EXHIBIT 5

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA

IN RE FLASH MEMORY ANTITRUST LITIGATION	Case No. CO7-0086-SBA
This Document Relates to: ALL DIRECT PURCHASER ACTIONS	

DECLARATION OF ROGER G. NOLL

My name is Roger G. Noll, and I reside in Palo Alto, California. I am a Professor of Economics *emeritus* at Stanford University. I also am a Senior Fellow and the Co-Director of the Program on Regulatory Policy of the Stanford Institute for Economic Policy Research, and a Senior Fellow in the Stanford Center for International Development. A list of my employment history and publications is contained in my curriculum vitae, which is included as Appendix A to this declaration.

My main field of research is public policies toward business, including the economics of antitrust. Before retiring from the Department of Economics at Stanford, I taught graduate and undergraduate courses in the economics of antitrust and regulation. I am the author, co-author or editor of thirteen books and the author or co-author of over 300 published articles and reviews, many of which deal with antitrust and/or the information technology sector of the economy.

I have testified on antitrust issues before Congressional committees and the Federal Trade

Commission as an independent expert at the request of a committee or the Commission. I have served as a consultant for Congressional committees, the U. S. Department of Justice, the Federal Trade Commission, the Federal Communications Commission and several private litigants on competition policy matters. I have provided live testimony in court in the following antitrust cases that are still active pending appeal or that have concluded in the last five years.

Metropolitan Intercollegiate Basketball Association vs. National Collegiate Athletic Association (U.S. District Court, New York, New York);

Gordon, et al., vs. Microsoft (Superior Court, Hennepin County, Minneapolis, Minnesota);

Seven Network v. News Limited (Federal Court, District of New South Wales, Sydney, Australia);

In Re Tableware Antitrust Litigation (U. S. District Court, San Francisco);

In the Matter of Adjustment of Rates and Terms for Pre-existing Subscription and Satellite Digital Audio Radio Service (Copyright Royalty Board, Washington, D. C.); and

Bernard Parish, et al., vs. National Football League Players Association (U. S. District Court, San Francisco).

I also testified at an arbitration hearing to resolve disputes over retransmission consent between Fox television network and multi-channel video programming distribution systems:

Echostar Communications vs. News Corporation.

In addition, I have submitted expert reports and/or been deposed in the following other cases that are still pending or have reached conclusion within the last five years:

National Association of Optometrists and Opticians, et al., vs. Lockyer, et al., (U.S.

District Court, Sacramento);

Fran Am Partnership vs. Sports Car Clubs of America (U. S. District Court, Denver);

Intertainer vs. Time-Warner, et al. (U.S. District Court, Los Angeles);

Joe Comes, et al., v. Microsoft (District Court for Polk County, Des Moines, Iowa);

In Re Dynamic Random Access Memory (DRAM) Antitrust Litigation (U. S. District Court, San Francisco);

Brian Bock, et al., vs. Honeywell International (Superior Court, San Francisco);

Vincent Fagan and Anthony Gianasca v. Honeywell International (Superior Court for Middlesex County, Boston, Massachusetts);

John McKinnon v. Honeywell International (Superior Court for York County, Alfred, Maine);

Fleury vs. Cartier International (U. S. District Court, San Francisco);

Eric Seiken vs. Pearle Vision (Superior Court for San Diego County, San Diego);

Jason White, et al., vs. National Collegiate Athletic Association (U. S. District Court, Los Angeles);

In Re Static Random Access Memory (SRAM) Antitrust Litigation (U. S. District Court, San Francisco);

Fair Isaac, et al., vs. Equifax, et al. (U. S. District Court, Minneapolis);

Apple iPod iTunes Anti-Trust Litigation (U. S. District Court, San Jose);

Minority Television Project vs. Federal Communications Commission (U. S. District Court, San Francisco); and

Novell vs. Microsoft (U. S. District Court, Baltimore).

I also was the co-author of an *amicus* submission to the Supreme Court in *PSEG, et al., vs. Riverkeeper*.

ASSIGNMENT

Attorneys for the direct purchaser plaintiffs in the flash memory antitrust litigation have asked me to identify the economic evidence that would be used to determine whether the alleged price-fixing activities by the defendants harmed competition by artificially increasing the price of flash memory products, and whether this evidence involves the use of facts and methods that are common to all members of the direct purchaser class. Plaintiffs' attorneys also have asked me to describe methods that could be used to determine damages to members of the class and to determine whether the methods for calculating damages would be common to all class members. In carrying out this assignment, I assume that the plaintiffs' allegations about anticompetitive conduct are true, and focus on the methods an economist would use to prove that this conduct harmed competition and damaged members of the class.

To perform these tasks, I have examined the *Consolidated Class Action Direct Purchaser Class Action Complaint* (hereafter *Complaint*). In addition, either I or economists at OSKR working under my direction have examined discovery documents, trade press publications on the memory device industry and on flash specifically, the motions to dismiss filed on behalf of the defendants both individually and collectively, and the court's decision on these motions to dismiss. In addition, under my direction economists at OSKR have undertaken a preliminary analysis of transactions data that the defendants have produced. The documents that have been reviewed by me or those working under my direction are listed in Appendix B to this report.

Finally, I have relied on four decades of experience in studying antitrust economics and the information technology sector of the economy, including my research in connection with the DRAM and SRAM antitrust litigation. For my work on this matter I am being compensated at the rate of $750 per hour.

SUMMARY AND CONCLUSIONS

I have concluded that the economic analysis that would be relevant to establishing harm to competition arising from the alleged price fixing and the damages suffered by direct purchasers of NAND flash memory products would involve predominantly common methods. This section summarizes the key reasons for this conclusion; the remainder of the report provides more details, including evidence and citations that are the basis for my conclusions.

Characteristics of Flash Products

NAND flash memory is a semiconductor product, and as such its production exhibits economies of scale due to high fixed costs and learning by doing. NAND flash memory also has experienced rapid technological process that simultaneously reduces cost and increases product quality. For these reasons, prices per unit of capacity for NAND flash memory products decline over time, regardless of whether the market is competitive or monopolized. Consequently, if the alleged price collusion happened and was effective, the observed effect would be to cause prices not to fall as low as they otherwise would have, rather than to cause prices to rise.

NAND flash memory products also come in different forms. The technology of raw NAND flash is advancing not just in terms of the capacity of a chip of given size, but also in the design and packaging of the chip. Different types of finished NAND flash products memory

devices that contain flash memory that are either used as separate memory storage devices or embedded in an electronics product also are present, and these technologies, too, are rapidly evolving in that the most important types of finished products of a few years ago are not the most important products today. The key issues for class certification are whether product differentiation in NAND flash products causes the effect of price fixing to differ for each purchaser and whether rapid technological progress and product differentiation would undermine an attempt by the defendants to implement collusive pricing.

Common Impact of a Conspiracy

The issues that an economist would address in establishing that the alleged price collusion harmed competition involve analysis and evidence that would be common to all class members. One such issue is whether price collusion, if attempted, is likely to be effective in the NAND flash memory industry. The other is whether the extent of product differentiation would cause the effect of collusion to be different for each class member.

One economic issue is whether the defendants, acting as a cartel, would be likely to possess sufficient market power to be able to raise prices. This issue is addressed by examining whether the defendants collectively account for a large enough share of sales to be able to exercise unilateral market power as a group. In fact, for the class period the defendants have accounted for a sufficiently high fraction of total sales in raw NAND flash memory that collectively they are likely to possess monopoly power in the presence of barriers to entry. Moreover, high fixed costs and economies of scale are barriers to entry. Both market shares and factors that create barriers to entry are matters that involve industry-wide information about

sales, costs and technology, and so are common to all members of the direct purchaser class.

Another issue is whether the NAND flash industry exhibits other characteristics that facilitate the operation of an effective price-fixing cartel. One example of a cartel-facilitating practice is the existence of numerous forums in which executives of competitors regularly meet and exchange information. The defendants participate in numerous joint ventures and have belonged to several trade organizations that set standards for flash memory products. Neither of these activities, by themselves, are necessarily anticompetitive, but they provide an opportunity for engaging in other anticompetitive behavior. The evidence about whether such opportunities exist pertains to the companies, not buyers, and so is common to all members of the direct purchaser class.

Another example of a cartel-facilitating practice is contract forms that reduce the incentive of sellers to engage in price competition. [redacted]

To ascertain whether product differentiation leads to individualized products and prices, both published price information and the defendants' transactions data were analyzed to determine whether the price formulation process for NAND flash memory products is

predominantly common to members of the direct purchaser class. [redacted]

Damages

I have concluded that all three approaches to calculating damages that economists commonly use in antitrust litigation are applicable to this case, and that all involve methods that are common to members of the direct purchaser class. The foundation for each method is to relate product prices to supply and demand conditions in the market, including technical characteristics of the product, market structure (the extent of competition), production volume (to account for economies of scale), and demand conditions. [redacted]

[redacted]

Damage calculation methods are based on a competitive benchmark ("but-for") price that would have been charged in the absence of anticompetitive conduct, and comparing that price with the price that actually was charged. The damage arising from a transaction is the difference in these prices. Economists normally use one of three basic approaches to damage estimation: a before-after test, a comparable products test, or a mark-up (or profitability) test.

A before-after test compares prices during the period that was affected by anticompetitive conduct with prices before and/or after the period of anticompetitive conduct. For this test to work, there must be periods when conspiracy was not present. One then tests whether the price formulation process shifted when the conspiracy began and then after it ended.

In this case, plaintiffs claim that price collusion began on January 1, 1999, and continued "to the present," which I infer to mean when the *Complaint* was filed. Prices before January 1, 1999, can be used to estimate the effect of the conspiracy for a while after January 1, 1999, but the pre-1999 period would not be sufficient for calculating damages after the boom in the use of NAND flash in small consumer electronics products starting around 2002. The reason is that the technology and uses of NAND flash changed substantially during the class period. Thus, the

before-after test requires transactions data from the defendants for a period after the end of the class period. Because a technology generation in the semiconductor industry is roughly 18 months, data should be collected for all of 2008 plus early 2009.

