Competitive pricing and learning in CPU sockets

by

Mehrafshan Tabassum Rahman
B.S. Electrical Engineering, University of South Alabama, Mobile, 1995
M.S. Electrical Engineering, University of Alabama, Huntsville, 1998

Submitted to the MIT Sloan School of Management and the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degrees of
Master of Business Administration
and
Master of Science in Engineering Systems

In conjunction with the Leaders for Global Operations Program at the
Massachusetts Institute of Technology

June 2011

Signature of Author ______________________________
MIT Sloan School of Management, Engineering Systems Division
May 13, 2011

Certified by ______________________________
Duane Boning, Thesis Supervisor
Professor of Electrical Engineering and Computer Science

Certified by ______________________________
Donald Rosenfield, Thesis Supervisor
Senior Lecturer, MIT Sloan School of Management
Director, Leaders for Global Operations Program

Accepted by ______________________________
Nancy Leveson, Chair, Engineering Systems Division Education Committee
Professor, Aeronautics and Astronautics and Engineering Systems Division

Accepted by ______________________________
Debbie Berechman, Executive Director of MBA Program
Executive Director of MBA Program, MIT Sloan School of Management

Competitive pricing and learning in CPU sockets

by
Mehrafshan Tabassum Rahman
Submitted to the MIT Sloan School of Management and the Engineering Systems Division on May 6, 2011 in Partial Fulfillment of the Requirements for the Degrees of Master of Business Administration and Master of Science in Engineering Systems

Abstract

An Intel processor can be electrically attached to a PC motherboard permanently or via a component called a socket. Intel defines the critical interfaces between the socket and the processor. Independent suppliers then manufacture the sockets and Intel validates the design of the sockets before they are sold to the original equipment manufacturers (OEMs). Sockets are the preferred mode of processor attachment for OEMs; however, the increase in price when a new socket is introduced has been a source of complaint by OEMs. This project seeks to better understand what factors contribute to socket costs and what can be done to better understand the increase in price when a new socket is released. This thesis provides a complete analysis on socket supplier development costs and determines that there is an optimal market situation that will minimize the socket cost for OEMs. After investigating different factors it is determined that the number of suppliers and level of competition are most strongly correlated with socket price. Furthermore, research shows that experience curves using competition as a factor are the most useful way of understanding socket price. Recommendations on ideal market share by supplier are provided as part of the results.

Thesis Supervisor: Donald Rosenfield
Title: Senior Lecturer, MIT Sloan School of Management

Thesis Supervisor: Duane Boning
Title: Professor of Electrical Engineering and Computer Science

This page intentionally left blank.

Acknowledgments

I would like to thank Intel Corp. for offering me this internship opportunity at their headquarters facility in Santa Clara, California. I would specifically like to thank the following people:

- Jason Ku – For sponsoring and creating the project, mentoring me during my internship and providing career guidance.
- Russell Aoki – For taking the time to explain the technical background I needed to complete this project.
- Andrew Nelson – For providing the data and insight on suppliers that was essential to this project.
- Mingji Wang – For his exceptional knowledge of socket manufacturing that he readily shared with me during supplier visits.

I would also like to thank my thesis advisors Duane Boning for reviewing my project and providing feedback on my research approach, and to Don Rosenfield for taking the time to visit me during my internship and providing the guidance I needed to complete the project. Finally I would like to thank my family for supporting and encouraging me through these two years.

This page intentionally left blank.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

This chapter will provide background information on the project and the sponsor company, Intel. The research approach and the problem to be solved are discussed in detail. The chapter concludes with an outline of the thesis.

1.1 Problem Statement

The socket provides the electrical interface between the processor and the motherboard and as a result is a critical component of a computer system. Intel produces processors; however, independent suppliers manufacture the sockets. Intel defines the interfaces between the processor and the socket, the suppliers manufacture the socket according to the requirements, and Intel validates the socket before the supplier sells them in the open market. Since there is a large degree of interaction during the development phase, a unique relationship has developed between Intel and the supply base for sockets. However, recent changes in the industry have resulted in challenging market dynamics. The purpose of this internship research project is to gain insight into the industry supply chain, the current market situation and the customer-supplier relationships in order to recommend strategies and options that will better understand what affects prices.

1.2 Background

Intel Corporation was founded in 1968 by semiconductor pioneers Robert Noyce and Gordon Moore. Initially the majority of the company's business was centered on the development and manufacturing of SRAM and DRAM memory chips. In the 1980's with the introduction and subsequent popularity of the personal computer, microprocessors became the primary business for Intel. Over the years, Intel has grown their market share of microprocessors to 80% [1].

Currently Intel continues to focus on what it does best - developing and producing advanced microprocessors. By targeting new areas for growth such as virtualization, cloud computing and data center platforms, Intel will continue to provide the processor of choice. Within Intel, product groups focus on core architecture and manufacturing operations within specific markets. These groups are aligned with the end uses for its products -- PC Client, Data Center, Embedded and Communications, Digital Home, Ultra-Mobility, NAND Solutions, and Wind River Software.

In recent years, Intel has filled in their product line by acquiring companies that will help expand their product base. For example, the acquisition of Infineon's wireless unit, which was part of Intel's strategy to establish a portfolio of chips for smartphones and other wireless devices. Intel also recently purchased security software provider McAfee. With these new procurements, Intel can now offer its clients a comprehensive package of hardware, software, and services [2].

In addition to acquisitions, Intel has also ramped up its R&D efforts, specifically its "tick-tock" technology development process. During the “tick” cycle, the silicon process technology is improved which allows for increased transistor density on the wafer and enhanced performance. During the “tock” cycle, the new architecture is optimized based on the new silicon process. Intel plans to release a new microarchitecture for its PC processors every two years, while improving the next-generation silicon manufacturing processes in intervening years. In 2011 Intel plans to spend about $9 billion investing in capital improvements to equip its next-generation 22nm manufacturing capacity. A description of the tick-tock cycle is shown in Figure 1 [3].

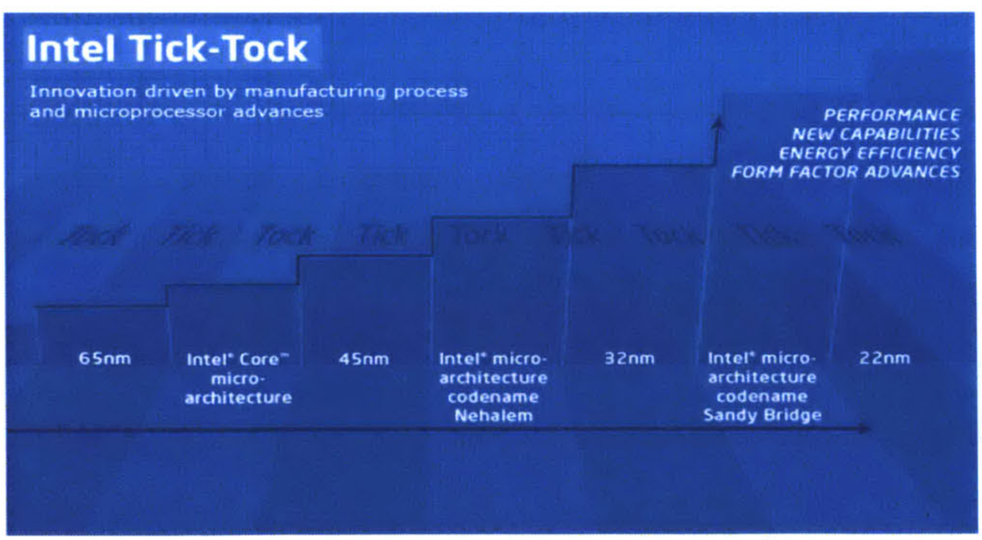

Figure 1: Intel Corporation tick-tock cycle

1.3 Purpose of Study

In order to maintain their strong position in this industry, Intel not only focuses on their technology development but also on how their processors are integrated into computer systems. The manner in which Intel processors are integrated into a computer system can vary based on the type of system. In other words, different system types will have different processor requirements. One type of processor is a socket-less, or ball-grid-array (BGA) type processor, where the processor is attached directly to the motherboard. This type of processor is most commonly seen in notebook and netbook applications. Another alternative is to use a component called a socket to attach the processor to the motherboard. The socket is one of the most critical components of a system since it provides the interface between the processor and the motherboard. This study focuses on the processor socket and was sponsored by the PC Client Group (PCCG), a part of the Intel Architecture Group (IAG) that designs socket and processor package requirements. Last year this same group sponsored a study by an LGO student to determine if the industry could move towards using a BGA or socket-less processor package. The results of that study determined that sockets provide flexibility in inventory management and design that customers are willing to pay for. Therefore, sockets will still be used for the foreseeable future to attach processors to motherboards [4].

When a new processor is designed, a compatible socket is also designed as part of the process. Once the socket design is complete, suppliers are selected and the phase of producing a validated socket begins. It is important to note that this is a collaborative relationship where Intel works closely with the suppliers to resolve any technical issues that may arise. Although this overall process may look very simplistic, the supplier selection methodology can be complicated.

The process of how socket suppliers are selected and managed has evolved over the years. Supplier selection is an important aspect of Intel's product management strategy since having insufficient socket suppliers would lead to insufficient capacity. In other words, there would not be enough supplier resources to meet the demand for sockets by system manufacturers; this could then delay Intel product offerings and could also result in higher socket prices. Given these circumstances, even though Intel does not directly buy sockets, they have a vested interest in ensuring that they are offered to customers at a reasonable price. As technology improves, new sockets have to be designed to be compatible with the new processors. This process cannot be escaped; however, gaining a better understanding on how socket prices are determined and how to minimize the cost impact to the OEMs would help Intel evaluate technology transitions. Given the importance of sockets in the PC industry, the question of how many suppliers to engage to stimulate competition and ensure sufficient capacity was the initial stimulus behind this study.

Therefore, the purpose of this study was to gain a better understanding on how socket prices are determined and how to minimize the cost impact to the system manufacturers while still ensuring sufficient capacity.

1.4 Research and thesis overview

This first part of this project focuses on data collection of socket suppliers, socket prices and the socket development process. Information on socket suppliers is used to understand the socket supplier ecosystem and how a specific supplier impacts the market. Socket price history is collected to identify trends and determine if there is a correlation between market situation and socket prices. Finally the socket development process is investigated as another possible influence. A sample of the socket price data collected is shown in Figure 2[*]. The figure shows the socket price per quarter for three different generations of a desktop socket. PGA 478 (blue) is the oldest socket, LGA 775 (pink) is the first land grid array socket, and LGA 1155 (yellow) is the latest socket. The limited data points for the LGA 1155 is due to the fact that it had only recently been introduced. Therefore, the price trend over time is only available for three quarters.

[*] The data in Figure 2 reflects the price trend for the industry and not a specific supplier. The actual prices have been concealed due to confidentiality reasons.

From reviewing Figure 2 certain trends can be identified. Firstly, the socket price decreases over time. Secondly, when a new socket is released it is offered at a higher price than the previous socket.

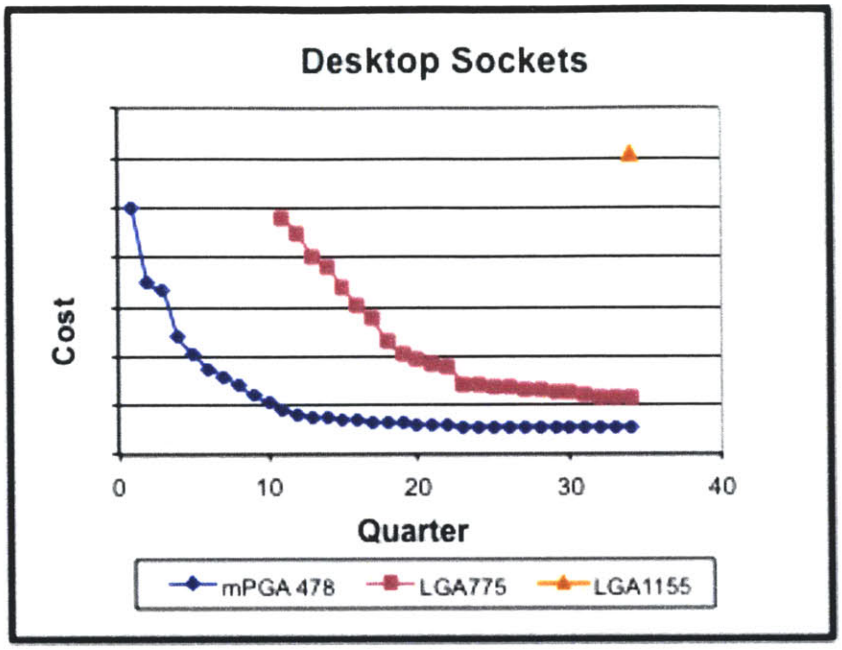

Figure 2: Plot of socket prices per quarter for 3 different sockets

After the data was collected interviews, were conducted with analysts within Intel to provide more insight on the price curve. The additional information and questions that were raised are overlaid on a typical price curve shown in Figure 3†. The questions posed by the analysts and MIT advisors helped steer the remaining research. The questions and how they is addressed are as follows:

- What accounts for the starting price? To understand the starting price, socket developments costs are estimated to determine if this is a driver for the price jump when a new socket is launched. Market dynamics are also considered as a potential driver of the price jump.

† End of life price is the amortized cost of the initial capital investment by the supplier plus labor, material and margin.

