Stylized Facts of Firm-Level Investment Behavior in the Semiconductor Industry

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This paper presents basic firm level statistics on Japanese and US firms in the semiconductor industry in the attempt to capture the stylized facts, if any, that exist in the data. While the data spans from 1980 until 1997, particular attention will be drawn to the period of the Semiconductor Trade Agreement (1987-1996) to search for anomalies that might exist due to the imposition of a market share policy. Prior to examining the data, some historical background and theoretical predictions are outlined. This is an exploratory work, which hopes to lead to a more rigorous testing of theory by means of econometric work at some later date. Comments and suggestions are welcome.

1. INTRODUCTION

The Semiconductor Trade Agreement (STA), which was signed in July of 1986, specified an expectation of foreign chip producers' share of the Japanese market to reach 20% by the end of 1991. In return, the Department of Commerce dropped its Section 301 case and anti-dumping suits. The arrangement also set out the basic guidelines for a cost and price monitoring system (Flamm 1996). MITI and the US Department of Commerce collected firm costs and determined "Fair Market Values" (FMVs) for the semiconductor industry. Efforts were also made on behalf on MITI to monitor Japanese exports (especially of DRAM) and limit production and investment (in capacity) by Japanese firms (Flamm 1996).

By 1991, Japanese producers had fallen short of the 20% target, only reaching around 15%. Another five-year STA was re-negotiated, and the deadline was extended for one year. By the fourth quarter of 1992, foreign market share (approximately 85% being US-made) had surpassed 20%, and the agreement was lauded by government officials and most American producers as a success. Whether or not this success was due

to government intervention, or simply rapidly changing market conditions is not easily determined.   Irwin (1994) feels that this agreement clearly diminished competition, facilitated collusion and restricted output to the detriment of the consumer and to the benefit of both Japanese and US firms.   Flamm (1996) holds a similar view, and additionally demonstrates that the majority of the gains made in foreign market shares were, in fact, due to market penetration, rather than shifts towards US-made CPUs and the like. (Flamm, pp. 286-287).

1987 Rank	Top Merchant SC Manufacturers
1	NEC
2	Toshiba
3	Hitachi
4	Motorola
5	TI
6	Phillips
7	National SC
8	Intel
9	Matsushita
10	Fujitsu
11	Mitsubishi

Semicondutor International, November 1988

2. DATA (see attached data Tables and Charts):

2a. Japanese Firms

The *Nihon Handoutai Nenkan* (Japan Semiconductor Yearbook) presents data on all major Japanese firms and many foreign firms as it pertains to the semiconductor part of the firm. That is to say, although NEC produces a wide range of electronic goods and services, only the investment allocated towards the production of semiconductors is included. The investment data is for plants and equipment and does not include R&D

investment. The original source of this data is the World Semiconductor Trade Statistics (WSTS), a data collection organization exclusively for semiconductor manufacturers. Production figures for semiconductors are also included. Although the yearbook covers a number of Japanese firms, many firms were late entrants, exited the industry or merged. As a result, the reliable data set of `consistent` firms is considerably smaller. In Table 1 Production figures are presented for 12 Japanese firms, namely, NEC, Hitachi, Toshiba, Fujitsu, Mitsubishi, Matsushita, Sanyo, Sharp, OKI, SONY, Ricoh, and Rohm. In Table 2, Investment numbers are presented. Both series span from 1980 until 1997. These firms account for the bulk (over 85%) of all Japanese semiconductor production, and all of the Japanese firms in the `Top Ten` world producers are included in the data set.

This data is not without its problems, however. The Sony Corporation changed its accounting period from October to March in 1986, thereby leaving no data for that year. Sanyo also recently changed its accounted methods and as a result the 1996 figure is suspiciously low, perhaps reflecting only a half-year of data.

Sony, Ricoh and Rohm only offer data from 1984 onwards, and Ricoh and Rohm only begin being real competitors in the industry in the mid-80s.

2b. Foreign Firms

Although data for many foreign firms is presented, it is not done in a consistent and complete fashion. While it would be very worthwhile to include European, Korean, and Taiwanese firms in the sample, the data is, in general, sparse and with respect to investment, virtually non-existent. As a result, major foreign firms such as Siemens,

Phillips, SGS-Thompson, Samsung, and Taiwan Semiconductor are not included. In fact, only the major US firms presented investment figures and even these figures are much shorter samples than the Japanese data. At the bottom of Tables 1 and 2, US investment and production figures for the Intel, Motorola, Texas Instruments (TI), National Semiconductor and Advanced Micro Devices (AMD) are presented. As mentioned below the tables, only sales (not production figures) for US firms are shown. In the case of Intel, total investment is given rather than the amount attributable to semiconductor (SC) production, although it must be noted that Intel SC sales account for essentially all of its sales. In fact, the data presented in the yearbook is identical to Intel`s annual reports such that an update through 1997 was possible and is presented in Tables 1 and 2. In 1993, the Yearbook ceased detailed publication of foreign data and thereafter only offered descriptive reports.