The comparable products test requires identifying another product that is similar to NAND flash that was not subject to anticompetitive conduct. I have identified one such product: DRAM during the "kill Hynix" period in 2001 when price collusion gave way to an attempt to drive financially stressed Hynix out of business, and after the collapse of the DRAM price conspiracy in 2002. This test requires estimating price formulation models for both NAND and DRAM, and comparing the drop in DRAM prices during the competitive periods with the behavior of NAND flash prices during the same period.

The mark-up method can be implemented in several ways. One is to estimate the mark-up (or operating profit) that would have arisen in NAND flash memory products had they been similar to mark-ups in other industries in the information technology sector or had produced a competitive return. The other is to construct a structural model of the NAND flash industry, calculate the prices that would emerge from profit-maximizing behavior under the assumption that the defendants colluded, and then to recalculate prices under the assumption that the defendants did not collude, given the degree of concentration in the industry.

All of these methods hinge on the predominance of common factors in determining the price of a particular product to a particular buyer. Because this has been established in the preceding analysis, a common formula can be developed for calculating the price effects of collusion if there were such effects. If the conspiracy did not occur, or if the conspiracy was not effective, the estimated damages will be zero.

INDUSTRY BACKGROUND

Flash memory is a form of non-volatile erasable memory that is widely used in electronics products, including digital cameras, cell phones and media players. Non-volatile memory is memory that does not require power to be maintained. By comparison, dynamic random access memory (DRAM) and static random access memory (SRAM) are forms of volatile memory, which means that the stored information disappears if power is not supplied. Erasable memory allows the user to erase and replace files on the same memory device. By comparison, a floppy disc is non-volatile, erasable memory, but a CD is non-volatile memory that is not erasable.

Flash memory was invented by Fujio Masuoka, an engineer at Toshiba who was assigned to lead an R&D project on DRAM but who believed that non-volatile memory held more promise and so worked on it without authorization.[1] In the 1980s Masuoka invented two flash technologies, NOR (for not/or) and NAND (for not/and).[2]

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[1] Benjamin Fulford, "Unsung Hero," *Forbes Magazine*, June 24, 2002, at www.forbes.com; "Fujio Masuoka: Thanks for the Memory," *Business Week*, April 3, 2006, at www.businessweek.com; and Anca Rusu, "The Flash Memory Inventor Settles with Toshiba," *Softpedia*, August 3, 2006. at news.softpedia.com. Toshiba initially claimed that Intel had invented flash, and tried to transfer Masuoka out of research. In 1994, Masuoka left Toshiba to become a university professor, and in 2006 Toshiba settled a lawsuit by Masuoka over the rights to flash for $760,000.

[2] For more information about NOR and NAND technologies, see "NAND vs. NOR Flash

NOR flash connects the transistors in the memory chip in parallel, which provides extremely fast access to stored information and facilitates random access storage. NOR is commonly used to store program code that, because of NOR's speed, can be directly executed. Because NOR was commercialized earlier than NAND, NOR also was used for standard file storage purposes in the first generation of small consumer digital devices.

NAND transistors are connected in series, which reduces the speed of access but also vastly lowers both the size and cost per unit of capacity. NAND is especially attractive for storing large amounts of data. Around the year 2000 NAND began to replace NOR as the standard component for storing very large files in portable consumer electronics products, such as digital cameras, personal digital assistants (PDAs), media players, third-generation cell phones, and external memory sticks for personal computers. Masuoka's original goal for NAND flash was that it would replace hard drives and floppy disks, as it has in the products that require miniaturization of the hardware. Because NAND is an inexpensive technology for providing very large, very compact memory, NAND now dominates flash sales. In 2001, NOR outsold NAND by more than four to one, but by 2007 NAND outsold NOR by five to one, with the annual number of NAND units shipped growing from 132 million to over three billion.[3]

[redacted]

Memory: Technology Overview," Toshiba America Electronic Components.

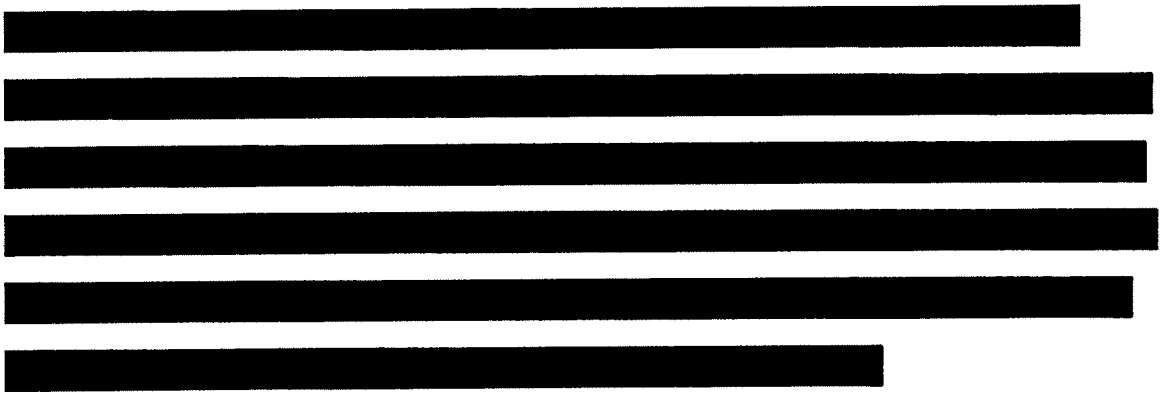
[3] Web-Feet Research, "Flash Memory Reporting Association Quarterly Flash and Combo Summary," 2001-2007.

[redacted]

The term NAND flash memory is used in reference to two types of products. The first is "raw" or "component" flash, which is the basic flash memory wafer that is manufactured at a semiconductor fabrication plant (a "fab"). The second is finished NAND flash memory products that are used in or with various electronic products. Raw flash is used in many finished products, including a variety of memory devices ("cards," "drives" and "sticks"). All of the defendants manufacture raw flash, although SanDisk does so through a joint venture with Toshiba and has announced a similar joint venture with Hynix. All of the defendants except Hynix also manufacture finished flash products.

The *Complaint* defines the direct purchaser class as purchasers of NAND flash memory from the defendants. Some direct purchasers buy raw NAND flash. Among these purchasers are manufacturers of finished memory products and of electronic equipment, which are called original equipment manufacturers or OEMs. Other direct purchasers buy finished NAND flash products from the defendants. These direct purchasers can be OEMs, distributors, retailers, and even consumers who buy directly from the defendants over their web sites. In addition some direct purchasers acquire both raw NAND and finished NAND products. Some flash memory products also contain a microcontroller, which is a semiconductor that interfaces the electronic equipment and operates the flash memory. I understand that purchasers of these products are members of the class. Finally, some products combine flash memory with other memory products (SRAM and/or DRAM) or microprocessors ("system on a chip"). I understand that these combination products are not part of this litigation.

[redacted]



Raw flash technology progresses rapidly. All semiconductor production follows Moore's Law, which states that the number of transistors that can be placed on a silicon chip of given size doubles every 18 to 24 months. NAND flash technology has progressed even more rapidly than most semiconductor products, with density doubling roughly annually.[5] A practical implication of Moore's Law is that flash memory simultaneously has grown smaller in size, larger in capacity, faster, and less costly per unit of capacity. In addition, the manufacturing process for flash memory, as with other semiconductor devices, experiences "learning by doing," which means that manufacturing costs per unit of output decline as cumulative output increases. The source of learning by doing is that the amount of wasted silicon wafer and defective dies declines as the manufacturer gains experience in producing a product. Together these two factors cause long-run costs per unit of memory capacity to fall, but sometimes temporarily to rise when a new technology is introduced until learning-by-doing restarts the trend of falling unit costs.

Raw NAND flash is used in several types of finished memory products, most of which are built to comply with an industry standard. Initially nearly all finished flash memory products contained NOR flash, but today nearly all use NAND. Among the finished flash products that

[5] See www.researchandmarkets.com/reports/613646 and napkinlinks.com/node/2013/.

use NAND are compact flash (CF),[6] smart media (SM) cards,[7] memory sticks (MS),[8] multi-media cards (MMC),[9] secure digital (SD) cards,[10] extreme digital (xD) cards,[11] USB Drives,[12]

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[6] CF originally used NOR technology, but switched to NAND. The Compact Flash Association (CFA) promotes the use of CF technology. CFA has a large number of members, including SanDisk and Toshiba. CF standards are available for download on the CFA web site. See digitalsignagenews.blogspot.com/2008/08/morning-press-digital-signage-news-for_11.html and www.digiprintuk.com/information.php?info_id 11.

[7] The trade association for promoting standards for SM cards was the Solid State Floppy Disk Card Forum, which was established in 1996 and disbanded in 2007. SM cards had individual identification to facilitate securing property rights in media files. See www.digiprintuk.com/information.php?info_id 10 and www.pctechguide.com/37portableRAM_SmartMediaCard.htm.

[8] Memory sticks arose from a proprietary standard owned and licensed by Sony. Joint R&D involving SanDisk started in 2005. An industry support group has over 700 members, including all defendants except Hynix. See www.digiprintuk.com/information.php?info_id 12 and www.memorystick.com/en/companies.html.

[9] Multimedia cards were developed jointly by SanDisk and Siemens in 1997, using Toshiba raw flash. The trade group to promote MMC standards, which are open, was the MultiMedia Card Association. MMCA was dissolved into the JEDEC Solid State Technology Association in 2007. See www.digiprintuk.com/information.php?info_id 8 and www.mmca.org/.

[10] Secure digital memory was developed jointly by SanDisk, Mitsubishi and Toshiba. The SD Card Association was created in 2000 to promote SD technology. Standards for SD cards are available to members, including all of the defendants. See www.sdcard.org/home and

and PC cards.[13]

In 2006 another standards organization was formed, the Open NAND Flash Interface (ONFI) Workgroup. The goal of ONFI is to standardize interfaces between flash devices and host systems. According to ONFI, the association is "dedicated to simplifying NAND flash

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www.digiprintuk.com/information.php?info_id 9.

[11] The xD card is a proprietary standard that was developed by Fujifilm and Olympus to compete with memory sticks and SD cards, but is licensed to others. Samsung, SanDisk and Toshiba sell xD cards. See www.ehow.com/facts_5009589_what-xd-card.html and www.digiprintuk.com/information.php?info_id 7.