- Can the price curve be modeled? After reviewing literature it is noted that the experience curve can be used to model the price curve. Furthermore, the number of suppliers and market competition are identified as external factors that could impact the price curve.

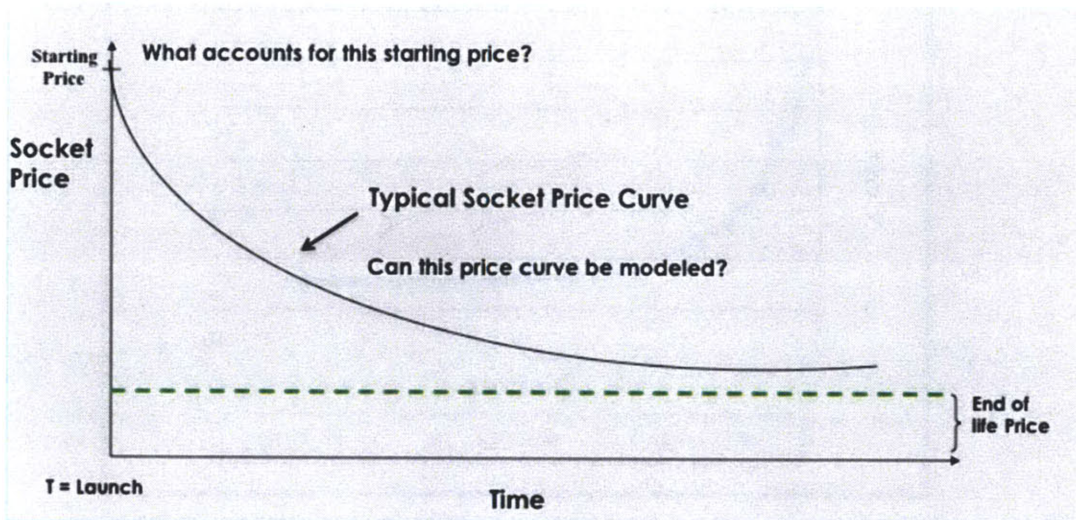

Figure 3: Socket price curve

Visits and interviews with socket suppliers were conducted to verify assumptions on socket development and manufacturing costs. These interviews were extremely helpful in evaluating socket starting prices. From this information socket development costs are estimated to determine if this is a driver for the starting price. Finally, as mentioned previously, the shape of the price curve is modeled using the experience curve. The experience curve defines a relationship between volume of sockets produced and socket cost. By analyzing the data in this manner, trends and anomalies can be identified and further investigated. Results from the experience curve analysis are then applied to the current sockets to determine what trends and price changes could be expected over the life cycle of the product.

The remainder of the thesis is structured as follows. In Chapter 2, processor package types and socket types are introduced. An explanation of the socket development process from Intel and the supplier's perspective is also included. The chapter concludes with a review of the socket suppliers and their characteristics. In Chapter 3, the primary focus is socket development cost and how this relates to the socket starting price. Development cost estimates for two sockets are presented and analyzed to see if the socket starting price is justified. Chapter 4 begins the analysis using the experience curve. Again two specific sockets are analyzed using this technique and conclusions regarding two factors; number of suppliers and market competition are identified. Chapter 5 focuses on looking at market competition as an indicator of price change, and Chapter 6 applies the knowledge learned from the previous sockets to the current sockets on the market.

1.5 Conclusions

The purpose of this internship regarding how Intel can better understand the supplier socket ecosystem was introduced in this chapter. Background on Intel itself was also presented to give the reader an idea of the company technology and strategy. Finally an outline of how the remainder of this thesis will be organized was presented. During the remaining chapters socket price volume data will be analyzed as well as the socket starting price. Tools such as the experience curve will help provide better insight into price volume trends. These conclusions will be used to predict what will happen with future sockets.

2 SOCKET BACKGROUND

In this chapter the different types of processor packages and sockets are explained. Next the socket development process is presented from the Intel and the supplier perspective. The chapter concludes with and explanation of the socket supplier ecosystem and the current market situation.

2.1 Processor package and sockets description

The computer industry has evolved over the years; as a result there are numerous computing devices available geared towards specific tasks. Everything from high-speed gaming systems to portable tablets and ultrathin laptops are now being offered in the market. Given the variety of computing devices available, there are different processor packages to meet the needs for different applications. Therefore, system manufacturers select the type of processor package based on the computer system.

A processor package consists of the silicon die mounted on a substrate. The substrate then makes the electrical connection, translating between the connections on the die to the connections to the system. The type of package depends on the type of system implementation. When computer manufacturers choose which processors to install in a computer, they have the option of three different processor package types. The three different package types are Ball Grid Array (BGA), Pin Grid Array (PGA) and Land Grid Array (LGA) [4].

A BGA package consists of a die placed face-down on a substrate. The bottom of the package has solder balls attached to it, which act as contacts for the processor. The advantage of using balls instead of pins is that there are no leads that can bend. When it is attached to a motherboard, the BGA package is placed on top of the appropriate copper pads and then heated to permanently attach the package to the motherboard. This type of attachment process is normally used in systems where there is a low profile (z-height) requirement, such as in a mobile computer. A typical BGA type processor is shown in Figure 4 [5].

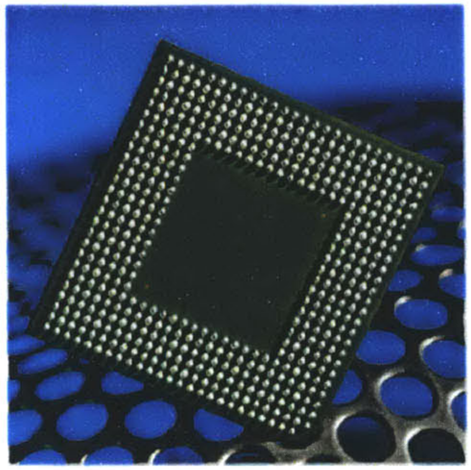

Figure 4: BGA type package

The PGA package is similar to the BGA, except instead of balls pins are used on the bottom of the package. This type of package is shown in the Figure 5 [6]. If a PGA processor is used, then it has to be attached to the motherboard via a socket. A socket is an electrical component that is mounted to the motherboard. The processor is then placed in the socket and locked in place by a mechanical device to complete the connection. The socket designs allow zero-insertion force removal and insertion of the processor. A typical PGA socket is shown in Figure 6 below [7].

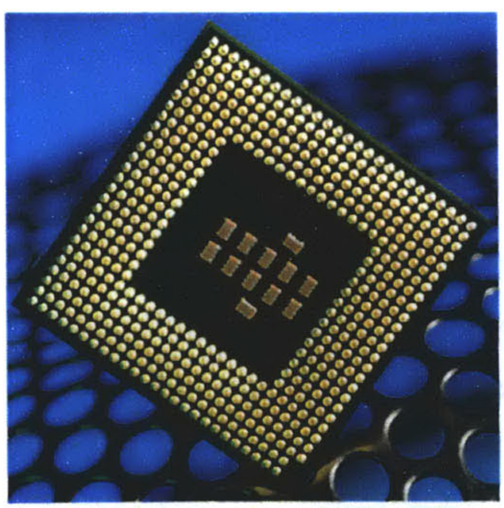

Figure 5: PGA package

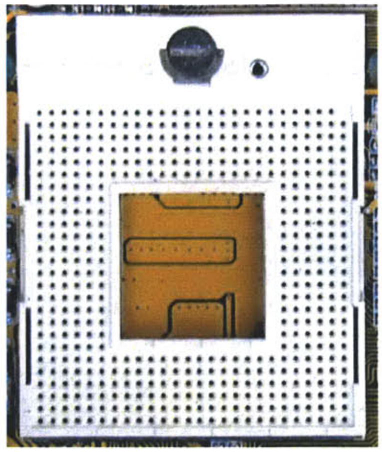

Figure 6: PGA socket (socket 479)

An LGA processor is similar to a PGA processor in that it requires a socket to be attached to a motherboard. This package consists of a processor die mounted on a substrate land-carrier. An Integrated Heat Spreader (IHS) is attached to the package substrate and core, and serves as the mating surface for the processor component thermal solution such as a heatsink [10]. The LGA processor package has contact pads at the bottom that are used to make the electrical connection to the socket. The processor is then engaged by a loading mechanism to secure the processor to the socket. The loading mechanism, or ILM as it is often called, is a metal plate with a lever that is used to lock the processor into the socket. Finally, since the profile (z-height) of this type of package is typically higher than in the PGA package type, it is most commonly used in desktop systems. An example of an LGA processor package is shown in Figure 7, while the socket is shown in Figure 8 [8][9].

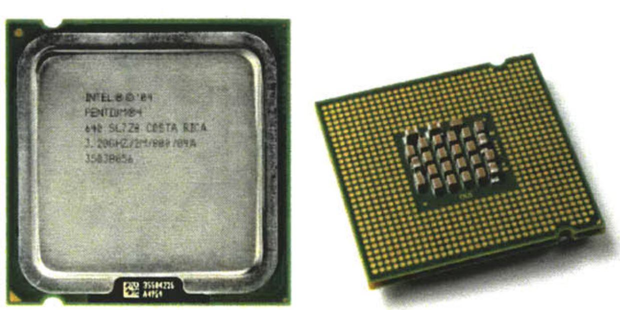

Figure 7: Intel LGA Package (top and bottom)

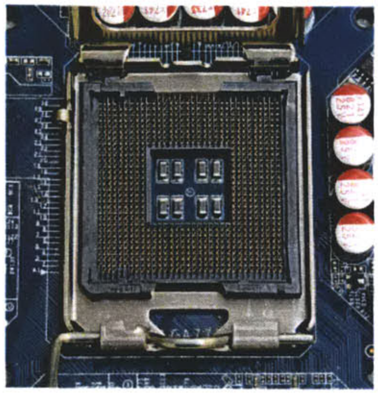

Figure 8: Intel LGA Socket (LGA 775)

Due to the popularity of mobile computers, the market for mobile processors is expected to grow. This will continue to make PGA processor types a product that will be in high demand for the coming future. Since desktop volumes are also expected to remain strong over the next several years, LGA processors will also remain an important product line for Intel.

The latest mobile socket is the mPGA 989. This socket has a different footprint, smaller pitch (the distance between pins), and double the contact count compared to the previous generation socket. This represented a significant engineering effort for both socket suppliers and Intel. The latest desktop socket is the LGA 1155. This socket also underwent similar changes from its predecessor with a smaller pitch, increased contact count, and new footprint.

2.2 Sockets used in research

Since there have been new processor offerings by Intel over the years, there have also been different sockets manufactured to support these processors. Sometimes the same socket can be used for multiple generations of processors; however, this is not always the case and a new socket often has to be released. As part of the initial data compilation, information from as many sockets as were available was collected. This data was collected by performing online research and interviewing analysts at Intel familiar with sockets. This effort resulted in the following information for nine different socket types: socket price, number of sockets sold and supplier market share. After reviewing the data it was determined that even though there was information for nine different sockets only a small segment of the data could be used. This was due to two reasons. The first reason was that some sockets have very low volume sales, making any interpretation on price trends difficult. Secondly, two of the sockets, mPGA 989 and LGA 1156, were recently released and only had three quarters worth of data available. In summary, only sockets that had sufficient data available are used in this analysis in order to ensure the results are meaningful. After the analysis is complete, the findings are used to postulate what would happen with the new PGA 989 and LGA 1156 sockets. The list of sockets used for this project and a brief description of each are shown in the Table 1 [10].

Segment	Name	Description
Desktop	LGA 775/ Socket T	First land grid array socket; has exposed contacts that mate with bare lands on the bottom side of the package to make electrical contact
Desktop	LGA 1155/ Socket H	Latest desktop socket, similar in design to LGA 775
Mobile	mPGA 479	Contacts covered by a plate with holes that match with pattern of pins that are soldered to the bottom of the package. Uses cam mechanism to secure processor in place
Mobile	mPGA989	Most recent mobile socket, smaller pitch than predecessor
Both	PGA 478	First PGA socket, Contacts covered by a plate with holes that match with pattern of pins that are soldered to the bottom of the package

Table 1: List of sockets used for analysis

2.3 Socket Development Process – Intel Perspective

The socket development process is a multi-year process that ultimately results in an Intel verified socket. There are two distinct phases during the socket development process. There is a pathfinding phase and a socket validation phase. The pathfinding phase occurs when Intel is still developing new processors. During this phase, socket technology improvements and new ideas are shared by the suppliers. As new processor designs are developed, Intel communicates the associated socket requirements with the socket suppliers to get their feedback. This feedback is used to determine if the socket design can be implemented and manufactured. Since this is a collaborative relationship with the socket suppliers Intel is aware of their capabilities and can define new sockets around technologies that are available. Figure 9 below depicts the collaborative relationship between Intel and socket suppliers.