Charts 1, 2 and 3 plot investment to production (I/P) ratios, production, and investment respectively. While it seems apparent that production fluctuations and investment fluctuations may be correlated, as with most any business cycle, investment shows the widest fluctuations and as a result even in the investment/production ratio there exists a strong cyclical movement.

Looking at Chart 1 we see that there were two major production slumps industry-wide, the first occurring in mid-1984 and the another occurring in 1995. Another smaller downturn occurred in around 1990, precipitated by a general slump in electronics demand in Japan. During both of these well documented industry downturns, investment also falls.

3. SOME THEORIES

A natural response to falling prices is to cut back production capacity and avoid exacerbating an existing glut of chips. However, it has been argued by Flamm (1996) that during the Semiconductor Trade Agreement (STA), which began in 1986, that even after the 1984 downturn when chip demand began to rise again, some Japanese manufacturers cut back on investment into greater capacity in response to MITI pressure. By restraining capacity, chips prices would soar and both goals of the STA, namely 1) increased foreign market share and 2) higher DRAM export prices would be achieved. While Flamm offers some anecdotal evidence of such cutbacks in investment and there clearly was a shortage of DRAM at that time, for the industry as a whole it does not appear to be the case. If we look at either Chart 1 or Chart 3, both investment ratios and investment alone seem to be experiencing a cyclical upswing at this time. In fact, Sumita and Shin (1996) argue that Japanese firms invested heavily during the 1988-92 period (the second half of the first STA). These authors also feel the STA had a significant, albeit different, effect which caused Japanese firms to overinvest in DRAM production. (At this time about 60% of Japanese capital spending went into DRAM production).

It is important to note that these series are for investment in *all* semiconductor production. Memory chips account for around 30% of Japanese production at this time (Nihon Handoutai Yearbook, 1991), a sizable amount, but not the majority. If we look at Chart 1 more closely, we see that Toshiba, the largest producer of DRAM in the world at this time *does* appear to have a flat investment/production growth during this time, while the industry as a whole is rising.

This brings up two issues. One, it seems quite plausible that investment cutbacks and capacity shortages in the DRAM sector caused the rise in DRAM prices during this time. Whether or not this was due to the STA or simply poor planning in the face of very uncertain demand is not clear. Two, although it may be argued from Flamm`s anecdotal evidence and casual inspection of Toshiba`s investment/production ratio that investment may have fallen below its otherwise normal cyclical trend, this story does hold for the market as a whole. In particular, this research is concerned with the effect of the STA on investment in the entire industry through primarily two channels. One is the possible reduction in investment due to the strict fair market value (FMV) price floors enforced for DRAM and EPROMS in the first STA agreement (1986-1991). The second hypothesis posits that the `forced` market share aspect of the agreement, which arguably had its largest effect during the second signing of the agreements in late 1991, when the initial 20% target had not been achieved, may have reduced Japanese investment and increased US investment.

If we look at again at Charts 1 and 3, it does appear as though investment falls at this time. This is roughly consistent with theoretically predictions that would require Japanese producers to cutback capacity to comply with the target market shares (see below). Note, however, that this does not necessarily imply that Japanese profits fall, but simply that market shares do. It has been shown that in the face of a market share voluntary import expansion (VIE), that both prices *and* profits of both firms can increase under such a `facilitating` policy (Krishna, etal. 1996).

However, the theoretical predictions about investment are somewhat weaker. The Krishna paper and others in the VIE literature (see Greaney, 1996) do not include

investment as part of the firms' decision. Nagaoka (1992) includes investment in a two-period game theoretical model, and predicts that the VIE will, in fact, reduce investment in addition to Japanese production. Unfortunately, this model also has limitations in describing this particular form of the VIE. Nagaoka`s paper models a VIE as an implicit import subsidy to US firms to meet the market share, when in reality, the STA is better modeled as a market quota. The effect of this alternate specification of the VIE on investment is unclear. In a similar literature, Reitzes (1991) has shown that in the case of *quotas* and *tariffs,* the impact on R&D in a two-period game will differ. It remains to be seen whether or not an import subsidy/production tax VIE would have the same effect as a market-share VIE on investment. This is, in fact, another topic this author is researching.

If we look at the investment decision faced by firms as one under uncertainty the results can be very different under the STA. As the first STA was effectively a price support, Dixit and Pindyck (1992) find that investment would increase for all firms under the umbrella of such a support. This would imply that, contrary to Flamm and Nagaoka, that Japanese firms would increase production of investment (in DRAMs in particular) as would US firms[1]. Naturally the theoretically predictions are varied and one does not necessarily preclude the other and so it becomes an empirical question.