[12] In November 2003, a group of companies led by Lexar and including Samsung formed the USB Flash Drive Alliance (UFDA) to promote "a generic industry recognized category (USB flash drives)." A year later, it decided to pursue the development of USB drive standards, but this effort apparently failed as five proprietary USB technologies were available in 2007. Whereas these products differ among manufacturers, they must be compatible with USB ports of a computer and so are substitutes. The UFDA apparently died in 2007 (I can find no more recent references to it, and the association website, www.usbflashdrive.org, has disappeared). See regulations.vlex.com/vid/notifications-usb-flash-drive-alliance-22776858 and newtechrules.blogspot.com/2007/05/microsoft-sandisk-take-smart-usb-drives.html.

[13] PC card standards were promulgated by the Personal Computer Memory Card International Association. PCMCIA was founded in 1989, and developed PC card standards through 2001. The most recent memory device that conforms to PCMCIA standards is the ATA PC card. See www.pcmcia.org and www.syncotech.com/support/faq-ata-flash-pcmcia-pc_cards.html.

integration into consumer electronic products, computing platforms, and any other application that requires solid state mass storage" because, before ONFI, "host systems had to accommodate differences between vendors' devices and adapt to generational changes in parts from a single vendor."[14] Among ONFI's members are SanDisk, Hitachi and Hynix.

Table 1 shows the sales shares of finished flash products. The table reveals that finished flash technology has evolved rapidly. In 2007 the most important finished products, with nearly 70 percent of revenues, were USB memory drives and SD cards. These products accounted for less than two percent of revenues in 2001. The leading product in 2001, accounting for 45

[14] See onfi.org/about/.

Table 1:
Revenue Shares of Finished Flash Products

Finished Product	2001	2002	2003	2004	2005	2006	Q2'07
Compact Flash	44.79%	36.99%	25.75%	22.03%	14.05%	10.43%	9.51%
Memory Stick	25.26%	25.28%	17.73%	13.99%	12.77%	12.07%	12.79%
Multimedia Card	2.89%	2.82%	1.09%	0.50%	0.17%	0.11%	0.04%
Other	1.24%	0.81%	0.63%	0.99%	0.85%	1.06%	1.39%
PC Media Card	2.42%	1.52%	0.35%	0.22%	0.14%	0.12%	0.13%
Secure Digital	1.53%	10.65%	23.00%	24.26%	31.85%	35.44%	31.75%
Smart Media	21.65%	16.05%	4.40%	1.30%	0.65%	0.25%	0.02%
USB Flash Drive	0.21%	4.30%	19.22%	28.18%	32.44%	34.70%	38.11%
Extreme Digital	0.00%	1.57%	7.83%	8.53%	7.07%	5.82%	6.27%

Source: The NPD Group, *Technology Market Tracker - Memory Cards*, November 2004 and June 2007.

percent of sales, was CF, which by 2007 had fallen to less than 10 percent. SM cards accounted for 22 percent of revenues in 2001, but had essentially disappeared by 2007.

COMMON PROOF OF HARM TO COMPETITION

I understand that an attempt by competitors to fix prices, either directly by agreeing to a price or indirectly by agreeing to reduce supply, is a *per se* antitrust violation. *Per* se violations do not require an economic analysis to define the relevant market and to establish that the defendants collectively enjoyed market power. I understand that the role of an economist at the liability stage of a *per se* case is to provide information that is relevant to ascertaining whether the attempt to fix prices actually worked and, as a result, caused harm to competition. This section reviews the evidence that would be used to establish harm to competition for the purpose of determining whether the proof of harm is predominantly common to all class members.

Market Share, Entry Barriers and Market Power

A necessary condition for collusion to be effective is that the colluding firms, if they act in concert, have sufficient market power to cause anticompetitive harm. As defined by the United States Department of Justice and the Federal Trade Commission in the *Horizontal Merger Guidelines*, market power is the ability to increase profits by causing a significant non-transitory increase in prices above the competitive level. The standard approach to ascertaining whether firms enjoy market power is to determine whether the market is concentrated (only a few sellers account for nearly all sales) and whether the market has barriers to entry.

Market Concentration

In the presence of barriers to entry (either *de novo* entry by firms that are new to the industry or capacity expansion by existing firms), the degree of concentration of sales within a market commonly is used as an indicator of market power. Economists commonly use as indicators of market power the market share of the largest seller and the Hirschman-Herfindahl Index (HHI). The HHI is the sum of the squares of the market shares of all of the firms in the industry. In the presence of collusion, the sum of the market shares of the colluding firms is used in determining the extent of concentration in the market. In the presence of barriers to entry, a large firm (or a group of colluding firms) is regarded as likely to enjoy market power if its market share is above 50 percent, and a group of firms (or separate groups of colluding firms) are regarded as likely to enjoy market power if the HHI exceeds 2000.[15] In calculating market shares, groups of colluding firms are treated as a single seller with a market share equal to the sum of the markets shares of the firms in the group.

To demonstrate that the market is sufficiently concentrated for the defendants collectively to enjoy market power requires data on sales for all firms in the industry that have significant sales. Flash sales shares are frequently reported in the trade press. Table 2 shows data on the

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[15] The *Horizontal Merger Guidelines* of the Department of Justice and the Federal Trade Commission (April 8, 1997) state: "Where the post-merger HHI exceeds 1800, it will be presumed that mergers producing an increase in the HHI of more than 100 points are likely to create or enhance market power or facilitate its exercise." If one firm has 45 percent of the market and all others are small, the HHI will exceed 2000.

shares of manufacturers of raw NAND flash, which is the type of data that would be used to show that collusion plausibly could increase the market power of the defendants. The salient features of Table 2 are as follows.

First, the industry is sufficiently concentrated that the leading firms are likely to enjoy market power in the presence of barriers to entry. Samsung, the leader in market share, is large enough that during a few years it may have enjoyed some unilateral market power as a dominant firm. The HHI ranges between 2000 and 4000 in all years. Consequently, in the absence of collusion the market is not likely to be highly competitive; however, the extent of market power in the absence of collusion also is likely to be less than monopoly power.

Second, the combined market share of the defendants is extremely high, with the HHI roughly three times as high if the defendants are treated as a single colluding firm. The standard model of price formulation in concentrated markets predicts that prices will be substantially higher if the HHI increases by as much as the difference between the HHI under collusion and the HHI if each firm acted independently.

I have not calculated the shares of the defendants for finished products because I anticipate that this will not necessary. The high share of raw NAND flash sales accounted for by the defendants is sufficient to show that effective collusion could be effective. The next step is to show that the market price of raw NAND flash affects the price of finished NAND products, as economic analysis predicts. This task requires a regression of finished product price on the price of the raw flash component a few weeks earlier, an indicator variable for each of type of finished product, and the interaction of these variables. [redacted]

[redacted]

Table 2:
Raw Flash Revenue Shares of Defendants

Revenue Market Share	2001	2002	2003	2004	2005	2006	2007
Hynix*	NA	NA	NA	4.2%	13.2%	18.6%	17.1%
Hitachi*	12.0%	6.4%	NA	NA	NA	NA	NA
Mitsubishi*	0.5%	0.1%	NA	NA	NA	NA	NA
Renesas*	NA	NA	9.4%	4.4%	3.7%	3.2%	1.7%
Samsung*	30.7%	47.1%	49.4%	56.7%	52.9%	43.4%	37.3%
SanDisk*	13.5%	18.3%	9.7%	12.1%	7.9%	9.4%	11.5%
Toshiba*	40.7%	28.0%	31.4%	21.0%	16.1%	17.2%	20.4%
Fujitsu	2.5%	NA	NA	NA	NA	NA	NA
Infineon	NA	NA	NA	1.2%	1.3%	0.8%	0.0%
Intel	NA	NA	NA	NA	NA	1.6%	3.4%
Micron	NA	NA	NA	NA	1.9%	4.2%	6.2%
Msystems	NA	NA	NA	NA	1.2%	0.1%	0.0%
STMicro	NA	NA	NA	0.4%	1.8%	1.6%	1.3%
Others	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	1.0%
Defendants*	97.4%	100%	99.9%	98.4%	93.8%	91.7%	88.0%
HHI	2,928	3,380	3,608	3,842	3,315	2,645	2,291

NOTES:

NA indicates a firm not included in data, either because it was not in the market that year or because its sales were too low to be recorded in the data.

* Indicates defendants. Renesas was created by the merger of the flash businesses of Hitachi and Mitsubishi. "Others" includes AMD, Macronix, PSC, SMIC, Spansion and unidentified others.

Source: Flash Memory Reporting Association (FMRA) Quarterly Summaries, as published by Web Feet Research.

[redacted] If the defendants have effectively colluded on raw flash prices, their profit-maximizing strategy is likely to be to set the prices of finished flash products roughly equal to the finished products of their raw flash customers. This behavior implies that finished product prices will rise and fall with raw flash prices.

The preceding analysis of raw flash sales needs to be refined to establish that the defendants collectively could enjoy market power. Other companies collect and publish sales data, and the data shown in the table do not encompass the entire class period. But the preceding analysis illustrates that common methods would be used to prove that collectively the defendants could have increased their market power had they engaged in price collusion

Barriers to Entry

Market share is a reliable indicator of market power if the market has high barriers to entry. A barrier to entry is a substantial advantage to incumbents that an entrant can overcome only by making large expenditures and capturing a large amount of sales. Examples are high brand loyalty to incumbent products (which may be overcome only if the entrant invests in product promotions), intellectual property rights (which may be overcome by investing in research to "invent around" the IP rights), and high fixed costs or economies of scale for efficient capital facilities (which implies that an entrant must be able to sustain prices above average variable cost of production and must capture a substantial share of the market in order to recover the cost of entry).

For semiconductor products, fixed costs are extremely high. A semiconductor fabrication facility (or fab) typically costs billions of dollars, and must be completely retooled roughly every

five years.[16] Some companies participate as "fabless" suppliers by designing semiconductor products and contracting with separate owners of fabs to manufacture their product. Fabless suppliers participate in the flash business, but collectively their share is limited to a few percent because higher volumes of output can not practically be contracted out to another manufacturer. As a result, all of the companies with significant sales of raw NAND flash own fabs.

