworked) economy,”²¹⁴ to refer to the danger of the high efficiency, high productivity, but low value of Taiwan’s industries.²¹⁵ There are also many high-tech engineers and managers who transformed their careers to “more meaningful” jobs such as organic farming or the food

²¹⁴ *Karoshi* is a term coined by the Japanese, meaning death due to overfatigue brought on by overworking. Here the scholar uses the first part of the term *Karo* to mean the dark side of Taiwan’s industry.

²¹⁵ By Chuei-Ling Shin, Don’t Over-glorify Economic Liberalization, in *United Daily*, 1/3/2014.

industry. For example, the former CEO of AUO Optics, L. J. Chen, changed his path from LCD production to producing and making pineapple cakes (a famous Taiwan desert) in 2012 because he felt that it made little sense that Taiwan's high-tech industry spent so much energy in pursuit of the worldwide market share by increasing the production capacity with big investments and lowering the price of products. He commented that the high-tech industry in Taiwan in the past three decades did only one thing: cut the cost of products from 100 to 1 dollar(s). By contrast, he is now happy to think about ways to increase the price of pineapple cake from 1 to 100 dollars. The logic is completely the opposite.²¹⁶

These criticisms or reflections, however, could not stop the trend of further cost reduction in the industry. Certain computer brand-name firms have drawn on the cruel inner competition among Taiwanese producers. Since 2000, some leading laptop brands have even adopted the "online bid" model for deciding the lists of contract manufacturers, and cancelled the traditional fees for the product design service, which would leave the CMs to absorb them by themselves—so whoever could give the lowest unit price usually would win the bid. Brand-name firms would not worry about the product quality due to lower prices—because they knew the design and manufacturing capabilities that these Taiwanese producers have and they knew the CMs would simply self-compete and serve them well. Brand-name vendors, who were also in severe rivalry, profit from others' competition, a reality

²¹⁶ See *Business Weekly*, Issue 1375. 3/19/2014 (Chinese).

of capitalism. Even though no outside enemy could catch up with Taiwan, Taiwanese producers continued to fight with each other. A government official said,

“There is a blue sea (a good niche without severe competition) if we look at Taiwan from a global perspective, but there is a red sea (severe competition) within Taiwan.”²¹⁷

Although analysts have urged the Taiwanese CMs to merge in order to prevent self-competition and mutual killing, it is not clear who is willing or able to realize this, based on the pervasive small- and middle-enterprise culture in Taiwan.

Overall, although there are many disputes about what Taiwanese computer contract manufacturers should do in the future, many people in Taiwan, either in the public sector or within the industry, agree that their value in global value chains is cheapened. I argue that real innovations are taking place, but these are devalued because there is no need to reward any of them if others are also innovating. This “de-valuing” process suggests the notion that the more skilled you are, the more de-valued you might become, as long as self-competing and capable CMs exist. This is dissimilar to Braverman (1974) or Noble’s (1984) notion of “de-skilling,” that workers become de-valued when their skills are deprived of or are made insignificant by capitalists and managers.²¹⁸ Taiwanese engineers, even with more experience and more skills in hand, face the “blue-collarization” in the competitive global

²¹⁷ Interview conducted on 10/27/2010.

²¹⁸ Zuboff (1988) instead offers the idea of “reskilling” of workers, saying that workers only require different and new skills to deal with the evolving automation machines. All of them explore the relation either between managers and workers, or between capitalists and laborers, and mainly focus on the skills of workers.

division of labor and power asymmetry between brand-name business and contract manufacturing. What they join is a **global “de-value chain”** rather than a global “value chain,” since it is a chain that always attempts to devalue others. Within this de-value chain structure, it is very likely that *the more skilled you are, the less valuable you will be*. This idea of the global de-value chain will be also discussed in Chapter 5.

Conclusion

In this chapter, I first discuss how the CMs’ profit margins have been shrinking. The central consideration of cost reduction shaped and directed the innovations and choices of technological practices in laptop production in Taiwan. Then I went on to describe their innovative practices for the purpose of cost reduction as a form of field knowledge. This knowledge practice was commonplace in Taiwan’s laptop producers and was the result of their active interaction and resource utilization with the local supplier network and within other business partners.

Field knowledge is generated in practices that involve frequent multiple-sited or trans-organizational exchange between actors. I argued that field knowledge is a better notion to represent the knowledge activities of Taiwanese CMs than some of the existing concepts, such as situated knowledge, local knowledge, tacit knowledge, or interactional expertise. Field knowledge is closely related to the central theme of this dissertation on the

dynamic relations between design and manufacturing laptops. Although the latter is broader in its meaning -- there might be different dynamics between design and manufacturing -- so field knowledge is a special kind of dynamics that represents an intensive interaction with multiple actors from diverse organizations and sites in the process of making the product.

I analyze how their practice of cost reduction, an important survival skill in the last decade, was a result of engineering efforts and innovation. I show how the contract manufacturers penetrated into the small material world and how factory teams incorporated design teams in a reverse fashion in order to reduce the defect rate. As middlemen, the CMs needed to possess a broad range of knowledge and expertise surrounding the design-manufacturing spectrum. They needed to constantly use resources from multiple fields and to produce field knowledge in order to assure their own prosperity.

The practice of field knowledge is influential in helping the concentration of notebook production in the hands of Taiwanese. In particular, with a great deal of components suppliers locally, many Taiwanese companies are used to this networked business environment that they can gain useful information and ideas to quickly innovate their products. Frequent emails, frequent conference calls, and frequent visits with internal and external partners are natural to them. This carousel-like working style helps the CMs' employees to gather and extract information from diverse and heterogeneous sources to help them pursue their business success. I argue that the practice of field knowledge plays a crucial role in maintaining their

advantages in making laptops. The importance of field knowledge will be further exemplified in Chapter 5. I believe that the notion of field knowledge, as a concept that embraces multiple geographical spaces and social relations, can serve as an analytic tool to open up the black box of many cross-boundary or cross-organizational activities.

A final remark in the chapter concerns the relation between engineering innovations and their perceived value. While performing design-manufacturing for brand-name customers, the Taiwanese CMs' values were confined primarily to what they were good at in regard to electrical engineering, mechanical engineering, software engineering and their ability to integrate the computer system. Although their innovations are hidden, the CMs continued innovating within the small cosmos that they could control.²¹⁹ However, innovations, skills, and experiences do not necessarily result in higher value. In a global de-value chain, each party has tried to decrease other's value as much as possible for the gain of their own interests, as long as they have the power.

The next chapter will explore characteristics of the CMs as engineering mediators in the producer world, and then structurally delve into the topic of the way in which contract manufacturers were devalued by their powerful partners. If the idea of field knowledge

²¹⁹ I am aware that I did not pay special attention to the CMs' engineering science or engineering "expertise" in this chapter. But it does not mean that these CMs did not employ them at all. They did, all the time. When they decided what parts counts they could change, what design steps could be simplified, and what procedures could be integrated, they needed to refer to both experience and explicit engineering knowledge. Here I just highlighted the unique part about their practices of knowing.

represents the strong agency from the Taiwanese producers, Chapter 4 will then give a gloomy picture about how the negative force is shrinking their innovative space.

CHAPTER 4

HOW TAIWANESE LAPTOP PRODUCERS ARE STANDARDIZED AND CONTAINED

In Chapter 3, I show how the Taiwanese laptop producers, facing ever-decreasing profit margins, used different strategies, including engineering innovations and supply chain management, to secure their competitiveness. In particular, the producers' field knowledge practice, demonstrating their agency and activeness, has been significant in maintaining their success in the industry. In this chapter I will analyze the negative forces and the coercion from their powerful partners that constrain their value and innovation.

Engineering Mediators inside Producers

Compared to their brand-name partners, the Taiwanese CMs are characterized by a double middleness. First, they occupy a middle and usually invisible position in the industry between brands and consumers. A second middle position is their role of engineering that mediates ideas and things, and which is the most important advantage that the CMs have.

First of all, although having capabilities and ambitions, the Taiwanese producers have to face the reality that they are subordinate contract manufacturers to their powerful brand-name clients. Therefore, what they can do is not to try to replace the status of their

clients, but to maintain a niche or a zone of focus among powerful actors.²²⁰

The second middleness is their comprehensive engineering role of transforming ideas and materials into computer systems. Scholarly works have investigated the role of engineers as mediators,²²¹ but the engineers in these Taiwanese CMs differ in their collective invisibility and their confinement by powerful brand-name clients and industrial structure leaders (mainly Microsoft, Intel, and Apple).

Combining the two characteristics, I argue that these Taiwanese companies are important engineering mediators inside the so-called “producers.” In general, the participants of modern economic activities are usually divided into three main categories: producers, distributors, and consumers. Within this three-level relationship, distributors, for example, are regarded as mediators between producers and consumers. In the literature of STS, home economists (Kline 2000), sales agents (Pinch and Trocco 2002), and community video store owners (Greenberg 2008) are identified as mediators because they mediate between users and producers.²²² These mediators interact with and bridge two or multiple socioeconomic groups.

²²⁰ Just like the Schulumberger Company’s middle position between influential international oil companies see Bowker (1994).

²²¹ For example, Bell’s (2011) work on engineers as socio-technical mediators who bridge society and technology-- they can incorporate the value of sustainability from society into their design practices. Also, in analyzing the rise of engineers and technocracy in early 20th century France, Amzaak (2011) discusses how engineers were viewed as a stabilizing element mediating between laborers and owners, and engineers were not “pure” technicians, but could play an important social role.

²²² Although video store owners are viewed more as free agents than the former two, who are hired by the producers themselves, see Greenberg (2008)

In my research, I further examine the inner dynamics within the category of producers itself. Producers are not homogeneous. Within them, the relationships among different actors can be convoluted. Some actors also can be other actors' consumers or users. For example, laptop system producers such as Quanta are the users/consumers of laptop parts and components manufacturers; thus, Quanta is both a (business) consumer and a producer. Although it forms partnerships with certain brand-name companies, and seems to have a subordinate status, the business relation between them can change, and also, the brand-name firms do not hire Quanta's employees. In other words, the ecology within the "producer" world is also comprised of social relations and power structures that are worthy of exploration.

The CMs are indeed intermediaries among groups of social actors. Internally, the CMs' various departments, from design to factory, need to work together; thus, groups of engineers in the CMs work in between owners/shareholders and factory workers. Externally, engineers and managers of the CMs have to mediate between brand-name teams and numerous smaller suppliers. They are thus material and social shuttle agents who are busy pulling elements together and who ensure a seamless transfer of material flow in the design-manufacturing world.

The CMs' Middle Zone

Overall, the Taiwanese CMs maintained zones and attempted to expand them whenever possible. But the CMs were facing many powerful players who could seriously constrain their innovation areas. Thus the middle space the CMs occupy seems to be shaped both by the containment of the brands and by the CMs' creation of the zones. Therefore, although not a homogeneous industrial group, the CMs' middle zone or the niche they created, maintained, and constrained by powerful actors shared the following common characteristics:

1. They appeared to function as the mediator between brands and end-users, but in fact they had relatively *little knowledge about the end-users* in consumer markets.²²³ Such knowledge was usually possessed and kept confidential by their brand-name customers. It was one of the last things that brands would share with their contract manufacturers. The CMs could not extend themselves to branding or marketing since brand-name leaders marked those core domains as taboo, or since those areas simply were too risky for the CMs to explore. They were constrained to a zone in which there were no end-users to refer to, so they were better off only dealing with the material world. The CMs, due partly to imposed discipline as well as self-discipline, tended to remain in their D-M comfort zone in order to avoid risks that might impede their own advantages.

In other words, the CMs were merely the "middlemen" within the producer world, and

²²³ See Woolgar (1991) for the idea of configuring users, and Cowan (1987) for consumption junction, and Oudshoorn and Pinch (eds, 2003) for users' roles in technological choice or production.

did not usually have a clear image of the end-users—or, if they did, it was a translated image derived from their brand-name clients, or merely a vague image from the CMs' own limited end-market research, with the aid of imagined users. Therefore, the users could be viewed as non-resources or merely as mediated or translated resources from the brand-name customers. When the CMs undertook engineering efforts, they were oriented toward the material world, concerned primarily with technological performance, cost reduction, and with the brand customers' expectations, instead of with the experience and expectations from large numbers of actual end-users.

2. The top laptop makers that I studied were in severe competition with one another, with none of them achieving apparent dominance. Namely, the makers occupied a middle space in the broader producer category, but this middle space was crowded. A contract manufacturer could be pushed out at any time. However, within such an active and dynamic environment, they could also learn from one another through frequent movement of employees among the laptop makers on the small island of Taiwan, building advantages in Taiwan's laptop industry in the global market. This is best illustrated by the remarks of a government official in Taiwan:

“There is a blue sea (good niche without severe competition) if we look at Taiwan from a global perspective, but there is a red sea (severe competition) within Taiwan.”²²⁴

²²⁴ Interview by author with “Ching” (10/27/2010).

3. There were two main groups of industrial actors that imposed various constraints in order to standardize or contain the Taiwanese laptop CMs: (1) Microsoft and Intel (the so-called “Wintel,” a compound word representing Microsoft’s Windows operating system and Intel chip technology) prior to the late 2000s, and increasingly afterward, Apple , and (2) the laptop brand-name companies. The standardization from Wintel has lasted for more than thirty years in the personal computer industry. Although Wintel dominance has been diluted by Apple since the late-2000s, especially by Apple’s iPad after 2010, the Taiwanese CMs continue to face subsequent regularization from Apple. These concerned the fundamental paradigmatic frame of the PC industry, which was buttressed by a huge number of players who belonged to the same camp and community; hence, it was more than difficult to break free from this industrial frame, even when Wintel or Apple did not exert direct power over the technological choices of the Taiwanese CMs. The CMs would self-censor and anticipate being punished by the market or the community if they were to overstep the boundary. Second, the containment from the brand-name firms was less related to the choice of industrial architecture and more a result of how the brand-name firms limited sources of innovation and reduced the potential for accrued value from any innovations that the CMs managed to make.

In many respects, the computer brand-name companies were also somewhat constrained by Wintel and its ecosystem. Relative to Microsoft and Intel, the (non-Apple)

computer brand-name companies also conducted constrained innovations, but compared to the doubly constrained CMs, brand firms were freer and not subordinate to other industrial players, except partially to Wintel. I say “partially” because powerful brand-name firms could occasionally threaten not to use Wintel.²²⁵ Before the revival of Apple’s notebook and the rise of its iPad tablet in recent years, the PC and notebook industry reflected the basic hierarchical power structure, from high to low as: Wintel →→(←) brand-name firms →→ CMs for almost three decades (the reverse arrow from brand-names to Wintel means that those brand-name firms could sometimes choose to use a non-Wintel platform, but the result was usually not effective). This industrial (power) structure brought about discrepancies between high and low engineering culture, high and low value, and creative and routine engineering and manufacturing, discrepancies that were worsened by the stereotyped dichotomy between West and East that devalues Asian innovations.

Standardizing and Containing CMs

I argue that there is a double devaluation on the laptop CMs. The first level of devaluation concerns the constraint of their knowledge and range of their innovative activities, and the other level pertains to the devaluation of an already restricted range of innovations. That is, not only was the CMs’ range of innovative engineering limited by their powerful

²²⁵ For example, before the late 1990s, IBM still had its own computer operating system and microprocessor chip technology. It and other companies such as Compaq could also use CPUs from AMD and National Semiconductor rather than from Intel.

partners, but also their existing innovations within that zone were not given due credit.

In this chapter, the first level of devaluation, knowledge and innovation constraints will be the focus, as I have discussed the second level of devaluation, regarding the lack of recognition and compensation for successful innovations in cost reduction in Chapter 3. In earlier chapters, I use the idea of the industrial class to express the high-low engineering cultures between the CMs and their brand-name clients. This chapter will further explore *how* these Taiwanese producers were standardized and contained by their powerful industrial partners in order for the latter to secure their own interests. I argue that although the CMs made various efforts to increase their own value and innovation, they were still inevitably largely regularized and contained, by their more powerful partners due to asymmetric power relations between them.

I. Standardized by Wintel

Since 1981, the PC operating system giant, Microsoft Corporation, and the microprocessor dominator, Intel Corporation, though passing their peaks of power now, have been the main drivers of PC technologies. Their every new generation products directly influenced the directions of PC firms and numerous supply chain companies and application providers. As a result, Wintel came to form the most important part of a “technological frame” (Bijker 1995).

In his work, Wiebe E. Bijker uses this concept to extend the method of SCOT (social construction of technology) to connect the relationship between the relevant social groups and the artifacts. He says that the concept of technological frames is one of the many implications of Kuhn's paradigm (1962),²²⁶ and is probably most similar to Constant's idea of the tradition of practice (1980). Like Kuhn's paradigm, Bijker's technological frame concerns not merely "pure" technology. Rather, it refers to a frame that includes theories, practices, culture, and tools, and is both constraining and enabling. Bijker further divides the technological frame into three configurations: those having no single dominant technological frames, those having one dominant frame, and those having two or more dominant frames. He claims that it is probably the second type (with one dominant technological frame) that is the most common configuration, which, borrowing from Kuhn, can be called "normal sociotechnology"; given the monopolistic circumstances, "innovations tend to be conventional."²²⁷ The single dominance of the Wintel platform in the PC world seemed to represent this idea, and tends to make other innovations banal.

However, in the 1970s, when PCs were in the early stages of development in several countries, it was not clear what types of technology would succeed and what architectures should be developed or complied with. In other words, *there was no straightforward paradigm or technological frame to follow*. This is exactly what D.Y. Yang described in an oral history.

²²⁶ Bijker, 1995, p126.

²²⁷ P.276. For the whole discussion of the three configurations, see p.276-279.

Yang, who was a key figure in Taiwan's first integrated circuit transfer project in 1976, also directed the Computer Project carried out by ITRI (Industrial Technology Research Institute) beginning in 1978. He said that, compared to the integrated circuit technology, which had fewer options and was easier to predict, the biggest challenge in developing the computer industry in Taiwan was that there were too many choices (he used the term "blossom everywhere" to express the idea) in the arena. At that time, it was unclear which technology the Taiwanese team should learn and develop. It was fortunate that they chose Intel's microprocessors as one of the chip platforms, earlier than IBM decided to do so. This meant that later Taiwan was able to seize an industrial opportunity in 1981 when the then computer giant IBM adopted Intel's product in its first PC²²⁸ (although at the time they were unable to predict that Microsoft's DOS would later dominate computer operating systems). Instead, they worked on DEC's (Digital Equipment Corporation) CP-M.²²⁹

As I discussed in Chapter 1 on early Taiwanese laptop history, after the Taiwanese government's ban on arcade game consoles, many local electronics firms turned to Apple II clones, and then later to IBM clones in reaction to Apple's lawsuits regarding the imitation of their products. IBM was much larger than Wintel in 1981 and they semi-contingently formed

²²⁸ The Oral History on Taiwanese IT Pioneers: D.Y. (Ding-Yuan) Yang. Interviewed by Ling-Fei Lin on February 23, 2011 in Taiwan. CHM Reference number: X6290.2012. CHM is the Computer History Museum in Mountain View, CA. Peter Wang in another interview (see the next footnote) added that before switching to Intel, they in fact chose Zilog's microprocessor to learn the hardware architecture for developing the 8-bit computer system first.

²²⁹ Author's interview with Peter Wang and Houn-Ching Shyu (10/29/2010).

an alliance to begin a new computing era that penetrated to families and individuals around the world. Accompanied by related industries, a pool of engineers, and supportive industrial policies, Taiwan's computer industry prospered with the rise and dominance of the open IBM-Wintel structure. At that time, many computer engineers in Taiwan had an "IBM Bible" (see Figures 4.1 and 4.2), the nickname for the open document for the IBM-PC architecture in hand, in order to explore the technical details and learn from it. The original copy was too expensive for them to buy, so many Taiwanese engineers bought xeroxed copies or translated and digested copies that included further explanations from the local community.²³⁰ Later, Intel's "yellow book" replaced the "IBM Bible" as their most important design reference,²³¹ which I will discuss in the next section.

²³⁰ Author's interviews with "Rob" (1/17/2011) and with "Frank" (07/23/2011). "Rob" is a senior R&D manager in Quanta, and "Frank" worked for several Taiwanese laptop producers, but now works for a U.S. company.

²³¹ Author's interviews with "Rob" (1/17/2011).

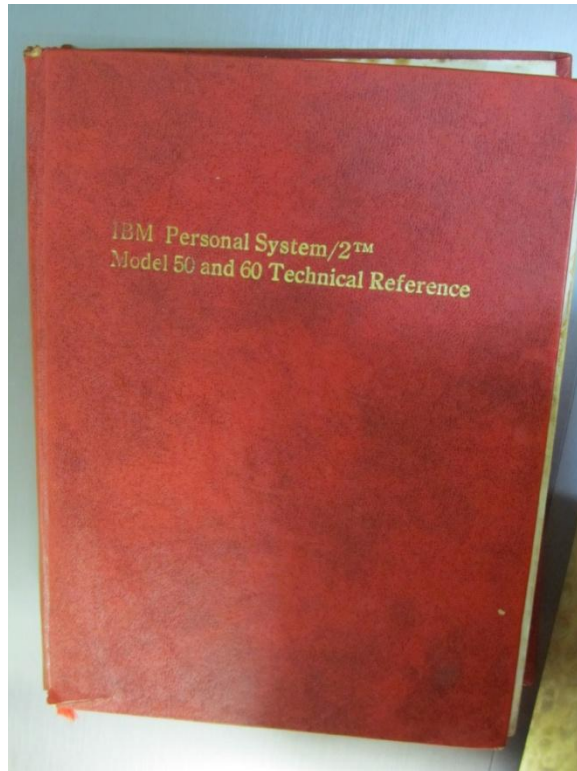


Figure 4.1

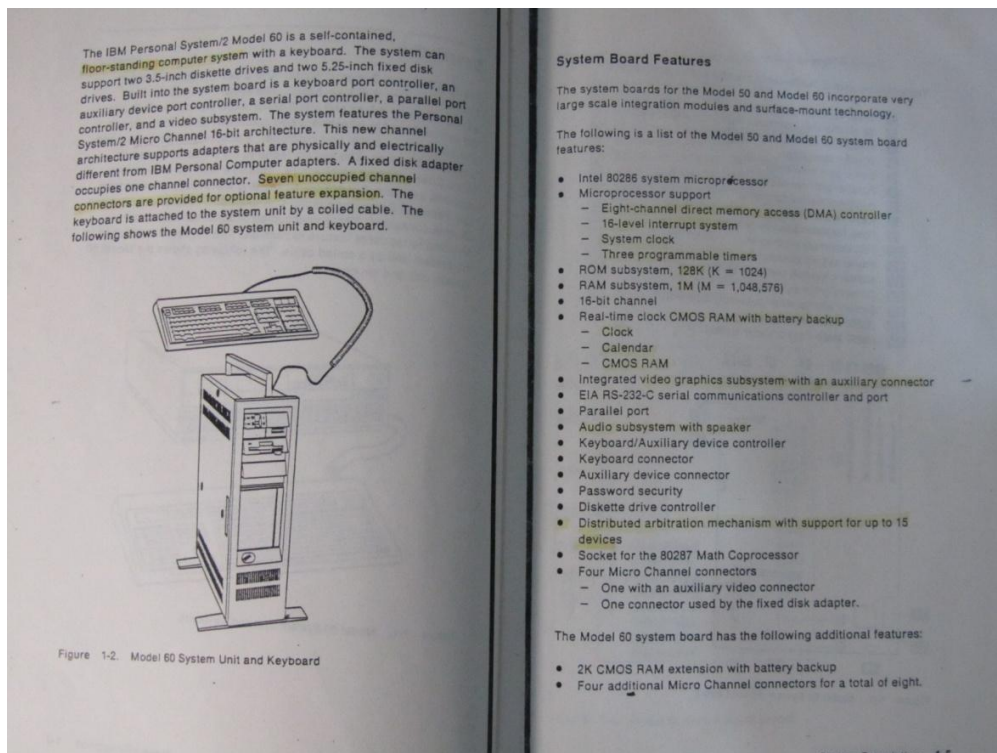


Figure 4.2

The so-called “IBM Bible” from the early 1980s. Cover and two of the inside pages. Photos by Ling-Fei Lin in January 2011. Document provided by Quanta’s manager, “Rob.”

The Carrot: Encouragement to Stay inside the Frame by Providing Information and Support

A strategy that Wintel adopted was to provide important information in order to attract industrial players to stay inside Wintel's knowledge platform. Because major personal computer brand-name companies always purchased the operating system and the central processing unit (CPU, or microprocessor) themselves, there were few direct transactions between Wintel and the Taiwanese laptop CMs. However, to ensure a workable and reliable computer design, the knowledge exchanges between Wintel and the CMs were frequent. By 2001, Taiwan was one of the few places where both Microsoft and Intel held their annual technological forums. In recent years, Wintel even skipped interaction with the brand-name companies and communicated directly with the Taiwanese CMs because a great deal of laptop design work was conducted by the Taiwanese CMs (except for Apple's projects), so it became most effective to talk with the CMs rather than with the brand-name firms.²³² "Rob" from Quanta said that, in the earlier years, their notebook circuit diagram design would be given to their brand-name clients, who would then ask Intel to do specific design reviews, but in recent years, Intel has directly negotiated with and given feedback on the notebook circuit design to the CMs, since the design was the CMs' work.²³³ Simon Lin, the Chairman and CEO of Wistron, indicated that after 2007, Taiwan had controlled and dominated all the

²³² From author's interviews with Simon Lin (5/26/2010) and with "Rob" (12/31/2010). Lin is the CEO of Wistron Corporation. "Rob" is a senior R&D manager in Quanta.