4. DATA BY FIRMS

NEC Investment/Production Ratio

NEC	Total Firm (1 million yen)			Stock of Capital		Actvity in Semiconductor Division only(mill y			
	Sales	Profits	after-tax P	Plants	Equipment	Production	Prod/Total	Investment	Inv/Tot.sale
1980	719773	23514	13131	n/a	n/a	221500	0.308	30000	0.042
1981	892810	35191	18045	n/a	n/a	264000	0.296	40000	0.045
1982	1054049	43556	21328	n/a	n/a	293500	0.278	48000	0.046
1983	1253588	52122	26735	60649	48043	385000	0.307	67000	0.053
1984	1459738	66812	34643	60690	52435	590000	0.404	140000	0.096
1985	1889340	125899	51099	62234	52449	450000	0.238	100000	0.053
1986	1970499	94516	53016	71390	63259	460000	0.233	40000	0.020
1987	2123538	52288	28119	79017	70521	510000	0.240	40000	0.019
1988	2304392	74177	37477	90349	75319	630000	0.273	90000	0.039
1989	2542047	102139	55339	96794	79851	680000	0.268	105000	0.041
1990	2760682	133235	74896	183906	99965	725000	0.263	100000	0.036
1991	2961097	140522	58081	186597	99673	755000	0.255	70000	0.024
1992	3049450	80006	38740	193035	99183	750000	0.246	80000	0.026
1993	2869533	18154	16528	188616	85954	810000	0.282	125000	0.044
1994	2899362	31859	16755	186276	74673	930000	0.321	210000	0.072
1995	3006905	60508	30287	182180	67074	1170000	0.389	190000	0.063
1996	3448793	100615	55615	186192	59584	1100000	0.319	190000	0.055
1997	n/a	n/a	n/a	n/a	n/a	1260000	n/a	n/a	n/a
1998	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

NEC

This huge electronics giant produces a wide variety of DRAMs, SRAMs, ROMs as well

as microcontrollers in its semiconductor division. In 1996, it was second only to Intel in

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[1] For a more detailed description of possible theoretical modeling of the effects on investment see Parsons (1997).

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semiconductor revenues worldwide. In 1988, memory production accounted for 30% of manufactured semiconductors, microcontrollers (20%), LSI chips (30%), and 20% discretes and others. Semiconductor production has accounted for anywhere from 25% to 40% of total sales reaching a peak in 1984 and then more recently in 1995 reaching 39%. Incidentally, these two peaks of semiconductor activity on behalf of NEC coincide with dramatic increases in both sales and investment. So much investment so that, in fact, its investment/production ratio also peaked at this time. Another high point in I/P ratio was in 1990. It does not appear that investment slowed down at all during the first STA. In fact, given NEC's large role in the memory market, it is surprising that investment as a fraction of production increases dramatically at this time, contrary to what Flamm's anecdotal evidence would suggest. Profits in the late eighties are far from spectacular during the late eighties, however these are *firm* profits, not simply semiconductor profits.

Hitachi Investment/Production Ratio

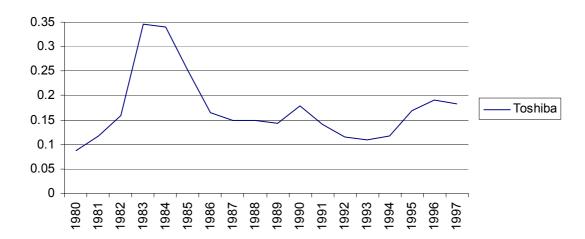| Hitachi	Sales	Profits	after-tax Pro	Plants	Equipment	Production	Prod/Total	Investment	Inv/Tot.sales
1980	1698130	106652	53088	n/a	n/a	165000	0.097	23000	0.014
1981	1947029	117738	61846	n/a	n/a	206000	0.106	34000	0.017
1982	2140905	140359	66778	n/a	n/a	248000	0.116	41900	0.020
1983	2333273	157138	74538	68287	118915	360000	0.154	81000	0.035
1984	2648207	187219	83419	78664	134960	540000	0.204	130000	0.049
1985	3025754	255911	105411	84732	150013	420000	0.139	90000	0.030
1986	3003390	158038	88038	102817	167033	385000	0.128	30000	0.010
1987	2924634	88538	53306	136604	143898	410000	0.140	40000	0.014
1988	2919539	132897	65138	107961	106484	482000	0.165	70000	0.024
1989	3232001	191138	100350	107170	156346	540000	0.167	95000	0.029
1990	3525254	220841	115006	139286	186349	580000	0.165	110000	0.031
1991	3788812	205812	123301	172096	219261	560000	0.148	80000	0.021
1992	3925250	128872	82286	187560	215025	560000	0.143	60000	0.015
1993	3811498	78056	57356	190852	211059	610000	0.160	95000	0.025
1994	3739534	71804	45904	208680	224376	740000	0.198	120000	0.032
1995	3741552	88966	56466	205297	232357	960000	0.257	185000	0.049
1996	4126419	128806	71786	219334	240174	795000	0.193	150000	0.036
1997	4310787	84318	58018	242640	221003	780000	0.181	140000	0.032
1998	4078030	17220	10236	237866	222572	n/a	n/a	n/a	n/a

Hitachi

Hitachi was sixth in worldwide production of semiconductors in 1996. Semiconductor

production ranges from anywhere from 10% to 26% of total firm sales reaching its peak

in 1995. The breakdown of products is similar to NECs as is the investment/production

cycle throughout the same period. In 1988, memory accounted for 34% of total

production microcontrollers (10%), discretes (10%), logic ICs(20%), and bipolar (26%).