As discussed above, semiconductor manufacturing is characterized by learning by doing.[17] Learning by doing does not carry over from one technology to the next. In addition, technological progress is rapid due to Moore's Law. To remain effective competitors in each succeeding technology, firms undertake substantial research and development to obtain the next step in unit cost reduction arising from Moore's Law. A firm's R&D plans as well as plans for retooling fabs are summarized in a "roadmap,"[18] a detailed plan concerning a firm's expectations about the introduction and availability of each succeeding generation of new products.

Barriers to entry do not imply that entry never occurs, but that it is not so easy that, in the

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[16] For a recent discussion, see Clayton M. Christensen, Steven King, Matt Verlinden, and Woodward Yang, "The New Economics of Semiconductor Manufacturing," *IEEE Spectrum Online* (May 2008) at www.spectrum.ieee.org/may08/6179.

[17] See, for example, Douglas A. Irwin and Peter J. Klenow, "Learning-by-Doing Spillovers in the Semiconductor Industry," *Journal of Political Economy*, Vol. 102, No. 6 (December 1994), pp. 1200-1227.

[18] For examples of product roadmaps, see *Product Guide: NAND Flash Storage*, Toshiba, at www.semicon.toshiba.co.jp/docs/catalog/en/BCE0005_catalog.pdf, [redacted]

presence of prices substantially above average cost, entrants will quickly come into the market and force the price down to the competitive level. In fact, some entry into raw flash production has occurred in the past few years. One of the defendants, Hynix, entered in 2004, and quickly captured more than 15 percent of raw flash sales. Offsetting this entry, defendant Renesas announced in December 2005 that it had ceased developing new flash products and expected to exit the flash business when its existing products reach the end of their life cycle.[19] By 2007, Renesas's share of raw flash sales had fallen below 2 percent, compared to over 9 percent when Hitachi and Mitsubishi merged their memory chip business to form Renesas.

Besides Hynix, the most important new entrant is IM Flash Technologies, a joint venture between Intel and Micron in 2005. IM is a captive producer for its owners, with all of its output sold by the venture partners under their own brands.[20] Together Intel and Micron accounted for about ten percent of raw flash sales two years after IM was launched, more or less replacing the sales lost by Renesas. Other firms also have attempted to enter, notably Infineon (a major player in other memory products) and STMicroelectronics. Neither firm succeeded in obtaining

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[19] Wolfgang Gruener, "Renesas Exits Flash Business," *TG* Daily, December 8, 2005, at www.tgdaily.com/content/view/23104/118/. See also Yoshiko Hara, "Renesas Denies Flash Memory Exit," *EETimes India*, December 12, 2005, at www.eetindia.co.in/login.do?fromWhere /ART_8800399780_1800009_NT_3bc079fb.HTM, which actually confirms the abandonment of product development and hence eventual exit. Finally, see Peter Clarke, "Renesas Completes Exit from Flash Memory Market," *EETimes Europe*, May 22, 2008, at www.eetimes.eu/ showArticle.jhtml?articleID 207801757.

[20] See www.imftech.com/company/manufacture.html.

significant market share. While further work is needed to assess the significance of entry in manufacturing raw NAND flash, the low sales of Infineon and STMicroelectronics and the exit of Renesas soon after it was formed imply that successful entry is not easy.

For purposes of class certification, the important point is that assessment of barriers to entry requires a detailed examination of the experiences of recent entrants. Because this analysis focuses on firms, not individual buyers, this inquiry is common to all class members.

Elasticity of Demand

The price-responsiveness (elasticity) of demand also affects the likely effect of collusion on prices. If the elasticity of demand is low, firms have much to gain from even a small reduction in competition because an increase in price increases profits per unit sale without causing much of a reduction in the quantity sold. If sales volume is highly sensitive to price, a firm or collusive cartel with a dominant market share or firms with market power due to high concentration are unlikely to be able to raise price much above the competitive level.

In the case of flash memory, the elasticity of demand is likely to be low (i.e., the quantity sold is not likely to be very responsive to changes in price). NAND flash memory products are used either as a component of electronic products, such as a media player or cell phone, or as a stand-alone complementary product for an electronic device, such as a PC, PDA, or digital camera. The elasticity of demand for an input or a complement for which there is no substitute is the elasticity of demand of the final product bundle times the share of the bundled product cost that is accounted for by the input. In this case, the key product for which there is no reasonable substitute is the raw NAND flash memory.

If flash products constitute a small fraction of the cost of the electronic equipment that contains them or with which they are used, then the demand for flash products, whether raw or finished, will be inelastic, so that the potential gain from effective collusion is substantial. For example, a USB drive can be an expensive product (ranging from under $10 for a 2GB unsecured device to hundreds of dollars for a 64GB device with password protection).[21] These prices are much lower than the combined costs of a personal computer, an operating system, and an office productivity suite, which together produce the files that are saved on a USB drive.

For purposes of class certification, the important point is that the methods for analyzing demand elasticity are common to class members. A more comprehensive analysis than is presented here of the fraction of the cost of ownership and usage of an electronic device that is accounted for by flash memory involves collecting a wider array of product prices. Demand elasticity also can be measured directly by examining how changes in price affect sales. The information that would be used to demonstrate that the demand for flash is not elastic involves the use of aggregate cost, price and sales data, and so is common to all class members.

Conditions That Facilitate Collusion

A high market share in the presence of barriers to entry is likely to confer market power on a firm, but it does not necessarily confer market power on a group of firms that engages in collusion. In order for collusion to be successful, members of the conspiracy must be able to observe whether other members are honoring the agreement not to compete. This section reviews conditions in the market that facilitate effective collusion.

[21] The prices of numerous USB flash drives are shown on www.supermediastore.com.

Contact

Activities that do not themselves constitute anticompetitive conduct sometimes facilitate an anticompetitive practice by giving firms an opportunity to engage in collusion and/or to monitor compliance with an anticompetitive agreement. Three examples of such activities are joint ventures, membership in standards organizations, and purchases from each other.

As discussed elsewhere, all of the defendants participate in standards organizations for flash memory products. Standardization can provide benefits to those who buy NAND flash products by facilitating multi-sourcing of a key electronic component and increasing the rate of technological progress. But standards organizations also can be used for anticompetitive purposes, such as freezing out competitors or providing a forum in which participants discuss matters beyond the scope of the standards organization, such as prices and production capacity.

The defendants participate in joint ventures of two forms. The first is joint production facilities, such as the Flash Vision, Flash Partners and Flash Alliance joint ventures between SanDisk and Toshiba[22] for manufacturing raw NAND flash for both companies, and a similar announced joint venture between Hynix and San Disk.[23] The second is joint product

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[22] The current state of these ventures is described in Brooke Crothers, "Toshiba, SanDisk Restructure Joint Ventures," *CNET News*, October 20, 2008, at /news.cnet.com/8301-13924_3-10069988-64.html.

[23] Jeremy Kirk, "Hynix, SanDisk Announce Patent Pact, Joint Venture," *PC World About.com*, March 21, 2007, at pcworld.about.com/od/techindustrytrends/Hynix-SanDisk-announce-patent.htm. Apparently the manufacturing joint venture has not yet been implemented.

development work, leading to jointly owned intellectual property. For example, the Hynix-SanDisk agreement also covered joint development of four bit per cell NAND flash memory.

[redacted]

The preceding discussion does not contain a complete description of all of the contacts among the defendants, and is not intended to make the case that this contact did in fact facilitate collusion. Instead, its purpose is to illustrate the type of information that an economist would analyze in reaching a conclusion on this issue. This analysis would be informed by additional discovery that will follow after the class is certified. For purposes of this section, the contacts among the defendants and an analysis of their effects represent evidence that would be common to all members of the direct purchaser class.

Contract Forms

The form of contracts offered by vendors affects the likelihood that collusion will occur

[redacted]

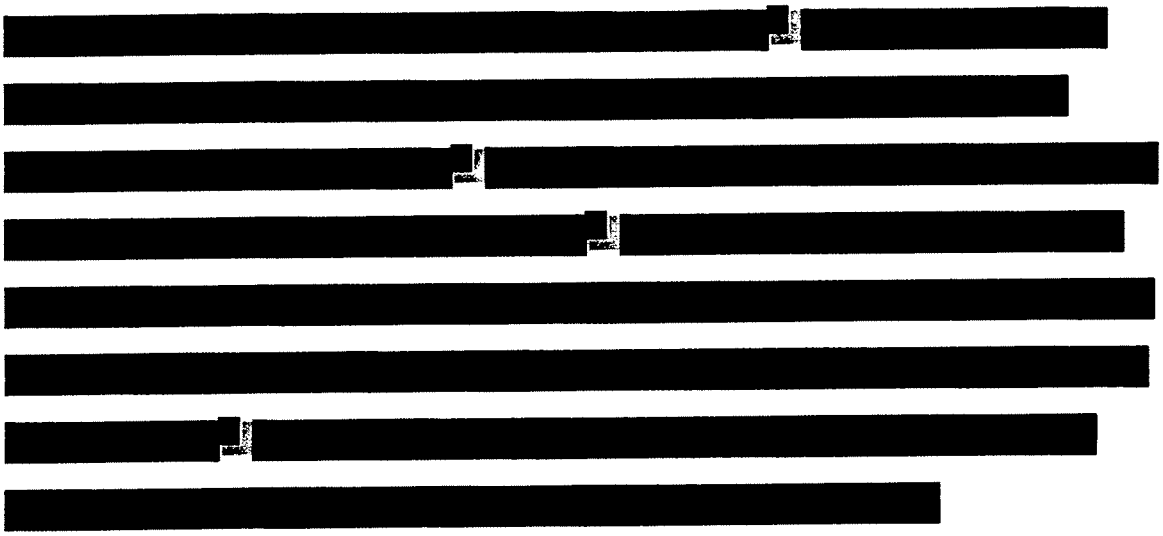
and be successful against all buyers. [redacted]

[redacted]

[redacted] One problem for price-fixing cartels is that a participant in the cartel has an incentive to "cheat" on the agreement to fix prices by offering the customer of a competitor a lower price. [redacted] Of course, further discovery is required to ascertain the nature and extent of all contract provisions of this form. For purposes of class certification the important point is that the analysis that is based on the nature and scope of these contract provisions is common to all class members. Moreover, the effect of a contract provision on class members as a whole can be very different from the impact on the party to the contract. For example, an OEM may derive a small benefit from its most-favored-customer status, but all customers including that OEM suffer harm if these contract provisions are widely used and collectively facilitate collusion among the defendants.