²³³ Author's interview with "Rob" (12/31/2010).

design for Wintel notebooks,²³⁴ but this did not mean that the design work was simple, since he also mentioned that the US Wintel notebook companies now have little expertise in designing new generations of laptops.

Providing information and detailed design references was an important way to market and promote a fundamental component product, because if the chipmakers could better serve their producer-customers with crucial and useful information, this would lower the technical barriers and facilitate design/production cycles. As a result, they would sell more products. For example, in the case of Intel's yellow book distribution, whenever there was a new CPU, Intel would generate seven to eight yellow books, including information on how to design the circuits, how to enable software, and how to solve thermal, signal, or power consumption issues. Intel would ask how many copies each CM needed, and after registration, Intel would give the CMs the copies of those documents, with the names of the registered people and numbers on the documents. Later, Intel would receive the yellow books back when the time was up. The detailed yellow book began around 2000. Prior to that time, just as other chipset providers did, Intel maintained simpler versions of design guides and references. By contrast, yellow books were very detailed and formal because Intel made an even more serious and extensive effort to produce those documents.²³⁵ Another strategy

²³⁴ From author's interviews with Simon Lin (5/26/2010).

²³⁵ Author's interviews with "Rob" (1/17/2011).

from Wintel was to provide direct supporting teams to help the CMs design their products.²³⁶

“Eli” from Compal said that when you bought a new CPU, Intel would then teach you how to design a computer motherboard based on it, because it was Intel’s strategy to standardize and make it easier to implement the technology.²³⁷ The convenient technical support from Wintel was very attractive and could habituate engineers to the model. One interviewee from Quanta said that when they started a product project with Google, which gave only references but not standard specs, they were not accustomed to the new model.²³⁸ Or, more directly, if a Taiwanese computer company that used Wintel to produce its own brand-name products (companies such as Acer, Asustek, and Twinhead all had their own brands in laptops), or to produce “Intel-inside”²³⁹ computers for other smaller brands and local-channel brands, they were likely to get discounts based on the volume of the purchase.

The Stick: Punishment upon Overstepping the Boundary

The non-proprietary structure of Wintel was an enabling, but also a constraining, force on Taiwan’s computer industry. Stan Shih, the co-founder of the Acer group, said, “If there had been no Wintel, there would not be the [prosperous] industrial status of Taiwan

²³⁶ Author’s interview with “Eli” (12/7/2010). He is a procurement manager in Compal.

²³⁷ Author’s interview with “Eli,” *ibid.*

²³⁸ Author’s interview with Roger Huang (1/17/2011).

²³⁹ “Intel Inside” has been a famous slogan for Intel’s marketing and for the tags pasted onto computers that adopt Intel’s microprocessors.

today,”²⁴⁰ because Wintel helped transform the computer industry from vertical integration to horizontal disintegration, thus enabling the smaller Taiwanese companies to join the game. However, Shih also questioned certain strategies that the powerful actors adopted. He believed that Wintel had the intention of becoming a monopoly and maximizing its profits in the market, which was partially due to the fact that in the U.S., the interest of shareholders was put above everything.²⁴¹ He said that Acer never pursued a monopoly because it would lead to corruption and eventual failure of the company.²⁴² The restrictions and confinements from Wintel sometimes resulted from typical business strategies, but sometimes edged up to the border of the law, since we know that throughout the world there had been anti-monopoly lawsuits against Microsoft and Intel.

Interestingly, in the hardware-oriented computer industry in Taiwan,²⁴³ the CM engineers and managers whom I interviewed had many fewer complaints about Microsoft than about Intel. This may be due to the fact that Intel, as a main CPU provider, had a more direct technological relation with the PC/notebook CMs in Taiwan. Precisely how Intel

²⁴⁰ Author’s interview with Stan Shih (9/14/2010). P.8 for the direct quote. “Rob” and other industrial managers had a similar opinion about Wintel’s contribution to Taiwan’s computer industry.

²⁴¹ For Acer, however, the interest of shareholders was ranked only third, after customers and employees, Shih said in the interview.

²⁴² Although Acer was not very successful in the U.S. market, its market shares of laptops in many countries have been high since the late 1990s. He said, For example, when Acer’s market share in Mexico reached about 30% one year, they knew it was enough, and would not push any more consolidation of that market.

²⁴³ Taiwan also tried to develop its computer software companies, either in the private sector or from the government. There are some successful software firms, such as the Trend company, but overall, the software industry is much smaller than the hardware one in terms of revenues, numbers of employees, or influence in the world.

standardized the Taiwanese notebook producers involved a legacy from its earlier containment of Taiwan's desktop and motherboard industry.

A Message from Intel: Move Forward and No Second Source, Please

In the early years of the IBM-PC era, starting in 1981, although Intel was chosen by IBM to be its partner in providing CPUs, Intel had an unstable status in the new PC industry. Neither IBM nor other brand-name companies always complied with what Intel wanted. One reason that Acer launched their 32-bit computer in 1986, ahead of IBM worldwide, was that IBM showed a reluctance to cultivate Intel; Intel instead came to ally with Compaq and Taiwan's Acer.²⁴⁴ But, later, when Compaq also showed resistance to following Intel's roadmap, Intel turned instead to Dell Computer and fostered a close partnership with the company.²⁴⁵ The incessant alliances and enrollments of related actors made up an important strategy for Intel to maintain its leading business position.

For the Taiwanese computer industry, however, no other event caused more resentment against Intel than Intel's move into the desktop motherboard business in the mid-1990s. This was a very important business for many Taiwanese computer vendors, who held more than half of the PC motherboard market share worldwide. The PC motherboard industry was a main customer for Intel's CPUs, so Intel's new move to produce motherboards

²⁴⁴ From Shih (1996), and author's interview with "Mark," a retired manager of the Acer group on 6/2/2010.

²⁴⁵ Author's interview with "Mark," *ibid.*

effectively meant that it was competing with its own clients.²⁴⁶ Taiwanese PC and motherboard producers were discontent with Intel's action because they feared that Intel would withhold the technical specifications of their new CPU products and would even adopt unfair pricing and delivery strategies.²⁴⁷ A delay in the release of technical specifications did in fact happen in the case of Intel's Pentium CPU.²⁴⁸

Intel's explanation for its move into the low-margin motherboard business was that this strategy would facilitate the acceptance of its new Pentium CPU on the market, because Intel thought that the PC and motherboard makers were too slow to adopt their new technology.²⁴⁹ With regard to this "delay" in upgrading their products, an executive of a major Taiwanese motherboard producer said in a conference: "Why should we spend so much time on the Pentium motherboard when the 486 was selling so well?"²⁵⁰ But this deferral in adopting new technology was not what Intel preferred. Taking a rigid approach, Intel could sue a local manufacturer for different reasons, or adopting a softer approach, it could penalize those who did not adopt their products with unfavorable pricing and allocation practices.²⁵¹

Intel used other business strategies in order to increase its market shares in addition

²⁴⁶ Author's interview with "Mark," *ibid.*

²⁴⁷ Liu, 1995, cited in Tengli Lin, 2000, p.264.

²⁴⁸ Wilson, 1995, cited in Tengli Lin, 2000, p.264.

²⁴⁹ Wilson 1995, Liu 1995, Baum 1995a, Commercial Times, Oct. 5, 1995. All cited in Tengli Lin, 265.

²⁵⁰ Wilson 1995: 39, quoted in Tengli Lin 2000, p.265.

²⁵¹ Winzenburg 1995, and Wilson 1995, both were quoted in Tengli-Lin p.268

to endorsing a quicker adoption of its new product. A former manager of AMD Taiwan (AMD is a main competitor of Intel in the PC CPU market) recalled that if a producer decreased its purchases from Intel and increased those from Intel's competitors, the producer would neither receive early production information, nor get Intel's product at all,²⁵² although later Intel stressed that there would be no discriminatory treatment against Taiwanese manufacturers.²⁵³

In general, Intel seemed to use pricing control and product delivery strategies to spur on and tame the producers. It was the motherboard companies, brand-name firms, or those CMs who bought microprocessors for their smaller clients who would have direct transaction relations with Intel. But as I mentioned, another important strategy was to limit information, and this was also what the notebook players cared about. As the scholar Tengli Lin said, "The CPU is more than a critical component; it also embodies a whole array of technological know-how that a computer maker must acquire before or at least during the design stage."²⁵⁴ Several interviewees for this project highlighted the same idea. "Eli" from Compal indicated that the prices of Intel's CPU had nothing to do with the notebook CMs, so what they feared was that if Intel did not offer them Intel's future roadmap, or cut down half of the number of Intel's supporting team in the CM, the CM's competence for new product design would be

²⁵² Wilson, 1995. Cited in Tengli Lin, 2000, 268.

²⁵³ Commercial Times, Oct. 5. 1995. Cited in Tengli Lin, 2000, p.269.

²⁵⁴ Tengli Lin, 2000, 262-263.

affected, which was a risk they would not take.²⁵⁵

Therefore, most Taiwanese computer producers became accustomed to being subject to Intel because if they followed the rules from the big player, their business generally would operate more smoothly, but once they attempted to cross the line, a warning or punishment from the structuring power might follow, either in a direct way, or in a subtle way of manipulating information and technical support. Sometimes, the producers disciplined themselves simply based on different rumors about Intel circulating in the community.

Regularized by the Wintel Ecosystem and the “New” Apple

In the final discussion of the Wintel technological frame, instead of pointing to just Intel and Microsoft, I would instead highlight the unseen but omnipresent power from the whole Wintel community. There exists an integrated structure formed by the sociotechnical and industrial communities, or what we can call a Wintel ecosystem. The open and compatible architecture based on Wintel has forged prosperity and exultation for certain players for three decades since the early 1980s. This new business ecosystem is not achieved by a single technology or a single company, but by absorbing into a vortex like a black hole many different company entities and people, based on the pursuit of potential huge growth and profits. In the first and second decades, it involved an ever-increasing community.

²⁵⁵ Author’s interview with “Eli” (12/7/2010).

Initially the various Taiwanese computer firms were greatly enabled by the sociotechnical frame: they could design, produce, and sell computers to the world. After all, it was a new scenario that was hard to imagine earlier, when computer players had been primarily large Western enterprises. In the first decade of development, the Taiwanese players were freer to be involved in innovating and improving many aspects within the new frame. Their contributions were invisible but significant, including helping computers to become much cheaper and to prevail in the world.²⁵⁶ However, the Wintel ecosystem, while enabling, also structured and restricted many players. These Taiwanese firms became increasingly constrained by this framework, since not only did the technology and market become more mature, but also they themselves grew in strength and significance, thus feeling more limitation of the space. More importantly, as they expanded, their potential threats or 'disobediences' would cause containment if they were to explore the non-Wintel world. Several of the CMs had tried in different time periods to develop more AMD-based computers or more Linux-based machines,²⁵⁷ which would provide them more freedom in product innovation, but those products either failed or were too few to shake the giant Wintel

²⁵⁶ This help is not limited to only the Wintel PC world. Even the re-emerging Apple in the twenty-first century had to rely on the existing PC supply network from Taiwan, which greatly reduced the price level of Apple's new innovative products. In the past, Apple was also famous for its innovative products, but most of them were more expensive than their competitors. The comeback of the new Apple was based partially on its quality products at affordable prices.

²⁵⁷ AMD is a main competitor of Wintel in the computer microprocessor market, but its market is far smaller than the latter. Linux is an open-source software system that aggressively challenged Windows more than a decade ago, but its market share in the personal computer has been very limited, even now.

ecosystem.

After 2001, the re-emergence of Apple Computer brought another challenge to the Taiwanese laptop OEMs. The Apple hardware ecology is very different from that of Wintel. While Wintel controls the OS and CPU platform, they also offer an open structure for many other companies to participate and co-thrive in. Apple, however, has been well known for its proprietary system. In the past, it developed its own OS, CPU, computer systems, and many parts and peripherals. Today, even while Apple has embraced the existing Wintel PC supply chain and transformed some of the supply chain companies to customize products for Apple, it remains a computer brand-name company, which is different from Wintel. Wintel has been powerful, but at least Microsoft and Intel were not computer-brand companies and the Taiwanese laptop OEMs received orders from HP, Dell, and Sony, rather than from Wintel. Currently, the new Apple is as powerful as the past Wintel, but it is also the laptop OEMs' direct client, which combines the power of both the industrial platform and the computer product orders. The advantage for the OEMs is that they have to deal with only one boss rather than several, but the disadvantage is that this sole leader might be too powerful for them to negotiate any other possibilities.

Another important difference between the Wintel PC and Apple computer worlds is that Apple tends to control the majority of design jobs for their computers, while Wintel PC OEM brands such as HP and Dell tend to assign most of the product design jobs to the

laptop CMs of Taiwan. In the eyes of the Taiwanese CMs, compared with other brand-name companies, Apple in particular did not wish its CMs to have too many original ideas, but instead required them to be obedient, following what Apple wanted them to do.²⁵⁸ As discussed in Chapter 2, Apple has a relatively design-centered culture. This means that factory teams have to find different ways and make extra effort to produce Apple's products no matter if the design itself is very difficult to mass produce (so, it adopts a principle close to MfD, i.e., manufacture for design, rather than the other way round). Compared to the Wintel products, the Apple products require the CMs to adjust their relative capabilities away from the pole of design and toward the pole of factory manufacturing.

II. Contained by Brand-name Companies

In addition to the framing power from the Wintel camp, a second constraining force for the Taiwanese computer CMs came from the CMs' brand-name clients. The containment from the brand-name companies had two major purposes: to avoid losing knowledge and commercial credentials to production partners and competitors, and to gain maximum monetary value by limiting CMs to delve into any profitable areas that the brand companies were interested in.

²⁵⁸ Author's interview with "Eli" (11/17/2010) from Compal; also from the interview with Wistron's "Jonathan" (12/1/2010). Both are senior engineer-managers.

I continue using spatial analogies (zones, areas, fields, middleness) in this dissertation to describe the specific positions of the Taiwanese CMs, here I will use another notion, *containment* feature to describe their situation. Containment as an important analogy was first used by George F. Kennan (May 1988), who claimed that the power of the Soviet Union would not threaten national security if it could be contained within a clearly defined sphere of influence. He implies a strategy to confine dangers within a limited range, with fortified boundaries between them and the concerned entity. "Containment was the key to security" (May 1988: xxiv), no matter if they are dangerous nations, dangerous substances (such as the atom bomb), or dangerous people (such as Communists). Dangerous things do not have to be the most powerful or advanced; as long as they might endanger the concerned party, they must be contained in order for the party to protect or secure the precious things they have. I argue, although not the most powerful, the Taiwanese CMs did show potential threats that need the containment from the brands.

Co-opetition: Hiding or Sharing Knowledge?

In business alliances, although actors share some common goals and interests, they still make different calculations based on their own interests in order to adopt appropriate actions. For example, in high-tech development alliances, each partner needs to contribute resources for a successful result; also, reciprocal information exchange and mutual

adjustments are needed for the success of the alliance. However, such exchanges also enable actors to appropriate knowledge from their partners. Therefore, in alliances, there are often ways to avoiding unnecessary loss of knowledge to partners. Firms can influence their partners' learning opportunities with strategies that take into account the partner's intent, reciprocal trust, and ability to learn. One study finds that a partner's intent and learning ability are positively related to the extent to which it protects its firm-specific knowledge. Also, with more trusted partners, firms are less protective of their own knowledge (Patricia 2004).

In the case of notebook contract manufacturing, I have discussed the knowledge and power struggle between the design and the factory team, and will analyze this struggle between the Chinese branch and the Taiwanese headquarters within CMs in Chapter 4, but what about the knowledge conflict between CMs and brand-name companies? Although the degree of knowledge acquisition and protection did not reach the level of corporate espionage, in many ways, the brand-name companies showed clear intentions to protect their own knowledge and restrict the range of innovation of their CM partners which might encroach upon their own interests. Although the brand-name companies and CMs were not direct competitors, the CMs could serve the competitors of the brand name, and it was possible that in the future, the CMs would extend their capabilities to encroach upon the design and marketing prerogatives of the brand-name company itself.

Securing Knowledge in Collaboration

Although foreign computer brand-name companies show a clear intention to protect their own knowledge and know-how, the extent to which they did this was less in the early years. This was especially so for the US company, ITT Corporation, which came to source PC manufacturing in Taiwan in 1982. David Lee, the founder of Qume (a company that merged with ITT in 1978), mentioned in an interview with me that a top manager of ITT hoped to source PC products from either Malaysia or Spain, but partially due to his own Chinese background, he finally chose Taiwan as the outsourcing site. ITT selected MiTac, and then MiTac introduced Acer (which was called Multitech at that time) to share the volume production of ITT's IBM PC-compatibles. Lee remembered that Acer did not even have a decent factory at that time, and needed to ask for financial help from others in order to build its factory, but he believed that Acer had the capability to produce PCs. As a result, they decided to give the contract orders to Acer.²⁵⁹

A then-ITT manager, "Yao," said that Acer did not have the knowledge and expertise to mass produce computers. So, when ITT transferred technology and trained Acer's employees in valuable skills such as testing procedures and production process control, ITT required Acer to sign a non-disclosure agreement in which it promised not to produce and sell their own brand PCs to compete with ITT on the market. A few months later, Acer proposed the founding of a new company to be dedicated to manufacturing ITT's products. This would

²⁵⁹ Author's interview with David Lee (12/11/2010). He is the founder of Qume, and served as a top manager of ITT after ITT merged with Qume in 1978.

free Acer from restrictions against making PCs themselves. Furthermore, Acer guaranteed that the two companies' personnel would be separated, and there would be no exchange between the new company and Acer. Although ITT questioned the possibility of not exchanging information between the two related companies, ITT still agreed to the deal because Acer and Taiwan were not threats to them at that time.²⁶⁰ In other words, Acer was not dangerous enough for them to contain.

The possible conflict between Acer's own brand-name business and their contract manufacturing business, however, gradually became a concern of Acer's potential brand-name partners, especially after Acer became one of the top ten notebook brands in the world's PC industry in the mid-1990s. Dell Computer directly told Acer that Acer would gain no notebook orders from Dell if Acer possessed their own-brand products because that would mean that Dell was cultivating a brand competitor for themselves.²⁶¹ This long-standing issue finally led to the separation of Acer's own brand business and contract manufacturing business (the latter business became Wistron) in 2001, although there were other crucial factors that contributed to the separation, such as the internal conflict of a market-oriented or technology-oriented culture in managing the company.²⁶² Even after the separation of the two businesses into two companies, other CMs and brand-names still did not believe that

²⁶⁰ Author's interview with "Yao" (12/14/2010).

²⁶¹ Author's interview with Max Fang (3/19/2010), a retired and former general manager of the international procurement department of Dell Asia Pacific.

²⁶² Stan Shih, 2004.

they were completely divided until Acer (which kept its brand business) did not renew a large portion of their product order given to Wistron (the new CM company spun off from Acer) and outsourced their own notebooks to other CMs.²⁶³

The concern over the possible appropriation of firm-specific knowledge from brand-name companies was not unique in the case of Acer. It also applied to pure CMs like Quanta, although the level of concern was different. Quanta did not produce or sell its own-brand product, so its brand-name partners did not fear engaging in knowledge and resource exchanges with Quanta in this regard. However, given that Quanta had multiple major brand-name customers, such as Dell, HP, and Sony, the brand-name companies instead needed to prevent the loss of trade secrets or knowledge to competitors through the middleman, Quanta. Therefore, there was a so-called firewall arrangement in Quanta (also in other CMs), depending on how rigid the brand-name clients were. The basic firewall for major clients consisted of assigning a factory or a separate floor to each client, with a security check, dedicating the same group of Quanta employees to the same client, and the signing of a non-disclosure agreement.

To accommodate different clients' requests as well as the contract companies' own management and integration needs, organizational changes in the CMs were common. In the past, some CM organizations were divided by functions. For example, all design engineers for different clients would belong to the same division led by an R&D head, and all factory

²⁶³ Author's interview with "Jonathan" (12/1/2010), a Wistron manager now.

members would be directed by a central head. In recent years, however, the most popular model was to organize according to the client-base. This was called a BU (business unit). For example, BU1 might refer to the teams belonging to the client Dell (or the Dell BU), and BU2, for HP. In a CM's BU, all related employees, ranging from various levels of engineer to the factory workers, were assigned to that client, and were managed by a BU head.²⁶⁴ A third arrangement was the matrix model. For example, Compal was once divided by functions, then by BUs, and in 2010, they changed to a matrix design of organization. That is, it was a mixed model between functions and BUs, and each member basically had two bosses.²⁶⁵ These organizational arrangements have their functions and meanings in knowledge exchange and organizational learning.

Nevertheless, there was a very special client, Apple, which had a much stricter way of protecting its own product information and knowledge, partially due to the fact that its products were non-Wintel and were proprietary. Hence, Apple had more unique product features, requiring more know-how and secrets that they strictly protected. While it was possible for the engineers and managers from different BUs to share certain experiences and learning from their different Wintel clients, it was completely forbidden to do so for Apple's

²⁶⁴ Although, in general, many people in a business unit (BU) were in fixed positions, the shop floor workers were movable between different factories or different clients, because there was less concern about knowledge leaking at their level. Although the laborers were relatively movable, the factory site and equipment were dedicated to the client unless the client greatly reduced their product orders and the CMs hence needed to adjust the factory allocation.

²⁶⁵ Author's interview with "Stuart" (7/21/2010).

project members, who as a result became isolated and less connected to their other colleagues in Quanta. Furthermore, Apple did not allow non-related people to enter their factory base in Quanta; not even the top managers of Quanta could be there without proper reasons and applications.²⁶⁶

Containing CMs for Self-Survival

As middlemen, the most protected type of core knowledge that brand-name companies would withhold from Taiwanese CMs was their end-user data. They knew this was taboo information and never tried to ask for it (unless certain producers also developed their own brand business and built their own end-customer data). As a result, the CMs had been concentrating on developing the material world until they found that this route was also blocked. That is, the field knowledge practitioner (CM) has limitations on gathering information or knowledge from the field of the powerful.

There were reasons for the brand-name firms' containment of Taiwanese CMs. They went beyond defending their own knowledge in order to secure their own jobs and to maintain profits as well. Indeed, after the Taiwanese laptop CMs gained more expertise in the industry, increasing job loss became a problem for the employees of brand-name companies. A senior Quanta R&D manager, Roger Huang, felt sympathetic about the dissolution of a design

²⁶⁶ Author's interview with "Christopher" (7/23/2012), who is a factory manager of Quanta Shanghai.

division in Corvallis, near Portland, Oregon. He knew that the former HP (before merging with Compaq) had hired one to two hundred notebook designers who lived there, but after more design jobs were assigned to the Taiwanese CMs, and after the takeover of Compaq by HP in 2002, the entire division was dismantled. Senior engineers at HP were forced to either transfer to the printer division or to simply leave the company.²⁶⁷ Another senior Quanta manager recalled that in the 1990s, Quanta had a major client from Europe. There was a group of teams who came to a meeting with Quanta, but the second time he met with them in Taiwan, only one person came, and he was told that whole group had been dismissed.²⁶⁸ Therefore, it was understandable that brand-name companies would push the CMs back when their encroachment seemed too much for them.

Nevertheless, not all brand-name teams tried to hide knowledge from their CM partners. For example, Arimasa Naitoh, the Vice President of the Thinkpad notebook business unit²⁶⁹ at the Yamato Lab in Japan, said that he always tells his members to teach their Taiwanese CM partners, for the reason that “teaching is the best way to learn.” He thinks it is counterproductive to hide knowledge, because that will only keep engineers doing the same thing. He admitted that ODM, (or CMs) the teams of their Taiwanese partners, partially compete with Yamato Lab’s engineers, but he encourages his engineers to enhance their

²⁶⁷ Interview by author (1/17/2010).

²⁶⁸ Author’s interview with “Joseph” (5/20/2010).

²⁶⁹ Thinkpad was originally a notebook business in IBM, which was sold to Lenovo in 2004. Naitoh has been the division head since the IBM era.

own value in order to justify their need to be hired. Otherwise, they would be replaced by Taiwanese engineers.²⁷⁰ Due to overlapping design jobs and multiple possible divisions of labor spanning the design-manufacturing process (as discussed in the case of Ten Miles of Yangtzi River in Chapter 2) the brand-name members had often subtle competitive relationships with the CM partners. Amidst the close collaboration between brands and CMs, there were often disputes over issues such as the ownership of rights to design because their collaboration built upon ideas or elements stacking upon each other. In such disputes, it is usually the CMs who need the contract order to compromise.

These conflicts illustrate the poor credit that Taiwanese CMs often received for their product innovations in the D-M process. Indeed, the CMs began to be aware of the issues of patent rights and to use different incentives to encourage their engineers to file patents. Nevertheless, significant innovations were not paid for or given any credit, let alone the numerous “smaller” ideas or innovations that they might have skipped over when filing a patent, given the expense and energy required by the filing process.