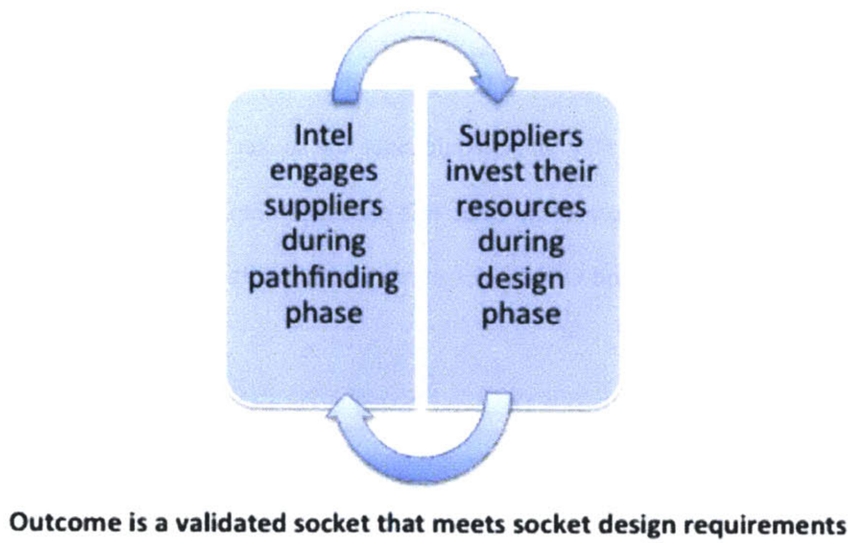

Figure 9: Intel/Socket supplier relationship

The entire socket development process can be more or less complex based on the type of modifications made to the socket. If a whole new design, such as a new form factor, contact design, or pitch is required, then the development process can start as much as three or four years in advance. If the change is minor, as in a rekey or change in the plastic cover where the tooling change is minor, then the development can be completed in less than a year.

Given the complexity of a new socket design, the pathfinding phase can last about a year and a half. During this time there can be several design iterations and different samples being generated by the socket supplier for Intel to test. Once the design is finalized, a design guide that documents the requirements and the needed capabilities is released, the suppliers start producing, and the validation phase begins. Intel verifies the socket designs by each of the socket suppliers. Again it is important for Intel to make sure their processor will function properly with the socket, since any defect in the socket design can have an impact on how the processor functions. Intel performs rigorous mechanical and electrical tests, based on specific internal test guidelines, on upwards of 10,000 sockets per supplier. The testing is designed to be thorough and the results are carefully monitored and recorded. Since Intel works closely with socket suppliers, any design changes that need to be made are identified during this time. Intel then verifies the design changes through additional testing. The complexity of this phase can vary based on the level of changes between the current and previous socket generation. The validation phase can last up to a year and a half if the socket design changes significantly. However, it is important to stay on schedule since the socket release needs to be timed with the release of the associated Intel processor. Once this phase is complete the socket is verified and is sold in the open market to OEMs and ODMs. A summary and timeline of this process is shown in Figure 10.

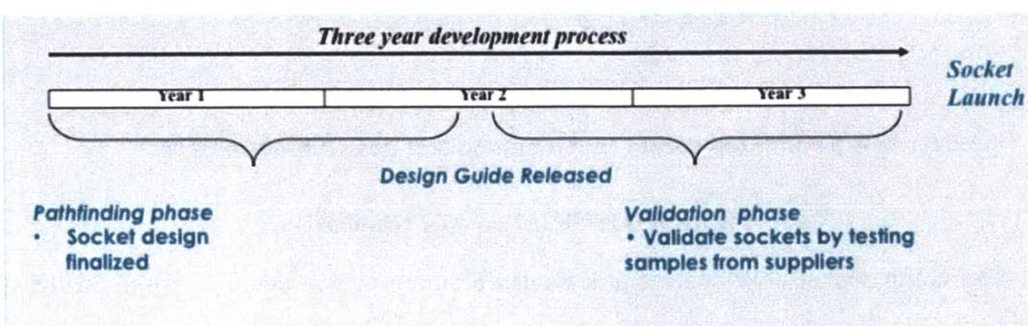

Figure 10: Socket development process

2.4 Socket Development Process – Supplier Perspective

In the past Intel would only engage two suppliers during the pathfinding phase, since this was sufficient to meet the industry capacity needs for socket demand. The initial two socket suppliers would then invest their own resources during the pathfinding effort. In return they would have the opportunity to come to market first on the final design. After the new design launched, other socket suppliers were given access to the design guide. Other socket suppliers could only start developing their socket designs after the design guide had been released. Since the design guide just specifies the requirements for the socket, each supplier can have a unique design and manufacturing process for their socket, optimizing for their own capabilities. Therefore, Intel performs a validation on each socket design.

From the supplier's perspective, the pathfinding phase can be a challenging time since they may be working on multiple designs simultaneously. Even though all designs may not make it to market, socket suppliers still have to invest their own resources during this time. From interviews with socket suppliers, there is concern that the additional work may tax their resources and they may be passing this additional cost on to their customers in the form of higher socket prices. Intel may then face pressure to lower the processor price to offset the additional cost of the socket. A flow diagram of how the pathfinding phase looks from the supplier's perspective is shown in Figure 11. The additional resources required to investigate potential socket designs that do not go into production have also been included.

Figure 11: Socket development process flow

Socket development costs, including pathfinding costs, are explained in more detail in the next chapter, where development costs are used to estimate socket starting price.

2.5 Socket Supplier Ecosystem

There are currently five major socket suppliers in the market. Socket suppliers vary in size and manufacturing capability. They are all based in Asia and have manufacturing facilities located in China. From Intel's perspective, since there are only a few suppliers, adding additional suppliers would increase competition and capacity and could potentially impact socket prices. On the flip side, Intel needs to be aware that exposing their brand name to more suppliers could be risky. Additionally, validating an additional supplier can be costly and time consuming. These are tradeoffs that Intel needs to consider when adding additional suppliers.

There are several dynamics to understand when looking at the socket supplier ecosystem. First, some computer manufacturers only use components from specific socket suppliers. For example, a major computer OEM may have a relationship with a specific socket supplier, so Intel needs to make sure that particular socket supplier is always included in the socket development process. On the other hand, some socket suppliers only produce for the first 1-2 years of the socket product life cycle when they can maximize their profits. So Intel needs to make sure they have enough suppliers producing sockets over the entire product life cycle. Thirdly, there is strong competition between the socket suppliers. In fact there have been accusations of Intellectual Property (IP) violations between some of the socket suppliers that have sometimes required third party companies, such as Intel, to intervene. Finally all socket suppliers are not equal. It is becoming more apparent that the type of supplier, specifically a low cost supplier, can have a big impact on the market. Therefore, there are several layers of complexity to consider when looking at socket suppliers.

As mentioned previously, there are five major socket suppliers. Due to confidentiality reasons their names are not used here, but instead are referred to as Alpha, Beta, Theta, Phi and Omega. A brief overview of each supplier is provided. Alpha and Beta have been manufacturing sockets for several years, while Theta and Omega are new entrants to the market, and are low cost suppliers. Important points of each company have been included in the description to give the reader a better understanding of how the socket manufacturers vary in size and strategy. The company highlights below concludes this section on socket supplier ecosystem.[‡]

Company Alpha

Company highlights related to socket industry:

- Historically dominant player in socket market, generally included in early pathfinding phase.
- State of the art manufacturing. Company also has system manufacturing capability.
- Has deep engagement on products outside of sockets. Stable company.
- If company Beta drops out of business, then Alpha will become the most experienced supplier and could have more control over socket direction.
- IP litigation with other socket suppliers.

[‡] Company highlights derived from internal Intel interviews and site visits to the suppliers

Company Theta

Company highlights related to socket industry:

- Sockets are primary source of revenue.
- Innovative approach to manufacturing results in low cost and market pricing pressure.
- Less mature socket development ability limits their technical problem solving expertise.
- Known to produce sockets to end of life.

Company Beta

Company highlights related to socket industry:

- Long history of working on sockets gives them a highly experienced team.
- Consistent participation in socket development activities.
- Known to expend significant resources in pathfinding opportunities.
- Actively pursuing new technologies.

Company Phi

Company highlights related to socket industry:

- Company recently reorganized to increase competitiveness.
- Manufacturing and development are collocated making problem resolution more efficient.
- Partnering with other companies to lower costs.

Company Omega

Company highlights related to socket industry:

- Secured major investor that will also be a large customer for sockets.
- New to the market and looking to increase market share rapidly.
- They have low overhead and good tooling capabilities.
- As a low cost supplier they could increase price competition in market.

2.6 Current market situation

The current market share by supplier is shown for two desktop sockets. Figure 12 shows the market share for an earlier socket generation, the LGA 775. Company Alpha has 80% of the market while the next closest competitor Theta only has 14% of the market share. However, as shown in Figure 13 for the latest desktop socket, the market share between suppliers is quite different. Alpha has lost considerable market share to other suppliers.

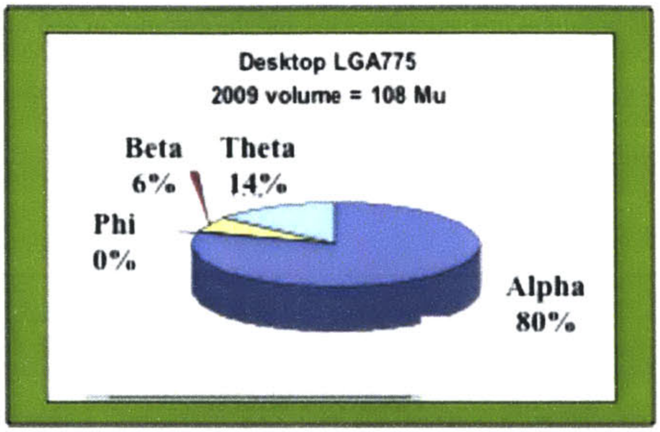

Figure 12: Market share of supplier for LGA 775 socket

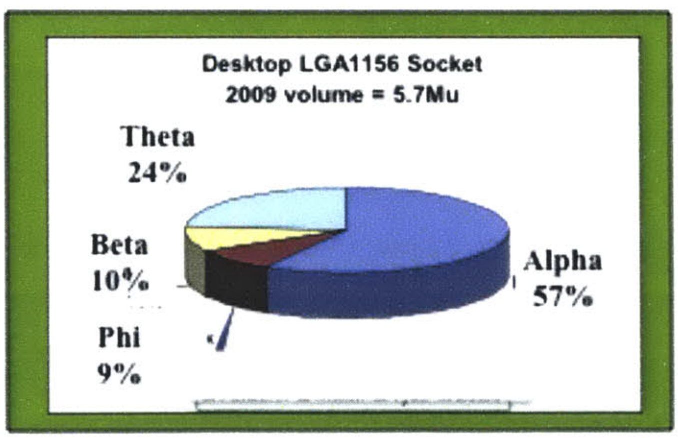

Figure 13: Market share of LGA 1156 socket

Since the market share by supplier is so important, an additional plot is shown of market share by supplier over the lifetime of a socket. The data in Figure 14 is for the LGA 775 socket. From the data it can be seen that Alpha has had the largest market share for sockets and continues to produce the socket late into the product life cycle. Company Beta manufactures sockets from the beginning but then stops producing the socket approximately five years later. Company Theta, which is new to the industry, is now the only other producer of this socket besides Alpha. Finally company Phi, which was never a big player in the market, eventually stopped producing the socket. Since there are only a few socket suppliers and with some suppliers not producing sufficiently, it further reduces the competition in the market.

In summary, the exiting of one supplier (Phi) and the entrance of another supplier (Theta) has changed the dynamics of the industry. Market share is shifting and competition is now coming strongly from one particular supplier, Theta.

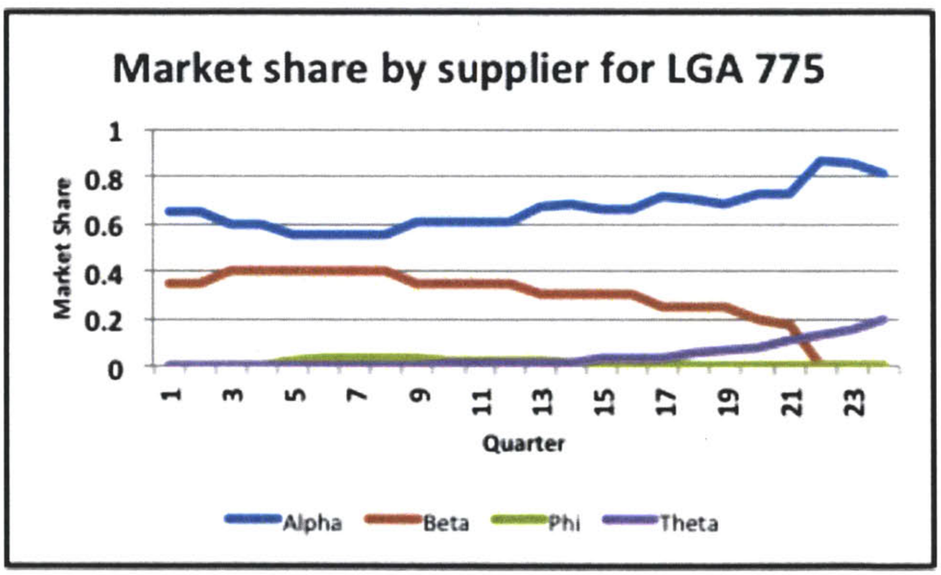

Figure 14: Market share of suppliers per quarter for LGA 775

2.7 Conclusions

This chapter provides the foundation information for the remainder of the thesis. The different processor packages and socket types were explained and the sockets analyzed for this project were presented. The socket supplier ecosystem and current market situation completed this chapter. The reader should have a better understanding of the supplier ecosystem and how the market has changed recently with the introduction of a new low cost supplier.

3 Understanding Socket Price at Launch

In this chapter we present a hypothesis as to why the socket price increases when a new socket is launched. Socket development costs are explained and then two cases are presented to determine if the hypothesis is true or not.