The price negotiations associated with contracts are not a vehicle for introducing substantial variation in price for otherwise similar customers and transactions. Negotiation outcomes are bound by pricing rules. [redacted]

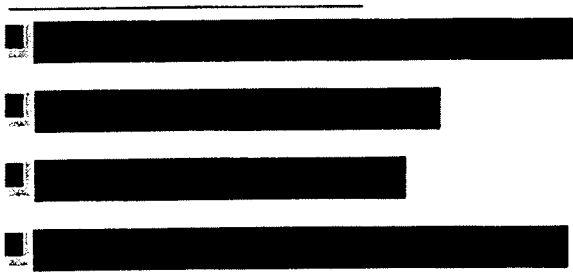
[redacted]



Product Differentiation

The defendants sell many different flash products that differ technically. Raw NAND flash has undergone rapid technological progress not only in the classic sense of packing more transistors on a silicon chip of given size, but also in other characteristics, such as the packaging methods and chip design, such as whether memory is single level cell (SLC) or multi-level cell (MLC). Finished NAND products come in several different formats. Thus, NAND flash memory is an example of a differentiated products industry.

For purposes of class certification, the important issue is whether differences among underlying NAND flash technologies cause each customer to have little or no choice in buying



NAND flash memory products. The presence of several different types of raw NAND products on the market simultaneously raises two questions: whether the same fundamental process (including the extent of competition) determines prices for each product, and whether each customer has a genuine choice among substitute products. In a nutshell, the relevant issue for class certification is whether product differentiation creates a circumstance in which a significant number of products that are offered by one manufacturer do not have close substitutes that are available from other manufacturers.

If the products of each manufacturer are sufficiently unique that the products of other manufacturers are not close substitutes, cartel members face two problems. First, collusion has a small payoff because each firm can raise the prices of its products above the competitive level without causing its customers to switch to the products of another. Second, collusion is more difficult because of the absence of common products for which a common price can be set.

The term "commodity" is used to describe products having a sufficiently large number of close substitutes that, in the absence of collusion, no seller enjoys market power. Industry analysts frequently refer to NAND flash memory as a commodity,[31] [redacted] The

[31] Some articles referring to NAND flash as a commodity are Mike Clendenin, "UMC Targets CPUs, Mulls Commodity Flash," *EETimes*, May 7, 2007; Roger Barth, "ITRS Commodity Memory Roadmap," *Records of the 2003 International Workshop on Memory Technology, Design and Testing*, August 18, 2003, ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber 1222362; Jonathan Heller, "SanDisk: A Wild Ride in a Sturdy Vehicle," *TheStreet.*com, March 17, 2009, www.thestreet.com/p/_search/rmoney/semiconductors/10473341.html.

[redacted]

distinction between commodity and non-commodity semiconductor products is based on whether the product is designed and produced for a specific product and customer. This section discusses evidence pertaining to whether NAND flash products are commodities.

For raw flash, each new technology is applied to the same uses and products. For example, the range of USB drives available for use with personal computers gives consumers a choice of how much flash capacity to acquire for storing files in several different formats. The capacity of USB drives has increased one thousand fold since they were originally introduced,[33] but all work on the same computer. Likewise, electronic equipment manufactures that place embedded flash in such products as PDAs, media players, digital cameras and 3G cell phones offer different capacities of flash drives for the same product, giving consumers a choice. For example, the Apple iPod nano, which originally could be acquired with 2GB or 4MB of memory,[34] is now available on the Apple web site with either 8GB or 16 GB of memory.[35]

Another aspect of product differentiation arises among finished products that are made for use with different types of electronics products. For example, some memory devices are manufactured for use with digital cameras, while others are used with personal computers. These different finished products may have different direct purchasers and ultimate end-users.

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[33] See "Review of USB Flash Drives," *Associated Content*, March 22, 2007, at www.associatedcontent.com/article/178538/review_on_usb_flash_drives_.html?cat 15.

[34] See "Apple unveils iPod nano, ROKR phone, iTunes5," *MacWorld*, September 7, 2005, at www.macworld.com/article/46806/2005/09/special.html.

[35] See store.apple.com/us/browse/home/shop_ipod/family/ipod_nano?intcmp AIC-WWW-NAUS-BUYNOW-FOOT-IPODNANO-080910,

The fact that two products have different buyers does not imply that the effect of price fixing does not have predominantly common effects. First, price collusion on raw flash will affect the manufacturing costs of all finished products, which can be demonstrated by showing that variation in raw flash prices causes variation in finished product prices. Second, if some vendors sell more than one type of finished product, supply-side substitution may be sufficient to link the prices of products in both categories.

A potential challenge to the commonality of impact is the extent to which products are "custom" products that are specifically designed for and sold to one buyer. All memory products, including flash, must be compatible with the electronics equipment that makes use of them. And all semiconductor components of any final electronics product have a qualification process, whereby the buyer first decides the features that are required of a memory component and tests whether any given memory product meets that standard.

In most cases, the extent of "design-in" of flash products is sufficiently small that (a) the same product is sold to many vendors and (b) several vendors sell compatible products that any given vendor can use. The basis for this conclusions is as follows.

As discussed above, most flash products are based on industry standards that have been developed by large groups of buyers and sellers, or that have been developed by one or two firms but have been licensed to others. Since 2006, a committee (JC-64) of the Joint Electron Devices Engineering Council (JEDEC) has promulgated standards for NAND flash products that are available on the JEDEC web site.[36] According to the website, "JEDEC is the leading developer

[36] *JEDEC Committee Scope Manual*, JM18L, October 2006, p. 13. See www.jedec.org for information about JEDEC and JC-64 meetings and standards concerning flash memory.

of standards for the solid-state industry. Almost 3300 participants, appointed by some 295 companies work together in 50 JEDEC committees…" Prior to the creation of JC-64, a variety of other voluntary organizations promulgated standards, and even the proprietary standards were widely licensed. [redacted] Based on my experience in studying the semiconductor industry, I am confident that each defendant has much more complete information about the technical characteristics of each of its products, so that discovery will produce information that will permit more accurate, comprehensive classification of products

[redacted]

according to technology type and other product characteristics. For class certification purposes, the utility of this information is that it reveals groups of products that the defendants regard as substitutes and use as a basis for identifying the products they can offer to substitute for a competitor's product.

Beyond the reasons given above for concluding that NAND flash products are commodities, the SRAM litigation provided some concrete guidance for identifying custom products for which class certification is not appropriate. The specific wording of the SRAM decision was as follows.[40]

> "Customized SRAM is defined as
>
> (1) SRAM that was designed and sold by only one manufacturer in order to meet a set of defined performance characteristics established by only one purchaser; and
>
> (2) that set of defined performance characteristics was not met by SRAM designed or sold by any other manufacturer; and
>
> (3) the SRAM was designed as a completely new SRAM or required substantial change to an already-existing SRAM."

I have implemented this definition for NAND flash products. Under my direction, economists at OSKR analyzed defendants' transaction data to determine the extent to which products are sold to a single customer. [redacted]

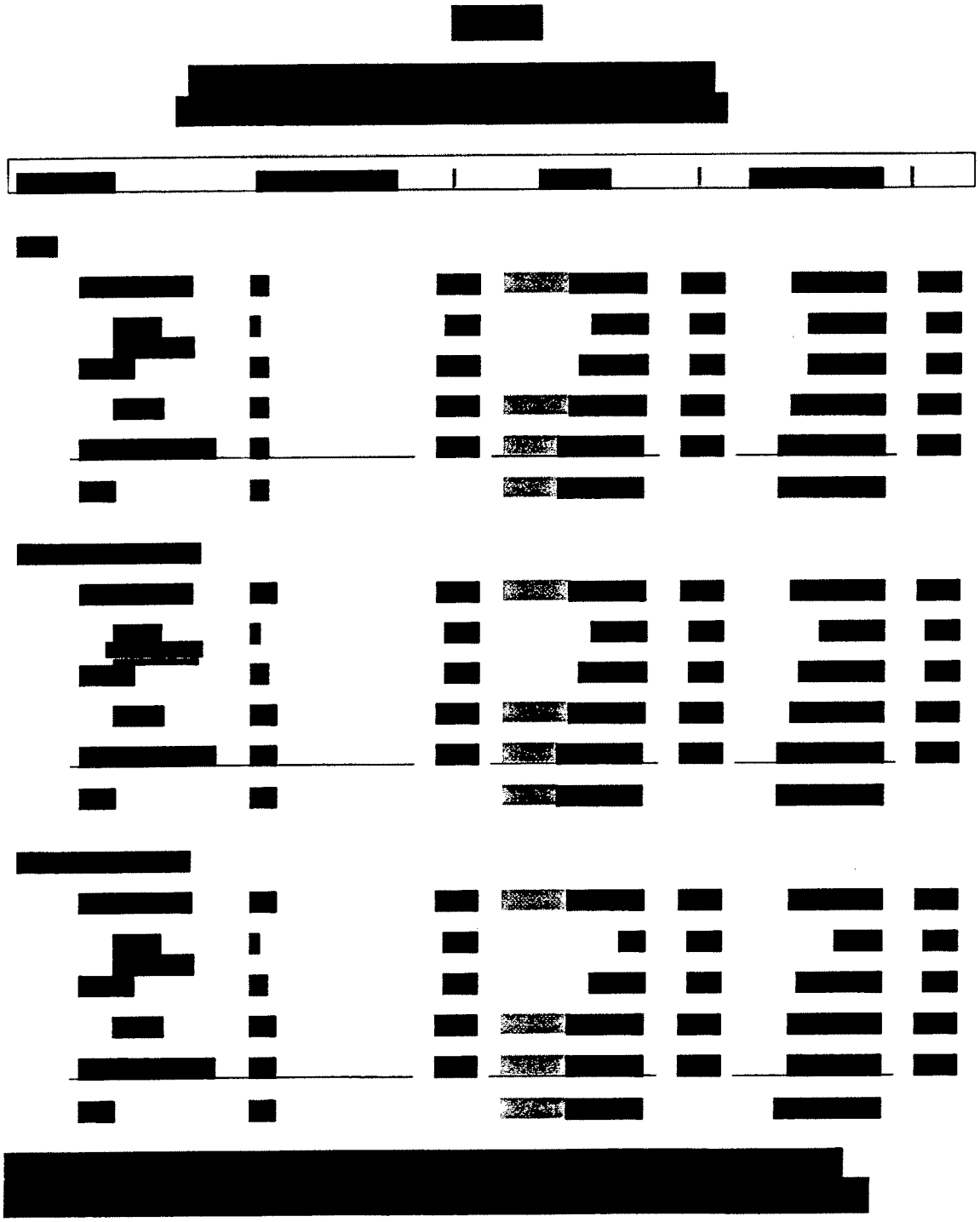
[40] *In re Static Random Access (SRAM) Antitrust Litigation,* "Order Defining Custom SRAM," United States Distrrict Court Northern California, December 19, 2008.