The I/P ratio peaks are in 1984, 1990, and 1995. After-tax profits from 1986-1988 were notably low, although they seemed to pick up in 1989-1991, the final years of the first STA.
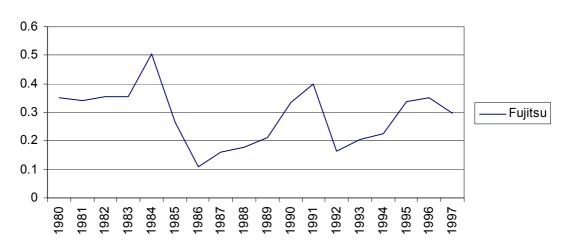
Toshiba Investment/Production Ratio

Toshiba	Total Firm (1 million yen)			Stock of Capital		Actvity in Semiconductor Division only(mill yen)			
	Sales	Profits	after-tax Pro	Plants	Equipment	Production	Prod/Total Co	Investment	Inv/Tot.sale
1980	1427670	75322	41039	n/a	n/a	150000	0.105	13000	0.009
1981	1547611	82816	44238	n/a	n/a	170000	0.110	20000	0.013
1982	1747224	92047	47292	n/a	n/a	200000	0.114	32000	0.018
1983	1773128	82465	46171	83414	97467	280000	0.158	97000	0.055
1984	2025731	104374	50235	106671	126311	435000	0.215	148000	0.073
1985	2525953	144034	65534	122908	163735	360000	0.143	90000	0.036
1986	2519557	80462	54062	136820	193518	410000	0.163	68000	0.027
1987	2503429	41201	23701	138705	198051	470000	0.188	70000	0.028
1988	2682781	65064	37040	152450	198294	600000	0.224	90000	0.034
1989	2921473	149010	61320	153478	199901	660000	0.226	95000	0.033
1990	3060886	201831	96865	158259	196682	700000	0.229	125000	0.041
1991	3227711	175434	93772	190629	222199	710000	0.220	100000	0.031
1992	3185061	70725	42425	224722	221698	690000	0.217	80000	0.025
1993	3150572	54824	25324	249587	222488	730000	0.232	80000	0.025
1994	3256247	53741	31441	259713	263993	850000	0.261	100000	0.031
1995	3325082	71539	42222	251655	251737	1005000	0.302	170000	0.051
1996	3713023	121409	62509	264917	244939	890000	0.240	170000	0.046
1997	3821676	96801	60135	266158	237121	925000	0.242	170000	0.044
1998	3699969	38601	33047	264798	275983	n/a	n/a	n/a	n/a

Toshiba

In 1996, Toshiba followed NEC as the third largest in semiconductor revenue worldwide. In 1988, Toshiba's production was 34% memory, 26% logic ICs, 23% discretes, and 17%

bipolar. Toshiba was the leader in DRAM market share throughout the late eighties. Although Toshiba produced only slightly more memory as a percentage of total production than NEC (compare 34% to 30%) investment ratio behavior is quite different. Toshiba's I/P ratio does peak at 194, 1990, and 1995, but the 1990 and 1995 peaks are far less pronounced. It appears that Toshiba never really approached its pre-1985 investment ratios again. It is particularly flat relative to other Japanese firms at this time. This observation seems to fit the Flamm story of investment restraint during the first STA, particularly in a firm which depends so heavily on DRAMs, the target product of price supports. It is unclear, however, why this would not occur in NEC as well.
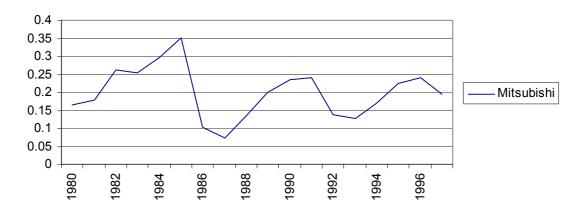
Fujitsu Investment/Production Ratio

Fujitsu	Total Firm (1 million yen)			Stock of Capital		Activity in Semiconductor Division only			
	Sales	Profits	after-tax P	Plants	Equipment	Production	Prod/Total	Investment	Inv/Tot.sales
1980	501000	33424	15645	n/a	n/a	77000	0.153693	27000	0.053892216
1981	581678	32417	44897	n/a	n/a	96800	0.166415	33000	0.056732419
1982	671080	50048	63302	n/a	n/a	121200	0.180604	43000	0.064075818
1983	806769	63016	29555	53380	50437	181000	0.224352	64000	0.079328779
1984	991671	79297	16279	62762	72317	260000	0.262184	131000	0.132100263
1985	1291734	117592	32066	83136	128096	200000	0.154831	53500	0.041417196
1986	1429497	37855	51523	109620	115137	201000	0.140609	21800	0.015250119
1987	1482188	22698	16276	114237	94449	247000	0.166646	39700	0.026784726
1988	1714425	60453	32066	132981	88198	370000	0.215816	65000	0.037913586
1989	2004605	106376	51523	136092	98311	413000	0.206026	87800	0.043799152
1990	2125674	127046	66189	151986	114252	415000	0.195232	138000	0.064920585
1991	2337784	127261	81687	163170	128919	401000	0.17153	160100	0.068483658
1992	2434073	40007	34100	184014	141319	385000	0.158171	63000	0.025882543
1993	2397589	−8704	−7352	214724	110083	405000	0.16892	82800	0.034534693
1994	2172984	28908	17048	204022	104746	475000	0.218593	106600	0.049056965
1995	2259842	60107	30508	193600	104102	590000	0.26108	198700	0.087926501
1996	2602216	84956	44515	212351	193600	550000	0.211358	192300	0.073898554
1997	3123672	95759	60137	209023	147400	610000	0.195283	180000	0.057624488
1998	3229084	80108	50900	211712	146611	n/a	n/a	n/a	n/a