3.1 Hypothesis

As mentioned in Chapter 2, socket development costs are completely borne by the socket supplier as an investment in the opportunity to become a lead supplier for a new socket design. In this chapter we attempt to make a connection between the socket pathfinding and development costs, and the cost of the new socket. As has been pointed out in earlier sections, the socket price at launch is usually significantly higher than the price of the previous socket. The hypothesis is that socket suppliers are trying to recoup their investment costs during the first six quarters, and this is the reason the price goes up so significantly. In this section, we will estimate development costs for two different sockets by two different suppliers and compare these results with historical socket price data. If the hypothesis is true then our socket starting price based on socket development costs should be fairly close to the historical prices. If they are not similar, then the hypothesis is false and there are other reasons for the increase price of new sockets.

3.2 Quantifying socket development costs

Before calculating the development costs, it is worthwhile to take a step back and look at the price volume data when there is a transition to a new socket. Figure 15 shows the transition between PGA socket 478 and LGA 775. The purple bars show how the new socket volume increases over time as more system manufacturers adopt the new socket. The yellow line shows the price of the socket. We see that the price jumps by more than four times the cost of the previous socket when the new socket is released. The price subsequently falls, but the even after more than a year it is still not at the level of the previous socket. Another aspect that is shown is something called the "break even triangle". It is suspected that socket suppliers attempt to recoup their investment during the first six quarters. This break even triangle is highlighted in the graph as well, and is essentially the value we will try to compare to development costs. In order to do this, supplier volume and price data is needed. This was ascertained during the initial data collection. Additionally, interviews were conducted with suppliers to ascertain what their initial investment would be for a new socket. Given this information a dollar amount can be estimated for this break-even triangle.

The analysis is performed for LGA 775 and PGA 989. These sockets are chosen since they represent significant changes from the previous socket and thus have high investment costs by the socket supplier. The suppliers used for comparison are company Alpha and Beta. They have been in the industry the longest and were able to provide sufficient data to perform the analysis[§].

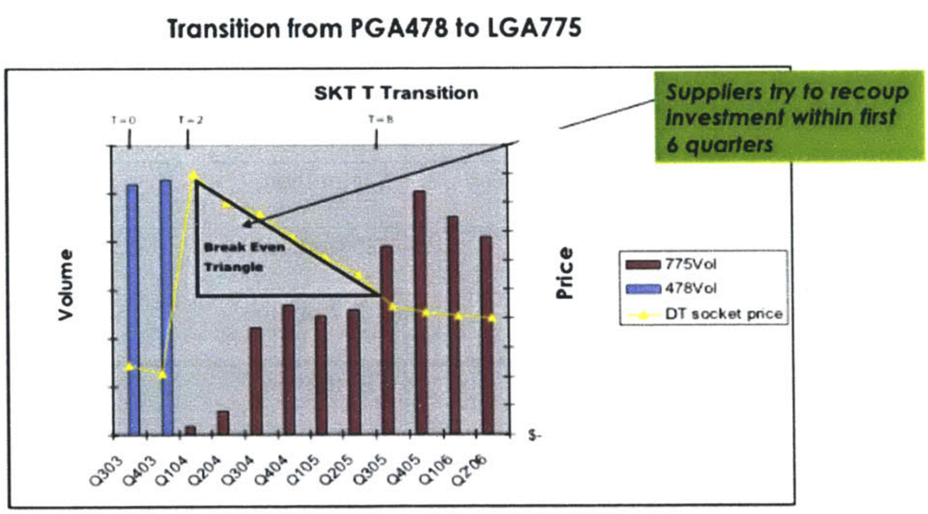

Figure 15: Transition from PGA 478 and LGA 775

§ Alpha and Beta were provided questionnaires relating to manufacturing and development costs. This information was then used to determine costs for the specific sockets

3.2.1 Case 1: LGA 775

The estimated development cost and first six quarters of revenue data for LGA 775 are shown in Tables 2 and 3 for company Alpha and Beta, respectively.

Alpha – LGA 775	
Revenue	$116.5 million
Material + Overhead	$34.5 million
Investment	$25 million
Pathfinding	$1.17 million
Profit	$56 million

Table 2: Estimates on revenue and profit data for Alpha LGA 775

Beta – LGA 775	
Revenue	$79.5 million
Material + Overhead	$23 million
Investment	$25 million
Pathfinding	$1.17 million
Profit	$30 million

Table 3: Estimates on revenue and profit data for Beta LGA 775

For both cases the investment costs to develop the new sockets, including the engineering work and the cost to bring up the new production lines, are estimated at $25 million dollars. As mentioned in Chapter 2, since not all design efforts lead to a product on the market, those additional pathfinding costs are included in the cost calculation. For this socket, since there were several design iterations, the additional pathfinding cost seems reasonable in this case. Intel socket analysts estimated material cost to be approximately $1.16 per socket. An additional 10% margin is added to provide a reasonable markup value. The same assumptions are used for both Alpha and Beta. Finally, since the number of sockets sold and the price of the socket for each quarter are available, the revenue can be calculated based on this information. Taking all this data into account Alpha made approximately $56 million in profit in the first six quarters the socket was produced and Beta made an estimated $30 million in profit during the same time frame. Since suppliers are making such large profits in such a short period, the hypothesis that they are trying to just break even does not seem to hold true in this case and it appears that the initial price of the socket is an attempt to reap extraordinary profits.

A plot of the volume of sockets sold and the price trend over time is shown below for Alpha (Figure 16) and Beta (Figure 17). Again the volume and price data have been normalized for confidentiality reasons. The price drops by 36% in the first six quarters, and the socket now sells for approximately 20% of the original price. The socket has been on the market for several years and now only two suppliers produce this socket.

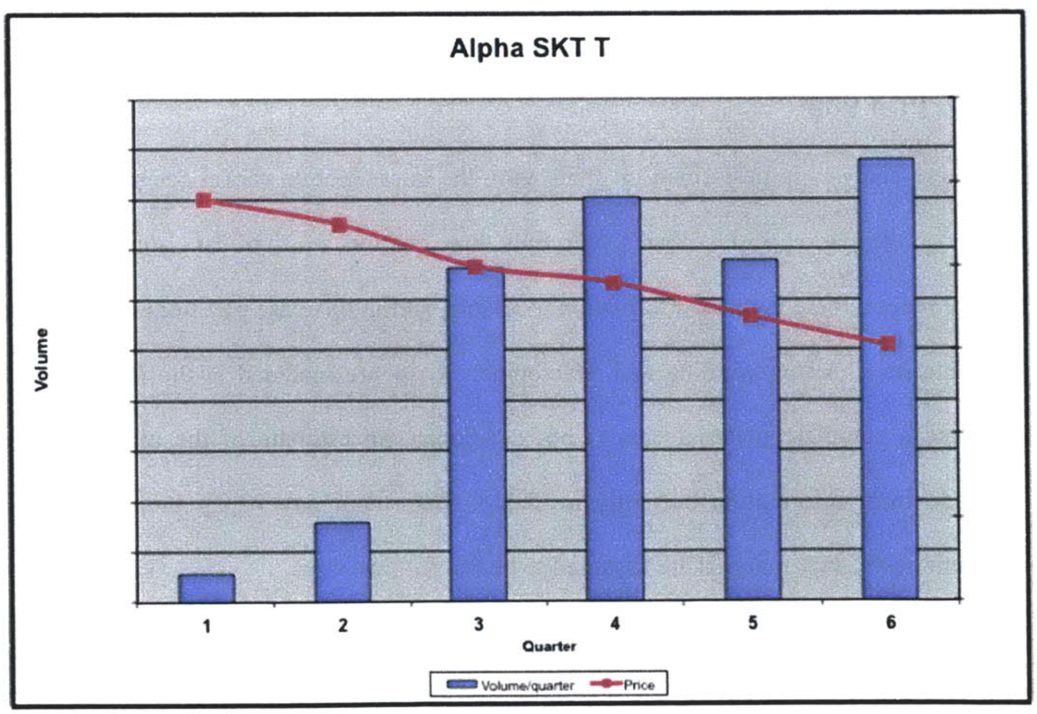

Figure 16: Company Alpha - Volume and price for first six quarters of Socket T (LGA 775)

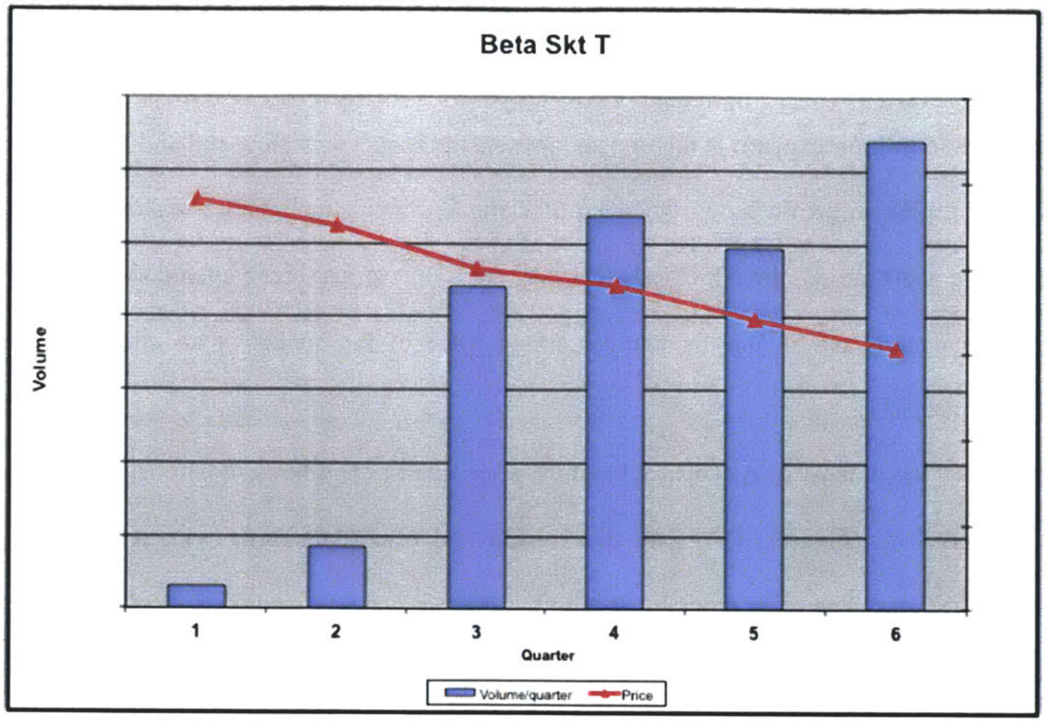

Figure 17: Company Beta - Volume and price for first six quarters of Socket T (LGA 775)

3.2.2 Case 2: PGA 989

This same analysis is performed on PGA 989, the latest mobile socket released. Since the socket has been on the market for less than a year, only three quarters worth of data is available. Since the data is more recent, there is more information available, and in this case pathfinding is not added as a separate line item. All pathfinding and development costs are included in the investment line item. Also, since a complete material cost is not developed, an estimate of the margin for each supplier is made from information currently available. Since company Alpha invests heavily in streamlining their costs, their margins are assumed to be 8% for this case.

Alpha – PGA 989	
Revenue	$112 million
Material (8%)	$9 million
Investment	$7 million
Profit	$97 million

Table 4: Estimates on profit and revenue for Alpha mPGA 989

Beta – PGA 989	
Revenue	$10 million
Material (10%)	$1 million
Investment	$6 million
Profit	$3 million

Table 5: Estimates on profit and revenue for Beta mPGA 989

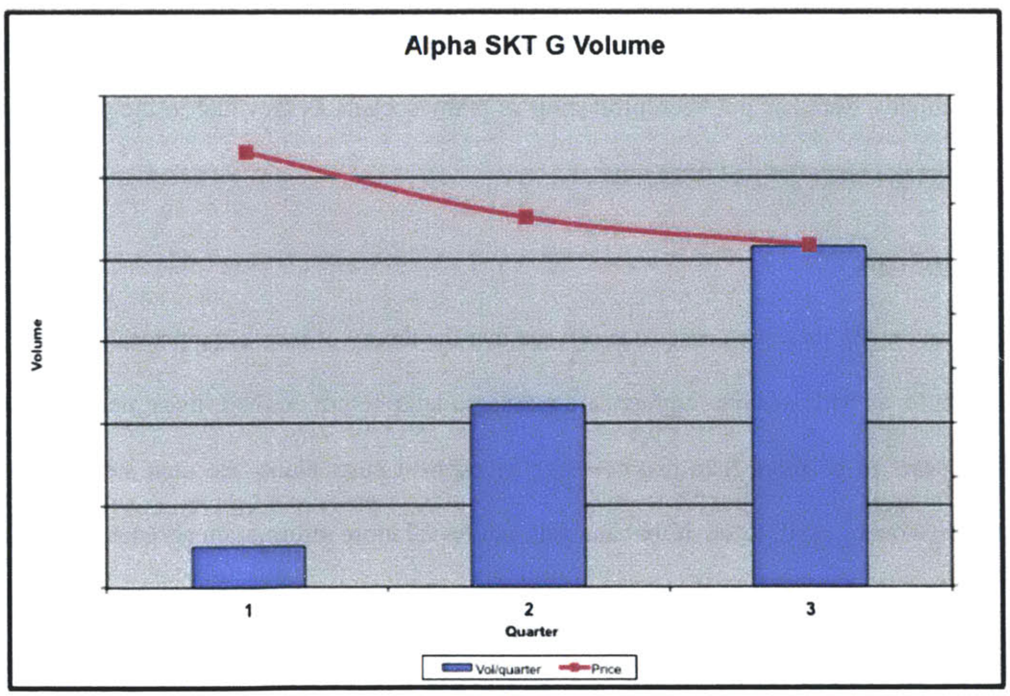

Figure 18: Company Alpha - Volume and price for first three quarters of Socket G (mPGA 989)