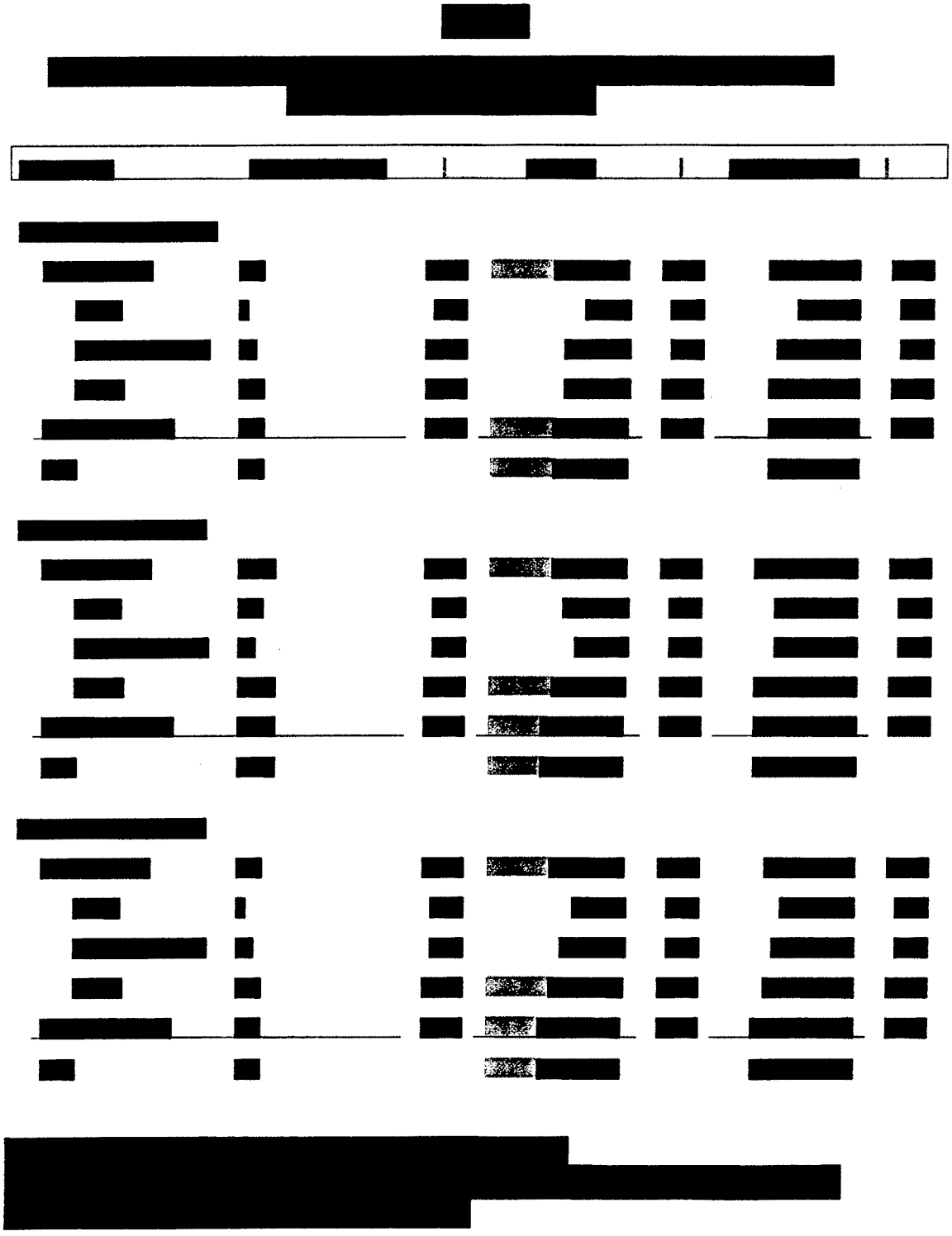
[redacted]

The results of this work are summarized in Table 3 for raw flash products and in Table 4 for finished flash products. The basis for these tables is included in Exhibit A to this report.

[redacted]

[redacted]





[redacted] These results imply that product differentiation does not, for the vast majority of cases, extend to the individual buyer.

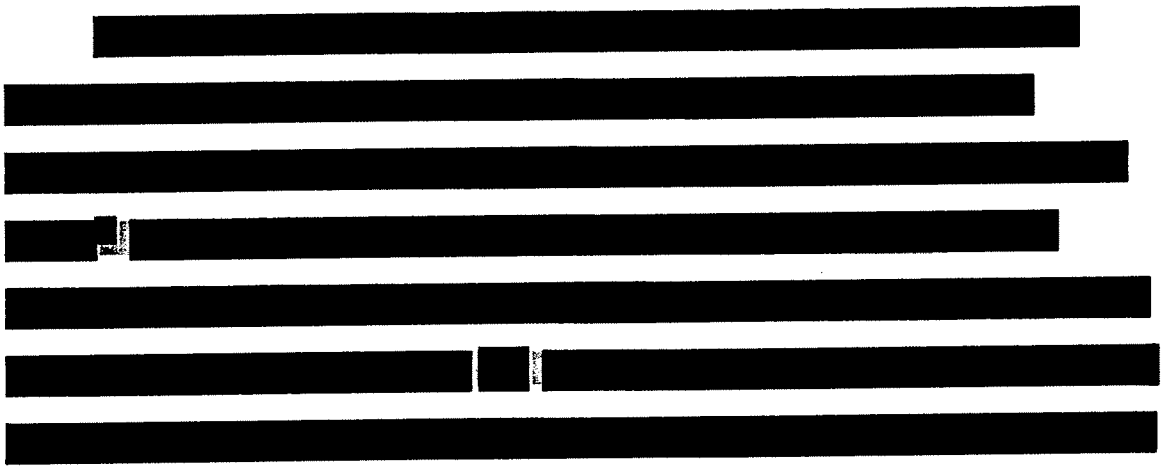
Commonality of Price Formulation Process

The final step in demonstrating that individualized factors do not predominate in the pricing process is to show that common factors are responsible for most of the variation in pricing. The purpose of the analysis in this section is *not* to show that collusion worked, but instead to show that, within a group of products defined by their technical characteristics, different vendors set the prices for similar products in the same way. The test of whether the process of price formulation is predominantly common is the extent to which prices of technically similar products are correlated, either within the same firm or among firms.

The test performed here is the same as the test that was used in the SRAM litigation. Here I repeat a caveat about this analysis. *Price correlation is a weak test for the commonality of a pricing mechanism because it has low power, and so is biased in favor of finding that the pricing process is not common among a group of products.* That is, in applying this test, the deck is stacked in favor of the defendants.

The reason that price correlation analysis is a low-power test in the sense stated above is that it does not take into account variables that easily could be taken into account in a regression analysis to explain prices. Theoretically, prices should differ among purchasers due to factors related to the cost (including risk) associated with the transaction. For example, both buyers and sellers benefit from long-term contracts that reduce the variance in sales to the seller and product availability to the buyer. Consequently, prices of products bought through a long-term contract with supply and purchase commitments are likely to differ from prices that are not part of a long-term commitment by either party. In addition, sellers typically offer quantity discounts, which can produce price differences among transactions. These differences can be taken into account in a regression model of price formulation by including transactions volume as a determinant of price. Finally, as discussed above, specific types of products (in this instance varieties of finished flash devices) are likely to have different costs, and effective price collusion may lead to price discrimination among these products. This source of differences, too, can be taken into account in a regression model.

[redacted] All of the results are reported in Exhibit B of this report.



[43] The power of correlation analysis (i.e., the chance of finding a true relationship) is low if the number of observations is small. The test statistic for determining the statistical significance of a correlation coefficient is t r(N-2)$^{1/2}$/(1- r^2)$^{1/2}$, where r is the correlation coefficient (r^2 is the standard measure of association used in regression analysis) and N is the number of observations. If the number of observations is 20 and t > 1.33, the probability that r is positive (a one-tailed test) is .9. (The critical value of t varies with the number of observations, but is 1.4 or less if the number is ten or more.) Suppose r .5, which means that common factors explain half of the differences in price from period to period. If there are 11 observations, t 1.3 (.5 is not significantly greater than zero). Thus, if the true correlation is .5, correlation analysis would be unlikely to detect it at the 90 percent confidence level if there are fewer than 12 observations. Of course, if the estimated value of r is substantially great than .5, fewer observations are required for the estimate to be statistically significant.

[44] The test for significance used here is the 90 percent confidence level; however, this test may be too demanding for the legal test of preponderance of evidence, which most scholars in law and economics interpret as "more likely than not."

[redacted]

A related issue is whether transactions prices closely track the spot market prices reported by DRAM Exchange. [redacted]

DAMAGES

Economists calculate damages by comparing actual prices with the prices that would have occurred in the "but-for" world in which the alleged anticompetitive conduct did not occur. The latter constitutes a hypothetical "competitive benchmark" in which prices are determined solely by competitive behavior among sellers. Three methods are commonly used to establish

the competitive benchmark: "before-after," "yardstick" or "comparable products," and "operating profit" or "mark-up."

The before-after method compares prices during the period in which the alleged anticompetitive acts reduced competition with prices before and/or after. The comparable products method identifies other products that were not affected by the same or similar anticompetitive acts and that have sufficiently similar supply (technology, seller market structure) and demand (buyer market structure, nature of buyers) characteristics to make comparisons meaningful. The mark-up method estimates the difference between price and average operating cost that would arise under competition, using models of the competitive process and information about mark-ups in similar industries or the same firm in other markets.