Limiting Component Procurement Rights

One important strategy of brand-name companies for confining the added value of these ever-capable CMs was to control the laptop supply chain, an influential source of value

²⁷⁰ Author's interview with Arimasa Naitoh (8/27/2010).

and innovation for most Taiwanese computer producers. By calling upon this active local supplier network, Taiwanese computer system producers could not only receive flexible services and lower prices, but they could also work closely with suppliers to make design and manufacturing innovations (as discussed in Chapter 3 on cost reduction practices). But, in addition to the non-key parts and components, the relationship between CMs and the multinational key component suppliers was another source of innovation. Key components refer to those relatively expensive and fundamental components such as CPUs, memory, LCD modules, and hard disk drives. Richard Lee, the Chairman of Inventec (which is also a global top-five laptop CM), indicated that in its early years, his company had the freedom to collaborate directly with key component suppliers, and in fact, Inventec had spent a great deal of energy in collaborating with them for production integration. Later, however, the laptop brand-name companies gradually controlled all procurement rights to those crucial components. This greatly reduced the CMs' involvement with them. Lee said that when CMs had direct business relationships with key component suppliers, they could work together and gain knowledge of components from the collaboration. Thus, they were able to provide better system integration. On the other hand, the compulsory lesser degree of involvement with key component suppliers for CMs meant that their designs and innovations were limited. Lee suggested that this limited freedom in innovation partially led to the more recent predicament

of Taiwanese laptop CMs.²⁷¹

The rights to purchase components have changed over time. According to a Quanta manager,²⁷² Quanta had three-stage changes with one major customer, Dell, on procurement rights. In the beginning, Dell purchased all materials for its products. In the second stage, when Dell thought Quanta was qualified, Dell allowed Quanta to buy the materials and handle the inventory. And in the third stage, Dell wanted to control the key components due to the shortage of key components. But this generated another problem for Dell: sometimes there were dramatic price drops for key components. As a result, the inventory management was an issue; hence Dell shifted and asked Quanta to use the “buy and sell” model. This meant that Dell assigned the materials, but it was Quanta who actually paid for their installation into laptops first. Afterwards, Dell would “buy” the materials from Quanta when the laptops were shipped to Dell or Dell’s customers. These changes in procurement models are calculated and controlled by the powerful brand clients, rather than by the CMs.

Controlling component procurement rights is crucial to the CMs for both innovation and profit issues. According to a Quanta member,²⁷³ there are four kinds of profits for contract manufacturers: from R&D services, from procurement, from manufacturing, and from

²⁷¹ Author’s interview with Richard Lee (9/30/2010).

²⁷² Tsai (2005).

²⁷³ Tsai (2005), attachment E about the interview transcript of a Quanta interviewee.

management, and the profit from procurement is especially important. When a BOM (bill of material) chart of a laptop is extended, it is an extensive list with thousands of items. It is possible for the brand-name companies to take care of every part of it, but this costs them a great deal of energy. At the high peak of a “touchless” model,²⁷⁴ the brands tended to give the purchasing rights of “non-key-components”²⁷⁵ to its CM partner rather than handling them by themselves.

The relative freedom in handling non-key components gave Taiwanese players the opportunity to increase profit and innovation efforts. As discussed in Chapter 3, the Taiwanese CMs could redesign the inner part of the product in order to decrease the part counts or PC board layers as well as to standardize certain parts and components that they used for different products and for different customers. The change of the cost structure in the industry also made the CMs work hard on the issue of saving component costs. The cost structure changed from push to pull. In the past, the cost structure was “cost plus,” that is, the price the CMs gave to their brand-name customers was “cost plus profit.” But in the recent decade, it became the pull model, that is, the customers gave the CMs a fixed price (usually a low price), and the CMs needed to go back to work on their own cost and profit.²⁷⁶

²⁷⁴ Which means the brands do not have to touch the PC. There is another term, “PCless,” which is used to describe PC companies that sell but do not produce PCs. For detailed explanation of the touchless model, see Chapter 2.

²⁷⁵ Again, key components refers to those that are expensive and sensitive to seasonal changes and storage days, such as hard disk drives, microprocessors, and dynamic random access memories.

²⁷⁶ Author’s interview with “Craig” (6/18/2010).

When the rules from the brands are flexible, there will be space for manipulation. The tricks that the CMs and the brands played with each other seem like an “information spy game” to obtain information on the cost of components. In 2001, after the Taiwanese producers began moving their factories to China, most of the design teams were kept in Taiwan. Their brand-name customers also got close to this Taiwan-China base. With the Taiwanese government’s new incentives to attract foreign companies to set up R&D centers in Taiwan (to help “upgrade” industries in Taiwan), one by one, computer brands announced that they would set up R&D centers there, which was hailed by the Taiwanese government and media. Yet, within only a few years, what was going on in these brand-names’ R&D centers triggered resentment from the Taiwanese laptop producers. When brand-name companies built their so-called R&D or design centers in Taiwan, they poached R&D members from the Taiwanese CMs. In addition to project management, one main thing these people did was to closely monitor the detailed cost of each item on the bill of material.²⁷⁷

As one interviewee told me, brand companies would ask them to break down every single component’s price. They would compare the costs among different CMs. And when they were ready to give CMs the projects, the clients would say, “No, this is more expensive than others, and that is also more expensive than others, and then they would squeeze the

²⁷⁷ Author’s interview with “Bruce” (7/9/2010), a senior R&D manager in Wistron; and with “Eli” (12/7/2010), who is a senior engineer-manager in Compal.

price to the bottom.”²⁷⁸ That is, brands tried to cut every cent off from the CMs’ profits by controlling part of the components, since these former employees knew so well about how the CMs did business with local suppliers and partners. By recruiting more Taiwanese engineers to the R&D centers, brand-name firms controlled more local knowledge about the use and price of diverse components and parts supplied by Taiwan.

When the CMs retained the rights to purchase components and parts, they could get better under-the-table prices and better profits than when those components were bought by their customers. One way in which certain CMs “resisted” the current trend of low profit from procurement was to ask for rebates from suppliers, which might cause the problem of bribery, if not handled well between the two parties. These rebates were not disclosed directly as with accounting numbers, but were important sources to enhance these laptop producers’ profits. Regarding this sensitive issue, an interviewee said that brand companies actually know this well, but it is very hard for them to prove it officially.

Since the Taiwanese CMs could not control the component procurement rights, and since they needed to grow their businesses, they could choose to produce some components themselves. Indeed, the importance of components motivated the laptop CMs to sink deeper roots into components when their profits became increasingly thinner. Several of the larger Taiwanese laptop CMs began to invest and build their own LCD panels, optical-drive disks,

²⁷⁸ From author’s interview with “Eli.” Ibid. p.16.

cases, and various parts or components. “Stuart” from Compal described how CMs were shifting from manufacturing toward the “bases for manufacturing,” which means components and raw materials. He said,

“There is nothing special if you can produce an iPad; it is more remarkable if you can make touch-panel technology.”²⁷⁹

This issue became more important after brand-name firms had more transparent information about the local supply chain’s costs after they built design or R&D centers in Taiwan.

To produce innovative products, Apple has adopted an innovative cooperation model with parts and components suppliers. Instead of using currently existing parts or components, they often ask for new and customized ones; hence, they work with their selected suppliers for two to three years before a new product is launched. Apple has a massive R&D team which can deal with detailed choices regarding each component. This model of early engagement with components suppliers is now gradually being copied by other computer companies as well.²⁸⁰

Overall, this strong control of the supply chain by the brand-name companies also results in further squeezing of the innovative space for the laptop CMs, unless the CMs themselves successfully create components which are adopted by the major brand-name

²⁷⁹ Author’s interview with “Stuart” (11/9/2010), who is a senior R&D top manager in Compal.

²⁸⁰ Author’s interview with “Ronnie” (9/29/2011). He is a senior venture capital manager who has worked in Silicon Valley for more than thirty years.

vendors. These contained strategies are continually looming for the Taiwanese CMs.

What Prevented the CMs from Rebellion, and Normal Innovations

Considering that contract manufacturers usually need to be submissive to a certain degree, the question arises as to why these capable Taiwanese producers do not “rebel” and conduct branding business by themselves or merge into one giant manufacturer in order to have a greater bargaining power against Wintel, Apple, or the traditional large PC-brand companies.

Although the Taiwanese CMs continue to resist complete control from powerful partners through various strategies (for example, increasing the AMD or Google’s platform), the established structure they exist within still renders most anti-mainstream-platform strategies ineffective. As for creating their own brand business, several of them indeed attempted to do so: Wistron was once a part of the company that with the Acer brand, Quanta tried to build its own brand in servers, and CMs such as Pegatron was also a part of Asus (which also aggressively extended their own brand business). The contract manufacturing’s revenue is too substantial to give up, so instead they rather kept both contract manufacturing and brand business, but they separated the two in order to avoid conflict of interest with their brand-name clients. These Taiwanese computer brands have been successful in Taiwan, China, and some other countries at different times, but a long-term and powerful world-class

brand business is in general very difficult for companies from a small island like Taiwan to build. The power of consumer brands is usually connected to the power of a nation. Successful brands are usually associated with a high degree of internationalization as well as global and cultural influence of their countries. For example, in the world's 500 most influential brands in 2011, U.S. companies occupied almost half of them.²⁸¹ Even for large countries such as Russia, Brazil, or India, world-known consumer brands are scarce.

Merging, then, seems a good choice for these CMs. The world's largest electronics contract manufacturing company in the world, Foxconn, which had a consolidated revenue of over 130 billion U.S. dollars in 2013, established strong bargaining power in its components and parts business, but in the laptop or pad-like business, it must compete with Quanta, Compal, Wistron, Pegatron, and so on. Although there have been voices to urge some of the CMs to merge, it has not happened yet, which might be because most of their founders or first-generation entrepreneurs, although closing to the age of retirement, are still in power. They do not want to relinquish the industrial power to their long-term competitors in the same country. They would rather choose to diversify their product composition to include devices such as game consoles, servers, LCD TVs, smart phones, or even to provide cloud computing solutions or build their own component companies, rather than merge with other companies to enhance their bargaining power in the laptop industry. In fact, diversifying their

²⁸¹ The United States had 239 brands in the top 500. France ranked No. 2 with 43 brands and Japan ranked No. 3 with 41 brands. See <http://www.worldbrandlab.com/world/2011/enews.htm>.

products is one important strategy that makes the laptop CMs continue to move forward. Overall, they all avoid completely relying on the thinner profits of the notebook business through internal business transformations, although the larger CMs did not wish to give up the laptop business yet since it still can generate significant revenues.

For now, the Taiwanese CMs seem to prefer the safer path and to not rebel, while resisting minimally and maximizing their proven strengths in their comfort zone. I want to highlight, however, that even though confined and regularized, these Taiwan CMs still strive to innovate and have succeeded in contributing to the global prevalence of the machine within that contained area. I argue that innovation, even in an ever-shrinking zone, is imperative, regardless of proper recognition, for the CMs to maintain their business in a competitive business environment. While others keep innovating, a CM who does not innovate will be unable to survive.

Just as accidents are more normal than imagined,²⁸² so are innovations. Innovations are embedded in the daily practices of CMs. Take the experience of the CM's design managers as an example; they are highly skilled, but are seldom recognized. Wistron's senior notebook R&D manager, "Bruce," argued that most American companies had no ability to design computers by themselves in a timely manner. Because "even R&D has economy of scale," he claimed. Since Wistron would design more than a hundred models of notebooks a

²⁸² The idea of "normal accidents," see Perrow (1984).

year for different clients, the experiences and expertise they accumulated was far greater than any single brand-name firm in the Wintel camp. Through daily practice and effort, it is not difficult to find certain models a year that can be attributed as being innovative to a certain degree.

. Engineering innovations are normal to the CMs, although whether the innovations can generate monetary value is another issue. Indeed, their innovations largely concern details, but details are significant. As Foucault quoted Marshal de Saxe:

“Although those who concern themselves with details are regarded as folk of limited intelligence, it seems to me that this part is essential, because it is the foundation, and it is impossible to erect any building or establish any method without understanding its principles. It is not enough to have a liking for architecture. One must also know stone-cutting” (Saxe, p5, quoted in Foucault, p.139).

Foucault also said,

“...every detail is important since, in the sight of God, no immensity is greater than a detail...” (p. 140).

It is not that marketing, branding, and making product proposals are more “innovative” and with “a larger picture” in nature, so the team members in the brand-name firms should enjoy higher salaries, bonuses, and being thought highly of. Those jobs are, in essence, also about details. It is largely that the market dominance power and the industrial power structure determine the distribution of wealth, as I have discussed in Chapter 3.

Conclusion

In this chapter, I first explore the roles of Taiwanese CMs as mediators within the producer world, as opposed to simply producers with a homogeneous function. In addition to analyzing the characteristics of the middleness of the CMs, I delve into the topic of the specific way in which contract manufacturers were devalued. I reveal the in-between and squeezed zone of the Taiwanese laptop CMs. First, they were enabled, but also gradually standardized, by Wintel and the Wintel ecosystem itself, since potential negative consequences might come not directly from the powerful actors, but from not joining in the Wintel ecosystem. In recent years, Apple also emerged to be the new industrial leader that both enabled and constrained them, though in a different manner. Second, as the CMs' business grew and the notebook market became mature and the profit margin became thin, the containment from powerful brand-name vendors also restricted the CMs' possible innovations within the material world. Not only was the field of the end users blocked by the brands, but also the field of the material-oriented supply chain, their main source of value and innovation in the past, was impeded. That is, the important multiple-sited and trans-organizational field knowledge practice (see Chapter 3) with the various suppliers was partially blocked.

If field knowledge epitomizes knowledge that comes from a more active and expansive force from the CMs themselves, the containment and regularization from the powerful partners in

this chapter, then, represents a negative force. It is the dynamic struggle between the forces that are their major concerns. I will further discuss this struggle in the next chapter, although this time in the wider context of the geopolitics of laptop production.

CHAPTER 5

MOVING FACTORIES TO CHINA: ASSEMBLING (ASSEMBLED) IN CHINA, AND THE GLOBAL CONVEYOR LINES

A year after the Democratic Progressive Party (DPP) became the ruling party of Taiwan in 2000, the Taiwanese government officially lifted the ban on laptop investment in China. This new openness from Taiwan was initiated by multiple factors: in addition to China's open policy after 1978, there were Taiwan's domestic political changes, a global economic recession, further cost reductions sought by the laptop industry, and Taiwan's lack of human and land resources needed for the ever-increasing large-scale production. As early as the 1990s, due to a lack of workers, Taiwanese laptop companies had been importing foreign labor, primarily from several Southeast Asian countries. But after 2000, they decided that rather than importing more foreign laborers, it might be a better option to export their own factories to China. This came at a time of a gold-rush-like enthusiasm to invest in China. In addition, many computer components suppliers, who found they were not banned by the Taiwanese government, had already moved to China. Some laptop firms had even secretly invested in China through a third country. This official lifting of the ban initiated what became a collective movement of laptop factories.

Popular views of factory relocation often assume replication – that a successful factory in one location can be “copied” to another location, or even physically uprooted and moved. But moving factories is not like using a door-to-door moving service that transports everything from an old home to a new one. The process of moving plants and the production of a new manufacturing site is much more complicated. Even when moving to a new home, people do not transport everything with them.

This chapter explores the factory relocation of Taiwanese laptop contract manufacturers (CMs) since 2001. I argue that this factory migration entails multiple transformations. The factory-moving process is far from a simple “cut-and-paste” replication; instead, it is a gradual process intertwined with the social, political, and economic conditions of the movers and their partners, as well as the original and new local environments. During the process of Taiwanese laptop factory relocation, existing factories were disassembled, and groups of people were divided, some of whom were transported to and reestablished in the new place. Furthermore, factory documents and databases were copied and brought to the new location. New elements, such as the incorporation of Chinese workers and new machine technology were added, and the companies, their supply chains, and their customers also needed to adapt to this “geographical” shift, or to be more precise, they reacted to the social-historical-cultural-geographical change. When these human and technology systems relocated and encountered a new local society, a new socio-technical system was created.

The unique focus of this chapter addresses how the relocation of factories changed the technological practices among Taiwanese players and how they re-deployed their knowledge, know-how, human and other resources to work within a very different culture, society, and political system. The crucial question is: did their design-manufacturing practices and relationships to others change in the new location? In what ways did these changes matter?

Disposable Factories? Non-Disposable Contract Manufacturers?

In a study of RCA's seventy-year quest for cheap labor, Cowie (1999) indicates that after the 1920s, RCA's factories frequently moved to domestic locations with higher unemployment rates and weaker labor unions. RCA began hiring lower-wage female laborers as early as 1919. As a result, its later offshore relocations to Mexico and Asia did not come as a shock. In addition, in a journal article written by an industrial consultant, George Stalk,²⁸³ the author introduces the strategy of "the disposable factories" to lower overall costs, reduce capital risk, and to save valuable time getting to market. This strategy can provide a low-risk way of entering and exiting a fast-moving market. He writes that the disposable factory idea is

²⁸³ See Stalk (2008: 19-20). The author explains why disposable factories are important through an example. One large pharmaceutical company had spent large amounts of money and time on building facilities which were highly automated and engineered for low costs from large-scale and flexible production, and although it had superior technology and much more experience, it still lost its position and share of the market to its competitors based in China, who built labor-intensive and short-lived plants.

not new, but it has expanded to more industries. The main principle of the idea is that “the disposable factory is a manufacturing operation that is built as inexpensively as possible with the primary purpose of getting a new product into the market. It is also designed to be easy to shut down if the market demand isn’t what you expect.” In addition to factories, he suggests that the disposable model can be applied to many other aspects of business, including organizational structures, management teams, distribution channels, and even strategies. In this vein of business strategy theory, it seems that the different elements of a company can be easily separated and changed without significantly influencing other elements. But is this so? If some factories seem more disposable (such as in the RCA case), my question is: are laptop contract manufacturers destined to encounter the same fate? Considering the laptop industry, it seems the answer is both yes and no. Yes, these Taiwanese CMs are disposable to some extent. There is nothing new about a brand-name company changing its CM partners in the industry. In recent years, these companies have even used auction models to force their CM partners to bid online. But if we look at Taiwanese CMs as a whole, they have not been so replaceable. The reason is that, although the large brand-name companies switch CM partners, the partners are nearly always from several top Taiwanese laptop companies. Furthermore, large brand-name companies such as HP often distribute projects for different products to different CMs in order to reduce risks of over-condensation. For example, in recent years, HP has been a customer of Quanta, Compal, and Wistron.

In other words, producers from Taiwan became an “obligatory passage point” between the US and China.²⁸⁴ In 2001, around 50% of laptops worldwide were made in Taiwan. By 2005, however, Taiwan’s open industrial policy of investing in China allowed the growth of 80% of laptops worldwide to be made in China. Nevertheless, these Chinese factories were under Taiwanese control and ownership, and many design and engineering jobs were still kept in Taiwan. In addition, US brand-name companies did not find manufacturing partners in China by themselves, but instead had Taiwanese CMs perform the intermediary work. In what follows, I argue that, at the current stage, Taiwanese CMs are less disposable because they are not just factories of low-skill assembly-line workers; the design, engineering, managerial, and integrating capabilities that CMs contribute are also of significant value. These CMs cannot be easily disposed of.

Although factory relocation involves the transfer of technology, this chapter will not focus on the process and difficulties involved in replicating certain technologies of notebooks to China, but will focus instead mainly on how the socio-technical practices changed when the factories relocated, and on how the Taiwanese laptop firms prevented the spillover of knowledge and know-how to Chinese employees. If the ease or difficulty of technology replication initially seems insignificant, this may be due to the fact that the relocation was an inter-organizational rather than an intra-organizational event. The Taiwanese government

²⁸⁴ “Obligatory passage point” is Callon’s term. See Callon (1986).

and Taiwanese companies have complex concerns related to spillovers of technology or industrial ability (Blomström & Kokko 1998). They are afraid of losing industrial competitiveness, should Chinese employees or local Chinese companies acquire their abilities and technology. Spillovers of technology or knowledge in the industry are common among Taiwanese companies. The nation is small, and companies often hire each other's former employees. However, since the new locality was in China, which has a unique historical and political relationship with Taiwan, things became different. In a later section of this chapter, I will discuss the Taiwanese effort to maintain their established knowledge hierarchy between Taiwanese headquarters and Chinese subsidiaries.

In this chapter, I will reveal that the relocation process was not only about factory relocation, or simply "transferring" or "diffusing" technology. Many elements from design to manufacturing were disintegrated, displaced, and re-assembled. Moving factories provides an opportunity to re-deploy knowledge, technology, people, and their practices. Not all parts of a factory can be moved or replaced at the new site. Even if some parts of a factory, such as inexpensive equipment and low-skill workers are treated as more disposable and replaceable than others, there are other parts of the factory that might require more consideration. In this fast-changing laptop industry, I argue, engineers and managers are significant carriers of knowledge, and as a result they must be moved. I argue the field knowledge of these engineers can explain this phenomenon.

For the past two decades, the deployment of people and technology in the CMs has evolved due to the incessant shift of technology in the industry as a whole. However, the CMs' documentation of knowledge has not been able to catch up with the quick pace of the industry and these technological changes, causing many experienced people to become crucial carriers of knowledge and know-how that are important for their companies' ability to compete. As a result, the engineers and managers have become the most "non-disposable" parts of the CMs' factory relocation process. Important knowledge will be absent in new factories, creating a void, if these people do not move with them.

To briefly recap, field knowledge is an engineering-managerial practice and process that helps people to gather information or generate useful knowledge from their multiple-sited and trans-organizational field to enhance their design and manufacturing work, with an understanding of their own industrial status (see Chapter 2 for details). It requires certain CM employees to constantly communicate with partners and to frequently travel outside their regular working circles. This was the case for a retired factory head manager of Quanta "Yao," who visited hundreds of factories and learned improved methods of production. His story shows that acquiring field knowledge is a process, rather than static content. As a result, the impact of the factory relocation on the movement of the CM employees and the formation of new collaborative relationships and new practices among groups of people are crucial.

In this chapter, the foreign (Taiwanese) engineers who are present in China are

primarily divided into two types: those who live in China, and those who travel to China frequently. The former requires more rootedness, but the latter requires more mobility. These engineer-manager-travelers have to “flow” or circulate, communicating, mediating, and integrating knowledge from different fields among sites. This chapter will exemplify my concept of field knowledge by examining the changes after factory relocation. I will use the travelling engineers and managers, in particular, as the main example to present the idea of field knowledge. These travelling employees are themselves information collectors, data evaluators, and knowledge integrators who can correlate and produce useful integrated knowledge based on the information from their fields that come from multiple sites.²⁸⁵ But politics, struggle, and resistance over people’s relocation and new division of labor exist as well.

Finally, I also argue that laptop factories are important sites for knowledge production. Such factories are not just places for assembly workers; they also include R&D people and factory engineers who meet and work with the material. In the making of laptop computers: the intense face-to-face interaction and constant collaboration among different groups of people surrounding the production line and the machines in the factory is crucial: they offer

²⁸⁵ This is not to say that the immigrant engineers/managers (who belong to the factories) are not field knowledge practitioners. For example, although they do not frequently move between Taiwan and China, or between their own company and components’ companies as the design teams do, they do move among different factories, and when design people come to their factories to collaborate, the factory engineers and managers will also absorb copious information and ideas from the design teams. Therefore, their knowledge also involves information from different organizations and multiple sites.

the opportunity to produce multiple revisions and thus assure the best possible product.

To explore the changes brought about by the movement of factories from Taiwan to Mainland China, I organized my findings into three levels of analysis: zones/places, relocated workers and the production lines, and travelling and immigrant engineers. There are dramatic changes in each of these elements, and each of them shows the struggle between flows and rootedness. In the analysis of multiple modes of (im)mobility, I consider how these changes influenced the knowledge production and practices of the Taiwanese engineers and managers.

I. Zones and Mobile Clustering

Laptops are a globalized commodity, but one of the most intriguing points about their production is the geographical clustering of the manufacturing base. The global market for laptops increased to almost one hundred million units in 2007.²⁸⁶ Their manufacture has become highly consolidated since the mid-1990s, when it shifted from Europe, the US, and Japan to Taiwan. By 2000, production was primarily controlled by only a few big laptop companies, whose factories were located in a district in northern Taiwan. This geographical clustering continued even while factories were moving from Taiwan to China, as Barry Lam, the main founder of Quanta Computer, the largest laptop producer, noted:

²⁸⁶ Statistics from the research reports of Taiwan's Market Intelligence and Consulting Institute (Chinese).

“Let me tell you a story. There used to be a lot of tech companies on Nanjing East Road in Taipei. Nanjing East Road used to be the electronic factory road. We, manufacturers, all competed with each other along that street. Later, we moved to Taoyuan (a suburb of Taipei) to compete again... And then the competition continued in Eastern China. Now, we are going to Chongqing to compete instead. Businesses in this industry seem to be competing constantly in different locations, like how the martial arts masters have their sword fights, from one mountain to another. The sword fight happened every year to determine the ultimate master of kung fu (Chinese martial arts).”²⁸⁷

As Lam highlighted, when Taiwanese producers began moving factories to China in 2001, the companies all chose the geographical area near Shanghai, the most modernized city in China. In 2010, the migration route of the mobile clustering of the manufacturing base continued upstream along the Yangtze River, from coastal areas to the inland greater Chongqing area (Chongqing and Chengdu: the distance between the two cities is only about 300 kilometers). This was their second collective move within a decade, although whether the production scale of the greater Chongqing area will surpass that of the greater Shanghai region is not yet clear. The mobile clustering of laptop production sites occurred for complex socio-economical-political reasons, some of which I will discuss in the sections that follow.

Social Production of Space: Emplacement or Mobility?

The collective move of laptop plants resulted in part from the creation of special economic zones (SEZs) in China. SEZs are specifically constructed spaces in which the role

²⁸⁷ From the Taiwanese IT pioneer oral history collected by Computer History Museum (CHM, Mountain View, CA). Interviews with Barry Lam. CHM Reference number: X6260.2012.

of the state is designed to seem invisible, with the exception of providing infrastructure and services for the purpose of nurturing economic development, thus minimizing the tax and regulatory burden on companies. There are at least nineteen terms, such as free trade zones, industrial free zones, special processing zones, and tax free zones, which are used to indicate similar kinds of spaces.²⁸⁸ Although there are some discrepancies among these zones in different countries and time periods, they share the features stated above.²⁸⁹

It is clear that these industrial zones are a special product of a modern state. According to Henri Lefebvre (2009), space is a “social product” and a “historical product” (p. 171), as well as a political product. For Lefebvre, space is not objective and neutral, but rather it is “produced” (from “production in space” to “production of space”) to meet the requirements of the power center, which is controlled by capitalists in many contemporary societies. Lefebvre observes further that many modern states produce specific spaces that can maintain and facilitate the survival and reproduction of capitalism; he considers them to be capitalist spaces. One of his core ideas about spatial theory is the spatialization of production and production activities. Lefebvre indicates that the concept of space is absent from Marx’s works. In Marx, there is a void between the relations of production and the modes of production. For Lefebvre, “space” will be one of the solutions to solve this missing link

²⁸⁸ See Hsu (1991: 8).