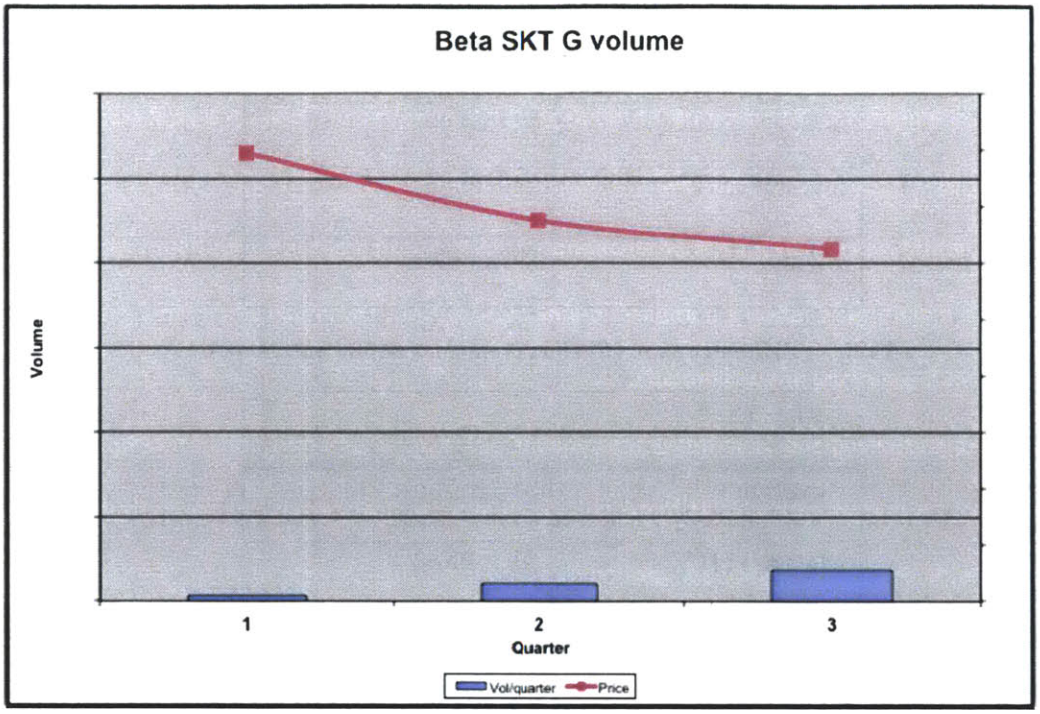

Figure 19: Company Beta - Volume and price for first three quarters of Socket G (mPGA 989)

Again, the suppliers are making significant profits during the first few quarters. In this case, company Alpha is estimated to make $97 million in just the first three quarters. Another interesting note is that company Beta has not been producing as many sockets as they had in the past, but they appear to still break even after just three quarters.

3.3 Conclusions

After reviewing these two cases one can see that the theory of increasing prices just to recoup cost does not hold, as both sockets suppliers are making a large return on their investments. Since the price jump appears to be more than just covering investment costs alone, the next step is to focus more on the price curve itself, to see if that analysis can reveal more information about socket pricing.

4 Socket Price Volume Curve Analysis

In this section, we analyze the socket price volume curve using the experience curve. The price volume curve is explained first followed by an explanation of the experience curve. Next, we analyze two different sockets using the experience curve. Conclusions are drawn from this analysis and explored further in the following chapters.

4.1 Socket price volume curve

In this section, we turn from looking at the starting price of the socket to the price curve itself. Given the known phenomena of prices dropping over time, a first-pass goal is to determine any trends and anomalies in the curve itself. The price-volume data plotted on a linear scale is shown for PGA 479 in Figure 20. The curve slopes down, appearing to follow an exponential curve, but is not perfectly smooth. The curve, however, seems similar to the experience curve, which gives a relationship between the volume of the product sold and the price. Before going into more detailed analysis, the experience curve theory is explained in more detail in the following section.

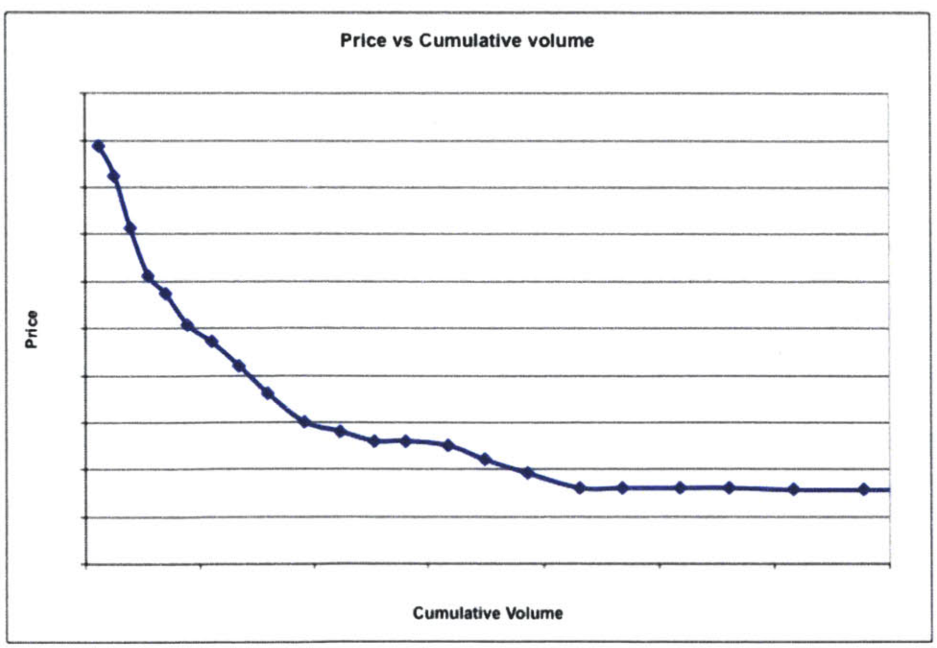

Figure 20: Price vs. cumulative volume for PGA 479

4.2 Experience Curve

The experience curve is used as the basis for analyzing socket prices. When working with this concept, it is important to make the distinction between the learning curve and experience curve since they are not interchangeable. The experience curve is used to quantify the rate at which experience of accumulated output, to date, affects total lifetime costs. The learning curve, in contrast, quantifies the rate at which cumulative experience of labor hours or cost allows an organization to reduce the amount of resources it must expend to accomplish a task. In other words, the experience curve effect is broader in scope than the learning curve effect, since it encompasses far more than just labor time. In essence, the experience curve states that each time cumulative volume doubles, value added costs (including administration, marketing, distribution, and manufacturing) fall by a constant and predictable percentage. Finally, it should be noted that the idea of experience curves is a relatively new concept and was made popular by the Boston Consulting Group BCG. Research by BCG in the 1970s observed experience curve effects for various industries ranging from 10 to 25 percent.

The experience curve can be expressed mathematically as follows:

$$C(n) = C_1 * n^{\ln(b)}$$

where the variables are describes as

C(n) = Cost on nth unit of production

C1 = Cost on 1st unit of production

N = Cumulative units of production

B = benefit of experience of doubling of output

As an example, a curve that depicts a 30% (B = 0.3) cost reduction for every doubling of output is called a "70% experience curve", indicating that unit costs drop to 70% of their original level. A graphical depiction of this experience curve is shown in Figure 21. The sample data shows the price curve plotted against cumulative volume. The plot on the right shows the same curve but on a log scale [11].

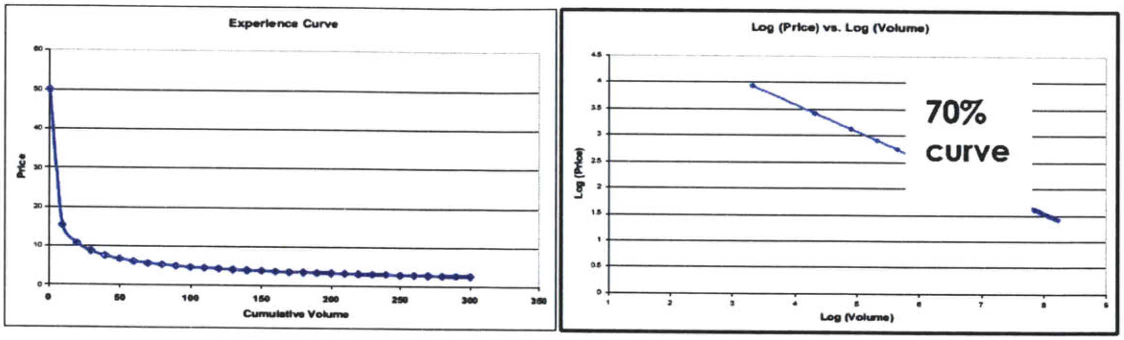

Figure 21: 70% experience curve in linear and log scale

When using the learning curve, it is common to transform the data set using the natural log. By performing this type of transformation, one can then look at the data on a linear scale as seen previously in Figure 21. A regression can then be calculated using statistical software or Excel, and the regression will give the user the slope and y-intercept of the line. These variables can then be used to find the coefficients in the learning curve. In summary, since we are most interested in the rate of learning as production increases, the change in slope of the line can be used to derive the rate of learning. Taking the natural log of the equation gives the following:

$$\ln\,(C(n) = \ln(C1) - b * \ln\,(n)$$

Next the regression is calculated on the data and the rate of learning is determined from the slope of the line.

$rate\ of\ learning = e^{b*lin(2)}$;where b is the slope of the line

The rate of learning can then be used to determine how the price changes as cumulative volume of sockets sold increases.

4.3 Experience curve analysis on socket price volume data

The experience curve is now applied to two sockets, PGA 479 and LGA 775. The price volume data is converted to a logarithmic scale and examined to determine if any trends or inconsistencies exist. Conclusions are drawn from this analysis and examined in subsequent chapters.

4.3.1 Case 1: PGA 479

Returning to the PGA 479 case, the price volume curve is shown again, along with the same data plotted on a logarithmic scale. Again, as mentioned in the previous section, if experience is constant during the lifetime of the product then the price drops by a fixed amount every time the production doubles. If this is not the case then the slope of the line will change, indicating that price drops do not occur at a constant rate. The price volume data is shown for PGA 479 in Figure 22.

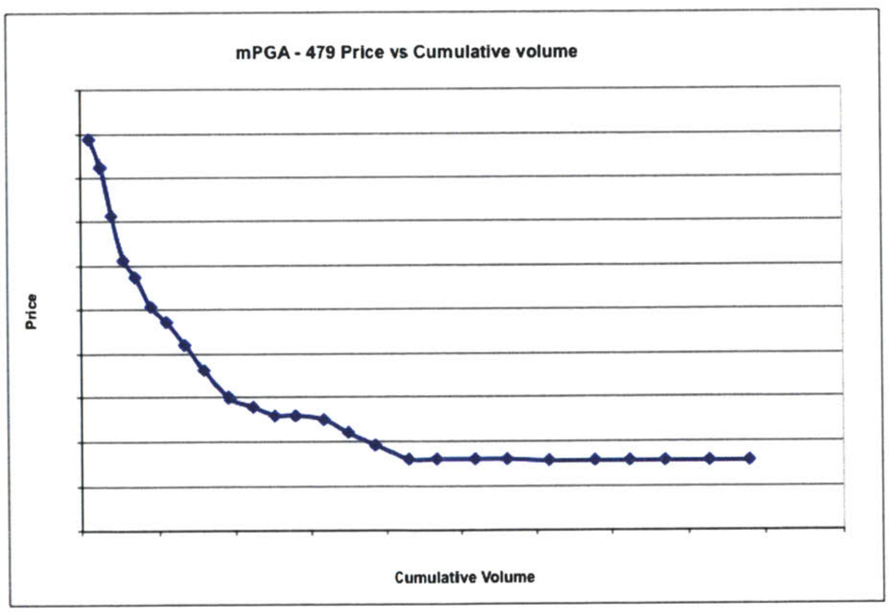

Figure 22: PGA 479 price curve in linear scale

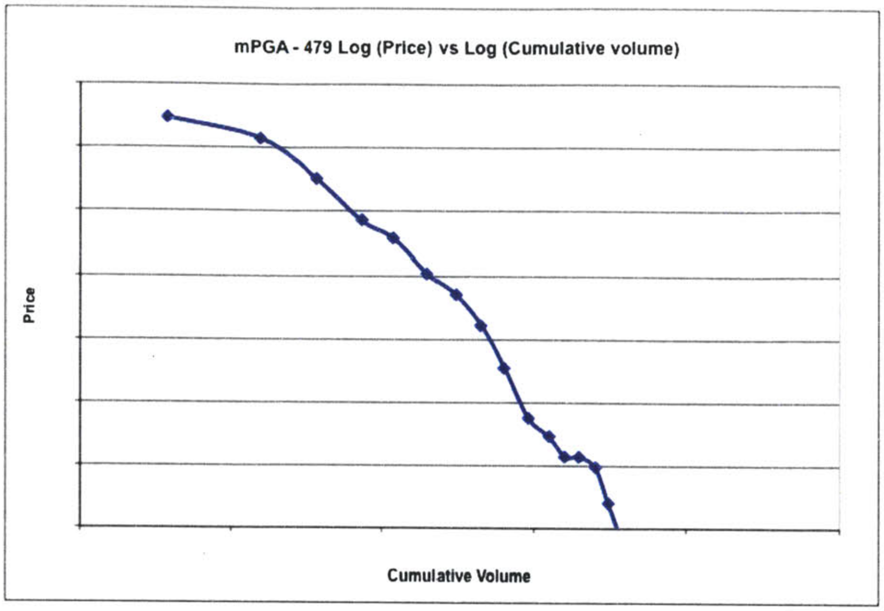

Figure 23: PGA 479 price curve on a log scale

As expected, the rate of learning is not constant and the slope changes over time. The slope of the line starts off with a certain steepness, then at about four quarters into the data the slope changes again with increasing steepness. The slope changes again towards the end, but this section of the curve is close to the end of life and is not relevant to the analysis. Only the initial change in slope that occurs earlier on is of interest.