Fujitsu

Fujitsu is a somewhat smaller player in the industry, at number eleven worldwide in 1996. Unlike the previously mentioned Japanese firms, Fujitsu's production consisted of a large share of ASIC chips (45%), and the balance split between microcontrollers and discretes (15%) and a whopping 40% in memories, mostly DRAMs. Given the large portion of production devoted to memories, the rise in Fujitsu's I/P ratio does not complement the Flamm hypothesis well. The climb in the I/P ratio is slow, however, for the first years of STA picking up pace in 1989. Perhaps this sharp decline in the first years of the STA is more of a response to the anti-dumping suits still in the minds of Japanese firms rather than any price support mechanism. However, given the large cyclical swings in data from year to year, this is only one of a host of other plausible stories.
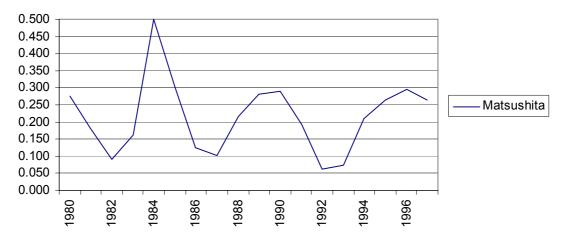
Mitsubishi Investment/Production Ratio

Mitsubish	Total Firm (1 million yen)			Stock of Capital		Actvity in Semiconductor Division only(mill y			
	Sales	Profits	after-tax P	Plants	Equipment	Production	Prod/Total	Investment	Inv/Tot.sal
1980	1075446	48733	25106	n/a	n/a	61000	0.056721	10000	0.009298
1981	1221397	47072	23191	n/a	n/a	73000	0.059768	13000	0.010644
1982	1315538	47726	22197	n/a	n/a	88000	0.066893	23000	0.017483
1983	1392234	50387	25080	49290	80782	139500	0.100199	35500	0.025499
1984	1587690	55521	28392	55051	111905	236000	0.148644	70000	0.044089
1985	1858269	85037	34537	60628	114767	165000	0.088792	58000	0.031212
1986	1820996	40305	24513	66186	151392	176000	0.09665	18000	0.009885
1987	1803551	26437	12737	73596	154023	220000	0.121982	16000	0.008871
1988	1954187	41819	19819	73844	155076	340400	0.17419	46000	0.023539
1989	2230104	93130	32476	79262	138465	361300	0.16201	72000	0.032285
1990	2387828	135331	56188	88330	127271	375000	0.157046	88000	0.036854
1991	2588840	136310	57167	102307	125326	375000	0.144853	90000	0.034765
1992	2611139	61531	29531	133234	136791	365000	0.139786	50000	0.019149
1993	2493612	32330	22030	158845	163470	390000	0.1564	50000	0.020051
1994	2394085	30059	11585	154549	141529	450000	0.187963	77000	0.032163
1995	2488382	63825	20094	148535	139233	550000	0.221027	123000	0.04943
1996	2751771	100799	38325	149528	156846	480000	0.174433	115000	0.041791
1997	2845004	61117	25823	155728	140813	540000	0.189806	105000	0.036907
1998	2811510	4225	–33853	165649	154380	n/a	n/a	n/a	n/a

Mitsubishi

Mitsubishi has maintained a fairly consistent position in worldwide semiconductor
production being 11th in 1987 and edging up to 10th in 1996. SC production ranged from
six to twenty-two percent of total sales. It seems the biggest jump was in 1983 and 1984
when it began mass production of 256K and 1MDRAM. In 1988, production was 80%

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integrated circuits (ICs), and 20% discretes. Although this gives no indication of what kind of ICs were made, they were well known as a DRAM supplier as well as a EPROM and ASIC maker during the eighties. Mitsubishi's I/P ratio follows closely with most other Japanese producers, but peaks about a year later some others. Peaks seem to occur in 1985, 1991, and 1996. Its swings are large. Profits are quite poor in the first years of the first STA, but then seem to pick up in the 1988-1990 period. Mitsubishi has seemed to keep semiconductor revenue at about 20% of total sales. In 1993, discretes, bipolar transistors and analog ICs were 34%, MOS memory 36%, and MOS logic 30% of output. (MOS chips are ICs as well).   This more detailed data suggests that Mitsubishi maintained a roughly similar composition of semiconductors throughout both STA, with memory likely accounting for over thirty percent.
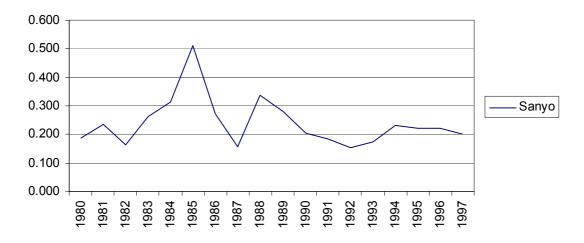
Matsushita Investment/Production Ratio