²⁸⁹ See Amirahmade and Wu (1995). One example of the definition of the EPZ is: “an industrial enclave that engages in export manufacturing with the assistance of foreign investment and enjoys preferential treatment that is not generally available in the rest of the country” (1995: 828).

between the two, since there exist not only abstract mediations, such as laws, but also concrete mediations, like space, between the base and the superstructure (pp. 211-217). When these social relations are crystallized in space, the social space is then created. Space itself is also “a means of production” that reproduces or reinforces social relations (pp. 188-189).

Lefebvre’s Marxist attention is paid to the relationship of the state and capitalism and the impact of that relationship on the production of space. But other scholars have tried to avoid a homogeneous top-down perspective when considering how space is shaped.²⁹⁰ Michel de Certeau (1984) proposes a “tactic” to look at space by “walking in the streets” rather than seeing it like a voyeur from above. But de Certeau’s perspective seems to be static and lacks a time dimension. The notion of “Walkers” may be applicable. They can have both a rationalized map in mind (a perspective from above) and a close-experience within the streets, and their interpretations of space can change over time. To account for this problem, it is helpful to add the “space-time” concept introduced by Doreen Massey (2005). She argues that any geographic explanation has to be historical. Historical struggles over gender, class, race, politics, and economic development often lie within a particular local spatial configuration.

²⁹⁰ Such as Craib (2004) and de Certeau. Craib discloses the formation process of mapmaking in the modern Mexican state through exploring the cartographic routines and the intermediary roles of surveyors and mapmakers.

In addition to these theories of special significance, a given space seldom exists without connections with other spaces and is not limited to geographic space. Manuel Castells (1992 & 2000) proposes the idea of “the space of flows” that reconceptualizes a new type of space characteristics of different flows of social practice: a flow of information, a flow of images and sounds, a flow of technology, a flow of people and capital, and a flow of organizational interactions. By flows, he means purposeful and repetitive exchange between geographically unconnected positions.

Even when social space is full of flows, as Castells himself highlights, the space of flows is never placeless. Thomas Gieryn (2000) stresses the idea of “emplacement” and promotes place-sensitive analyses for sociologists in his extensive review of theories about space. Place has physicality, and it is interpreted, narrated, and invested with meanings and values. He argues that we need to *emplace* difference, hierarchy, power, interaction, community, identity, and so forth. Place brings people together in bodily co-presence, but there are two possibilities: “engagement” or “estrangement”²⁹¹: engagement can be built into a space by designing facilities to maximize chance interactions; estrangement can also be built by establishing special spaces such as enclaves.

Drawing on these relationships between people and space, the present study aims to uncover how different levels of socio-economic-political elements have intertwined with the

²⁹¹ The terms are used by Sennett, 1990. Cited in Gieryn (2000: 476). Other materials are from pp.476-478 of Gieryn, 2000.

calculated interests of Taiwanese laptop producers regarding when they chose to move, where to move to, and what should and should not be moved during the transitional process of relocating production sites. That is, the struggle between emplacement and mobility and the way in which the struggle intersects with the actors' knowledge and practices will be a central focus of the chapter.

Special "Economic" Zones

The model of export processing zones (EPZs)²⁹² has been important for the economic development of Asian countries since the 1960s.²⁹³ In 1966, Taiwan established its first EPZ in Kaohsiung, in southern Taiwan,²⁹⁴ and South Korea followed suit in 1970 by building its Masan EPZ. Later, more and more Asian countries adopted similar strategies.

The major move of China in the late 1970s to establish four special economic zones (SEZs) in its southern coastal areas (as a laboratory for testing the transformation from a socialist state to including market-driven logic in its quest for development) further enlarged the influence of these special zones on Asia's economic development as a whole. Although

²⁹² I use the term export processing zone in a broader sense, to refer to export-oriented production zones, as compared with using it merely to refer to the assembly or processing of goods for foreign companies.

²⁹³ See, for example, Amirahmade and Wu, 1995.

²⁹⁴ In a brochure from the Taiwanese government, "The export processing zone of the Republic of China: Reviewing the past and mapping out the future" (1996, by Ministry of Economic Affairs, p. 4), the government claims that its EPZ is the only such zone in the world, since before Taiwan's EPZ, there were only free trade zones and industrial zones in the world. EPZs differ from the free trade zone and industrial zones, and are claimed to combine the strengths of two earlier models of zones.

the numbers and origins of special industry zones vary,²⁹⁵ there is little dispute that Asia has the largest number of EPZs (80 out of 200 EPZs in the world in 1995), and they are actively utilized. These zones are important because they are emblems of economic success and key policy tools for these developing or undeveloped countries' political efforts to pursue their development ideals. The thriving of these zones influences and changes the global economic activities and division of labor, since these special spaces facilitate the consolidation of many large-scale production activities in those regions.

Officially, Asian countries have seldom referred to their economic zone models as imitations of earlier adopters of similar models. However, it is clear that all models share some common features, such as offering special infrastructures, lower taxes, and other preferential treatments for attracting foreign investors. This is especially true for the industries involving mass volume production for global markets, in order for them to effectively establish their economic development momentum of the zone.

While the comparisons and discrepancies among different models of zoning have been studied, many studies tend to limit their focus to the analysis of policies, institutions, organizations, management, and so forth.²⁹⁶ That is, the unit of analysis for these studies is

²⁹⁵ For example, Amirahmade and Wu argue that Shannon Industrial Estate was the first such zone, which was opened in Ireland in 1959, and that the Kandla EPZ was the first Asian zone built by the Indian government in 1965. But another book argues that Italy had the first special economic zone in 1547, and there were 75 special economic zones in 26 countries or regions before WWII; see Tao and Lu (2008).

²⁹⁶ See, for example, Amirahmade and Wu (1995), and Basile and Germidis (1984).

the “structures” from the state or local governments imposed on zone participants. However, by adopting the method of “following the actors” (Latour 2005) who have participated in at least one of these zones, my research on Taiwanese laptop producers focuses on a different perspective: to see what the producers saw, what challenges they met, and how they resisted or solved problems during the process of moving their production sites from one geographical space to another. Special attention will be paid to whether certain parts of their businesses were easier to transport across space, or to reproduce far away, and why these features were “sticky.”²⁹⁷

Taiwan’s Export Processing Zones

After the great success of the export processing zone (EPZ) model, different EPZs, or industrial parks, were created in Taiwan, including the high-tech-oriented Hsinchu Science Park, which was established in 1980. Furthermore, every local government in Taiwan could also build its own industrial parks with their own special incentives, in addition to the established nation-wide tax holidays and exemptions (followed by preferential income tax rates) or special treatment for high-tech industries. Therefore, the earlier model of EPZ flowered everywhere in Taiwan after the 1970s, and the industrial players became accustomed to the environments of science and industrial parks. Almost all the big players in the Taiwan laptop industry were located

²⁹⁷ “Sticky” is common term used to describe how knowledge that is more tacit than explicit is harder to move – it will tend to remain stuck in its original place.

in the region between the capital Taipei and Hsinchu, a distance of less than one hundred kilometers. More importantly, a strong cluster of computer parts and components manufacturers also gathered in the same region and offered a great support network for quickly and cheaply producing laptops in Taiwan. This supply chain clustering has been regarded as a key to the success of laptop production in Taiwan.

China's Special Economic Zones

These manufacturers had other neighboring nations in Southeast Asia to choose from, where many Taiwanese companies had gone to invest in the past. Whether to “go south” (to Southeast Asia) or to “go west” (to China) was actually a long-term policy debate in the Taiwanese government at that time, but as some earlier investments in Southeast Asia were not effective, and the rise of China was so apparent at the turn of the new century, there was a gold rush-like atmosphere to invest in China. So, for many Taiwanese firms, the decision to make China the main expansion site seemed relatively clear.



Figure 5.1

Kunshan Processing Zone in Jiangsu, China, 7/2012 (Photo: By Ling-Fei Lin).

The question then became where to move within China? This question led to the consideration of China's overall policies on regional development. After the Open Policy was affirmed, Chinese government officials actively visited twenty countries and fifty different economic zones in 1978. Taiwan was not among the places visited, given the existing tension between the two regions. In 1979, the first four "special economic zones" were established in the southern coastal area (the Pearl River Delta) of China, due to its proximity to Hong Kong. Hong Kong was economically thriving and was attractive for foreign investment, but the cost of land and labor had also been increasing. Given these conditions, China's government anticipated that

the Pearl River Delta could be a more attractive site for investment.²⁹⁸

Economically, the initiatives of special economic zones (SEZs) in the southern coastal areas (i.e., the Pearl River Delta) were successful, but by 2001, China had already shifted the focus of its regional development from the southern to the eastern coastal area, especially the greater Shanghai region. Attracted by the low tax rates and other incentives offered by the local governments, by still relatively cheap land and labor, and by its convenience for both export and domestic businesses, as well as by Shanghai's potential for being a "global city" (Sassen 2001), Taiwanese merchants began to trickle in. The largest laptop producer in the world, Quanta, chose Shanghai (Songjian District); the second largest, Compal, chose Kunshan, a city that is only about 40 miles away from Shanghai City; Wistron and Inventec, the other two of the top four players, also chose Kunshan and Shanghai respectively. Within a few years, almost all laptop factories that had been located in northern Taiwan relocated to the Greater Shanghai Region.

These laptop manufacturers were by no means the first Taiwanese companies to move their production bases to China. As early as the late 1980s, apparel, sports shoes, and other computer parts companies began establishing factories in China. These types of products were not on the list of national controls of Taiwan, and China was greatly encouraging the development of its southern coastal region. But unlike earlier Taiwanese

²⁹⁸ See Tao and Lu (ed.), 2008, Chapter 1.

firms that tended to cluster in southern China, Taiwanese laptop players made a clear choice regarding the new plant location at the turn of the twenty-first century. The choice of their manufacturing sites, therefore, seems to show a strong influence from the state of China.



Figure 5.2

Before. Quanta, Shanghai. It was still farmland in 2000, (Courtesy of Quanta).



Figure 5.3

After. A view near the F1 factory of Quanta, Shanghai, 7/2012 (by Ling-Fei Lin).

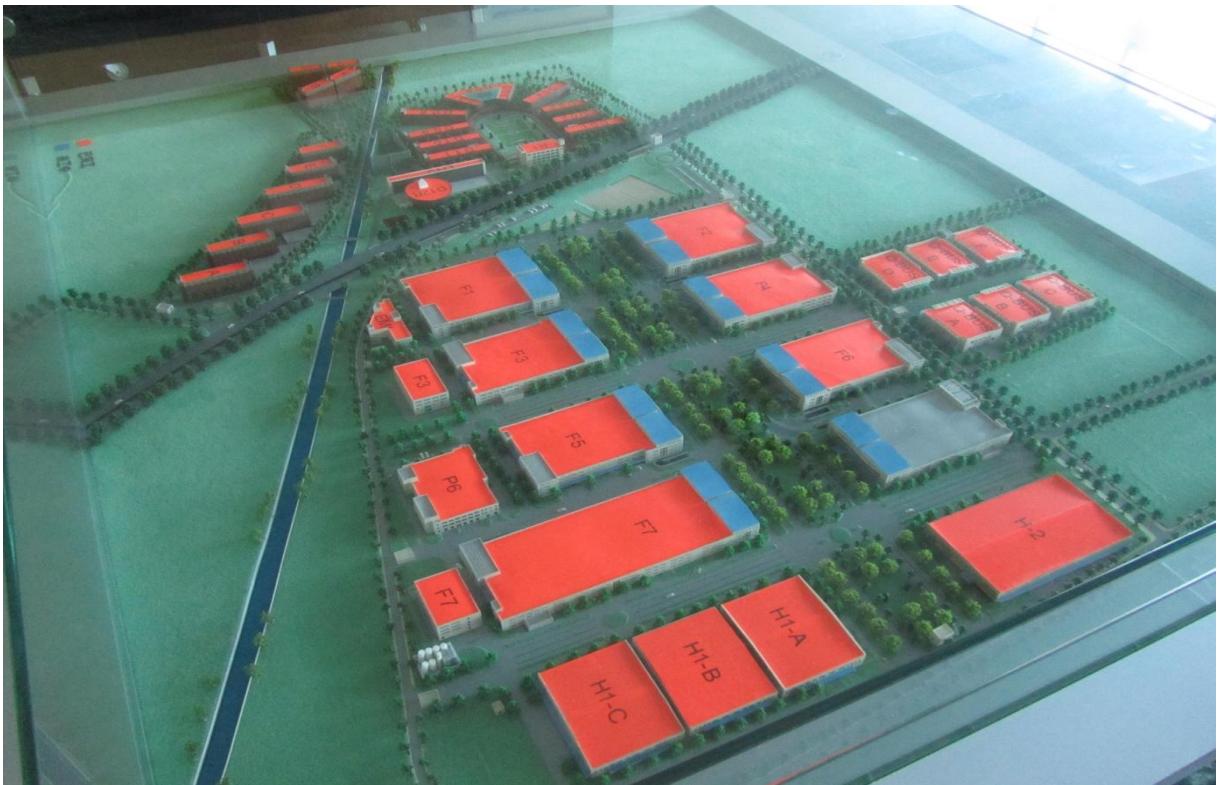


Figure 5.4

A model of Quanta Shanghai, 7/2012 (by Ling-Fei Lin).

The Enlarging Scale and Overcapacity

For the past decade, the global production of laptops has been highly concentrated, with only a few big producers, and with their production facilities in close geographical proximity. Both trends helped produce huge modern factory bases. In Quanta Shanghai, there were huge factories, and they produced laptops for many well-known brands (see Figure 5.4): in 2012, the F1 factory was for Dell; F2 was for Amazon and Toshiba; F6 was for Sony, NEC, and Lenovo; F4, F5, and F7 were all for Apple's notebooks. The huge F7 is almost equal in size to the four other plants combined. It is clear that Apple occupied much of Quanta's capacity at the base. Another big customer, Hewlett Packard, has already moved to Quanta's Chongqing base; when I was there in the summer of 2012, Acer and Asus were also moving to Chongqing. The plants marked Q-Bus are producing other types of products such as GPSs and LCD TVs, and the H-buildings are the warehouses for components and parts.

The top part of Figure 5.4 shows the living areas: the dormitories and campus for operators and other employees, and the dormitories for Taiwanese managers and engineers. There were about 80,000 employees in Quanta Shanghai in 2012, including several thousand Chinese engineers and more than three hundred engineers and managers from Taiwan. This single Quanta Shanghai base produced 54 million laptops in 2011, which was about 27% of the total shipment worldwide that year, not yet including its production at Chongqing. There is a special living area for the Taiwanese (the round building in Figure 5-4).

It is for the engineers and managers who travel from Taiwan to China, and a nearby building is a dormitory for the Taiwanese employees who moved and reside there long-term (although some chose to buy their own houses in other places). The round building has a large restaurant that is dedicated to Taiwanese food. It inevitably generates patterns of exclusion and segregation, which reproduce class distinctions and hierarchies in the living areas.

A massive scale of globalized production significantly differs from that of a smaller-scale laboratory or a factory. With the ample supply of land and labor, and the economy of scale, the production of these laptop companies achieved global dominance. In the year 2000, in Taiwan, each of the big four players could produce only a few million laptops a year, but in 2010, the production by each of them was between twenty to fifty million units annually.²⁹⁹ The relocation helped to further the consolidation of worldwide orders from big brand-names into Taiwanese hands. On a scale as large as Taiwan's laptop industry had become, a tiny difference in the process of product development and production could lead to a large discrepancy. The scale-sensitive knowledge becomes crucial because it involves not only different requirements of production equipment and arrangement, but also the management of workers and materials, and the practices that make up the design-manufacturing (D-M) process and the global logistics.

To a certain degree, the technology and knowledge involved in large-scale mass

²⁹⁹ Quanta, Compal, Wistron, and Inventec's public annual reports from their company websites.

production depends upon a complex social system. There are ever-changing social negotiations happening between different groups inside the company, between managers and workers, between the producers and their component suppliers, and between the producers and their customers. The knowledge of scale needs to accommodate to the entire scale of social knowledge. That is, in order to work smoothly, inclusive data of all the relations between human and material components are required.

Due to this unique spatial scale, the Taiwanese players had to redesign the factory layouts, rather than just replicating the spatial arrangement in the Taiwanese plants on a larger scale. "In China, you can easily get a factory plant that is one hundred meters by two hundred meters. This was not possible in Taiwan."³⁰⁰ Accordingly, designers could now freely plan the buildings based on their production traffic flows, and were no longer constrained by the outer physical space as in Taiwan.

Besides adapting to freer and larger physical spaces for production, the numbers of operators also needed to be taken into account on a larger scale. In Shanghai alone, Quanta had 80,000 employees. In Kunshan, Wistron and Compal each had tens of thousands of employees, as compared to the largest numbers in Taiwan of only a few thousands. In China, because many of their workers came from the rural and interior areas, the laptop companies would offer dormitories to accommodate them, and would also contend with various problems

³⁰⁰ *ibid.*

arising from the diverse cultural backgrounds of the workers. But because the worker composition was very different in the Chinese context from that of Taiwan, different understanding and knowledge were required to collaborate with the workers.

The growth and scale of buildings and people resulted in new burdens and problems. With cheap labor and land, all the major players kept expanding their Chinese factories in the first few years, which generated overcapacity and then low profit margins for the CMs. Roger Huang, a senior manager from Quanta said in a satirical tone:

“Then (people) even accepted an order which was lower than the cost of BOM [bill of material, meaning that they accepted an order whose price was lower than their material cost, not to mention overhead or other costs] ... it [overcapacity] was very clear in our clients’ eyes....It was silly that we invited them to visit our new plants. [Because] We were proud of our new plants”³⁰¹

Their race of factory production capacity in China indeed led to possible larger product orders, but unfortunately also exposed the weakness that they were so eager to gain orders that there was room for brand-name firms to further cut their prices for the manufacturers.

Satellite Suppliers and Mobile Clustering

As mentioned earlier, one of the most intriguing points in the relocation of production lines to China is their geographical clustering. This clustering is not limited to only the laptop

³⁰¹ Author’s interview with Roger Huang (12/31/2010).

system assembly firms such as Quanta and Wistron, but also includes most of their suppliers who need to move with them. The supply chains joined in the move either earlier or later than their main system customers such as Quanta. Many suppliers had already gone to China a little earlier, but Quanta brought another group of twenty-three vendors with it to its Shanghai base.

The clustering of comprehensive components and parts suppliers in Taiwan was regarded as a key factor in enabling Taiwanese laptop players to flourish. By the mid-1990s, except for key components such as microprocessors and hard-drive disks, Taiwanese laptop producers could source almost all other laptop parts and components from Taiwan itself. These suppliers were mostly small and medium enterprises, but they formed an important flexible network to support the computer industry in Taiwan and elsewhere in the world. As David Harvey (1990) explains, the small and medium Asian enterprises helped transform the production world from the standard mass production of Fordism to flexible accumulation. These small and medium businesses of the supply chain in Taiwan not only worked hard, but also offered timely and very flexible support and adjustment for their system customers for the longer term,³⁰² so it was hard for laptop system producers to move to China without them.

When partially replicating the material conditions in China, Taiwanese laptop producers also

³⁰² For example, one interviewee, “Bruce” from Wistron (04/16/2010), described how these SMEs were so flexible that they could come up with extra components in a very timely fashion, even before a formal contract was completed. Since both parties had long-term relations with each other, they always trusted each other. This was very different from doing business with firms like those from Japan and the USA, where a formal contract was always the first prerequisite.

wanted to replicate the social and economic relations of Taiwan whenever possible. Although there was already another cluster of component suppliers gathering in the southern coastal area (the Pearl River Delta) in the 1990s, it was mainly for desktop computers. The supply chain of laptop computers thrived later in the eastern coastal area (the Yangtze River Delta, or the greater Shanghai region) when their big customers moved there at the turn of the twenty-first century. These SMEs formed a satellite-like cluster surrounding the major Taiwanese laptop makers in the greater Shanghai region.

I refer to this collective movement as “mobile clustering.” On one level, although they change their locations, they still mostly aggregate together. But on another level, although they aggregate together, there is a question of whether the clustering stays the same. For Taiwanese laptop producers, the new geographical clustering seemed to have changed their design-manufacturing practices and the knowledge associated with those practices. Also, the collective migration was not a quick and clear-cut process, but rather a gradual and even elongated one. For example, Compal began to move their laptop factories to eastern China at the turn of the new century, but its last laptop production line in Taiwan was not closed until 2008.³⁰³ Wistron’s final move from Taiwan also occurred as late as 2005, and then in 2009 and 2010, all the major laptops firms had begun to move from the Yangtze Delta to the next destination in inland China. This process of institution-building across borders is not simple. Clearly, there is a struggle between emplacement and mobility, and in my notion of mobile clustering, instead of treating geography or place as unimportant, they matter a great deal.

³⁰³ Author’s interview with “Eli” (12/4/2011). He was a senior manager at Compal. He said it took 4 to 5 years for Compal to move all production lines to China, but “Howard” (7/18/2012), a factory engineer said he went to China in 2008 after their Pingzhen factory was closed, which was 7 years after the first move.

II. Relocated Workers and the Moving “Line”

After choosing location sites, the Taiwanese laptop producers did not transfer all they had in Taiwan with them to China. They moved part of their capital, and some of their machines, factory engineers, factory managers, and suppliers, but not their workers, older machines, or R&D team. There were different reasons behind these actions; some were for cost-saving, some were for know-how, and some were for accessibility to sources. As a result, different elements of their factories were moved differently.

In this section about the factory sites, it should be noted that this study does not aim to voice workers opinions and reveal workers' conditions as workers themselves might observe. This section, instead, addresses the relations between the material configuration and the factory workers and the way in which the Taiwanese engineers and managers envisioned and built their new factory sites. This section analyzes the boundaries between the workers and the objects, which can partially reveal what sort of knowledge and practices were designed by engineers and managers to efficiently realize the formation of a technological system.

The Taiwanese laptop companies did not move factory workers to China. In fact, the opportunity to exploit the vast supply of inexpensive and flexible labor in China was the major attraction for many foreign companies. Apple executives have been quoted as saying that going overseas, at this point, was their only option. One executive described how the

company relied upon a Chinese factory to revamp iPhone manufacturing just weeks before the device was due on shelves. Apple had redesigned the iPhone's screen at the last minute, forcing an assembly line overhaul. New screens began arriving at the plant near midnight. According to an executive, a foreman immediately roused 8,000 workers inside the company's dormitories. Each employee was given a biscuit and a cup of tea, guided to a workstation, and within half an hour started a 12-hour shift, fitting glass screens into beveled frames. Within 96 hours, the plant was producing over 10,000 iPhones per day. "The speed and flexibility is breathtaking," the executive said. "There's no American plant that can match that."³⁰⁴

Indeed, the "flexibility" (and docility or obedience) of Chinese workers is astonishing. The factory workers in China themselves are domestic migrants. They are also mobile workers, though not constantly. They often migrate from the countryside in neighboring provinces or economically weak regions of inland China. Therefore, it makes sense that their employers provide dorms for them. While they could also choose to rent a house and live outside the factory site, living in the dorms is usually much cheaper as it is one of the "welfare" measures that the employers provide. Therefore, most of Quanta's factory operators (called "OPs" in their factories) live in the dormitories provided by the company near the factories. They have college-campus-like living areas. Figure 5.5 (in 2012) shows a nice football field

³⁰⁴ New York Times, 1/21/2012.

around the dormitories. They had 80,000 employees who shared the campus.



Figure 5.5

Quanta Shanghai, living areas and campus for workers and other employees, 7/2012 (by Ling-Fei Lin).

Figure 5.6 is a picture taken during a shift change at night by the main gate of the processing zone that the workers to go through. It was very crowded, and various street vendors were trying to sell their food or wares to passing workers who were walking to Quanta's main dorm areas, just on the other side of the main gate of the processing zone.



Figure 5.6

Quanta Shanghai, the economic zone's main gate for workers, 7/2012 (by Ling-Fei Lin).



Figure 5.7

Workers swiping ID cards when going in or out of the dorm, 7/2012 (by Ling-Fei Lin).

Figure 5.8 shows one of the women's dormitories. Most workers were in their late teens or early twenties, so there were many young couples dating on the campus. Also, there were different club activities, such as the dancing club and the Judo club. When this photograph was taken, many boys were playing basketball in another corner.



Figure 5.8

One of the girl's dormitories in Quanta Shanghai, 7/2012 (by Ling-Fei Lin).

These workers seldom come from the local area. Most of them migrate from nearby provinces such as Anhui and Hebei, but it has become harder to find a sufficient number of

workers. As a result, the factories have recruited young men and women from areas further inland in China, such as Sichuan and Shangxi.³⁰⁵ They are temporarily relocated workers (*mingong* or *nongminggon*). The rigid household registry system in China, which limits most farmers' free migration, and is based on its population policy, made it difficult for workers to become permanent local residents in the coastal areas. As local outsiders, migrant workers have few resources, and cannot enjoy the social welfare offered for residents. Most workers are in their twenties, although some could be as young as sixteen. They came to the industrial cities to experience the city life and earn some money. They can switch to other factories when they find better terms in other companies. But a few years later, they usually go back to their hometowns to get married and run a small local business.³⁰⁶ For example, "Joy" said she came to the laptop company partially because Shanghai was such a prosperous place, young people should come to see it, but finally she would still go back to her hometown if there was no better development there.