4.3.2 Case 2: LGA 775

Looking at the LGA 775 socket, a similar trend can be seen. The price volume curve is shown in Figure 24, while the log of the data is shown in Figure 25. Again, the perfectly linear line is not seen when taking the log of the data; this means that the slope of the line is changing and thus the rate of change of the socket price is also changing over time.

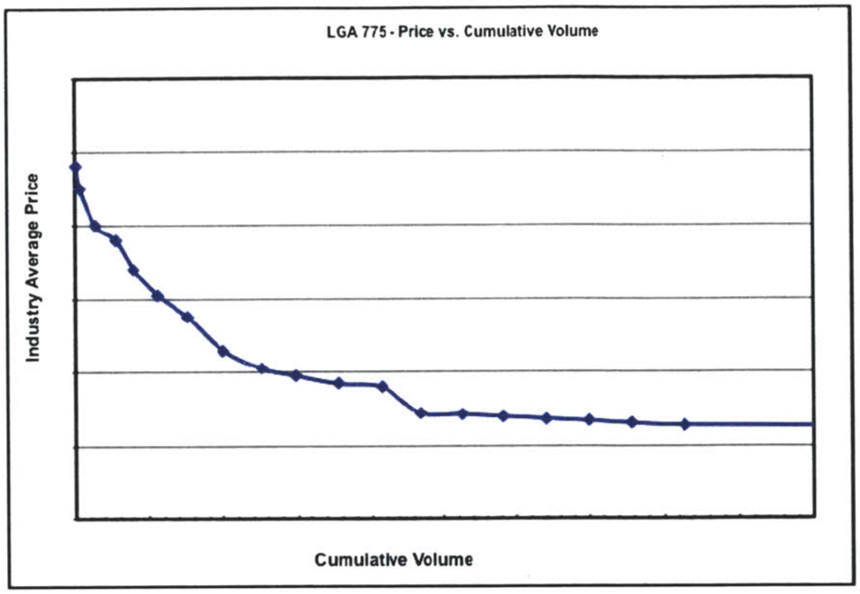

Figure 24: Price vs. Cumulative volume of LGA 775

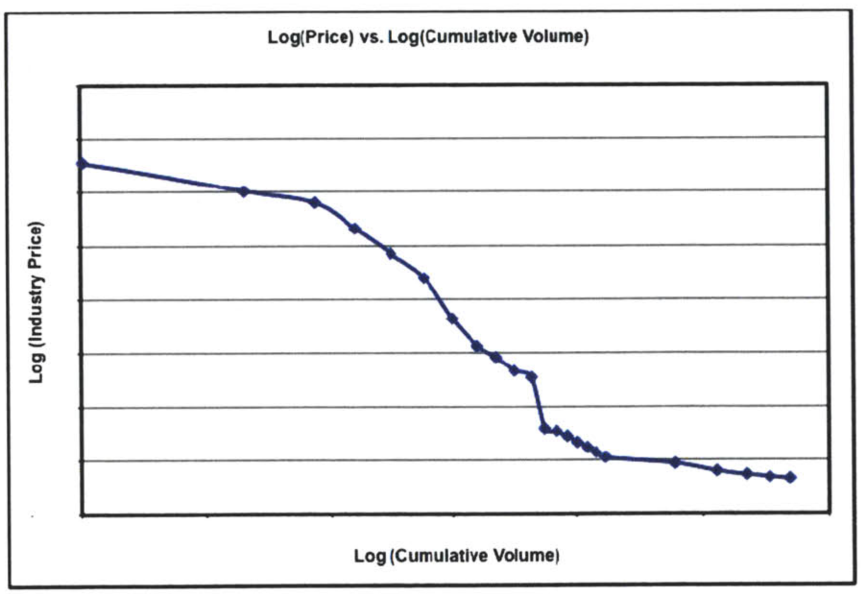

Figure 25: log Price vs. log Cumulative volume of LGA 775

4.4 Conclusions

The experience curve can be used to examine socket price data. The slope of the line will indicate the rate of learning and thus how the price is changing. However, looking at the socket data it was observed that the slope of the line is not constant, indicating there are other factors that are changing the rate of experience. Further investigation into this is discussed in the following chapter.

5 Market conditions and the experience curve

In this chapter we investigate reasons why the rate of learning changes for the experience curve. Market conditions such as number of suppliers and market competition are applied and conclusions are drawn from this analysis.

5.1 Possible factors that can affect socket price

At this point it is understood that the experience curve can be applied to the socket price curve, and that learning is not happening at a constant rate. The reasons for why the rate of learning is changing needs to be further investigated. Literature review on this type of analysis helps guide the remainder of the analysis. The literature review highlights the number of suppliers and market competition as potential factors to investigate when examining price volume curves. In the following sections a summary of the literature review is provided to give background as to why these two factors are selected. A section on market concentration is also included, since this will also be used in the analysis.

5.2 Case Studies Using Experience Curve in Industry

There has been extensive research done using the experience curve and market concentration to analyze reductions on price over the product life cycle. In research done by Brown, Meenan and Young in the medical devices industry, they conclude that "the 'experience curve' shows a consistent relationship between the cost (or price) of a product, and the total production volume to that point and is observable for a wide range of products, often over surprisingly long periods of time."

According to their research, costs should always come down with experience; however, prices can follow one of two paths. In the first case, prices can simply track costs, and hence fall at the same rate. In other words, leading companies in a specific industry would maintain their market share by minimizing their costs, due to their having the most cumulative experience. The second observed trend would be a two-phase price curve, in which prices stay high for an extended initial period before dropping rapidly. In the initial phase, as learning still occurs, costs will be reducing and margins increasing. At some point, often due to new market entrants, the price drops rapidly, faster than costs, resulting in companies with higher costs struggling with low margins. Figure 26 shows an example in which the manufacturers of a specific product are initially able to sustain a high price, despite the fall in underlying costs, until some element of competition enters the market and the price then declines, probably even more rapidly than costs. This phenomenon with a flat section followed by a steep experience curve is characteristic of an initial lack of competition, perhaps through patent protection. As soon as the element that restricts competition, however, is overcome or expires, the steeper curve emerges. This phenomenon is also observed in socket prices; therefore the number of suppliers and market concentration are used as factors that impact the price curve [12].

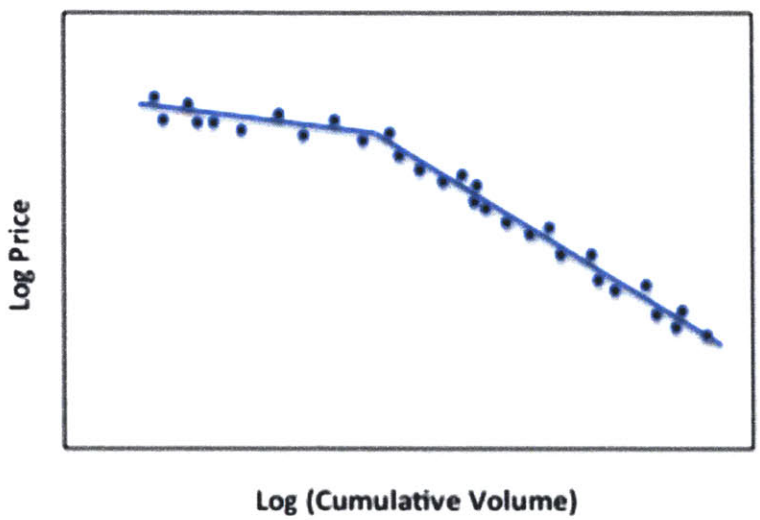

Figure 26: Example of two-phase price curve

Liebermann addresses the change in market situation and impact on price curve further in his paper on "Learning curve and pricing in the chemical Products Industry". Instead of looking at the number of suppliers, he focuses on the impact of market concentration on the change in price in his paper. In his research, Liebermann observed a sharp contrast in short-run price behavior between high and low concentration markets. Furthermore, he used the Herfindahl index (H) as a measure of producer concentration and set a concentration threshold to mark changes in price behavior [13].

The research in these papers helps guide the analysis for socket prices. Specifically, most of the analysis is performed using the experience curve, and then correlating changes in price to number of suppliers and market concentration.

5.3 Market Concentration – Herfindahl-Hirschman Index

After reviewing data on the different socket suppliers, it is evident that just looking at the number of suppliers as related to socket prices is not sufficient for the analysis. The competition level of each supplier needs to be quantified. This is done using a concept in economics called the Herfindahl-Hirschman Index (H - Index). The H- Index was originally used to determine if an industry is under a possible monopoly, but was later used to gauge the competitiveness of an industry by measuring the extent to which its output is concentrated among a few companies. To calculate the H-Index for a specific industry, the market share of each firm in the industry is squared then added up. The equation is as follows.

$MC = S_1^2 + S_2^2 + \ldots S_i^2$; where S is the market share of the i^{th} supplier/company

For example if the index is 1, then there is a monopoly. If the index is 0.5 then there are two equal sized firms in the industry. The higher the index, the more concentrated the market power and the lower the competition.

The main attribute of the H- Index is that it is straightforward and simple in its application. The one caveat is it relies on defining correctly the industry or market for which the degree of competitiveness is open to question. This is rarely simple and can in the end be a highly subjective number. For the case of socket suppliers, data had been collected over several years for a variety of different sockets. The group managing the socket suppliers had recognized the level of competition as an issue and therefore had been tracking this metric for some time. Although not all the data is available, there is sufficient information to perform the analysis.

The H -Index as well as number of suppliers was used extensively in the analysis to show a correlation between the change in price and the level of competition in the market [14].

5.4 Impact of number of suppliers on price curve

The number of suppliers is investigated as a potential reason for the change in the rate of learning for the socket price volume curve. Two sockets are analyzed for this case to see if there is a correlation.

5.4.1 Case 1: PGA 479

Returning to the case of the PGA socket 479, a regression is performed to determine the equation of the line in order to evaluate the slope. Due to the change in slope, the regression has to be performed in two parts, and therefore a cutoff point has to be determined. When the number of suppliers is overlaid on the price-volume curve, there is remarkable alignment to the change in the price-volume curve, and thus this becomes the cutoff point. The plot of the regression and the number of suppliers is shown in Figure 27.

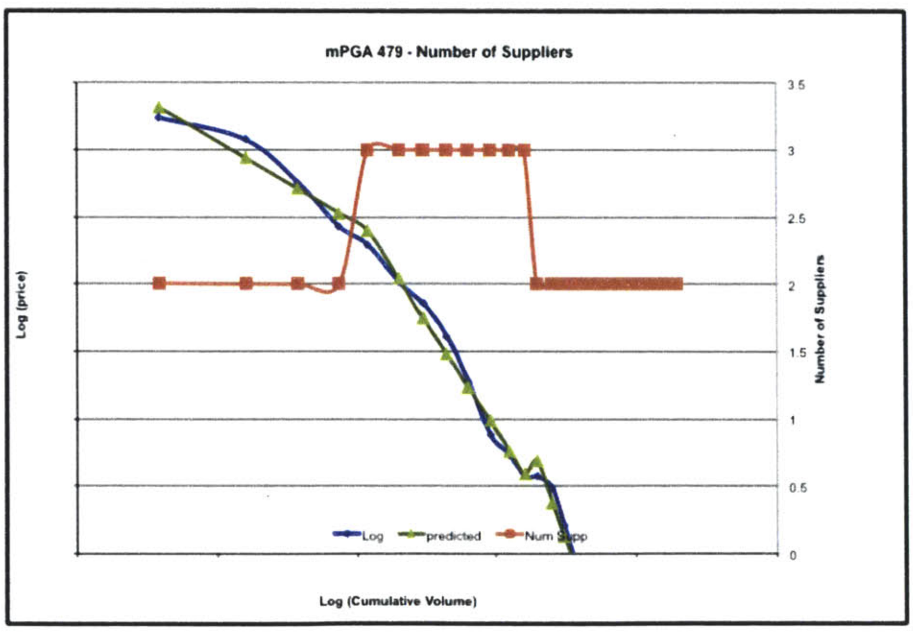

Figure 27: PGA 479 – Number of suppliers and regression

For this case, the regression not only shows how the slope changes but how the change in slope is related to the number of suppliers. The slope of the regression (b) and the rate of learning are given in Table 6. The rate of learning is found using the equation shown in the previous section on the experience curve.

$rate\ of\ learning = e^{b*lin(2)}$

	mPGA 479 (b)	mPGA 479 rate of learning
Starting with 2 suppliers	**-0.243**	**0.84**
2 to 4 suppliers	**-0.6433**	**0.64**

Table 6: Slope of Regression and rate of learning for PGA 479

Therefore, starting with two suppliers the price drops by 16% per cumulative volume increment. The price change is 36% when an additional supplier is added. In this case, the number of suppliers provides a good correlation for when the slope of the experience curve changes.