	Total Firm (1 million yen)			Stock of Capital		Actvity in Semiconductor Division only(mill y			
Matsushit	Sales	Profits	after-tax P	Plants	Equipment	Production	Prod/Total	Investmen	Inv/Tot.sal
1980	2015298	136225	73147	n/a	n/a	80000	0.039696	22000	0.010916
1981	2346296	170524	83613	n/a	n/a	110000	0.046882	20000	0.008524
1982	2473539	171815	95668	63714	33777	110000	0.044471	10000	0.004043
1983	2718812	189110	97484	62178	31835	142000	0.052229	23000	0.00846
1984	3257860	235014	101915	60092	33515	220000	0.067529	110000	0.033764
1985	3424135	250348	111689	68293	33492	200000	0.058409	60000	0.017523
1986	3169245	187517	95135	65666	29606	201000	0.063422	25000	0.007888
1987	1012610	50786	26654	63096	28718	215000	0.212323	22000	0.021726
1988	3277613	185724	85343	61631	35172	240000	0.073224	52000	0.015865
1989	4074674	249493	128493	71455	45276	255000	0.062582	72000	0.01767
1990	4248760	265239	145039	75604	55058	280000	0.065902	81000	0.019064
1991	4691556	276513	153313	98142	83228	290000	0.061813	56000	0.011936
1992	4994719	196405	109505	132419	108372	240000	0.048051	15000	0.003003
1993	4550086	96741	51041	166062	83476	270000	0.05934	20000	0.004396
1994	4349586	63854	43150	168045	62904	300000	0.068972	63000	0.014484
1995	4440966	87003	52703	159795	52034	340000	0.07656	90000	0.020266
1996	4441714	103173	74673	155924	61234	340000	0.076547	100000	0.022514
1997	4797706	143312	83125	148179	65159	380000	0.079205	100000	0.020843
1998	4874526	156350	91203	152571	84273	n/a	n/a	n/a	n/a

Matsushita

Although Matsushita continues to be a large electronics firm in Japan and the world, its semiconductor production was 9th in 1987 and has slipped considerably to 18th in worldwide revenues in 1996. SC production ranged from four to six percent of total sales, with one year (1987) rising to 21% (though this data is *highly* suspect due to the abnormal total firm sales for this year). Production was 50% MOS chips, 30% discretes

and 20% bipolars in 1988. From the *Handoutai Nenkan* data it is unclear as to how much of these MOS (Metal Oxide Semiconductor) were logic chips and how many were memory devices. In any event, Matsushita's I/P ratio follows closely with most other Japanese producers with peaks in 1984, 1990, and 1996 (rather than 1995). Its swings are quite pronounced. Profits are quite poor in the fist years of the first STA, but then seem to be fairly high in the 1988-1990 period. It may of interest to note near that it is not for lack of company resources that Matsushita seems to be slipping in the semiconductor market as SC production value as a percent of total sales is at its' historically high (8%). It has more to do with the seeming lackluster growth of the firm's sales as a whole, which have remained fairly flat throughout the nineties.
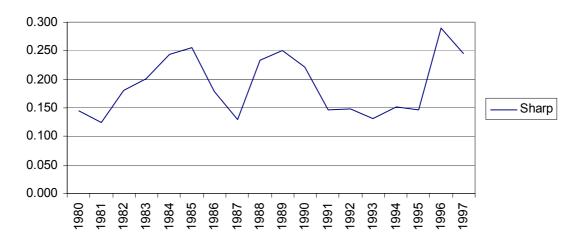
Sanyo Investment/Production Ratio

	Total Firm (1 million yen)			Stock of Capital		Actvity in Semiconductor Division only(mill y			
Sanyo	Sales	Profits	after-tax P	Plants	Equipment	Production	Prod/Total	Investmen	Inv/Tot.sal
1980	680590	39069	21152	n/a	n/a	43000	0.06318	8000	0.011755
1981	752403	43722	23947	n/a	n/a	52000	0.069112	12300	0.016348
1982	761418	44100	24690	41381	31943	55000	0.072234	9000	0.01182
1983	819766	42793	22866	44028	35537	76000	0.092709	20000	0.024397
1984	991708	55685	27536	43859	39948	110000	0.11092	34500	0.034788
1985	1047633	58494	28315	53619	47297	116000	0.110726	59200	0.056508
1986	838837	15158	12904	61882	54531	130000	0.154976	35300	0.042082
1987	909393	16059	14128	94917	94640	140000	0.153949	22000	0.024192
1988	987539	29216	17035	95154	94806	160000	0.162019	54000	0.054681
1989	1040151	40212	20284	98538	99230	194000	0.186511	54000	0.051916
1990	1104515	37026	22893	101136	92204	195000	0.176548	40000	0.036215
1991	1179852	37494	20457	105104	96798	218000	0.184769	40000	0.033903
1992	1081013	10688	5773	117749	101422	219000	0.202588	33600	0.031082
1993	1015728	6038	4074	119636	96429	225000	0.221516	39000	0.038396
1994	1065422	19668	7848	118412	98887	250000	0.234649	58000	0.054439
1995	1075139	28375	14387	120230	100353	280000	0.260431	62500	0.058132
1996	334219	6713	4483	117755	99578	89000	0.266292	19700	0.058943
1997	1104103	29136	16372	123529	104671	265000	0.240014	53000	0.048003
1998	1121939	25275	14146	121543	108122	n/a	n/a	n/a	n/a