Joy: My own plan is to go back to (her hometown)³⁰⁷ after I am 22. After 22, I don't want to stay away.

Author: But you are already 20 now. Why did you set the time at 22 years old?

Joy: because I have been out of my hometown since I was young. After 22, I want to stay at home. Unless you can find achievement in another place, and then if I haven't achieved anything, I would rather choose to go home to find

³⁰⁵ Author's interview with "Eli" (12/4/2011).

³⁰⁶ Author's interview with factory workers "Kang" and "Joy" from Quanta (7/24/2013).

³⁰⁷ Interview with "Joy" (7/24/2014), pp.6-7. For protecting her personal information, I omit her hometown because it might cause easy to identify who she is.

jobs.

Author: then do you find any sense of achievement here?

Joy: here?

Author: yes, maybe you will be promoted before 22.

Joy: I do have that expectation. But I don't know if this place can assimilate me.³⁰⁸

Inside a laptop factory, there are two main types of production lines: the first is for motherboards, the surface mount technology line, which was called the SMT line and which has been highly automated since Taiwan entered the laptop business. The SMT machines are the most expensive equipment in laptop factories. They help “mount” thousands of small components, including integrated circuits, onto the motherboard. The SMT lines also need workers to monitor the machines and do various jobs, but as they are highly automated, they require relatively few workers.

The second line is the final product assembly line, which is labor-intensive and also is the focus of many outsiders who are concerned about the working conditions in Chinese factories. I visited three companies' factories in the summer of 2012, but I was not allowed to take any pictures of their production lines, so instead, a picture from Quanta in 2007 is shown here (Figure 5.9). It should be noted that their factory layout and arrangement is not stable at all because managers always keep improving and changing it. “Christopher” told me in a follow-up interview over Skype phone in April 2013 that their factories had changed after my

³⁰⁸ Ibid.

visit in summer 2012.³⁰⁹



Figure 5.9

Operators and part of the “run-in carousel” system in Quanta, Shanghai, 2007. The run-in carousel refers to the moving plate carrying three rows/levels of laptops up in front of the workers (Courtesy of Quanta).

³⁰⁹ Author’s phone interview with “Christopher” (4/16/2013).

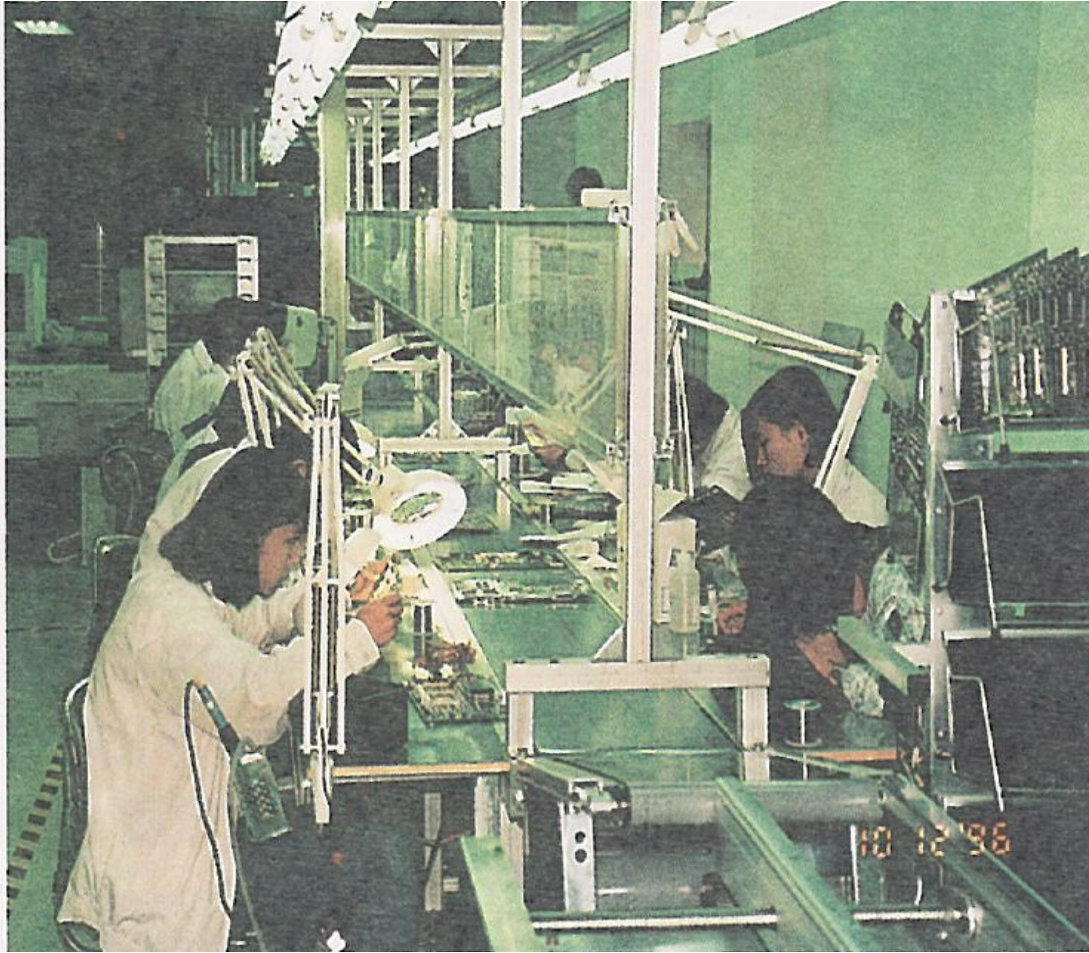


Figure 5.10

Quanta's early factory in Taiwan in 1996 (Source: *Quanta's*, December 1998, p.35).

The Conveyor Line as a Calculating Boundary: Manipulating Workers, Space, Time, and Material

Conveyor lines represent the rational calculation and facilitate the efficiency that a modern production system needs. In 1913, the Ford Motor Company introduced its first moving assembly lines based on Chicago's "disassembly" lines in slaughterhouses (where the workers cut out different parts of cows or pigs at different stations) and on the conveyor

systems in milling, brewing, and canning factories.³¹⁰ Today, conveyor lines are seen everywhere in our society: in airports for reclaiming luggage and moving passengers on automated sidewalks, in stores at check-out counters, in ski resorts for transporting skiers up the slopes, and in sushi bars for delivering food to customers. These lines are examples of an automated transportation and distribution tool that is widely used in warehouse, wholesale, transportation, manufacturing, and retail sectors. We can see their operations in production, distribution, and consumption.

One common feature of the conveyor lines is moving things or people from one point to another, that is, making a shift in location, but a different feature in factory assembly lines also concerns the time dimension. One possible interpretation of the assembly line is that it is a time calculator. The operators need to readjust themselves to get “into the flow” and are supposed to maintain the continuity between the global production and consumption systems. The three factories I visited in 2012 had different designs for their final assembly and packaging lines. Wistron asked their operators to stand, while the workers in the other two companies were seated. Also, while Quanta and Compal both used conveyor belts, Wistron did not use them. Instead, Wistron adopted a similar system called “flip flow,” in which each table plate in front of a worker would keep still for about 20 seconds, and then suddenly, the under roller would flip, creating a temporary flow for the product to be sent to the next station

³¹⁰ See Hounshell (1984: 241), and Chapter 6 on the Ford Motor Company.

or next person. A factory manager of Wistron explained that the line would be shaky if it kept moving, so the flip-flow line had the advantage of stability when workers were assembling products.³¹¹

There is no set agreement about using the more stable flip-flow system or using the continuous flow of a conveyor belt. A Compal factory manager told me that the traditional conveyor belt might make novice operators *linesick* (like carsick or seasick), since many things were moving in front of them. The novice then would have to gradually adapt to the line speed either by training at an initially slowed-down speed or just by observing the conveyor line.³¹² In these final assembly lines, they typically had several tens to more than one hundred of operators in each line, who were responsible for assembling, testing, checking, and packaging. A product would be materially born after flowing from one end of the belt to the other.

The line speeds varied for different phases and products. In Quanta, if it was a pilot run, the speed could be as slow as around 30 seconds, but if it was in the mass production phase, and for standard notebooks, the line speed was usually 12 seconds. That is, a worker needed to finish the assigned job in 12 seconds when the product was moving in front of him/her (i.e., from a worker's left-hand side to the right-hand side, it would take 12 seconds). The direction can also be from the right to the left-hand side, but according to calculations,

³¹¹ Author's interview with "Ryan" (7/18/2012).

³¹² Author's interview with "Howard" (7/18/2012).

this direction would take one to two more seconds for a right-handed worker than the other direction. For thin ultrabooks, it was about 14 seconds. For tablet PCs, it was 14.6 seconds. Quanta once tried to set the flow speed to 9 seconds for some products, but it failed because too many errors occurred at that speed. For Apple's notebook products, the flow speed for the mass production phase was usually slower—20-some seconds.

With such a tense working time schedule in mass production, repetition and alienation are the most serious problems, as the Marxists have claimed. For both the filmmaker, Charlie Chaplin, and the artist, Diego Rivera, the insanity-inducing assembly line was always their focus for the American factories in the 1920s and 1930s, because they both were far more interested in the pace and process of mass production than in the product itself (Hounshell, Chapter 6). "The 'real, inner truth' of mass production was what took place in the factory, not its product," as David Hounshell (1984: 323-324) summarizes. This situation remains true in the twenty-first century factories in China. An industrial engineer at Compal highlighted the pace of the workers, saying that if an operator worked for 8 hours (if not overworked), it would mean that the same motion would be repeated about 2400 times when that time period was divided into 20-second intervals. If the operator's motion happened to be installing the screws, they usually had to put in five screws in that station because placing a screw with an automatic screwdriver would take only about 3 seconds, so they would screw in 5 screws at a time, 2400 times a day, which means that an operator would have to put in

more than 10,000 screws in total, in a day.³¹³ Within the small space bounded by the operators' two arms, their lives are disciplined and measured by the conveyors day by day, second by second.

In addition to being a marker of time, the conveyor line is also a transformer and a flowing boundary between ideas and artifacts, and partially reflects how assembly knowledge and practice in the industry are produced. Along the spectrum for making a new machine from design to assembly, the final step is the only one done by operators. In other words, the conveyor line is the final boundary through which ideas change to material products. It is also a boundary that changes a spatial scale to a temporal scale in accordance with precisely calculated and arranged relations among humans' motions, numbers of workers, line lengths, and line speeds.

During the last steps of the detailed division of labor in their laptop factories, it is IEs (industrial engineers) or PEs (production engineers)³¹⁴ who translate and allocate the assembly motions for workers. Although the knowledge and design of assembly motions of workers are co-produced by the characteristics of the human body and the quest for industrial efficiency, the latter usually is privileged, so that it ends up pushing the human body's potential to its limits, as Taylorism aimed to do. Even when a factory has an unusual degree

³¹³ Author's interview with "Lila" (7/18/2012). She is one of the few female engineer-managers I interviewed, and she is Chinese. The intolerable repetition of a same motion is also well presented in Charlie Chaplin's classic film *Modern Times* (1936), also cited in Hounshell, 1984.

³¹⁴ For Compal and Wistron, IEs were the primary people who played the role, but in Quanta, it was the PEs. Interviews from multiple sources.

of power parallel to design teams, such as in Quanta's factories (as I discussed in the Chapter 2), and design people are willing to prioritize DfM (design for manufacturing), the purpose of the design is to maximize production efficiency, rather than to accommodate to the workers' limits and preferences.

Due to the organizational gap between brand-name companies and CMs, the geographical distance between the US and China, and the complex layers of engineering and division of labor, the working conditions in the factory could seem invisible and indifferent from the vantage point of the brand-name companies, and certainly from that of their customers. When outsourcing their products, the brand-name firms could also "outsource" their responsibility for relations of production by manipulating their auditing of their suppliers. In China, not only were the CMs' engineering effort and knowledge standardized and devalued, but also the workers' factory lives were further ignored. This situation was partially due to the fact that the design, engineering, and assembly jobs belonged to the contract manufacturers rather than to the brand-name companies. If the whole production process had belonged to the brand-name companies themselves, the value distribution might have been less uneven and the working conditions for factory operators might have been different, too.

The ideal motions designed for workers resulted from many earlier levels of design-engineering effort, as I showed earlier for the long process with the C-system or "Ten-Miles of Yangtze River." At the final level, a Compal IE (industrial engineer), "Lila," who

was a female Chinese engineer, said that the R&D people would come to teach the IEs how to assemble the product, and then together they would try to assemble it. After that, the IEs would prepare two to three sets of SOPs (standard operation procedures) to be discussed at meetings attended by different departments in order to make the final decision about the assembly motions to be assigned to workers. It required a great deal of experience to design an excellent SOP.

For “Lila,” the most important thing for SOPs was “balancing,” which meant assigning equal time for all stations (each station was responsible for different motions from the beginning to the end of the product assembly).³¹⁵ That is, when assembly motions were dissected, the ideal was for each worker to finish the assigned assembly task (such as inserting the hard disk, screwing on the cover, or mounting the keyboard), test the product, and even package it in just 14 seconds. If one station could finish its action in 10 seconds, but another needed 14 seconds, it was not “balanced” since some workers would have to wait for others to finish. As a result, if the assembly jobs were not balanced, the IE team would adjust it. IEs needed to stay on site every day in the factory to see what was going on in the assembly line and adjust/re-design operators’ motions according to the situations they observed.

As the line kept flowing, it was not possible for operators to leave their own stations

³¹⁵ Author’s interview with “Lila” (7/18/2012).

vacant, for example, to go to the restroom. The workers needed to ask the “multi-functional workers” (who are experienced in all assembly motions, in order to substitute for any worker in any station as needed) who were on standby at the line to take over for them. In the production world, the power of the workers is much less than that of the conveyor belts, which control their pace, actions, and working lives. In the mass production system for large-scale modern commodities, such rapid flows are deemed necessary for efficient and rational control over the production process.

Another extended but less-known style of production was in the “sky.” One of the sources of pride in Quanta’s factories was its “Run-in Carousel” (nicknamed “Skycart” or just “parking tower,” both in Chinese) and “Run-In Monitor System” (nicknamed “Skynet” in Chinese), the two other significant material configurations in the factory. The Carousel or Skycart system did not mean real carts running on rails. Like conveyor belts, it was a continuous belt and flow that could transport things. The Run-in-Carousel was actually a part or extension of the production line on the ground, the main difference being that it was raised higher and was not meant to be touched by most workers. After final assembly on the conveyor belts, all laptops would be lifted upwards by a slope belt (a continuous belt from the assembly line). Then they would be lowered a little and distributed into different levels³¹⁶ of

³¹⁶ At different time periods, the number of the levels is different. When I visited the one in Shanghai, it had 7 levels for the Carousel, but Christopher said that in Chongqing, there were already 10 levels in 2013. Earlier in Shanghai, the number of levels was fewer than seven (author’s interview with “Christopher” 4/16/2013).

the Carousel belts, which were still higher and were above the workers on the assembly lines. On this endless and circular transportation system, machines flowed continuously into different spaces to encircle in a carousel-like fashion. In fact, there were more flows in the plant than just the assembly lines themselves. On the Carousel, the laptops receive automatic run-in (or burn-in) and software downloading, which required 3-4 hours, before final testing. In the past, software downloading had been done off the line, which meant it required transportation (usually by people) to other stand-still shelves (which required extra factory space). After downloading software, they would be sent back to the production line for manual final testing. However, when I visited Quanta's factory, all of these phases were all connected by the Carousel system. By changing the organization of the process order, they saved a great deal of space and time, as well as labor and production costs.³¹⁷

More concretely, as "Christopher" described, the Carousel helped transform their production space "from 2-dimensional to 3-dimensional," and the capacity for the same factory was doubled because of this new design, initiated in 2007, and employed in almost all factories in Quanta Shanghai in 2008.

Each laptop on the Carousel was controlled and monitored by a central server system, the Run-in Monitor System (the Skynet), which was set up in 2009, in Shanghai. The Monitor System could inform engineers or technicians about any failed unit, so if any of them

³¹⁷ Author's interview with "Christopher" (7/19/2012).

had problems on the Carousel, they would be instantly identified and pulled down in order to be fixed. Also, managers could check the production situations and conduct resource management through Skynet.³¹⁸ Although they might have been simple technologies, conveyor belts, Skycart, and Skynet played a huge role in process innovation and brought big advantages to Quanta.

In terms of process innovation, these tools bear many social meanings. Just like a sushi conveyor line, which helps stimulate the customers to consume sushi immediately after it is freshly made behind the line by the chef, conveyor lines or the Carousel system in Quanta are also important for moving things between boundaries. They are themselves flowing boundaries that facilitate efficiency and represent rational calculation. They mark and mediate boundaries between humans and machines, between ideas and materiality, between design and assembly, and between time and space. They are boundary flows that are transformative.

Due to economies of scale, cost-saving, and efficiency-enhancing issues, the boundaries are both calculated (mainly by engineers) and calculating (of workers' output). They are calculated and calculating boundaries, and also time calculators and communication devices between managers and workers. A great deal of precise calculation and knowledge in the whole design-manufacturing process is for this important

³¹⁸ *ibid.*

flowing/changing moment. As requirements for increased speed and precision are imposed on the workers, their lives inevitably bear the boredom and burden of the global production system. The assembly of the products is precisely calculated and controlled by the various material configurations. This final step in making computers is not at all flexible or negotiable.

Economy of Scale and Workers' Silent Protests

But how does the “line” in China differ from the one in Taiwan before the factories were moved there? According to Christopher, their production lines keep evolving, because they keep improving different elements; even the production lines in 2012, when I visited them, and the ones in 2013, had differences. Depending on the time interval used in such a comparison, different degrees of change occur. In Taiwan before 2000, the production lines were much smaller and much less efficient than they are today in China. Also, the groups of people gathered around the production lines were quite different. In Taiwan, they were mainly Quanta’s own design teams, Quanta’s factory managers, engineers, and either local or foreign workers, and sometimes components suppliers in Taiwan and managers from brand-name companies. But in China, the composition of the groups became more complex—they were Chinese migrant workers, Chinese factory managers and engineers, managers from Taiwan (but located in China), design teams from Taiwan’s headquarters, as well as managers from brand-name clients and from components suppliers who could be

based in the US, China, or Taiwan.

As mentioned earlier in the discussion about zones, the global scale is important for understanding these Taiwanese factories in China. Many of the people at the Chinese factories who encountered the massive economy of scale at the interface of the “line” became anguished and agitated. As the history of mechanized labor testifies, the time-disciplined and intensive repetition of actions and the resulting alienation on an assembly line are never easy for human beings who are required to keep pace with the machines,³¹⁹ not to mention the imbalance between the high pressure and low income associated with such jobs. There was a series of suicides after 2009 at Foxconn, when a worker was accused of being responsible for losing a prototype of the iPhone 4. In 2010, fourteen more employees committed suicide in different Foxconn factories in China. Different accusations were aired; some accused Foxconn of being a modern sweatshop, and some accused Apple of indirectly exploiting Chinese workers. Other interpretations for the series of suicides also were given, for example, that it was partially the fact that Foxconn gave very generous compensation to the families of the employees that caused some young people to think about a way to make their family rich by their deaths. Or it was because the workers of the newer generation were quite different from their predecessors, since many of them were “over-protected” at home, following

³¹⁹ In Foucault’s term (1979), the disciplinary power (in his case, the military) fastens the body and the objects it handles into a “body tool” and “body-machine complex” (p.153). There is an instrumental coding of the body.

China's one-child policy, so they could not bear as much pressure as the former generation.

There are numerous news articles researching the encounter of Chinese workers with foreign capitalism, which emphasize especially negative aspects such as centralized, even military-like, management, slogan-filled factory spaces, overworked and alienated migrant workers, and possible issues regarding the deliberate separation of workers from their social networks.

These tragedies and pressures from the public have pushed both the brand-name companies and the contract manufacturers to make the whole production process more transparent and accountable. For example, Apple makes public the information about their top 200 suppliers and their eighteen final assembly facilities online,³²⁰ issues annual reports with the results of the previous year's audits and corrective actions on suppliers,³²¹ and constructs a more systematic way to assure their suppliers' responsibility related to the welfares of workers, labor and human rights, health and safety, and environmental issues.³²²

Still, the assembly work in a computer factory is hardly a dream job to most people after they have experienced it. In the laptop factories in China, there have been high turnover rates of these basic workers. The chief operating officer of Compal China, William Chang, told me that, in the past, in Taiwan the workers' annual turnover rate was about 12-15%, but

³²⁰ See <http://www.apple.com/supplier-responsibility/our-suppliers/>.

³²¹ For the progress report of 2014, see <http://www.apple.com/supplier-responsibility/highlights-2014/>.

³²² <http://www.apple.com/supplier-responsibility/>.

now the same number describes the monthly turnover rate in China. For a year, the turnover rate would thus be above 144% there. Even in the early years in China, the monthly turnover rate was around 5% (annually 50-60%).³²³ Wistron's factory manager "Ryan" also said that their monthly turnover rate in 2012 was more than 10%, which means that, on average, within a year, virtually all experienced workers would be gone (since the annual turnover rate was more than 100%).³²⁴ To solve this issue of high turnover rate, it is thus more essential for managers to divide the assembly jobs into many simple and routinized motions so that any novice operators without special skills or experience can quickly get into the flow speed of production lines. This is a typical vicious cycle that alienates and disempowers workers further.³²⁵

Stereotypes on Workers

There were other challenges besides workers' high turnover rate. Culture shock was one of them. The Quanta factory manager, "Christopher," really wanted to change the workers' daily living and working attitudes: he observed that workers today do not follow traffic rules even in front of the main gate. Some of them also would not pick up trash from the ground even if they saw some. To him, this was a puzzle. He considered that if employees' daily living attitude could not be changed, there was little hope that they would make products

³²³ Author's interview with William Chang (7/16/2012).

³²⁴ Author's interview with "Ryan" (7/18/2012).

³²⁵ I discussed the issues of deskilling workers in the Introduction and Chapter 3.

with the greatest quality. He said that, despite his best efforts, few things changed, and he wondered if the Taiwanese managers should even try to change Chinese workers based on the former's own ideals. Was the issue a real cultural difference, or did it involve carelessness or deliberate disobedience that might be a result of operators' exhausted daily lives or be a silent protest against their boring lives? Or, could the issue be a result of a complex cultural shift in the transition from socialism to capitalism and various individual perceptions of dramatic societal change?³²⁶ In any case, numerous events exposed how Taiwanese producers in the long term still did not fully understand or fit well into the Chinese environment. This issue was especially serious, given that their workers came from so many different provinces with diverse cultural backgrounds and living experiences.

In the earlier years in Taiwan, the laptop producers primarily hired local middle-aged women and young country girls from middle to southern Taiwan, but starting in around 1992, because of a shortage of workers, they began to use foreign laborers from several Southeast Asian countries.³²⁷ Several managers whom I interviewed said that the foreign workers in

³²⁶ See Elizabeth Dunn's *Privatizing Poland*. It should be noted, though, that her research and mine have some major differences: She studied a Polish baby food company that was merged into a US company only a few years after the end of Poland's Marxist-Leninist government. At that time, the company retained many existing employees from the Polish company, and these workers sensed a dramatic change between the two eras, but what I studied was factories set up by Taiwanese companies themselves at a time after 2001, more than two decades after China's open policy. Consequently, the young shop floor workers (mostly in their late teens or twenties) did not experience the dramatic changes of the companies' systems or working environment as the Polish case. Also, Dunn focused more on factory workers' voices, but my study reports mainly on the perspectives of Taiwanese engineers and managers.

³²⁷ Taiwan officially opened the policy of importing foreign workers for the manufacturing industries in 1992 due to the shortage of fundamental workers in Taiwan and the increasing wages and land costs. Within three years, the number of foreigner workers surpassed 150,000. The number doubled in 2000.

Taiwan were “so easy to manage” because their main purpose was to earn money in Taiwan and send it back home, so the workers usually adhered to the discipline imposed by the company and worked dutifully. Even when the Taiwanese CMs had just arrived in China, the expectation from workers was similar, so the companies could select workers, and could select women rather than men, since in their minds, women were far more docile than men in their factory performance. A Compal manager told me that sometimes the selection rate for workers in the early years was one out of ten, and that some candidates even cried when they were not selected. However, the situation has changed drastically in recent years: salaries have been increasing dramatically, but these companies still cannot find enough workers.

All three companies (Quanta, Compal, and Wistron) said that now 50% or 60% of their operators are men rather than women. Overall, these laptop companies do not want male workers because they are “hard” to manage, because they sometimes even fight with one another, but the companies do not have any choice right now. Similar to news reports, some managers also speculate that this might partially be the result of the one-child policy. It is commonly believed that there is an obvious break in the mentality for work between the generations born before and after the one-child policy was instituted in the 1970s and also

Between 1994 and 1999, the workers came mainly from several different countries from Southeast Asia, including Thailand, the Philippines, Indonesia, and Malaysia. See a research project done for Council for Economic Planning and Development, Executive Yuan, Taiwan at <http://www.ndc.gov.tw/dn.aspx?uid=4416> (Chinese).

before and after the economic reform of China in the late 1970s. The two generations tend to show a contrast between left and right, collective and individual, idealistic and materialistic.³²⁸

Unfortunately, even though the managers and engineers alleged that the new-generation workers were so different, the jobs they designed for them seldom differed much from those given to the earlier generation of workers.³²⁹ A mechanical engineer-manager at Wistron pointed out that the design content itself seldom changed based on workers' characteristics. They did change design during the years in China -- for instance, they greatly reduced the number of screws in a laptop -- but this was for enhancing production efficiency, not to accommodate to the characteristics of the workers.³³⁰

III. Trans-border Engineers: Assembling in China (and Taiwan)

In section 5.1, I analyzed the importance of the mobile geographical clustering of Taiwan's laptop companies and their suppliers. However, the assemblage of people at a given factory is equally important. The Taiwanese laptop companies did not move assembly operators to China, but they did ask higher-level factory staff, such as the production engineers, industrial engineers, product test engineers, and different layers of managers, to

³²⁸ In China, there is a very famous and widely cited website discussion group called "Anti-Parents" (built in 2008, <http://www.douban.com/group/Anti-Parents/>) that is dedicated to discussing how different the generation born after 1980 is from their parent generation. They said that their parents are a group of the "end-executors of ossified state educational machine;" "home is the least understandable place;" and "here one era confronts another era."