5.4.2 Case 2: LGA 775

A similar analysis is performed again using the LGA 775 price volume data. The regression is shown in yellow, as is the number of suppliers. Again, the break point for the change in slope is chosen based on the initial increase in the number of suppliers. Notice for this case that the number of suppliers at one point goes to five before reducing to two suppliers towards end of life.

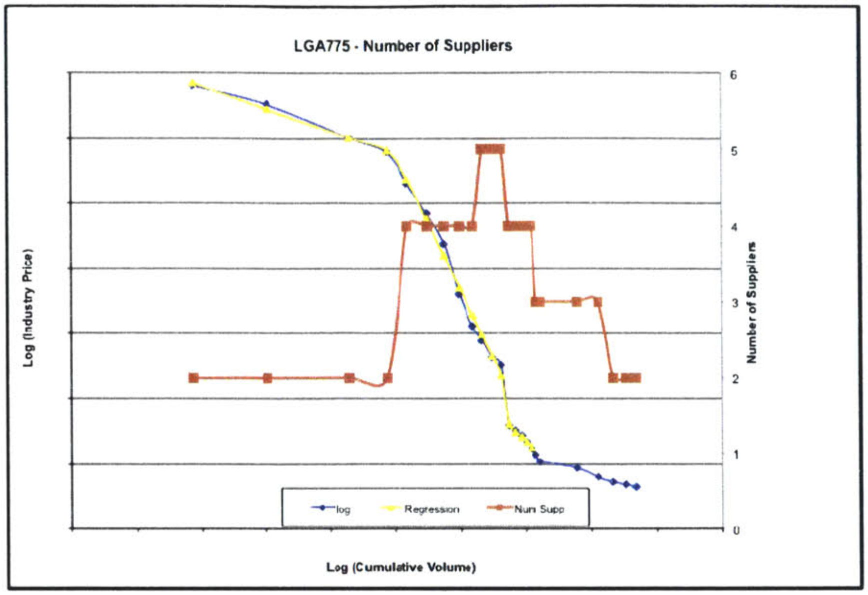

Figure 28: LGA 775 – Number of suppliers and regression

The slope of the regression (b) and the rate of learning are given in Table 7. The rate of learning is found using the equation shown in the previous section on the experience curve.

$$rate\ of\ learning = e^{b*lin(2)}$$

	LGA775 (b)	LGA 775 rate of learning
Starting with 2 suppliers	-0.06832	0.95
2 to 4 suppliers	-0.4206	0.7

Table 7: Slope of Regression and rate of learning for LGA 775

With two suppliers the price drops by 5% for each volume increment. The price change becomes 25% when there are more than two. Again in this case, the increase in the number of suppliers provides a good correlation for when the slope of the experience curve changes.

For both the cases, using the number of suppliers as a factor to determine when the rate of learning changes seems to make a good fit. But in Case #2, the number of suppliers does not appear to completely explain the change in slope. Thus, another factor to consider is the impact of market share as a representation of competitiveness of the suppliers, as having an influence on pricing. The next section discusses the use of market concentration as a factor in analyzing the experience curve.

5.5 Impact of market concentration on price curve

For this section the market competition is now investigated as a potential reason for the change in the rate of learning for the socket price volume curve. Again the two sockets analyzed previously are used for this case to see if there is a correlation.

5.5.1 Case 1: PGA 479

Similar to the analysis using the number of suppliers, a measure of the market concentration can be overlaid on the price-volume curve. As discussed, the Herfindahl-Hirschman Index (H-index) provides a quantitative way to represent the level of competition amongst the suppliers, and decreases as competition increases. As mentioned in the literature review, the slope of the price curve line normally changes when there is a change in the market situation. In this case the trend for number of suppliers and the H-index follows each other closely. A plot of the number of suppliers and the H-index vs. the cumulative volume is shown for this case in Figure 29.

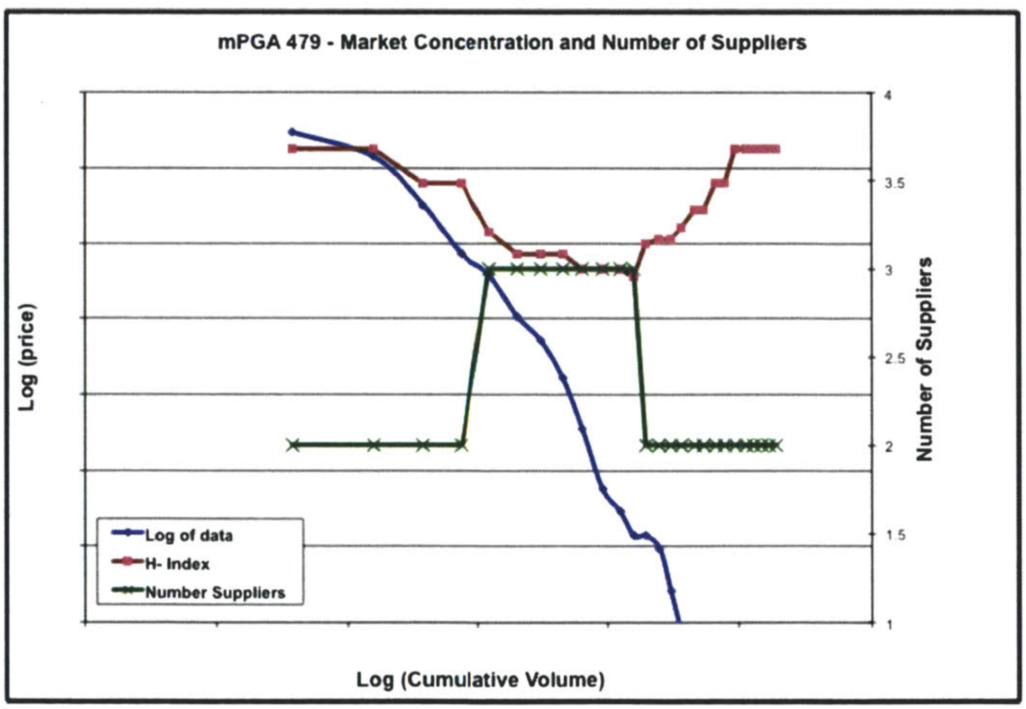

Figure 29: PGA 479 – Number of suppliers and H-index

The regression based on the H-index shows similar results to the number of suppliers case. This outcome is not unexpected due to the close tracking of the H-index with the number of suppliers. The regression and the H-index are shown in the Figure 30 below.

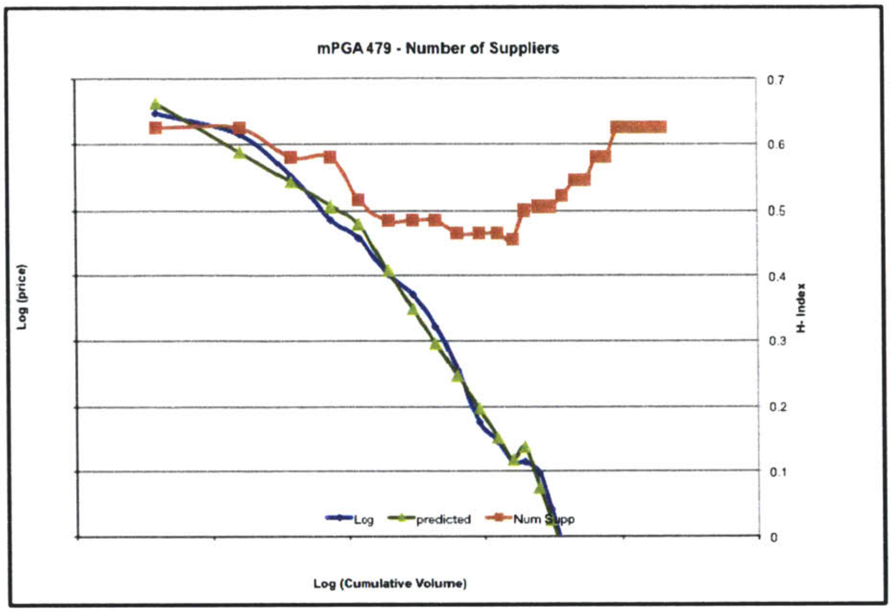

Figure 30: PGA 479 – Regression using H-index

In Figure 29, H-index (in red) has an inverse relationship to the number of suppliers and ranges in value from 0.625 to 0.425. The regression not only shows how the slope changes, but also how the change in slope is related to the number of suppliers and the H-index. The slope of the regression (b) and the rate of learning are again given below, in Table 8. This time the H-index has also been included.

	H-index	mPGA 479 (b)	mPGA 479 learning
Starting with 2 suppliers	0.625	-0.243	0.84
2 to 3 suppliers	0.485	-0.6433	0.64

Table 8: H-index and rate of learning for mPGA 479

So far the use of number of suppliers and market concentration seems interchangeable. However, there is still one more case to analyze: the LGA 775 case.

5.5.2 Case 2: LGA 775

For this case we will again look at market concentration to see if there is a correlation between the rate of change of the price curve and market concentration (H-index). However, before proceeding further for this case, the relationship between the number of suppliers and the market concentration should be revisited. One would expect there to always be an inverse relationship between the number of suppliers and the H-index. In other words, as number of suppliers increase, competition would increase and the H-index would go down. However, this is not always the case. In Figure 31 the number of suppliers and H-index are shown. The number of suppliers initially goes from two to four suppliers, and as expected we see that the H-index goes down. However, when the number of suppliers is increased to five the H-index increases as well, which is not what one would expect. In fact it is the opposite of what one would expect, since the larger number of suppliers would indicate more competition and thus a lower H-index.

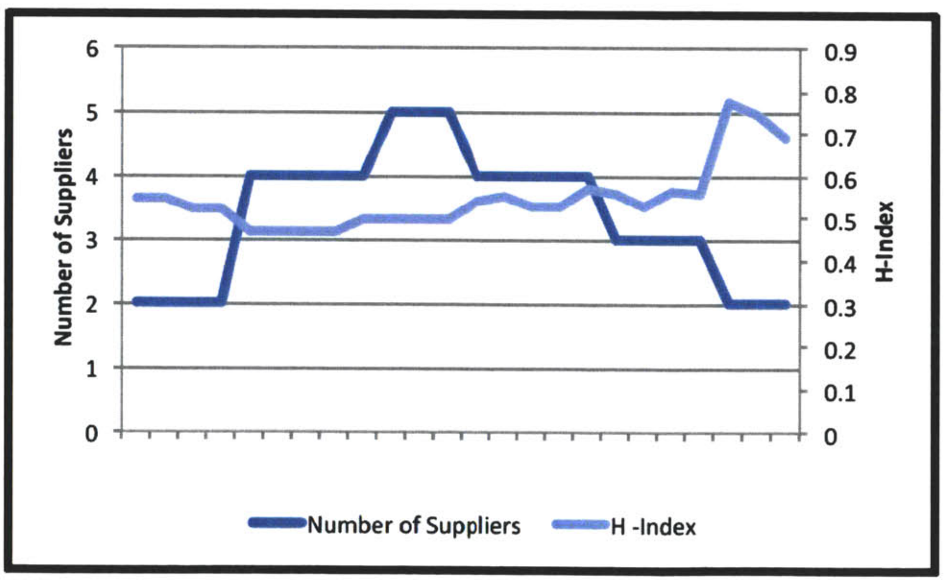

Figure 31: Number of suppliers and H-index vs. cumulative sockets sold

An overlay of all the information in Figure 32 shows the price trend, the regression, the number of supplier and the H-index. In this case there is a maximum of five suppliers and the H-index varies from 0.55 to 0.75. When the number of suppliers goes from two to four we see an increase in competition and a change in the rate of price change. This all coincides with what we had seen previously. However, when an additional 5th supplier is added it does not have an impact. In this case the additional 5th supplier does not provide increased competition and the level of competition actually decreases. Furthermore, the additional supplier does not have an impact on the rate of change of the price, indicating that the level of competition is a better indicator of price change than the number of suppliers. This would seem to indicate that purely adding additional suppliers may not result in increased competition, and that the type of supplier may be a more important factor than the sheer number. Not all suppliers are created equal.

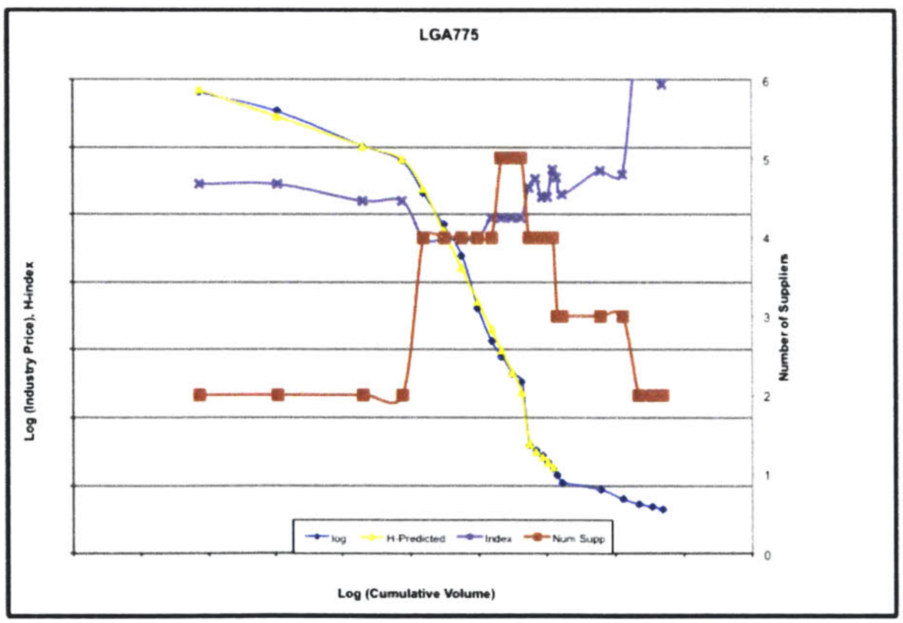

Figure 32: Regression, Number of suppliers and H-index for LGA 775

The slope of the regression (b) and the rate of learning are given in Table 9. The H-index is also added to show the relationship between the number of suppliers and the H-index.