Sanyo

Sanyo was never a top ten producer in the industry and produces mostly non-IC chips. In 1991, 26% off all production was MOS (including DRAM and gate array, microcontrollers, and EPROM) chips, the balance being analog IC (32%), hybrids and discretes. Linear (analog) IC tended to be ASIC chips. In 1988, MOS chips accounted

for 27% of production. The timing and the magnitude of the I/P ratio of this smaller player seems to differ from the larger Japanese firms. Though it peaks around 1985, the next peak is in 1988 and then a small one in 1994. There seems to be quick recovery following the 1985 slump, and appears Sanyo's experience was somewhat distinct from the other major players. SC activity as a percentage of total firm sales has been steadily rising from 7% to a high of 26% in 1996. 1989-1991 seem to have been good years for profit.
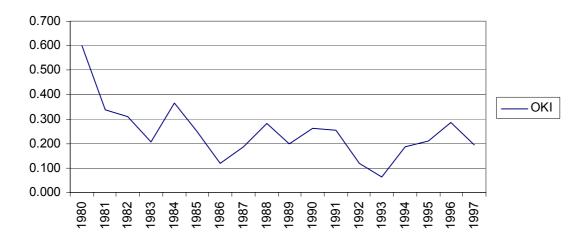
Sharp Investment/Production Ratio

	Total Firm (1 million yen)			Stock of Capital		Actvity in Semiconductor Division only(mill y			
Sharp	Sales	Profits	after-tax P	Plants	Equipment	Production	Prod/Total	Investment	Inv/Tot.sal
1980	395246	23575	12526	n/a	n/a	72000	0.182	10400	0.026
1981	501402	29243	16289	n/a	n/a	85000	0.170	10600	0.021
1982	580088	38887	20383	63714	33777	95000	0.164	17200	0.030
1983	649332	45513	26350	62178	31835	114000	0.176	23000	0.035
1984	756559	52173	29137	70620	54290	144000	0.190	35000	0.046
1985	909581	63384	33853	85442	70483	145000	0.159	37000	0.041
1986	955253	64370	34735	88585	80566	145000	0.152	26000	0.027
1987	868587	37821	20104	91442	79954	170000	0.196	22000	0.025
1988	872707	38276	18857	88803	85127	150000	0.172	35000	0.040
1989	992665	55234	26232	87851	85581	180000	0.181	45000	0.045
1990	1057282	72403	37536	102290	98714	190000	0.180	42000	0.040
1991	1152678	80225	44340	107371	108245	205000	0.178	30000	0.026
1992	1202014	70647	36063	123287	121416	188000	0.156	28000	0.023
1993	1152887	44538	25021	147187	111525	213300	0.185	28000	0.024
1994	1170221	45321	25529	147519	117632	236200	0.202	36000	0.031
1995	1261562	67073	34631	152057	139405	264900	0.210	38700	0.031
1996	1281752	70530	39372	160996	163462	249200	0.194	72300	0.056
1997	1375634	71400	39844	168422	206516	265000	0.193	65000	0.047
1998	1332152	33338	18330	184050	192320	n/a	n/a	n/a	n/a

Sharp

Also not a top-ten producer, Sharp main strength in the semiconductor industry in the late

eighties was specialty chips (ASICs) as well as memory devices designed specifically for

Sharp's previous strengths. Memory for calculators, as well as ASIC for compact discs

were a big part of their production and development strategy. They were, however, also

involved in mask ROM as well as DRAM production. All told, memory accounted for 65% of total production and CCDs (charge coupled device), CPUs and others accounted for 35%. It is not clear how much of this memory was DRAM, however. It is also unclear as to what kind of CPUs Sharp was producing, as they almost certainly were not of the same variety as the Intel or AMD "86" line. I/P ratios seem to bounce back quite quickly after the post-1984 slump. In Sharp's case, it seems as though they cutback on investment a bit later (1985) and recovered sooner (next peak in 1989). Its final peak is a bit later as well as occurring in 1996. It is hard to say anything about profit over the STA period. SC production as a percentage of total sales ranges between 15 and 20%.
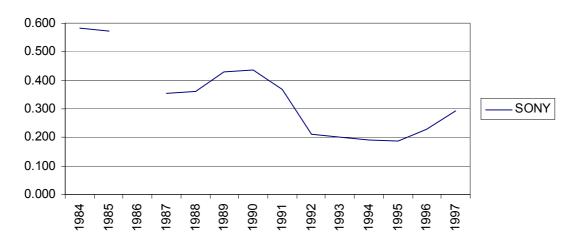
OKI Investment/Production Ratio