³²⁹ Author's interview with "Charlie" (4/9/2014).

³³⁰ Author's interview with "Charlie," *ibid.*

move to China. These people had a great deal of tacit knowledge and know-how of factory production and of how to bridge the gap between the production line and the design teams. Therefore, these factory engineers and managers became the key personnel who would be transported to China. However, for various reasons, CMs did not move R&D people and functions to China. As a result, the factory engineering teams in China gradually decoupled from the design engineering teams in Taiwan, analogous to a “wife and husband separated in two places...they gradually grew apart from each other.”³³¹

Decoupling Design and Factory

In Chapter 2, I broke down the design-manufacturing boundaries and relations, stating that their boundaries could be quite arbitrary and their relations unstable. The interactions between different phases from the design to the manufacturing of laptops were not always geographically proximate or distant—they changed over time. Before Taiwanese producers moved their factories to China in 2001, the geographical collaboration of laptop production was primarily between Taiwan and the West Coast of the US, and partially between Japan and Taiwan from 1988 to 2000.³³² Since the industry valued the integration of design and manufacturing (D-M), and since long-distance travel was a barrier both for parties

³³¹ Author’s interview with “Christopher” (7/19/2012), p.43.

³³² IBM had been a big customer of Taiwan laptop producers (especially Wistron) before its PC business was sold to China’s Lenovo. IBM’s laptop research and operations were mainly located in Japan. Lenovo continued this major cooperation with Taiwan after it bought the business from IBM in 2005, although later they also found some other partners or tried to produce their own laptops.

in Taiwan and in the US, and since the Taiwanese companies had great engineering capability in designing laptops, Taiwanese producers generally won more and more orders that required them to perform both design and manufacturing services. It was not that the US companies totally gave up “design,” but that in addition to maintaining the industrial design (which is mainly for designing product appearance, an important feature that brands preferred to control by themselves), they retained only a few key engineer-managers who could instruct and monitor the corresponding design teams of their Taiwanese partners. However, it was also true that the Taiwanese CMs gradually integrated the design-manufacturing process into their own hands.

This high integration from design to manufacturing and the clustering of the supply chain in Taiwan were regarded by the Taiwanese laptop producers as the best model for quickly and cheaply producing machines.³³³ However, when laptop assembly lines were relocated to China, a significant question then became how to deal with the division of labor along the design-manufacturing spectrum between the two sides of the Taiwan Strait. Taiwanese players deliberately left the design teams in Taiwan, rather than moving them to or replicating them in China.

Through years of practice, Taiwanese players had become accustomed to a high

³³³ From the author’s interview with Stan Shih, the main founder of the Acer/Wistron company. Interview conducted on 09/14/2010. This argument also draws from various media coverage and scholarly works in Taiwan.

integration of design and manufacturing, especially for Quanta, hence the disintegration of design and manufacturing in fact was a potential threat to their success. When asked about the changing relations between the R&D division and the factory division after the move to China, the Quanta factory manager “Christopher” sighed and said that they were “growing apart from each other...it’s totally the same as a separated wife and husband.... A lot of situations they encounter there, we can’t totally comprehend; what we face here, even after we talk on the phone, they also can’t understand...on top of that, if they have some bias toward each other, it will become very bad.” The only solution is to have more business trips for the engineers.³³⁴

The disintegration of design and manufacturing required very different practices for engineers inside the laptop producers. Since there were strong and intertwining relations between design and manufacturing in the laptop industry, the design teams of the two companies I studied (Quanta, Wistron) had to fly to China very frequently after the factory relocation. They would have to stay there for a couple of weeks at least every two to three months. This was quite different from the daily practices during the earlier era for Quanta, when both the design office and the factories were under the same roof in Taiwan.

Reluctant Immigrant Engineers: Site Engineers from Taiwan³³⁵

³³⁴ Author’s interview with “Christopher” (7/19/2012). P.43 of the interview’s transcription.

³³⁵ It should be noted that the way I use “immigrant” here is to refer to these engineers’ cross-border

The migration of engineers from Taiwan to China was never as smooth as outsiders might have thought. Indeed, greater Shanghai is a popular tourist destination as well as a rapidly growing modern city full of opportunity. Additionally, Shanghai has nice suburbs. Two of the most beautiful cities of China, Suzhou and Hangzhou, are located in this region (as an old Chinese proverb says: There is paradise in heaven, Suzhou and Hangzhou on Earth). But for Taiwanese laptop employees, these views were complex. While some workers were excited to go to China for a while, especially if they were young and single, many more were reluctant to go. William Chang, chief operations officer of Compal said, few of their Taiwanese employees wanted to make their homes in China. He said that he had travelled to Kunshan (China) once or twice every month or even every week, before he settled in China in 2009. After 2009, he lived in China, in Compal's dormitory, but his wife was still in Taiwan, and his children were all in the U.S. for their education. His family members never settled with him in China. They would travel to visit each other at different times.³³⁶ This sort of de-coupled family is not uncommon for these Taiwanese managers who work in China.

"Howard", an industrial engineer manager from Compal said that he did not want to come to China at all; it was not until 2008, when their last factory was closed in Taiwan, that he was forced to move to the base in China.³³⁷ One reason for his reluctance to move was

relocation, rather than saying they officially became citizens or permanent residents of China through an official immigration process.

³³⁶ Author's interview with William Chang (7/16/2012).

³³⁷ Author's Interview with "Howard"(7/18/2012).

family issues, especially concerning his children's education. This is not to mention the various worries about China's bureaucracy, air pollution, and food safety issues.

Many of the managers or engineers who went to China had to separate from their families, either between Taiwan and China or between the city of Shanghai and the more suburban economic processing zones in China, because even if their families moved to China with them, they did not want to live in an industrial zone. Their family members would choose the city of Shanghai or better suburbs in which to live. In such cases, due to busy work schedules, most of the engineers and managers lived in dormitories and went back to their own homes during weekends. For those who lived there by themselves, one of their happiest times was when they could go back to Taiwan for a visit. Companies such as Compal have been offering six round-trip tickets and holidays annually for the Taiwanese employees to visit their families in Taiwan.³³⁸

With some reluctance, these factory engineers had no choice but to move to factories in China, if they wanted to keep their jobs. They served as a crucial bridge between the upper-stratum design teams in Taiwan and the assembly of products by shop floor workers in China. As discussed earlier under the theme of workers and production lines, these factory engineers and managers were the "translators" who were responsible for assuring the smooth and quick product production. They needed to work with many locally hired factory

³³⁸ Ibid.

engineers and workers. In addition to the material characteristics of laptop production, what they also had to cultivate was knowledge about how to collaborate effectively with all the people in the factories. As a result, these locally settled engineers and managers overall possessed a kind of local knowledge that the travelling engineers from Taiwan would be less likely to have.

Travelling Engineers and Unwanted Mobility: The Long-distance Commuters and the Global Conveyor Lines

The geographical separation of design and manufacturing functions caused panic for engineers and managers in the current China-Taiwan collaborations. Similar complaints happened in earlier US-Taiwan laptop collaborations. A former Apple engineer, "Louis," described Apple engineers' and managers' reluctance to go to Taiwan when Apple sourced from Taiwan in the 1990s, because Taiwan "had mosquitoes" and their partner's factory still did not have restrooms inside the factories,³³⁹ which reminds us of similar colonial scenarios.³⁴⁰

As for the Taiwanese engineers/managers who traveled to China after 2000, a Quanta senior R&D manager, Roger Huang, said that the frequent travel often caused panic among R&D teams, because they needed to travel there frequently, and their time there was

³³⁹ Author's interview with "Louis" (10/01/2011, Mountain View, California).

³⁴⁰ For a broader exploration of the dispersion of engineers in colonialism during the 19th century, please see Buchanan (1986).

not only two or three days, but could be as long as two to three months when there were complicated production issues.³⁴¹ “Charlie,” a senior mechanical engineer-manager in Wistron, said that they traveled to China for about one-month intervals at a time, and they needed to stay in the factories of their own company or of their parts suppliers for about two weeks to a month, and when they came back to Taiwan to stay for a month, another group of colleagues would take their turn to travel to the Chinese factories.³⁴² “Susan,” a Compal engineer-manager based in Taiwan, needed to travel to China frequently because of the work. She said, in the early years, R&D team members had to travel and stay in China for two to five weeks at a time (and at least several times in a year), but many people responded that one month was too long to tolerate both due to the high work pressure and the foreign environment, so Compal changed to a two-week rotation system by making them take turns, since a two-week length was easier to stand. Usually, it was the phase close to mass production that would involve more people to go and a longer time to stay, because they needed to clarify what each production issue might be as soon as possible in order not to delay the shipment schedule, and more R&D team members going to the factory would shrink the time to solve different unexpected issues at the final stage.³⁴³

The close interaction between design teams and factories and between system

³⁴¹ Interview conducted on 1/17/2011 in Taoyuan County, Taiwan.

³⁴² Author's interview with “Charlie” (4/9/2014).

³⁴³ Interview with “Susan” (8/2/2010).

producers and their various parts suppliers facilitated the formation of engineers' and managers' field knowledge. The design teams were not confined only to their offices. They had to go outside to work with and check upon different departments and partners' teams.

The necessary face-to-face communication between the R&D team and the factory further supports my earlier argument that laptop design and manufacturing were not easily separated. The factories could not produce good laptops by simply following written rules relayed from the design team. It also demonstrates that *laptop factories are important sites of knowledge production, especially tacit knowledge.*³⁴⁴ A Compal line director (a line director at Compal is the R&D head engineer of a product line), "Susan," remembered that when she was just promoted to be a line director from the software application department, she was fearful about the new job, and she did not comprehend what meant what in a factory. For the first six months, she needed to follow her "coach" (a term used in Compal) everywhere to perform her on-the-job training. It was not until a year later that she was confident enough to do the job on her own. She said that many R&D team members needed to go into the production lines, and "the senior has to take the junior with him...what we do is on-the-job training. [We] can't do it through [only] document training."³⁴⁵ For example, when a computer had an issue (such as crashing) that needed to be solved (they called it "issue solving"), the coach would ask the trainee to guess what the cause of the problem might be, and then how

³⁴⁴ Tacit knowledge is a concept from Polanyi (1974 [1958]).

³⁴⁵ Interview with Susan (8/2/2010). The direct quote is on p.11 of the transcription.

to solve it. In fact, the pupil had to go through every procedure by following the coach in their daily practice, including going to the factory.

Author: I'm very interested in the idea of on-the-job training that you just mentioned... can you describe it?

Susan: it is about, for everything you will face on the job, you will be led to go through it...if you are the person I'm going to teach... since it's hard to just mention it, I'll accompany you in everything [we] do... This process is very long. Because a project's design could span several months, so we need to do it together. Initially,, we'll decide specs together. You can decide part of it, and then I'll help you. Using this working style, we work on everything together... The coach will teach you what to do when the requirements are unclear.

Author: coach?

Susan: yes, coach. [I'll teach you] At what time you should do what thing, then we work together to operate it. Then for the next project, you will understand the best way to respond at each time point.³⁴⁶

Clearly, laptop factories are important sites of learning for R&D teams as well.

Factories hide many secrets that the companies will not let outsiders observe. Even for a long-term Japanese brand-name client, Compal employees would never be allowed to go to its (the client's) factories when they went to Japan to meet with the partner.

Furthermore, as I have argued, the close contact between R&D and factory personnel came from the high speed pace of the industry. They did not have the time to report everything gradually through levels of management. Instead, *they needed physical proximity to the material to react promptly*. Also, many people from design to manufacturing

³⁴⁶ Author's interview with Susan (8/2/2010), pp. 13-14.

needed to work together to make the fast-paced production flow successful. When the factories were still in Taiwan, this integration was less of an issue than it has been after they were separated geographically between Taiwan and China.

In another sense, I argue that to some extent, these Taiwanese engineers were also on invisible *global conveyor lines*, though in contrast to their factory operators, their lines were invisible and ran along a larger trans-border scale. When they travelled from Taiwan to China, it was as though they were sent to one section of the moving conveyor lines. In Chapter 3, I use the term global de-value chain (as opposed to the popular business term global value chain) to represent how the CMs' profits kept declining, how they had to squeeze the profit of their suppliers, and how their innovations on cost reduction were taken for granted. It is the global de-value chain makes some of the middlemen engineers to be as though working on global conveyor lines. These two images are closely related to each other and both express how the high-tech product's value gap is further polarized and widened so that even the middle levels engineers feel exploited.

Beyond that long-distance travelling life, these R&D engineers' daily lives in Taiwan were also highly controlled and measured by time. Time and speed were critical factors in the computer and semiconductor industries. The demand for efficiency in the industry was both structured and structuring. Moore's Law, which is illustrated here, was not a natural law, but a result of human activities. The origins and maintenance of high-speed development in the

industry had complex economic and social origins that are beyond the scope of this project. But to clarify, when Taiwanese laptop producers joined the industry in the late 1980s, the industry “train” had already been running at high speed, and Taiwanese players seemed to increase its speed even more by intensely driving themselves.

We can see the statistical increase in production as a result of the Taiwanese influence. In 1998, there was the so called “955” fulfillment in the notebook industry, which meant that 95% of orders were filled in 5 days. The number became “982” in 2002, which meant that 98% of customers’ orders could be fulfilled in 2 days.³⁴⁷ That is, after getting the orders from customers, producers would assemble, ship, and deliver the computer products to them in two days. The speedy handling of orders was not possible without strict discipline and innovations in the product development process.

In a contemporary context, innovation is understood to be universally good. Innovation is usually associated with high value, but ironically, in the cases I studied, innovation did not in itself produce high value. Very often, the result was the opposite. As I discussed in Chapter 3 on cost reduction, after Wistron’s separation from Acer in 2000, Wistron faced a dramatic decrease in orders. Consequently, Wistron had to devise a new way to regain its orders. After brainstorming, an aggressive goal was set of “M5.9,” which meant developing a laptop model within 6 months. They had only 6 months to develop the product

³⁴⁷ Research Report of the AB Plans for the Electronification of the IT Industry for Ministry of Economic Affairs (MOEA), Taiwan, by the Department of Industrial Technology, MOEA. 1/21/2003, p.45.

from concept to mass production. A Wistron senior manager, “Jimmy,” said that M5.9 requires every team (such as the electrical engineering, mechanical engineering, and thermal team) to start the project simultaneously whereas the previous method had been sequential. He also indicated that the entire process, under time pressure, became not only overlapping, but also more dynamic and was ruled by people (rather than ruled by rules). When “Jimmy” began his job in 1991, the time for product development was still 18 months, and then it became 6 months for new models and then 3-4 months for old models by the time he was interviewed at the end of 2012. He said, “the time now is only one third [of the previous expected time], so it is really very challenging.”³⁴⁸

The strategy of M5.9 was a way that Wistron “innovated” in their development process to discipline and even exploit themselves. They innovated just to win product orders or to survive, but not to increase the value they could gain. It is possible that people innovate to bind, discipline, and even devalue themselves, when they have no better choices. Unlike production line operators, whose motions and fate are designed by production/industrial engineers or other managers, the Taiwanese laptop engineers seem to partially self-design their own invisible carousel. Although their jobs seem to involve more agency, less repetition and less alienation, these jobs could be boring and under great time pressure as well. Overwork, a rushed schedule, and frequent travel are the norms of engineering work in these

³⁴⁸ Author’s interview with “Jimmy” (12/20/2012).

companies. Engineers need to be strong and experienced to conquer the other form of “linesickness,” from having to keep up with the continuous flow of the global production-consumption belt.

In many discourses about modernity or globalization, principles such as “openness” and “flow” are usually associated with positive values, but for these Taiwanese engineers, to be mobile is not a blessing at all. Indeed, there is an argument that flow is not equal to being free, flexible, or full of agency. Flow can be rather negative and restraining. It can be a force of instability.³⁴⁹ For my interviewees, it seems that the more mobile you are, “the more work for you.”³⁵⁰ But did they get more pay for doing more work and being more mobile? Not at all. After moving their factories to China, these laptop CMOs’ profits fell. The economic and social effect of such low-price engineering and outsourcing is deeper: many engineers in Taiwan need to live unwanted mobile lives, while Chinese workers live alienated lives.³⁵¹

Assembling in China (and in Enclaves)

What other group of people also joined this move? Brand-name companies (i.e., the

³⁴⁹ See Deng (2012:78).

³⁵⁰ This is similar to the argument of “more work for mother,” in the book *More Work for Mother: the Ironies of Household Technology from the Open Hearth to the Microwave* by Ruth S. Cowan, 1985. While most people think that modern technologies liberate women from arduous household work, Cowan argues that they might instead increase the working load on women since now the expectations and standards for their work are higher.

³⁵¹ There is also an argument that outsourcing mid-level jobs to Asia may be one reason that the middle class in Silicon Valley is disappearing, and the rich-poor gulf in California is widening. By outsourcing the mid-level engineering work to Asia for lower prices, the higher-level managers of brand-names in Silicon Valley only become richer, and save only the high-end jobs and low-ranked service jobs in Silicon Valley.

Taiwanese manufacturers' clients) did, since their Taiwanese partners' factories were in China. They had to shift to be close to the factory sites as well. This site-sensitive collaboration further supports my argument in an earlier chapter that design and manufacturing are inseparable. Tim Cook, the current CEO of Apple said,

“We have executives that have stayed in dorms. It’s not unusual. Honestly, this wasn’t to see what life was like in a dorm. It was that we worked so closely with these manufacturing partners and in the manufacturing plants [that] it’s convenient to do...In addition, we have hundreds of people that reside in China in the plants on a full-time basis that are helping with manufacturing and working on manufacturing process and so forth. The truth is we couldn’t innovate at the speed we do if we viewed manufacturing as this disconnected thing. It’s integrated. So it’s a part of our process.”³⁵²

A highly design-centered company, Apple needed to conduct research in advance of possible new technologies and parts or components that could enable or could be integrated into their innovative products. For example, their collaboration with component manufacturers began two to three years earlier than when the iPad went on the market.³⁵³ Apple also needed to send many engineers to China to work with manufacturers there, although their manufacturers, such as Foxconn, in fact had a great deal of research and development capabilities themselves in parts and components.³⁵⁴ Other brand-name companies, including Dell and Hewlett-Packard (HP), needed to move their international purchasing office (IPO) to China. Their design teams also

³⁵² See Bloomberg Businessweek 12/6/2012.

³⁵³ Author’s interview with a senior high-tech manager, “Ronnie,” who has been working in Silicon Valley for more than three decades. Interview was conducted on 09/29/2011 in Santa Clara, California.

³⁵⁴ See Xu. 2008, Section III. Also from the author’s interview with Stan Shih, the main founder of the Acer/Wistron company. Interview conducted on 09/14/2010.

had to travel to China often, in order to check on the progress of their products throughout different design-manufacturing phases.

As for the laptop producers themselves, while they did move groups of people, of course they could not move all of their people nor the entire business and social environment in which they were situated. Yet they still managed to import part of the old social dynamic to the new location.

As I discussed in the section on mobile clustering, the laptop companies' suppliers also moved to China with them. In the eyes of Taiwanese laptop producers, the moving or replication of the laptop supply chain cluster from Taiwan to China was fairly successful. However, it seemed that they just created an enclave for themselves. Thus, the so-called special economic zones were more than "economic." They also were political, cultural, and social. "Eli," from Compal, said, "in China, Taiwanese are doing business with Taiwanese, Japanese are doing business with Japanese, and Koreans are doing business with Koreans," although after a decade in China, the Taiwanese CMs have found opportunities to do business with local Chinese suppliers,³⁵⁵ and the rise of Chinese local parts suppliers gradually threatened the survival of Taiwanese suppliers after 2012.

A study of Japanese and Korean small and middle manufacturing enterprises investing in Thailand since the mid-1980s, and in China since the early 1990s, respectively,

³⁵⁵ Author's interview with "Eli" (12/01/2011).

reveals that these SMEs often isolated themselves from local networks and knowledge flows, since they tended to do business with their home country's large firms rather than with local ones (MaNamara 2006). The weak local ties and the persisting links to home country networks show how geographical moves of manufacturing did not guarantee the overcoming of language, social, or cultural barriers. In my study of laptops, the Taiwanese system manufacturers and their component suppliers had been doing business with each other for a long time, and they usually formed firm and loyal relationships that were not easily replaced by others. The Taiwanese laptop producers did not yet trust Chinese companies, so the reproduction of the supply chain locally in the Yangtze River Delta was actually a reproduction of social relationships from Taiwan. These social relationships could not be reproduced only by replicating special economic zones.



Figure 5.11

The main building of the dorm for traveling engineers and managers from Taiwan in Quanta Shanghai, 7/2012. It is a round building that seems to isolate itself from neighboring environments (by Ling-Fei Lin).

My explanation for the migrants' isolation focuses on their "technical" role in the global division of labor. Because they conduct engineering, contract manufacturing, and global production, the immigrants have no urgency to understand more about the local culture. They do not need to face any end markets or end consumers, so it is possible for them to stay outside of the local Chinese society, just as the imperial armies and migrants could live in their own world, copied from their western hometowns. Unlike merchants who

conduct local business, and who need to expand their local social networks for business, there are no incentives for these technical immigrants to connect with the local society. In addition, they are usually overworked, spending much of their time in the factories and the adjacent dormitories dedicated for employees from Taiwan, rather than dining in local restaurants or chatting with local residents. Even when they do leave the work complex, they often choose to go to little Taiwan or Taiwanese-owned restaurants. For example, in Kunshan, there is a “Taiwanese Street,” where tens of restaurants specialize in Taiwanese cuisine, with a function analogous to the Chinatowns in many U.S. and European cities. According to many media reports, about half a million Taiwanese settled in or travelled frequently to the great Shanghai in the early 2000s. Again, the special “economic” zone was never just “economic,” it was also socially and culturally distinct from its locus.

The only two major contact points with the local society or local culture for the Taiwanese engineers and managers were the direct laborers (workers) and the Chinese indirect laborers (secretaries and accountants, etc.) and engineers. In the early years of the factory relocation, it was reasonable to keep as much of the original Taiwanese way (or the Quanta way, Compal way, Wistron way) as possible to reduce any uncertainties and risks involved in moving the factories. Yet, even after a decade, it seemed that the managers and engineers still kept their distance and did not deeply understand the Chinese workers and engineers. To a certain extent, they treated them as “the other,” which greatly influenced their

collaboration and design-manufacturing practices.

Urban places have been described as a locus of coping, frequent spontaneous interactions, freedom, creativity, and community.³⁵⁶ But nothing like this happened in the Taiwanese engineers' lives in China, no matter for the long term immigrant or short-term travelling engineers from Taiwan. It was as though these engineers were confined/imprisoned in the factory site because they did not need to get close to people and markets, but remained close to machines and materiality. There was a similarity between them and the workers on the production line—both were confined to the global production line (either real or virtual) and to their dormitories. It was the material, the machine, the parts that were flowing; they came from different places of the world, and, in turn, the finished product would flow to many other places of the world. People, in contrast, were either confined to a small space, or were fastened to certain points in their seemingly “free” and “mobile” work. While flow exists between Taiwan and Shanghai, it remains fixed within the two localities. Workers cannot move freely, and they do not have time and extra energy to move freely. Their working model seems to involve the so-called “mobile pods of seclusion,” as de Boor (1986) and Sorkin (1999) indicated in describing the suburban residents who are connected only by private car traveling at high speeds, without touching any point in between.³⁵⁷ These

³⁵⁶ Young 1990, cited in Gieryn 2000. P.476.

³⁵⁷ Cited in Gieryn (2000: 477).

traveling engineers were confined to the offices and factories in two cities, commuted by plane, and missed most things between them.

Assembling in Taiwan, too

In addition to the relationship between “design” and “manufacturing,” there was another relationship, within the design teams themselves, that needs to be considered. For a laptop product, there were at least three kinds of design teams from three corporate parties: the design team of the brand-names, the design team of the CMs, and the design teams of the component suppliers (I will use D-D-D to indicate these three design teams). In addition, there were other divisions of labor among the design teams within a single company. Here, I want to briefly highlight how the moving of factories to China changed these D-D-D relations (as I will call them).

In the late 1980s and early 1990s, when the US companies had first begun to source laptops from Taiwan, they still had many design team members in the US. When more design functions were replaced by the Taiwanese partners, the US headquarters still kept key design engineer-managers who could instruct and monitor the design teams of the Taiwanese partners with frequent communications and the occasional visit. The second flow was between Japan and Taiwan, since IBM’s laptop base was in Japan. The design teams of these CMs’ component suppliers also often came to meet with the Taiwanese producers’

design teams, so in general the three design teams met in Taiwan, and closely collaborated with the CMs' factories in Taiwan. The engineering knowledge flow at this stage was mainly between the US and Taiwan, and within Taiwan itself.

However, when Taiwan moved factories to China, several US laptop companies such as HP and Dell also decided to set up their own "R&D" centers in Taiwan by hiring more Taiwanese engineers. That is, they moved even the "higher" design function (high means being closer to ideas than things with a cultural implication that it belongs to a higher status) to Taiwan after 2001. This was partially a result of the new incentive policy offered by the Taiwanese government. This relocation of brand-name customers' design teams from the US to Taiwan helped the Taiwanese laptop players to keep their design teams in Taiwan and to maintain the connections that sustained their D-D collaboration.