	H- Index	LGA775 (b)	LGA 775 rate of learning
Starting with 2 suppliers	0.55	-0.06832	0.95
2 to 4 suppliers	0.46	-0.4206	0.7

Table 9: H-index and rate of learning for LGA 775

5.6 Conclusions

The data from these two sockets indicate that there is a relationship between the number of suppliers and the market concentration to the change in price. It also reaffirms what was known about socket suppliers: that they are all not created equal. Some socket suppliers are dominant in the market and that dominance is reflected in the price change. Although it would have been beneficial to have more sockets to analyze, these two were the only ones that had meaningful data over an extended period of time.

A key takeaway from this analysis is that it is ideal to have a market concentration below 0.5 as quickly as possible in order to have an impact on the socket price. This cannot be achieved by just adding more suppliers, but rather by adding suppliers that can compete in this market. In the final section these learning are now applied to the final socket analysis involving the latest generation socket for mobile processors mPGA 989.

6 Extending experience curve analysis to current socket

In this final chapter, the knowledge on experience curve and market conditions is applied to the current socket, mPGA 989. Trends for this socket are identified and then potential socket price curves are explored. The chapter concludes with what has happened with the socket price since this was completed.

6.1 mPGA 989

Since it is the newest socket on the market, the mPGA989 has the least amount of data available. This socket also represents a major transition from the previous generation, so it required a significant amount of engineering and manufacturing investment. As an additional note Intel modified its socket supplier strategy for this socket. Instead of having only two suppliers in the initial phase, there were four suppliers when the socket launched. This was done for increased competition and the need to meet the capacity requirements. The socket is an extremely high volume socket with expected sales of approximately 10x of the previous generation. Two of the additional suppliers were low cost suppliers and new entrants to the industry. These new dynamics had a marked impact on the price curve of the new socket. The socket price, number of suppliers and the market concentration are shown in Figure 33.

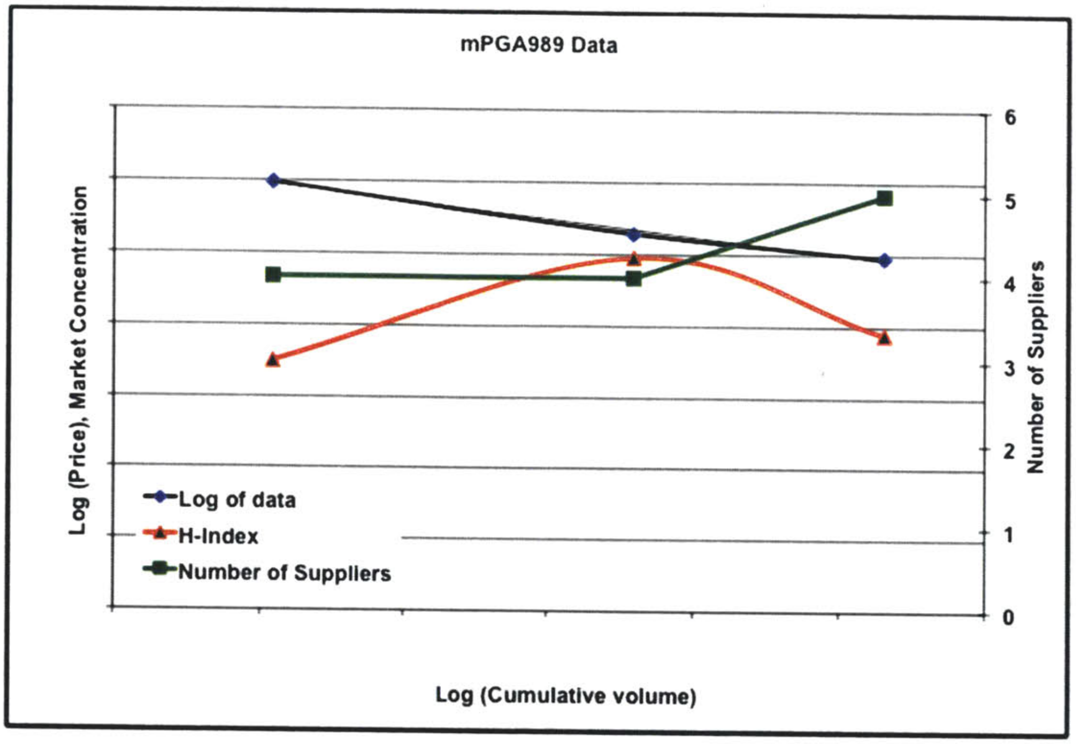

Figure 33: Trends for mPGA 989

Only the first three quarters worth of data is available, but there is a trend that is already different from the other cases. First the market concentration is the lowest seen for a socket at launch. The market concentration is 0.35 indicating a high degree of market competition. Furthermore, the rate of learning during this period is 0.88. Again this is a rate that is higher than previously seen for other sockets. Another aspect that is of interest is the comparison between this socket and the previous generation socket PGA 479.

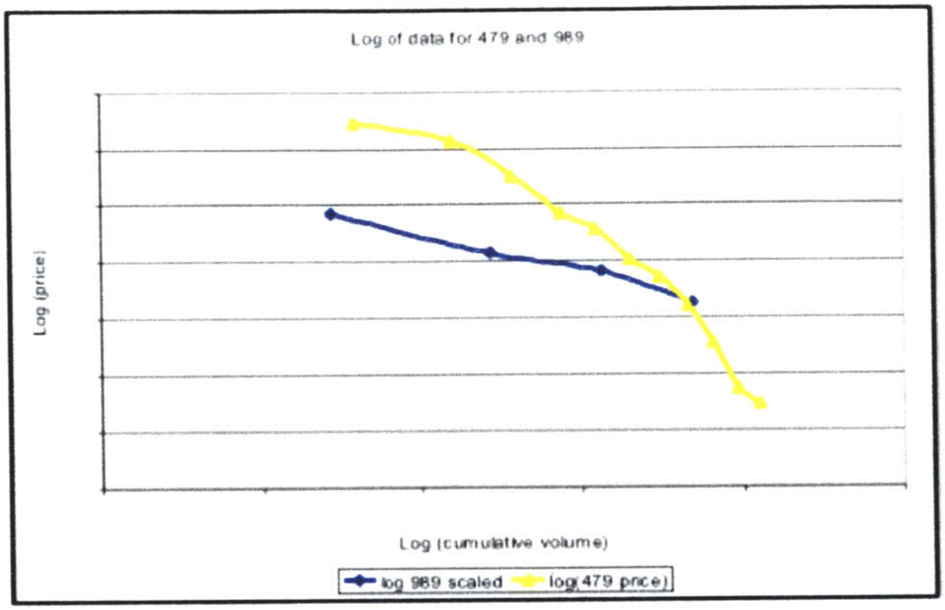

Figure 34: Price comparison of PGA 479 and mPGA 989

Figure 34 is a comparison of the starting price of mPGA 989 and PGA 479 sockets. The surprising finding is that the starting price for mPGA 989 is less than the starting price for PGA 479, even though it is a much more complex socket. Furthermore, mPGA 989 has sold the equivalent number of sockets in four quarters that it took eight quarters for PGA 479 to sell. The increased competition has not only increased the price drop, but has also helped to lower the initial starting price.

6.2 Conclusion

Since the mPGA 989 socket has only been out for a limited time, it is not clear how this trend will continue. Historically, we have seen a rapid reduction in price about six quarters into the product life cycle. This time there may not be that second price drop seen in the past. In other words, the competition in the beginning may have resulted in a one time price break, and prices may follow a set rate of decrease from here on out. Additional research did not yield answers as to what may happen in the future. Conclusions were made based on interviews and trends from the past and how much sockets actually cost. Additionally data from other PC components were investigated to compare their price curve to the socket but that was inconclusive and there was no additional information found in that area.

6.3 Key Takeaways

The experience curve is useful to understand cost considerations and price competition. By using the experience curve, management can gain insight on how number of suppliers and market situation can influence the price of the commodity over time. Furthermore, there is a relationship between the rate of learning and market situation. Given this insight, Intel should focus on engaging the right type and number of suppliers to achieve increased competition and the resulting price decline. Having more low cost suppliers and a market concentration of less than 0.5 appears to be the ideal situation. However, Intel needs to balance having enough suppliers with too much competition. Since suppliers have been known to stop producing when profitability declines (seen about two years into the product life cycle), Intel needs to encourage enough competition but not too much, as this could drive the suppliers out of the market. Furthermore, since there are only five major suppliers who can produce sockets, Intel needs to continue investigating other potential suppliers and socket technologies.

Another key finding from the study is that the increased competition early on as seen with the latest socket could provide a one-time price break and not the accelerated price drop that has been seen with previous sockets. Having a market concentration that is around 0.3 to 0.5 appears to be ideal. This level of competition seems sufficient to keep prices low, but not too much to drive out suppliers.

6.4 Opportunities for future research

As a potential follow on to this project the next step would be to quantify the costs to determine what would be the optimal number of suppliers. In other words, what is the ideal number of suppliers in the market such that it will be worthwhile for suppliers to enter the market and for Intel to get the best price on sockets. This would include determining what the best price for sockets that will make the initial investment on setting up facilities/machines for suppliers to enter the market.

6.5 Epilogue

At the end of this project, for the mPGA 989 case it was not known how the increased market competition would impact the price curve later in the product life cycle, including whether or not the change in slope or knee of the curve would be seen as had been the case with the previous sockets. During the subsequent time prior to publication of this thesis, the socket price has continued to drop and there has indeed been a change in the rate of price drop or the knee in the curve. Increased competition has continued to drive down prices much faster than anticipated.

7 Bibliography

Beckman, S., & Rosenfield, D. (2008), Operations Strategy: Competing in the 21st Century, Boston, Ma: McGraw Hill/Irwin

Winston, W. (2004), Operations Research: Applications and Algorithms, Indiana university, Thompson Books/Cole

Upton, D. & Macadam, S. (1997), Why and how to take a plant tour, Harvard Business Review

Jian-Jun W. & Hui-Fen L., "Developing a decision model in supplier selection", International Conference on Wireless Communications, Networking and Mobile Computing, 21-25 Sept. 2007

Wang D. (Dalian Maritime Univ., Dalian, China) & Zhao Y., "Decision-making for the optimal number of suppliers considering trade-off between supplier management cost and supply failure risk", IEEE International Conference on Industrial Engineering and Engineering Management, p 1664-8, 2007

Yewang Z.(Sch. of Transp., Wuhan Univ. of Technol., Wuhan, China) & Qingnian Z., " The study on the practical method of supplier selection", International Conference on Intelligent Computation Technology and Automation (ICICTA), p 789-93, Oct. 2008

Douglass, K., " What does product development really cost", Pivot international

8 References

[1] Nathan Eddy, "Intel, AMD Hold Lead on Microprocessor Market Share: Report," http://www.eweek.com/c/a/Midmarket/Intel-AMD-Hold-Lead-on-Microprocessor-Market-Share-Report-654921/, accessed April 2011

[2] Hoovers database, Intel corporation

[3] Intel website, http://www.intel.com/technology/tick-tock/index.htm?wapkw=(tick) , accessed April 2011

[4] C. Sailer, "Impact of Product Design Choices on Supply Chain Performance in the Notebook PC Industry," Massachusetts Institute of Technology LGO Thesis, 2010

[5] Intel website, http://www.intel.com/support/processors/sb/CS-009864.htm, accessed April 2011

[6] Intel website, http://www.intel.com/support/processors/procid/pix/FCPGABottom.jpg , accessed April 2011

[7] Wikipedia website, http://en.wikipedia.org/wiki/Socket_479 , accessed April 2011

[8] Intel website, http://www.intel.com/support/processors/sb/CS-009863.htm, accessed April 2011

[9] Wikipedia website, http://en.wikipedia.org/wiki/Lga_775, accessed April 2011

[10] Intel website, http://www.intel.com/support/processors/sb/cs-009863.htm , accessed April 2011

[11] Hall, G and Howell, S, "The experience curve from the economist's perspective," *Strategic Management Journal,* Volume 6, 197–212, 1985

[12] Brown A, Dixon D, Eatock J, Meenan B, and Young T, "A survey of success factors in New Product Development in the medical devices industry," *IEEE International Engineering Management Conference*, Europe, June 28-30, 2008

[13] Lieberman MB, "The learning curve and pricing in the chemical processing industries" *RAND Journal of Economics* ,Volume: 15, Issue: 2, 1984

[14] Economypedia, http://www.economypedia.com/wiki/index.php?title=Herfindahl-Hirschman_Index, accessed April 2011