The starting place for all methods of estimating damages in this case is a regression analysis of the price of raw NAND flash products. The section of this report on the core characteristics of flash memory provides the information necessary to describe the proper approach to estimating price equations for flash products. First, the price model must take into account both Moore's Law and learning-by-doing. All else equal, these features of semiconductor manufacturing cause manufacturing costs per unit of capacity to decline over time, but with occasional upward bounces when a new technology (a gain in density and/or a new chip design) is introduced and before learning-by-doing takes effect. Second, a proper price model must take into account the effect of other technical characteristics of a raw NAND flash memory product on price, via either cost differences or differences in demand.

A proper application of the economics of price formulation must take into account the fact that, regardless of the extent of competition in the market, cost is an important determinant

of prices. Even in a monopolized market, all else equal prices will decline if the marginal (or incremental) cost of a product falls. Of course, all else may not be equal demand may shift or market structure may change to offset the effect of cost on price. But holding these factors constant, falling incremental costs lead to declining prices.

[redacted] Thus, a method for calculating damages in this case will measure the extent to which new product prices start higher and/or fall less rapidly than otherwise would have occurred.

Technical characteristics of flash memory other than capacity also are likely to affect cost and price. [redacted]

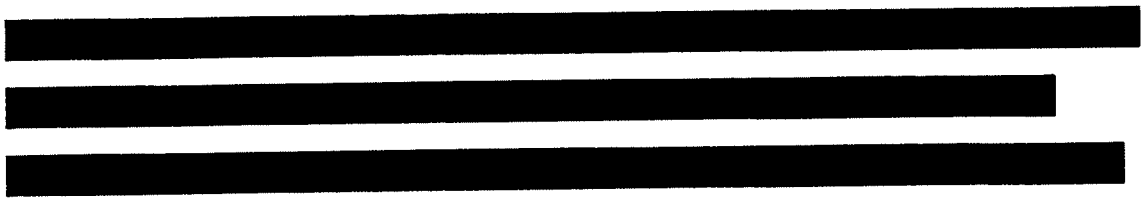


Table 5: Flash Memory Characteristics in Product Codes

NAND flash memory chips have long product codes that characterize the relevant technical features of the product.[45] [redacted]

Cell Level whether product is single-level cell (SLC) or multi-level cell (MLC).[48] A cell is a circuit required to implement a repeated function, such as record a bit on a memory chip.[49] SLC flash stores two levels of voltage (thus one bit per cell), while an MLC product stores four levels of voltage (thus two bits per cell), allowing more information to be stored in a single cell.[50]

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[45] For a map of Samsung's NAND flash product codes, see "NAND Flash Code Information," April 2009, Samsung, at www.samsung.com/global/business/semiconductor/products/flash/downloads/Nand_Flash.pdf.

[redacted]

[48] For discussions of mode designs and characteristics, see Masao Morimoto, Makato Nagata and Kazuo Taki, "Asymmetric Slope Dual Mode Differential Logic Circuit for Compatibility of Low-Power and High-Speed Operations," *IEICE Transactions in Electronics* Vol. E90-C No. 4 (April 2007), pp. 675-82, and "SLC vs. MLC: An Analysis of Flash Memory," Super*Talent, at www.supertalent.com/datasheets/SLC_vs_MLC whitepaper.pdf. For application in a family of Samsung NAND flash memory chips, see www.scribd.com/doc/7010329/Samsung-16M-x-8-Bit-NAND-Flash-Memory-Datasheet.

[49] www.sematech.org/publications/dictionary/c_to_ch.htm

[50] Dan, Raz and Rochelle Singer,. "Implementing MLC NAND Flash for Cost-Effective, High-

Table 5 (Cont'd)

Die Count usually "die count" refers to the number of dies that can be produced from a wafer, but in NAND the term also is used to refer to the number of dies in a flash memory device.[51]

Power the power required to program the flash memory. Flash memory power requirements vary widely among devices and vendors for two main reasons. First, flash cells require high voltage for programming. Different types of flash architectures and designs have different program/erase techniques that have differing power requirements. Second, different applications require different power supplies.[52]

Mode the features of the chip that enable reading and writing files.[53]

Generation the different iterations of a product, distinguished by differences in architecture or function. For example, Samsung's fusion memory semiconductors have been through three generations. The first was simply a physical combination of two or more chips. The second had multiple functions like logic, sensor and CPU integrated on one chip. The third had two or more kinds of memory chips combined on one chip to create synergy. Various kinds of data could be stored on that one chip.[54]

Package Type packaging around the chip. Semiconductor chips are very delicate. A tiny speck of dust or drop of water, and even light, can hinder their function. To combat these problems, silicon chips are protected by packaging.[55] Packaging differs among mount types[56]

Capacity Memory." *M-Systems Flash Disk Pioneers*. White Paper, September 2003, p.2.

[51] See www.imaps.org/abstracts/system/new/abstract_preview.asp?abstract 09dpc3d042 and www.sematech.org/publications/dictionary/df_to_dz.htm.

[52] smithsonianchips.si.edu/ice/cd/MEMORY97/SEC10.PDF, p.11

[53] Dennis Hessink, "SDXC Flash Memory Cards," *CES 2009 Reports*, January 7, 2009.

[54] www.samsung.com/global/business/semiconductor/products/fusionmemory/Products_FusionMemory.html

[55] www.necel.com/pkg/en/pk_01.html

[56] www.necel.com/pkg/en/pk_02.html.

Table 5 (Cont'd)

(the method for attaching a chip to a circuit board[57]).

Lead-Free an identifier for whether the packaging is lead-free. As semiconductors become more powerful and smaller, they generate more heat in less space. Heat can damage the semiconductor or degrade its performance. Packaging materials dissipate heat by filling the gap between the semiconductor and the heat spreader. Demand for lead-free material is driven in part by regulation.[58]

Temperature the temperature or temperature range at which a flash memory product works optimally. At elevated temperatures a silicon device can fail catastrophically, but even if it does not, its electrical characteristics frequently undergo intermittent or permanent changes. Manufacturers of processors and other computer components specify a maximum operating temperature for their products.[59]

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[57] www.toolingu.com/definition-660220-28811-surface-mount.html

[58] www51.honeywell.com/honeywell/news-events/press-releases-details/03.16.09PbFreeDie.html?c 31

[59] www.pcpower.com/technology/optemps/

Another factor that may affect transactions prices are contract terms. Large purchasers are likely to receive quantity discounts, and long-term supply and purchase commitments may also affect price. Contract variables can be created by examining contracts and recording whether key terms are present, and quantity discount can be taken into account by recording total sales to each customer over the period that is relevant for determining these discounts. If discovery reveals the quantity discount policies of defendants, recovering the discounts in the data analysis will be easy, but even if such information is not forthcoming, the pattern of quantity discounts can be estimated by entering quantity non-linearly in the regression analysis.

The preceding discussion focuses on raw flash, but some class members purchased finished flash products from the defendants. In comparison with raw NAND flash, the defendants are not as dominant in sales of finished flash products. Plausibly the appropriate economic model for the activities of the defendants in finished flash products is that they were price takers, in which case the damage analysis needs to measure only the effect of changes in the raw flash prices on finished goods prices. Economic analysis predicts that a change in raw NAND flash prices will soon thereafter be followed by a comparable change in the prices of the finished products that contain them.[60] The form of the regression here is simple: final goods prices are regressed on the transactions prices of the corresponding raw flash product a few weeks in the past, the type of finished product, and an interaction between the two.

If the defendants engaged in collusion on finished products, a more comprehensive price analysis is required, along the lines of the analysis of raw flash prices. Product characteristics

[redacted]

and other variables reflecting supply and demand conditions, including the price of the raw flash input, must be included in the price regression for finished products. This analysis is based on the transactions data plus other general measures of supply and demand conditions that would be common to all transactions within a category of finished products.

Once the key factors affecting the prices of products are identified, the next step is to determine whether prices are further elevated by anticompetitive conduct. The remainder of this section discusses how to implement each of the three approaches to damage estimation.

Before-After

The before-after method requires using the detailed transactions data to identify the important factors affecting prices for the class period and a few years before and/or after the class period. This method uses statistical analysis to explain price movements on the basis of supply and demand conditions, and then determines the extent to which these conditions under-predict prices during the period in which the alleged collusion took place. The basic approach is to regress price on a set of technical characteristics of products, the position of the product in its life cycle (including the cumulative output of that type of flash memory), measures of other demand and supply conditions, and the alleged presence or absence of price fixing conduct.

The advantage of the before-after method is that it does not require information about other products or the development and defense of a structural model of pricing behavior among firms in the industry. Although the regression analysis in the before-after method is built up from transaction records, the resulting regression analysis produces a damage formula that is common to all members of the class because the data that are used in the regression from the

transactions records are simply different values of the same set of variables for all purchasers.

The *Complaint* alleges a price-fixing conspiracy beginning on January 1, 1999, and continued until it was filed in February 2008. If the *Complaint* is correct, a before-after analysis would compare prices before 1999 and after February 2008 with prices in the period between. To implement the before-after method, transactions data are needed for a couple of years before the instigation of price collusion and a substantial period after the end of the class period. [redacted] Without such data, the before-after test can not be implemented. Prior to 1999, NAND flash memory was not a particularly important product. Innovations in both consumer electronics products and NAND flash memory in the early 2000s completely transformed the NAND flash memory market, increasing sales by two orders of magnitude. As a result, trying to compare the price formulation process in1997-1998 with prices after the boom in small consumer electronic appliances is unlikely to produce reliable results. The solution is to extend discovery beyond February 2008. The additional discovery must include transactions that reflect product innovations and introductions that were made after the end of the collusion period, which means discovery should include at least one year of transactions data after February 2008. Because other data are available only on a quarterly basis, I conclude that transactions data are needed through at least March 2009.