In the meantime, when Taiwanese components/parts suppliers moved to China, along with the laptop producers, they also kept many of their design teams in Taiwan. Consequently, much of the higher-level engineer meetings at that time still occurred in Taiwan. However, another important negotiation happened between R&D people from the CMs and the factories of their parts and enclosure suppliers. To ensure a seamless connection between parts and systems, much of the time that these R&D people (especially the mechanical engineers) from Taiwan spent was in their suppliers' factories.³⁵⁸

³⁵⁸ From the author's interview with "Christopher" (7/19/2012) and with "Charlie" (4/9/2014).

Thus, at this new stage, the engineering knowledge flow was primarily between Taiwan and China, as well as within Taiwan itself. It should be noted, however, that almost all large computer brand-name companies had multiple subcontractors, and contract manufacturers also had multiple brand-name clients, so the engineering flows among them were multiple and complex. However, if we look at the big picture, we can see two main engineer clusters after 2001. One cluster of engineers who were involved in the daily practices at the factories met in China (in the Yangtze River Delta, but after 2010, there was a second cluster in inland China), and there was still the other cluster left in Taiwan, mainly for earlier-stage R&D discussions. It was the design teams from Taiwan who needed to travel, in order to have face-to-face communication with the engineer groups in China, and to have close proximity to the factory and material production. The frequent trans-border flow of engineers between Taiwan and China, accompanied by the flows between the US and China, the US and Taiwan, Japan and China, and Japan and Taiwan, were what made the fast-changing pace in the laptop industry possible.

The Dilemma of Building (Site) R&D in China: Politics of Flow and Rootedness

The relocation did not merely entail the emigration and frequent travel of engineers and managers to China. There was less doubt about the “center of calculation” (in Latour’s term), which was in Taiwan, but the question was: did they need a second center of

calculation on site in China, and how powerful should this second center be? That is, did they need to build or shift R&D teams to China? This struggle between the politics of flow and rootedness has been a major source of debate for these CMs.

As we have seen, there has been much tension connected with the relocation of people. The politics associated with the division of the labor ranged from individual to national levels. Individually, the politics were between early comers vs. latecomers. A former top operations manager in Compal, "Aaron," complained that the first group of managers from Taiwan tried very hard to train local managers in China upon arrival, promising them that they would have good prospects for promotion if they worked hard, but once their factories in Taiwan were gradually closed, more and more Taiwanese engineers/managers came to China. And when they came to China, their positions were promoted one level. He said this made it hard to convince the Chinese employees that they would have good prospects for entering the positions now occupied by the Taiwanese immigrants.³⁵⁹

This struggle between rootedness and mobility is not unusual when the jobs in an industry or a particular company involve a cross-national distribution, but the dilemma was further intensified between Taiwan and China. The two regions have a sensitive political relationship due to their unique historical relationship. Taiwan was part of China for several centuries, and had numerous Chinese immigrants, but Taiwan was ceded by China to Japan as a colony between

³⁵⁹ Author's interview with "Aaron" (12/16/2010). He and his family had moved to China and lived there for years, but this interview was done when he traveled back to Taipei on a business trip.

1895 and 1945. Then in 1949, over a million Nationalists and mainland Chinese fled to Taiwan after being defeated by the Communist Party. The two sides of the Taiwan Strait were absolute political enemies without any kind of exchange for almost four decades. They restored some degree of interaction after 1987, but it was never a smooth recovery. Taiwan's government was more open to private sector investment in China in the late 1980s and early 1990s, but in 1996 it shifted to a more conservative policy of "No Haste, Be Patient," introduced by President Lee Teng-hui from the Kuomintang. Later, in 2001, when the DPP became Taiwan's ruling party for the first time, while facing a worldwide economic recession, President Chen Shui-bian changed the policy to "Actively Open, Effectively Manage," in reaction to pressures from the high-tech industries. The vacillating policies revealed the sensitive relationship between the two regions, which was further ignited by a possible service and trade deal with China in 2014. In the eyes of the large-scale supporters of the Sunflower movement led by many younger generations in March 2014, the Taiwanese Nationalist government was too pro-China, and not sufficiently transparent about that trade pact with China, which would impact the vast numbers of small and medium enterprises and the lives of millions of people in Taiwan.

A specific tension was whether Taiwanese CMs should have more "R&D" people in China. It should be noted that "R&D" in this context referred to the engineering teams that were responsible for design jobs and were closer to ideas than to the factory floor. There was a large group of factory engineers who did not count as R&D. Since they needed to work

on-site in the factory, there had been many factory engineers who were local Chinese, although the key positions were usually controlled by the Taiwanese.

Here I will borrow de Certeau's concept of changing perspectives for viewing space. Before the Taiwanese manufacturers settled in China, they needed to play it safe by assuming a rationalized view, as though from above, but when they really "walked in the streets" for a while, knowing what the local environment looked like, they could start playing very different games. For example, Compal initially did not think of establishing design teams in China, but a few years later, when the local government offered stipends, free offices, and incentives to encourage R&D functions, Compal decided to move "those design functions which were close to production" to China. But Compal insisted that the upper stratum of design would still be left in Taiwan, although the number of R&D people in China was already around one thousand in 2011.³⁶⁰

Quanta, on the other hand, struggled about whether or not to set up large-scale R&D teams in China. In the early years, one senior Quanta manager, "Rob," urged the company to establish a large R&D team in China, and even to move their notebook R&D division to China, because he believed that the new computing world would require many different R&D people, and that this arrangement would maintain a better design-manufacturing integration and hence reduce costs and shorten the learning curve. Product handover issues and the pain of

³⁶⁰ Author's interview with "Eli" (12/01/2011).

frequent travel for R&D people in Taiwan would also be solved. However, he was disappointed, because the top executives rejected this idea.³⁶¹ One reason they did so was that Quanta had already built a more fundamental research center in Taiwan, which had hired thousands of researchers and engineers. This was an internal political problem, as those design teams that stayed in Taiwan wanted to strengthen themselves and to increase their own value, but so did the Taiwanese managers in China.

There were multiple reasons to keep their R&D or design teams in Taiwan. First, they had no reason to give up their engineering workforce, which had required years of training and experience in Taiwan. Second, they did not have much trust in the Chinese engineers, who not only required much re-training for the laptop industry but, for various reasons, also tended not to stay in Taiwanese companies for long. In the view of the Taiwanese employers, the Chinese employees had little loyalty towards their companies. When they had the opportunity to change bosses, they would easily switch to another company, especially the higher-wage Western ones. That was why the key people for important departments in the Taiwanese-owned producers were Taiwanese. A third reason is much more complicated. When China rose to power, Taiwan worried that it would be marginalized economically, since Taiwan was gradually losing its manufacturing activities to China, and China was attracting so many foreign investors, including those from Taiwan, so the Taiwanese needed to control

³⁶¹ Author's interview with "Rob" (12/31/2010).

what they had very carefully when they invested in China.

Fourth, Taiwan was situated in a “not so high, but not so low” industrial status. When giving more product design jobs to Taiwan’s companies, employees in the US companies could transform themselves to do branding, marketing, services, and software, but Taiwan did not have international competitiveness at most of these areas partially due to its own small home market and systematic lacking of professional cultivation in those areas. Hence, it was harder for them simply to transfer R&D or design jobs to China. This was the middleman’s dilemma: there was a clear boundary or ceiling of what they could do and could not do.

Nevertheless, in 2010, Quanta already had established a small-scale R&D center in Shanghai. The R&D teams designed some notebooks, resembling the functions in Taiwan’s R&D team, and were managed from the Taiwan R&D headquarters. But Quanta’s factories in China had another much larger team (more than one thousand people in 2013), which was called ERD (Extended R&D). ERD originally included the very important PE (production engineers) team in Quanta’s factories, which belonged to the factory rather than to the Taiwan headquarters’ administration.³⁶²

Wistron also had two major kinds of engineers at their China base. In addition to large local factory engineering teams, after 2004 Wistron also gradually built “site R&D teams” to help with the later phases of the development process, with tasks such as revising drawings,

³⁶² Author’s interview with “Christopher” (7/19/2012).

documentation, approval of product parts, system verification, and engineering changes and follow-ups. One main purpose was to decrease the frequency and duration of business trips from Taiwan's R&D teams.³⁶³ Compal was similar. "Susan" said originally they were worried that their jobs would be replaced by the new R&D team hired in China, but later they found that things were fine, and that this strategy actually helped decrease the frequency of their business trips to China.³⁶⁴

The set up of the new local R&D divisions corresponds to my argument in the earlier chapter about the unfixed D-M boundary, in which I showed the interpretative flexibility of the term "R&D," and how each local department could grow its own version of R&D to enhance its own value, even though only functionally and psychologically, rather than monetarily. The political, economic, and social issues concerning how many "higher-level" jobs should be created in China, and how many should be kept in Taiwan, have been in constant dispute and continue to pose a dilemma for Taiwanese laptop companies.

Factory relocation provides the possibility of shuffling power, and each party wants to make itself stronger in the process. Taiwanese laptop producers now seem to be ambivalent: they play a role somewhat similar to a foreman. On the one hand, they feel they are exploited by their brand-name customers, but on the other hand, they seem to exploit others as well, or at least, devalue others (the local employees at the base factories) by replicating the high-

³⁶³ Author's email correspondence with "Charlie" (4/3/2014).

³⁶⁴ Author's interview with "Susan" (8/2/2010).

/low- dualism in the engineering culture.

Multiplication of Engineer Contact Layers and Compression of Value

Today, Quanta, Compal, and Wistron all have their R&D headquarters in Taiwan, but they have many R&D people in China as well. As a result, their R&D organizations have increased by an additional layer. Their primary model is for the Taiwan R&D to hand over to the China R&D teams the issues pertaining to products when they are ready for the mass production phase. This sort of organizational arrangement deals with interface problems—either between geographically separate organizational divisions or between different companies, which I will call the “engineering contact layer.”³⁶⁵ At this time, the engineering contact layer makes decisions on a case by case basis, and depending on each case, the contact layers between different projects and different companies can involve a heavy touch or light touch, and in some cases no touch at all.

The engineering contact layer is what the laptop industry has employed for years to monitor design/engineering projects or to relay design/engineering issues from one team to the next. The main idea is that each company and each location needs to have a team with a function corresponding with that of the other party. For example, at present a US brand-name

³⁶⁵ In STS, Galison (1997) proposes a metaphor, “trading zone,” to analyze how different cultures (in his case, science and technology) can exchange ideas and collaborate in a zone. The contact layer has a similar connotation in how engineers from different countries, companies, or departments can collaborate with each other in spite of bearing differences from their own working departments.

company will have an EE (electrical engineering) team and an EE project manager to monitor the progress of its Taiwanese production partner's EE teams, and then the Taiwanese EE teams will have at least one leader to monitor their EE teams at the Chinese site. Even with a laptop contract manufacturer, when the R&D team goes to the factory, the factory will have an engineering or quality assurance team who has functions corresponding with the R&D teams to communicate with them. The same principle applies to the mechanical engineering and software functions. This overlapping arrangement is an important mechanism for securing and solving any issues happening at the boundary of the relay process.

There are at least two ways to deal with the relay problems: through face-to-face communication and through detailed documentation. However, it is not so easy for the laptop industry to do this in practice. One senior manager, "Rob" from Quanta, said that when the factories were still in Taiwan, the D-M integration was ideal, because the design offices and the factories were together, but now it has changed. Although some managers wanted to document the D-M process (which is suitable for industries that change slowly), the speed at which notebook manufacture changed was so rapid that the attempt to document the process was not very successful.³⁶⁶

The primary model for communication in the industry still is based on first-hand communication, but the involvement of a company's communicative partners can be very

³⁶⁶ Interview conducted on 1/17/2011.

diverse. “Charlie” from Wistron described how in the early years, one famous US brand-name company’s involvement could be described as a “heavy touch”: the number of mechanical engineers that the company dispatched to monitor Wistron’s mechanical engineering team was almost the same as that of the Taiwanese team members that they were monitoring. However, with changing requirements for low-cost manufacturing, the brand-company’s policy became a “light touch.” In 2009, the same company dispatched one mechanical engineer to oversee a particular model of laptop. Sometimes, a single mechanical engineer would monitor two to three models. Other projects involved no “touch” at all. Although the situation differed in different projects, as a whole, “Charlie” observed a decreasing amount of “touch” from the major brand-name companies.³⁶⁷

The Taiwanese CMs took a similar approach with their Chinese R&D teams. As discussed earlier, the main task of the CM’s R&D teams in China was to help with the later phases of development jobs. “Charlie” said each design task remained the same, but it was further divided into earlier and later phases of job processes based on the C-system (which I discussed in Chapter 2 on the D-M boundary). In the past, when factories were in Taiwan, the same design team would be responsible for everything, beginning with the proposal phase to the mass production phase, but after 2004, the Taiwan team dealt with only the proposal phase and the laboratory pilot-run phase. Other phases (engineering pilot-run, production

³⁶⁷ Author’s interview with “Charlie” (4/9/2014).

pilot-run, and mass production phases) were covered by the China team. The Taiwan design team would be responsible for monitoring the corresponding function in China. Charlie went on to say that this decreased each design member's travel time to China. Before establishing the China R&D team, although they took turns, each member still had to travel to China nearly every month, staying there for two weeks to a month. After they built the China R&D team, the frequency of travel was roughly the same, but usually only the team leader was required to go to China.

After 2008, in addition to handling the later phases of development jobs, Wistron's China R&D division increased its responsibility to include a full range of design work for more standardized models. The percentage of models in which the Chinese division performed such design work was about 10% in 2013, but their goal was to increase it to 30% of their notebooks. This development then raised the question of what to do with the currently large Taiwanese R&D teams. Would they lose their jobs? "Charlie" said that they would have to upgrade themselves to engage in more "creative" jobs, or take part in earlier stages of the design jobs, such as the concept and proposal phases. In fact, by 2013, most brand-name companies, with the exception of Apple, simply defined their products and monitored their CMs, since almost all product proposals were already offered by the Taiwanese CMs. That is, all the hands-on jobs had already been given to the CMs. He did not know if any of them had lost their jobs due to the new China R&D division, because they could move their positions to

do other things within their companies.³⁶⁸ Quanta's "Rob" also said many Taiwanese R&D employees resisted the idea of building a large R&D center in China, because they feared they would lose their jobs, but he thought that transfer within the company for new projects was possible, just as he had done himself. He also did not think the transition would be very difficult.³⁶⁹

The Taiwanese teams shifted from the early years of resistance to a gradual acceptance of the establishment of China's R&D divisions, and they tried to "upgrade" themselves. However, while increasing their engineer contact layers (requiring more overlapping jobs to bridge the two parties, as discussed in Chapter 1), their value did not increase; on the contrary, it became further depressed. Consequently, the profit that each layer could share became thinner. Although they became more experienced at many engineering jobs, they were still further devalued, as I discussed in Chapter 3 on cost reduction.

Coda: Another Geographical Move, and Robots

Complicated social, economic, and industrial considerations were involved in the geographical movements of the CMs' factories described in this chapter. Materially, this new production base had a much larger and controlled production space at one single site, and

³⁶⁸ Author's interview with "Charlie" (4/9/2014).

³⁶⁹ Author's interview with "Rob" (12/31/2010).

the factories were full of expensive surface mount technology machines and other large-scale equipment. These were surrounded by the Chinese employees' dormitories and the warehouses of components suppliers, who were also from Taiwan.

Besides the physical characteristics, the relocation was a newly created social space that combined Taiwanese experiences with Chinese characteristics, including complex intermediary forces between them. An increasing number of Chinese engineers worked inside the factories, but key management and engineering positions were still controlled by Taiwanese. Designers and managers from the brand-name customers also would come to understand the situations in the factory, while many of their design teams continued to hold their meetings in Taiwan with the design teams of the Taiwanese laptop producers and component suppliers. Also, a great deal of negotiation occurred when the Taiwanese design teams regularly met at their own or at parts suppliers' factories in China. But the CMs also set up on-site R&D and extended R&D teams in China, in order to bridge design-manufacturing better and lower the frequency of business trips from Taiwan. In addition, this situation also increased the overlapping layers of engineering. Therefore, factory migration also involved a series of transformations. Hardly anything was the same in China as it had been in Taiwan.

In 2009, to accommodate the Chinese state's Western Development Drive, laptop producers were asked to move their factories to inland China. Under the strong command economy structure in China, it was hard not to move, although laptop players did have some

other choices, such as going to Vietnam or Brazil.³⁷⁰ Nonetheless, as China and Taiwan share the same languages (mainly Mandarin Chinese) and have similar cultures, on top of its promising development, China was still the number-one place to invest. One interviewee said that by shrinking the preferential treatment in the greater Shanghai area and continuing to raise the basic salary in coastal areas, as well as offering attractive treatment inland, few producers would refuse in the end to move to Western China.

It should be noted that this new move to inland China was not only designed to boost economic growth in the Western part of the country. It was also aimed at solving some immediate social problems. In addition to the environmental pollution consideration, a very important aim was to allow numerous male and female workers from inland or rural areas to stay in or near their hometowns, instead of migrating to distant economic zones. In the past, most of the special economic zones were concentrated in the coastal areas of China, so millions of migrant workers from far away were mobilized to join “the worldwide factories.” However, this temporary migration not only generated an outflow of young people from rural areas, but it also caused problems in the cities, as well as increasing the transportation burden during the long holidays, such as May 1st, October 1st, and especially during the

³⁷⁰ For example, Compal built its second production site in Vietnam in 2007 to diversify their risks. This decision was a result of their factories in the greater Shanghai being too large and expensive. But although the Vietnamese government gave Compal a huge allotment of land, Compal set up only a very small scale production facility there. The reasons, from Compal's side, were that the Vietnamese government “was not as determined as the Chinese government,” so the former did not provide a convenient enough infrastructure for them. Also, a Compal manager, “Eli” (12/01/2011), said that they felt that the Vietnamese government seemed to be “biased toward labor” in labor-capital disputes. Another example is that in 2010, Foxconn announced a plan to invest in Brazil.

Chinese New Year, when tens of millions of workers all wanted to go home at the same time.

The new initiatives to pull back the migration by moving part of the production base inland were designed to disperse them spatially and partially solve the problems caused by the current influx to the coastal factory zones.

Historical Cycle of Industrial Relocations

In fact, there have been repeated historical cycles of large-scale factory relocation in the postwar period. As mentioned, Taiwan established its EPZs as early as 1966, but it was understood at the time that Taiwan's EPZ model was partly inspired by Hong Kong, which had previously embarked on export-oriented industries after World War II. Hong Kong made this transformation in order to improve its own economy after China's trade was blocked by the West, following the Korean War. China was such an essential economy that Hong Kong relied heavily upon it in Hong Kong's role as an international middleman (Wong 1988). Scholars also further argued that the strong move towards the export-led industrialization of Hong Kong was initiated by the Shanghainese who escaped to Hong Kong in 1949. They brought not only machinery, technology, and capital, but also experience with exports and international trade from Shanghai, which had been a trade port for more than a century. The Shanghainese then copied the Shanghai model in their new home, Hong Kong (Wong 1988).

We now seem to be witnessing another historical-geographical cycle. The creation of

China's special economic zones starting in 1979 was said to be an imitation of Hong Kong's free trade port and Taiwan's export processing zone (Sachs et al.). China's special economic zones were initially located near Hong Kong, and later were created in the Yangtze Delta. Now, the new move to Chongqing seems to be repeating another historical cycle. Chongqing was the capital of China during the Sino-Japanese War in 1937-1946 (Chongqing remained the capital until 1947). When the Japanese conquered the eastern part of China, the Nationalists moved their capital from Nanjing, a city that was only three hundred kilometers from Shanghai and on the lower Yangtze River, to Chongqing, a major city upstream along the same river, and asked all defense-related industries to move their factories from the coastal areas to Chongqing, since the latter was an interior city with mountains and rivers that provided natural barriers and had been an important transportation hub to the Southeast.

Similarly today, the government's purpose is to create a viable economic zone that develops the great Western region economically and socially, and to further upgrade the industry in the coastal areas. The foreign industrial actors in China seem to have fewer choices in selecting where to move again. However, their choice of the actual content of what to move and what not to move will be a completely different story. Will the Taiwanese managers and engineers become even more reluctant to move or travel to the new place? In what ways will the new assembly of people and factories influence the practices of supply chains and brand-name customers? To what extent will the producers manage the new

workers there? New and unique transformations are at the fore and will present new challenges, implications, and advantages.

Robots vs. Geography

The time-disciplined and high-intensity repetition of actions that are characteristic of industrialized labor are not easy for human beings (e.g., attuning physical bodies to the flow of mechanized assembly lines and carousels). A series of suicides since 2009 at Foxconn illustrated some of these problems and drew international publicity to the imbalance between high-pressure demands, and simultaneously, under-compensated jobs in factories. As a result of these tragedies, one “solution” that the company, Foxconn offered was to use robots. It announced in 2010 that it would incorporate the use of one million robots in 2013. This “solution” only incurred more criticism of Foxconn (and of Apple, one of Foxconn’s main customers). Some commentators reported that what Foxconn would use is the new generation of industrial robots called Frida, made by the Swiss company, ABB. Foxconn did not confirm this, saying that they might develop the robots by themselves. But Frida is thought to be an example of what Foxconn wants. ABB’s website explains: “the robot is compact and intended to fit into spaces ergonomically designed for human workers. This allows the robot to be easily interchanged with a human coworker.” Today, some “foxbots” have been used to do jobs such as polishing the casing of an iPhone. Although not yet used

on a large scale, the prospect of robots and further automation is quite real. A Quanta R&D manager said that automation is a continuous job. “Just like girls buying clothes, it never ends.”³⁷¹ “Christopher,” a factory head manager in Quanta China said, “The motherboard production was already automated by SMT machines a very long time ago, and now we are discussing the possibility of using robots and other automated machines in the final assembly line.” In one notebook assembly line, they were using six robots and other automated test machines to replace human workers. They estimate that if they succeed, it will decrease the need for human workers by about 50-70% in the long run.³⁷² Although robots and other automation devices are doing what workers did in the past, and they partially replace the role of workers, one main sociopolitical difference in a communist sense is that they are the comrades of the capitalists, rather than those of the vast numbers of human workers (unless robots are someday to have their own thoughts and feelings). There will be a significant social and political impact that is worth further exploration.

Quanta and Wistron also indicated that they are studying new automation plans. Perhaps they will begin with the simple jobs, such as screwing in screws. But “Christopher” told me that a robot costs about twenty thousand US dollars, so that “using purchased robots to screw in screws is too expensive!” They use the outside robots (purchased from other companies) to perform the placement of the motherboard, hard disk, CPU and memory, but

³⁷¹ Author’s interview with “Taiwanese Laborer,” a pseudonym he wants to use (11/17/2010).

³⁷² Interview conducted on 4/15/2013-4/17/2013, through both email and Skype.

Quanta developed their own robots to put in screws. He said, a robot can be used for up to only three years and their motion remains slow, plus there is the fee for maintenance, so the cost is several times higher than hiring human workers to put in screws. He added that the real current issue is not money, but how to perform system integration. He also worried that the loss of jobs for workers in the future might cause social problems, but he emphasized that “The real evolution is that, in the process of developing automated production, the idea of product design will be changed, which will cost jobs.”³⁷³

“Christopher” claimed that rather than workers being replaced by robots, the important issue here is that the CMs will ask the R&D people to use new design rules from the factory to change their designs. In order to facilitate assembly by robots and other automated machines, engineers or designers need to have a new way to design the product. Currently (2013), for a new tablet PC project, the Quanta factory has asked the design teams to adapt their design for the factory’s use of the new automated machines and robots. He did not yet know what the result would be. However, according to the Japanese system integrator they were collaborating with at that time, there would be a great deal of resistance from the R&D teams.³⁷⁴

One of Quanta’s main reasons for undertaking further automation is to contend with the lack of low-wage workers in coastal areas. Another main reason is that “we don’t want to move anymore.” Instead of continuing to move to cheaper places, living like a nomadic people, this time they will use automation to conquer the many obstacles associated with

³⁷³ Interview conducted on 4/14/2013, through email.

³⁷⁴ Author’s interview with “Christopher” (4/16/2013).

production.³⁷⁵ As a result, now robots are competing not only with humans, but also with places and nations.

Conclusion

This chapter echoes several arguments from previous chapters: Chapter 1 shows that Taiwan's laptop industry emerged from a strong design/engineering capability; Chapter 2 explains how the design-manufacturing relationship is inseparable, and introduces the idea of field knowledge; Chapter 3 addresses cost reduction and related practices as a form of field knowledge. It also shows how the CMs' engineering and innovation were normalized and constrained by more powerful actors. This chapter, then, by simultaneously analyzing multiple (im)mobility issues through major geographical shifts, provides an ideal opportunity to further examine my theoretical discussions in the earlier chapters on design-manufacturing unity, field knowledge, global de-value chain, and the dynamic relations between design and manufacturing.

This chapter addresses how relocating factories to China altered the practices and knowledge production across the spectrum from design to manufacturing in Taiwan's laptop producers. I examine the relations between places, engineers, production line operators, and even robots. My questions surrounding the issues of relocation uncover a common theme:

³⁷⁵ Author's interview with "Christopher," *ibid.*

mobility, in the form of shifts of economic zones, exportation of factories, relocation of workers, migration of engineers, and the on-site roles of engineers. Many elements of factory relocation are on the move, virtually or actually, which could make employees in the industry “linesick” on a global scale.

Overall, I argue that Taiwanese CMs embodied an “obligatory passage point” in the industry. Whereas critical accounts (e.g., of the Foxconn’s employee suicides) often emphasize the binary division and conflict between laborers and capitalists, I show how the two poles of the design and manufacturing spectrum were (and continue to be) gradually mediated through many levels of engineering work. I also explore how moving Taiwan’s laptop factories to Eastern China after 2001, and then to inland China after 2010, not only resulted from China’s macro economic and environmental plans, but also had a transformative impact on the Taiwanese CMs’ knowledge-production and practices.