I anticipate that the duration of the collusion period is likely to be a matter of dispute in this litigation. The before-after damage method can be used to test whether other notable events brought an end to price collusion. For example, in other memory cases, the conspiracy was alleged to have ended when the Antitrust Division launched its investigation of that product, and

subsequently the analysis in the DRAM case confirmed that prices were statistically significantly lower after the DRAM investigation was begun. The investigation of the flash market by the U.S. Department of Justice was launched on approximately September 24, 2007.[61] Because the termination of the conspiracy would not immediately end the price effect of the conspiracy, a demarcation date of approximately November 1, 2007, can be used to test whether the investigation ended the conspiracy and caused prices to fall.

Further discovery also will reveal whether the exit of Renesas was in any way related to the conduct of the other firms. In the DRAM litigation, discovery revealed that price collusion was suspended for most of 2001 in response to the revelation that Hynix was in dire financial trouble. Some of the other firms sought to drive Hynix from the market by instigating price competition in DRAM, but this came to an end when the Korean government bailed out Hynix. If discovery reveals similar conduct regarding Renesas during any period before it announced its intention to withdraw from the market, a before-after test is appropriate for determining the effect of this behavior on prices.

The defendants also may argue that they reacted to the sentencing of executives of DRAM manufacturers on price-fixing charges emanating from the DRAM case. In particular, executives from Hynix and Samsung served prison terms.[62] The before-after method can be used to test whether criminal convictions eliminated or reduced the effectiveness of collusion.

In addition to product characteristics, another factor to be taken into account in a price

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[61] See www.allbusiness.com/legal/trial-procedure-suits-claims/6245582-1.html.

[62] Karen Gullo and David Dietz, "Busting the Chip Cartel," *Bloomberg Markets*, June 2008, at www.bloomberg.com/news/marketsmag/sr_0608_chip.html.

analysis is market demand. One common factor affecting all semiconductor products was the boom of the late 1990s followed by the bust in 2001, then a later boom in mid-decade, followed by the recent deep recession. The rapid growth in demand for small-scale consumer electronics fueled the boom in NAND sales in 2002-2007. Thus, an underlying supply and demand analysis of flash memory products must take into account the possibility that demand for different types of consumer electronics products differentially affected the pattern of demand and prices among the categories of raw NAND flash and finished flash products. Examples of measures of the demand for types of finished products and the raw flash memory that they contain are the sales of the most important final products that contain flash.

The market structure of the flash memory industry also can affect prices. Table 2 shows that raw flash sales became less concentrated at the end of the class period after the entry of Hynix and IM Technologies. A statistical analysis of prices can include a concentration measure to determine whether the entry of new firms, and the exit of Renesas, affected prices.

As is apparent from the discussion, the building blocks of the statistical model are data from the transactions and contracts of the defendants plus general data about the state of supply and demand in the industry. The statistical analysis will include all transactions, and thereby be common to all class members, since this is the most reliable way to test whether such factors as product type, contract terms and buyer type affect not only price in general, but also the effect of collusion on price. The same analysis would be required if this case involved a single purchaser because a data set involving large number of transactions and an analysis that took into account characteristics of each transaction would be necessary to obtain a statistically robust estimate of the damages for any direct purchaser.

The end product of the statistical analysis is a difference between an actual price and a but-for price for a given type of customers and products. If the details of transactions affect damages, the common formula will produce different damages for different types customers and products; if these details of the transaction turn out not to be important, the statistical analysis will so inform us, and damages will be the same for all class members. In either case, damages will be derived from a common formula that makes use of all transaction information to obtain a maximally reliable calculation of damages.

Comparable Products

The comparable products method requires identifying other products that have similar production technologies, market structures, and demand conditions in order to justify the claim that observed differences in prices are due to the presence of anticompetitive behavior in one market but not the other. As above, implementation of this approach requires using statistical analysis to explain price behavior in the yardstick market, taking into account technological innovation, product life cycles, market structure, and demand for final products of which the yardstick product is an input. The purpose is to account for all sources of price variation in both markets other than the presence of anticompetitive behavior in one. As with the before-after method, this method produces a predicted price for flash memory products, and the difference between the actual and predicted price is the damage.

The obvious candidates for a competitive benchmark to NAND flash memory are other semiconductor products: DRAM, SRAM, NOR flash, microprocessors, graphics processors, network processors, digital signal processors and analog-digital converters. These products have

overlapping customers and suppliers, similar scales of production, and similar production technologies.

The problem in using this method is in finding a yardstick semiconductor product that is sold competitively. Some of these products, such as processors, are sold in highly concentrated markets. Moreover, antitrust litigation has occurred or is in process in microprocessors, DRAM and SRAM. An attempt to use products as competitive benchmarks that are involved in antitrust complaints inevitably would lead to litigating these other antitrust cases as well as the NAND flash memory litigation. Finally, because of the overlap in suppliers among memory products, the validity of any as an example of a competitive market is questionable.

Nevertheless, DRAM is a reasonable comparable product. In particular, both parties in the direct purchaser DRAM litigation agree that DRAM prices were competitive during much of 2001 (the "kill Hynix" period) and after June 2002. If the NAND flash memory conspiracy was in operation during all of 2001 and after June of 2002, comparative analysis should reveal higher relative prices for NAND flash than for DRAM, thereby providing an estimate of the effect of the NAND flash conspiracy.

Mark-up

The mark-up (or profit margin) method estimates competitive prices from data about costs. As discussed elsewhere, all semiconductor products exhibit economies of scale due to the high fixed cost of research and development, the high fixed costs of fab facilities, and the effects of learning by doing. As a result, the average price of a product over its life cycle must exceed its average variable cost in order for the firm to recover its fixed costs and earn even a

competitive return on investment. The mark-up method estimates the operating margin (the mark-up of price over average variable cost) that would arise in the absence of collusion, and then calculates damages as the difference between actual prices and but-for prices. In this case, but-for prices would reflect all of the factors discussed above, such as technology, position in the life cycle, other terms of the transaction, and common industry factors such as demand and market structure.

A mark-up analysis involves at least one of three approaches.

One approach resembles a comparable products method in that operating margins are calculated for a number of industries in which such factors as R&D intensity, the ratio of fixed to variable costs, the nature and extent of product differentiation, and market concentration are similar. If the comparisons are apt, and differences between the products in demand and market structure are taken into account, the result is a competitive benchmark operating margin, expressed as a percentage of price and hence sales. This percentage is then applied to all transactions, assuming that evidence is developed that price variation according to types of products and other transactions terms reflects other supply and demand conditions that would remain in force regardless of whether collusion was present. The problem here, of course, is the same as the problem with the competitive benchmark method whether one can identify a product that is sold under conditions that reflect the extent of competition that would arise in raw NAND flash in the absence of collusion. As in the comparable products case, DRAM after the collapse of price collusion is a reasonable benchmark.

The second mark-up approach uses information about fixed costs to estimate the mark-up over average variable cost that would be necessary for the firm to earn a competitive return on

investment. The key to this approach is to estimate accurately the competitive return to investments (including R&D) for the industry, taking into account its risks. This estimated competitive return is then added to variable cost plus depreciation to calculate the benchmark average unit price.

The problem here is the boom-bust nature of the semiconductor industry. Firms in this industry almost never earn a competitive return in any single year. Instead they hope the booms (1999, 2006) will offset the busts (2001, 2008) to produce at least competitive returns in the long run. To account for this phenomenon, the method for calculating the benchmark returns in each year must take into account business cycle effects at both the industry and national levels.

The good news about this approach is that, although the financial analysis would be complicated, it is commonly done by finance experts in many settings, including regulatory proceedings to set prices for regulated public utilities. Moreover, this approach uses models and data that would be common to all members of the class.

The third approach uses a structural economic model of imperfect competition to calculate the effect of collusion on prices under the assumption that colluding firms behave as if they were divisions of one firm. Here the comparison is between a more competitive industry with the HHI of the market for raw NAND flash versus a highly concentrated industry with a dominant firm that, depending on the year, has a market share between 88 and 100 percent of sales (from Table 2). The analysis would be based on the costs of each type of product and conditions in the market, and so would be common to all members of the class.

The structural model that would be applied here is the dominant firm/competitive fringe model. This model assumes that sellers who are not part of the cartel will sell all they can, up to

production capacity, at the price established by the dominant firm (the cartel). The dominant firm sets prices to maximize its profits based on the part of the demand that remains unsatisfied by the fringe players. A key parameter demand elasticity is calculated to cause this model to fit the data, and a second model is then estimated under the assumption that the actual degree of concentration (HHI) indicates the but-for degree of actual competition. In this instance, one plausible model of the but-for world is a Nash-Cournot oligopoly. Damages are the estimated as the differences in mark-ups between the two models.

Among the measures that are needed for this exercise are product-specific marginal costs, which can be estimated from cost data (taking into account scale economies and learning-by-doing). Assuming that discovery produces such information, the existing transactions data or even average price data from DRAM Exchange can be used to calibrate the collusion model, and then to estimate the price effect of greater competition.

Conclusions on Damages

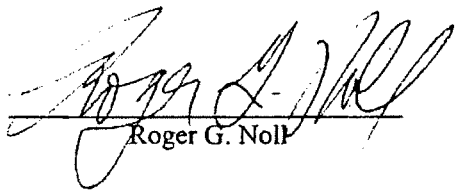
Because discovery already has produced transactions records, I am confident that all of these methods are feasible in this case. The two that seem most plausible to me, pending further discovery, are comparable products and before-after.

Probably the biggest hurdle is identifying a competitive benchmark for either the comparable products test or the version of the mark-up method that is based on other products. In both cases, DRAM products from April through November 2001 and after the government launched its investigation into DRAM price fixing offer a reasonable competitive benchmark that

has two additional benefits. First, the DRAM benchmark involves two of the same defendants,[63] which facilitates discovery as well as valid comparisons among products. Second, a damage analysis for the DRAM case already has established a period in which DRAM was competitive. The disadvantage of using DRAM is that it is a less concentrated industry, but this can be taken into account in the analysis by using variation in market structure over time as one of the variables to explain variation in prices.

If further discovery of transactions data is provided, the preferred approach is the before-after method because of its greater simplicity, its more limited requirements for discovery, and its ability to test alternative hypotheses about the beginning and end of the class period.

I declare that the foregoing is true to the best of my knowledge and belief. Executed at Stanford, California, July 21, 2009.



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[63] Mitsubishi was a DRAM manufacturer, but, as in this case, transferred its DRAM business to a new firm, Elpida, formed jointly with NEC, early in the class period.