More specifically, I examine three elements of factory relocation in this chapter. I first address the important role of the economic zones in Taiwan and in China in shaping their decisions about factory location, and then argue that there was an ever-changing mobile clustering of the laptop industry in these zones. I continue to describe the relocated workers and the production line in the laptop factories. The alienation of Chinese assembly workers differs little from the condition of modern factory workers across time and space. The phenomenon of relocated workers also is not uncommon in the history of industrialization.

However, I delve further into a specific analysis of the “line” as a control tool and as a boundary between idea and object, between human and machine, and between time and space. Altogether, the exploration yields a deeper understanding of knowledge translation in factories, the final stage of the long D-M production process, on which my dissertation focuses.

Last, I analyze the importance and struggle of migrant workers and traveling engineers. The transnational assembly of Taiwanese engineers in China, the commuting engineers in Taiwan, and the augmented engineering layers in both places changed the CMs’ design-manufacturing practices. In doing so, these engineers unintentionally de-valued themselves and others. As though entering a global virtual production line, the Taiwanese CMs and engineers pushed themselves into an empty space. Even though they had expertise, experience, and field knowledge, and kept specializing or “upgrading” their engineering jobs, they could not stop the devaluing of jobs, which contrasted with the increasing layers of engineering teams in Taiwan and China. I want to also further highlight the changing dynamics of design-manufacturing laptops. In this time period, not only is the Taiwanese producers’ design engineering capability and field knowledge practice still critical, their expanding expertise and knowledge in large-scale manufacturing and factories also made them an indispensable partners for brand-name companies such as Apple and Hewlett-Packard, which need to constantly work with the factories in China. The complexity and importance of

expertise in manufacturing or in factories is ever-increasing and demonstrates that a design-centered perspective is far from sufficient in explaining the development of high-tech products. Factory relocation to China was a watershed for the Taiwanese laptop producers. It entailed not only material relocation, but also transformative *flows* of multiple factors including suppliers, workers, and engineers. When Taiwanese laptop CMs and their employees moved to and encountered a new society, the dynamics of the system, as well as its parts, changed into something new. Behind the production of laptops lay the grand economic plans of Taiwan and China, involving multiple mobilities and resistances to them: how workers migrated and lived, how engineers (do not want to) migrated and travelled to China for collaboration (and competition), and how robots and automation influenced factory relocation and product design. These processes have been heavily intertwined with broader socio-economic-political issues.

The transitional process of moving factories provides us with an ideal opportunity to examine the complex relations between so-called “design” and “manufacturing” activities. The consistent theme throughout all three levels of analysis in this chapter is the struggle between *flow* and *rootedness*. I then call for an (im)mobility or an “emplacement vs. mobility” analysis to examine how, when an industry, a factory, or a technology moves, each important element of it shows a tendency to be either rooted or to flow, and to explore how elements vary or remain constant when they become mobile (mutable or immutable mobiles, in

Latour's terms). This approach illuminates the complex processes and influences associated with essential socio-technical relocation.

CONCLUSION

THE CHANGING DYNAMICS OF DESIGN-MANUFACTURING

LAPTOPS

In this dissertation, I examine the important role played by Taiwanese contract manufacturers (CMs) in the production of laptop computers. By exploring the mundane engineering practices, this project problematizes and complicates design and manufacturing and distinguishes between different sites and processes in laptop production. I show that these Taiwanese companies are critical middlemen within the producer world who design, manage, engineer, and physically transform abstract concepts into affordable machines.

My dissertation demonstrates the intricacy and changing dynamics between computer design and manufacturing across different time periods. It refutes a perception of linear progress (from manufacturing to design) and challenges the idea that manufacturing -- in contrast to design -- is less innovative and less significant. I argue that the design and manufacturing capability are both influential, and that the intensive interaction between design and manufacturing sectors, both internally and externally, matters in the laptop consolidation. Furthermore, I develop the notion of field knowledge to supplement the existing concepts in STS such as tacit knowledge and local knowledge to describe the knowledge generation practices which involve intensive trans-organizational and multiple-sited

exchanges between actors from heterogeneous backgrounds.

Fundamentals of the Study

A central goal of this research is to identify what unique knowledge and practices produced by Taiwanese laptop CMs contribute to the concentration of laptop production, and whether the production consolidation conversely shapes their knowledge practices. A few questions I examine in this historical and social study of technology are: What are the origins of the industry in Taiwan? How is a laptop computer (socially) produced, focusing on the perspective of contract manufacturers? Is design actually separate from manufacturing in the industry? What are the epistemic and social relationships between design and manufacturing? If cost reduction is one major capability of the Taiwanese producers, what are the particular ways of practice and knowledge production involved? What are the constraints of CMs as subordinate mediators in the producer world? And finally, what are the impacts and changes of CMs' design-manufacturing practices after they moved factories to China? I address these questions in five chapters, with a shared emphasis on examining the historical changes of their design and manufacturing dynamics.

Overall, this project provides a new way of examining the development of modern East Asia's industry and technology by exploring the mundane practices of the traditionally invisible and undervalued contract manufacturing process. It contributes to the literature of

science and technology studies (STS) by a new and close examination of industrial knowledge production, to the literature of the history of computing by exploring the rarely researched non-Western computer players and contract manufacturers, and finally, to the literature of social studies of engineering and manufacturing because it re-connects the dynamic relations between design and manufacturing processes.

Methodologically, this dissertation has its strengths and limits. As I discuss in the Introduction, I primarily drew upon qualitative in-depth interviews, supplemented by archival research, secondary literature, and news reports for my research. The strengths of the research are first, I gained a rare access to contract manufacturers who tend to maintain secrecy about their contract business, and second, I was able to conduct almost a hundred interviews, generating more than two million words of transcripts that offer a rich range of materials for my current and future research. However, there are also apparent limits of the empirical data that are based on interviewing the busy engineers and managers, who in general did not have time to accept more interviews and who did not want to disclose their clients' and companies' business due to confidentiality. This restriction was especially serious when I wished to have more detailed and diversified accounts to reconstruct certain important events.

Field Knowledge and the Dynamics of Design-Manufacturing Machines

I regard CM's knowledge production as being special because of the way it drew explicit attention to intensive interactions between design and manufacturing divisions, between brand-name firms and CMs, and between CMs and component suppliers. However, I could not find an appropriate concept in STS to best represent such interactions, so I developed a concept, "field knowledge," to describe the daily practices that involve multiple-sited exchange between actors with different expertise.

As middlemen in the producer world, they gather and extract information from heterogeneous sources and generate new knowledge in order to compete and survive, but it is difficult for them to learn systematically and freely from their powerful partners such as brand-name clients and Intel, even though they were interested in topics such as user experience. By contrast, it is easier for the CMs to incorporate their local components suppliers; or from the design team perspective, to incorporate their factory team. Thus, the middlemen's field knowledge is a particular kind or a subcategory of field knowledge. It is different from, for example, the field knowledge of powerful brand-name companies since the brand companies encounter less coercion or pressure than the CMs do. Brand firms' major constraints, by contrast, might come from the collective user market, policy, or from legal levels. Their information gathering and knowledge creation practices from multiple fields are thus distinct from those of CMs.

In examining the dynamics of design-manufacturing machines, I found that CMs' features in the industrial practice are partially shaped by an active and expanding field knowledge practice and by the limiting standardization and coercive containment from power players in the time period I study. The struggle between the CM's field knowledge and constrained engineering forms one major dynamic of their knowledge activities. This struggle is one kind of the complex design-manufacturing dynamics that the CMs face. The Taiwanese CMs' constraints and practices of field knowledge are the product of economic, social, and historical relations. In addition, these knowledge activities in turn, have also shaped or reinforced those relations. Will the coproduction loop continue on the same path, or will it shift to a new, transformative trajectory in the future?

Overall, although this research does not aim to analyze all significant factors to answer the question of "why most of the worldwide notebook production ends up in Taiwanese companies," in the project I demonstrate three of the influential factors that contribute to the laptop consolidation: the local industrial cluster formed by numerous parts and components suppliers, the existing design expertise and expanding manufacturing capability, and finally, the constant interactions between design and manufacturing teams from internal and external partners (or a carousel-like practice of field knowledge).

Although the beginning of the laptop industry in Taiwan seemed independent of manufacturing capability and dependent upon excellent design engineering capability, it was

in fact both a quickly growing manufacturing capability, along with design capability that made the Taiwanese CMs the most advantageous candidate to consolidate global laptop orders. Manufacturing or design capability alone would be insufficient for them to further grow after the first few years of contract business. To be reliable and effective mediators between ideas and things, they had to acquire versatile capabilities. A third element, the local network of supplies, provided the best environment for the CMs to nurture their field knowledge practices: they met each other frequently and thus the CMs could gather, extract, and integrate useful information from numerous sources to create useful knowledge to design and manufacturing computers that meet the needs of the fast-changing industry. Networking concerns not only power, but also knowledge.

Do We Need to Care the Possible Devaluation of Middle-Class Engineers?

In the dissertation, I also argue that Taiwanese laptop CMs made non-trivial contributions to the making of the globalized commodity. They struggled and innovated to extend their involvement from production (point), and process (line), to also incorporate components suppliers and other partners from the field (plane). However, overall they have remained invisible and gained little credit. Various reasons and mechanisms can be used to explain this devaluation, but primarily it seems to result from the competitive logic of capitalism and the fundamentally submissive role that CMs play.

To be clear, although several of my interviewees describe themselves as the working class, they are well-educated and enjoy a middle-class and even an elite life. Thus, the shop-floor workers are more likely to align these engineers and managers in the CMs more with the capitalists rather than with the laborers themselves, as I discuss in Chapter 3. There are few commonalities between the engineers and the alienated and low-paid shop floor workers, except that they are both overworked and devalued. Nevertheless, we should not belittle the mechanisms of devaluation of these middlemen, since they are a significant link that connects to a global de-value chain. If these engineers and managers in CMs are drawn in near the pole of “low-value” assembly in order for the more powerful firms to keep profits and credits for themselves, what will be the possible fate of other groups of employees and workers who have even more submissive status?

The managerial and engineering efforts in (the) CMs, in fact, could have potentially helped exacerbate the asymmetrical distribution of value in the global industry, shifting and condensing the value primarily to only one pole (the design/brand-name pole) but not the other (the manufacturing/CM pole). The laptop CMs are gradually devalued partially due to the fact that much design and engineering efforts in making laptops belong to contract manufacturers rather than to brand-name companies. After all, cutting down product or service costs from another company on the market is easier than doing it within one’s own firm. When more companies are involved in a product production process, it is more likely that employees at one end cannot

sense the levels of exploitation of the employees at the other end.

Industrial Studies and STS

In order to advance future research, I want to call increasing attention on industrial studies within the science and technology studies (STS). In this dissertation, I study industry and, more precisely, computer companies, through STS perspectives and analyses in order to examine the relations between design, manufacturing, and society. In STS, there are rich laboratory studies exploring knowledge production, practices, and the epistemic cultures of scientists. STS has cultivated an intellectual culture to challenge scientific hegemony and authority. However, STS has generally neglected a routine but important knowledge production site regarding also science and technology: industry. Although there are studies about industrial laboratories, about multinational pharmaceutical companies, about corporate and factory history, as well as about collaboration amongst government, industry, and the university sectors and financial markets, many gaps and potentials for new understanding remain.

It is reasonable for people to consider that knowledge produced from industry is not as scientifically authoritative as that produced from science laboratories. Scholars study the making of scientific knowledge to debunk the aura of “purity” that is often associated with science by exposing the complex social factors involved in knowledge production. By contrast,

industrial knowledge itself is mingled with many social and economic factors. However, this does not mean that industrial knowledge is not worth studying in STS. In particular, if we think about its impact on people's work, consumption, daily lives, and on the global environment, the relations between knowledge and society in the industrial world seem to demand more consideration by STS scholars. Industrial studies are currently covered by economics, sociologists, historians, anthropologists, and business management researchers, but I believe STS scholars will generate new insights and contribute to industry studies with new methods and perspectives that focus on the relationships between power, knowledge, and society, and with close and critical examination of the knowledge production process, knowledge content, and various disputes.

Questions for the Future: Design, Manufacturing, and Society

I believe my dissertation have opened up a few interesting questions that are worthy of future exploration. First, what are the roles of contract manufacturers and design-manufacturing relationships in other industries and how are they important in the relationship between design, manufacturing, and society? Are they similar to or different from my research? How so? These questions highlight my own future research interests. Based on my preliminary research and observation about another essential high-tech industry in Taiwan, the semiconductor sector, I have found several significant differences regarding the

epistemic cultures and history of knowledge production between the PC and IC (integrated circuit) communities that are worthy of further comparative studies. For example, both involved massive transnational knowledge flows and exchanges between Taiwan and the U.S, but compared to the highly-professional IC foundry industry, the PC industry was associated with much stronger local ties, lower entrance barriers, and more distributive mechanisms of knowing.

A second group of inquiries can center on the question: What are the connections among design, manufacturing, and consumption? Instead of viewing producers as a homogeneous group, when scholars delve into user or consumption studies, can they find different links when trying to analyze the producers themselves? For example, when my industrial interviewees mentioned that they tested their own user experience based on employees, employees' families, and the top executives, I wondered what might be their connection with the market user world, and how did it influence their product design and manufacturing.

Third, on the issues regarding the global division of labor and global production: What can we actually gain through a deeper exploration on the complexity of production process, global commodity chain, or the dynamics between design and manufacturing? How extensive should this be? I personally believe such deeper supply chain explorations have begun to influence the choice of consumers and thus push the changes of powerful companies'

practices in specific ways (for example, some consumers have refused to buy products that might be involved in sweat shop factories or risky working environments). But could we systematically or partially solve power differences and income injustices within the global division of labor by making the production process visible? If we believe that the transparency in commodity chains can help more companies to value corporate social responsibilities and thus transform to a “better” version of capitalist companies, what kinds of exploration should we prioritize?

Other potential future research questions include: how is the concept of field knowledge applicable and useful? How would the further rise of robots and automation technologies in industries compete with populous countries and transform different groups of people’s lives in the future? Will factories be moved back to the developed countries, and if yes, in what forms? Will the economic center-periphery argument (that the center exploits the periphery’s raw materials and low-cost labor to produce higher value products to be sold and profit through the process) be challenged due to the use of robots in the future? Last but not least, will digital manufacturing or the so-called new revolution of 3D printing technology eliminate the majority of the middleman and middleness of the design-manufacturing process, and how might the ideals of “green design” affect the complex production world? These inquiries remind us of the fundamental studies on the relations between design, manufacturing, and society.

APPENDIX

List of Interviewees

	Date of interview place/way of interview*	Name of interviewee	Company and position	Duration of interview (minutes)
1	7/2/2009 Skype phone, USA-Taiwan	Stan Shih	Acer/Wistron, main founder	62
2	7/2/2009 Skype phone USA-Taiwan	Max Fang	Dell former general manager of Asia Pacific's International Procurement Office	77
3	12/25/2009 Skype phone USA-Taiwan	"Konner" pseudonym**	Asus, senior R&D manager	27
4	3/8/2010 Taipei, Taiwan	Fred Lin	One of Acer founder and former manager	140
5	3/19/2010 Taipei, Taiwan	Max Fang	Dell former general manager of Asia Pacific's International Procurement Office	123
6	3/31/2010 Taoyuan County, Taiwan	"Jon" pseudonym	Quanta, senior manager	20
7	3/31/2010 Taipei County, Taiwan	"Myles" pseudonym	Wistron, senior manager	50
8	4/1/2010 Taipei, Taiwan	"Raymond" pseudonym	Compal, CEO	74
9	4/16/2010 Taipei County, Taiwan	"Bruce" pseudonym	Wistron, R&D manager	115
10	4/22/2010 Taipei, Taiwan	Stan Shih	Acer, main founder	102
11	5/20/2010 Taoyuan County, Taiwan	"Joseph" pseudonym	Quanta, R&D manger	191

12	5/25/2010 Taipei County, Taiwan	"Jaxon" pseudonym	Acer/Wistron R&D manager	87
13	5/26/2010 Taipei County, Taiwan	Simon Lin	Wistron, Chairman and CEO	69
14	6/2/2010, Taipei, Taiwan	Stan Shih	Acer, main founder	106
15	6/17/ 2010 Taipei, Taiwan	"Evan" pseudonym	Microsoft Asia, senior manager	95
16	6/18/2010 Taipei, Taiwan	"Garrison" pseudonym	Compal, Financial manager	25
17	6/18/2010 Taoyuan County, Taiwan	"Craig" Pseudonym	Quanta, procurement manager	140
18	6/23/2010 Taipei, Taiwan	"Marvin" Pseudonym	Microsoft Taiwan, R&D manger	90
19	6/23/ 2010 Taipei, Taiwan	"Harrison" Pseudonym	Quanta, retired R&D head manager	150
20	7/5/2010 Taipei, Taiwan	"Harrison" Pseudonym	ibid	214
21	7/9/2010 Taipei County, Taiwan	"Daniel" and "Bruce" Pseudonym	Wistron, R&D managers	104
22	7/9/2010 Taipei County, Taiwan	"Bruce" Pseudonym	Wistron, R&D manger	116
23	7/14/2010 Taipei, Taiwan	"Kent" Pseudonym	HP Asia Pacific Manager	50
24	7/15/ 2010 Taipei, Taiwan	"Alex" Pseudonym	Former Microsoft Taiwan manager	56
25	7/20/2010 Taipei, Taiwan	"Harrison" Pseudonym	Quanta, retired R&D head manager	89
26	7/21/2010 Taipei, Taiwan	"Stuart" Pseudonym	Compal, R&D manager	180

27	7/22/2010 Taipei County, Taiwan	Robert Huang Pseudonym	Wistron, President and COO	88
28	7/28/2010 Taipei County, Taiwan	"Richard" Pseudonym	Wistron and former Quanta manager	117
29	8/2/2010 Taipei, Taiwan	"Susan" Pseudonym	Compal, R&D manager	144
30	8/4/2010 Taipei County, Taiwan	"Richard" Pseudonym	Wistron and former Quanta, manager	140
31	8/4/2010 Taipei County, Taiwan	"Akasha+ Charlie" Pseudonyms	Wistron, R&D manager	136
32	8/4/2010 Taipei County, Taiwan	"Bruce" Pseudonym	Wistron, R&D manager	50
33	8/12/2010 Taipei County, Taiwan	"Charlie" Pseudonym	Wistron, R&D manager	170
34	8/27/2010 Yamato City, Kanagawa Prefecture, Japan Also email correspondences 10/27-28/2010	Arimasa Naitoh	IBM then Lenovo, Thinkpad notebook director,	104
35	9/7/2010 Taoyuan County, Taiwan	CC Leung	Quanta, CEO	117
36	9/14/2010 Taipei, Taiwan	Stan Shih	Acer, main founder	115
37	9/17/2010 Taipei, Taiwan	"Yao" Pseudonym	Quanta, retired factory head manager	217
38	9/30/2010 Taipei, Taiwan	Richard Lee	Inventec, CEO	96
39	10/20/2010 Taipei, Taiwan	"Yao" pseudonym	Quanta, retired Factory head manager	212
40	10/26/2010	"Yao"	Quanta, retired Factory head	26

	Phone interview Taipei, Taiwan	pseudonym	manager	
41	10/27/2010 Taipei, Taiwan	“Ching” pseudonym	A former board member of one of the top three laptop contract manufacturers	5
42	emails 10/27-10/28/2010	Naitoh	Thinkpad notebook director	(email)
43	10/28/2010 Taipei, Taiwan	Peter Wang	ITRI manager	35
44	10/29/2010 Hsinchu, Taiwan	Peter Wang + Houng-Ching Shyu	ITRI managers	129
45	10/29/2010 Hsinchu, Taiwan	Peter Wang	ITRI manager	204
46	11/9/2010 Taipei, Taiwan	“Stuart” pseudonym	Compal R&D head manager	153
47	11/17/2010 Taoyuan County, Taiwan	“Taiwanese Laborer” Pseudonym	Quanta, R&D manager	145
48	11/17/2010 Taipei, Taiwan	“Eli” Pseudonym	Compal, procurement manager	90
49	11/19/2010 Taipei, Taiwan	“Harrison” Pseudonym	Quanta, retired R&D head manager	221
50	11/23/2010 Taipei County, Taiwan	Scott Lin + Johnson Yeh	Acer, marketing managers	95
51	11/23/2010 Taipei County, Taiwan	Johnson Yeh	Acer, marketing manager	125
52	11/29/2010 12/02/2010 emails	JT Wang	Acer former CEO	(emails)
53	12/1/2010 Taipei County, Taiwan	“Jonathan” pseudonym	Wistron/Acer R&D manager	120
54	12/7/2010 Taipei, Taiwan	“Eli” pseudonym	Compal procurement manager	154

55	12/9/2010 Taoyuan County, Taiwan	“Jon” pseudonym	Quanta, manager	145
56	12/10/2010 Taipei, Taiwan	“Shang” pseudonym	Acer, manager	43
57	12/11/2010 Taipei, Taiwan	David Lee	Founder of Qume	110
58	12/14/2010 Taipei, Taiwan Also 12/15/2010 emails	“Yao” pseudonym	Quanta, retired factory head manager	222
59	12/16/2010 Taipei, Taiwan	“Aaron” pseudonym	Former Compal factory manager	63
60	12/31/2010 Taoyuan County, Taiwan	Roger Huang	Quanta, manager	116
61	1/5/2011 New Taipei City, Taiwan***	Akasha pseudonym	Wistron, industrial engineer	90
62	1/12/2011 T aipei, Taiwan	Huaichi Chang	Analyst	110
63	1/17/2011 Taoyuan County, Taiwan	“Rob” pseudonym	Quanta, R&D manager	192
64	1/26/2011 New Taipei City, Taiwan	Sid Wang	Former ITRI manager	89
65	6/1& 6/5/2011 emails	“Harrison” pseudonym	Quanta, retired R&D head manager	(emails)
66	6/13/2011 Skype phone USA-Taiwan	“Harrison” pseudonym	Quanta, retired R&D head manager	109
67	7/23/2011 Skype phone USA-Taiwan	“Frank” pseudonym	Former Quanta industrial engineer manager	152
68	9/29/2011	Ronald	Acer Venture Capital manager	150

	Santa Clara, California	Chwang		
69	9/30/2011 Santa Clara, California	Ed Yang	Former HP PC head manager	126
70	10/1/2011 Mountain View, California	"Louis" pseudonym	Former Apple product manager	253
71	10/7/2011- 10/11/2011 emails	"Harrison" pseudonym	Quanta, retired R&D head manager	(emails)
72	10/23/2011 emails	Yao pseudonym	Quanta, retired factory head manager	(emails)
73	12/01/2011 Skype phone USA-Taiwan	"Eli" pseudonym	Compal, procurement manager	70
74	12/4/2011 Skype phone USA-Taiwan	"Eli" pseudonym	Compal, procurement manager	56
75	4/05/2012 emails	"Harrison " pseudonym	Quanta, retired R&D manager	(emails)
76	7/16/2012 Kunshan, Suzhou, China	James Chou	Wistron China general manager	170
77	7/16/2012 Kunshan, Suzhou Province, China	William Chang	Compal China general manager	163
78	7/18/2012 Kunshan, Suzhou Province, China	"Ryan" pseudonym	Wistron factory manager	90
79	07/18/2012 Kunshan, Suzhou Province, China	"Howard" pseudonym	Compal industrial engineer manager	64
80	7/18/2012 Kunshan, Suzhou Province, China	"Lila" pseudonym	Compal industrial engineer	65
81	7/18/2012	"Yuna"	Compal, operator	60

	Kunshan, Suzhou Province, China	pseudonym		
82	7/19/2012 Shanghai, China	"Christopher" pseudonym	Quanta, factory manager	85
83	7/19/2012 Shanghai, China	"Christopher" pseudonym	Quanta, factory manager	248
84	7/23/2012 Shanghai, China	CT Huang	Quanta China, President	126
85	7/23/2012 Shanghai, China	"Christopher" pseudonym	Quanta, factory manager	34
86	7/23/2012 Shanghai, China	"Holden" and "Leo" pseudonyms	Both are Quanta, factory managers	57
87	7/23/2012 Shanghai, China	"Christopher" pseudonym	Quanta, factory manager	58
88	7/24/2013 Shanghai, China	"Kane" pseudonym	Quanta, operator	60
89	7/24/2012 Shanghai, China	"Joy" pseudonym	Former Quanta, operator	64
90	8/14/2012 New Taipei City, Taiwan	"Charlie" pseudonym	Wistron, R&D manager	153
91	04/15/2013- 04/16/2013 emails	"Christopher" pseudonym	Quanta, factory manager	(emails)
92	4/16/2013 Skype phone USA-China	"Christopher" pseudonym	Quanta, factory manager	83
93	6/16, 6/20, 6/21 6/22/2013 emails	"Christopher" pseudonym	Quanta, factory manager	(emails)
94	4/2/2014 & 4/8/2014 emails	"Charlie" pseudonym	Wistron, R&D manager	(emails)
95	4/9/2014 USA-Taiwan Skype phone	"Charlie" pseudonym	Wistorn, R&D manager	56

Total				9465 ns)
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Notes:

*The language of most interviews were in Mandarin Chinese (but mixed with large numbers of English terms, and sometimes, Taiwanese), except two interviews which were conducted in English (Naitoh and “Louis”).

**Most interviewees do not wish to disclose their personal information for this research. I coded their names as first-name pseudonyms, and I use quotation marks for those coded names.

***Taipei County was upgraded to a municipality and was renamed as New Taipei City on December 25, 2010.

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