OKI	Total Firm (1 million yen)			Stock of Capital		Actvity in Semiconductor Division only(mill y			
	Sales	Profits	after-tax P	Plants	Equipment	Production	Prod/Total	Investment	Inv/Tot.sal
1980	165501	9881	3061	n/a	n/a	25400	0.153	15300	0.092
1981	186075	7506	3909	n/a	n/a	37000	0.199	12500	0.067177
1982	214171	7707	3391	n/a	n/a	45000	0.210	14000	0.065368
1983	247551	6519	2913	23283	16178	70000	0.283	14400	0.05817
1984	303521	10440	5426	27207	21799	100000	0.329	36400	0.119926
1985	361866	16479	11008	26823	47174	85000	0.235	21400	0.059138
1986	361672	1391	1982	31295	40262	87000	0.241	10500	0.029032
1987	361072	−7450	−2437	29798	34094	113000	0.313	21300	0.058991
1988	416204	8672	4108	28578	37534	150000	0.360	42400	0.101873
1989	503786	17853	10040	34362	57922	160000	0.318	31900	0.063321
1990	552162	24143	14869	34028	58100	160000	0.290	42000	0.076065
1991	582184	20114	8971	43082	58234	170000	0.292	43200	0.074203
1992	585591	1280	1418	45821	72259	171000	0.292	20300	0.034666
1993	562991	−38334	−33194	49111	62787	190000	0.337	11800	0.020959
1994	565500	3884	−2903	n/a	n/a	209000	0.370	38800	0.068612
1995	536335	41509	29653	44985	43129	230000	0.429	48600	0.090615
1996	556345	48373	26039	50311	63072	151800	0.273	43700	0.078548
1997	540642	10838	9622	54090	63320	170000	0.314	33000	0.061039
1998	555066	3112	1883	54872	54732	n/a	n/a	n/a	n/a

Oki Electronic

Another 'smaller' player in worldwide SC sales, Oki has nonetheless generated roughly

20-40% of it revenue from semiconductor sales since 1981. In 1988, 35% of this

production was in memory, 35% in custom ICs, 15% in ASICs (also custom in a sense),

and 15% in MPUs and MCUs. DRAM was one of Oki's main memory products. In

1992, MOS memory accounted for 45% of production and MOS logic 53%. Profits for the firm are quite erratic and on more than one occasion they suffered a loss during both of the STAs. I/P ratios are also a bit unusual for the industry. There was apparently a massive expenditure on investment in late seventies (perhaps just entering the SC industry) and thereafter a decline. The I/P peaked in 1984 and had somewhat of a bimodal local maximum in the 1988-1991 period. It's last peak is in 1996 at the start of the latest industry recession.
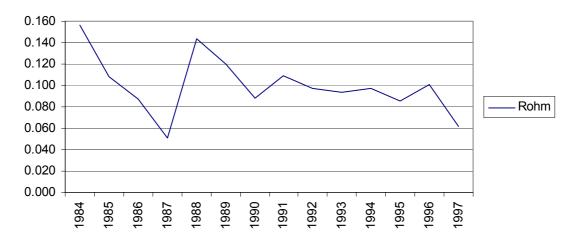
SONY Investment/Production Ratio

	Total Firm (1 million yen)			Stock of Capital		Actvity in Semiconductor Division only(mill y			
Sony	Sales	Profits	after-tax P	Plants	Equipment	Production	Prod/Total	Investment	Inv/Tot.sale
1980	605053	65222	32025	n/a	n/a	n/a	n/a	n/a	n/a
1981	777918	86020	47162	n/a	n/a	n/a	n/a	n/a	n/a
1982	832994	72308	41689	21754	21922	n/a	n/a	n/a	n/a
1983	770074	41451	25516	27978	21939	n/a	n/a	n/a	n/a
1984	911924	80467	35034	27454	22564	60000	0.066	35000	0.038
1985	1071361	91027	48957	28573	36526	35000	0.033	20000	0.019
1986	1036196	36449	30989	29064	33029	n/a	n/a	n/a	n/a
1987	396095	13195	7515	28539	35141	85000	0.215	30000	0.076
1988	1029891	43405	30681	31029	40747	125000	0.121	45000	0.044
1989	1258285	77203	42003	34575	56772	140000	0.111	60000	0.048
1990	1536463	93204	58192	43136	61967	160000	0.104	70000	0.046
1991	1880579	114500	69610	84778	94410	190000	0.101	70000	0.037
1992	1979061	24134	20684	93344	103928	190000	0.096	40000	0.020
1993	1869680	45750	25790	94324	105067	200000	0.107	40000	0.021
1994	1698333	30543	30042	103954	95262	210000	0.124	40000	0.024
1995	1881859	51396	36296	98580	88758	230000	0.122	43000	0.023
1996	1930998	28585	29145	94732	76316	220000	0.114	50000	0.026
1997	2169885	85727	39707	105439	72553	240000	0.111	70000	0.032
1998	2406423	118816	76356	107501	85003	n/a	n/a	n/a	n/a

Sony

Of their IC production, SRAM, DRAM, bipolar and analog IC, and logic chips were
typically made. In 1991, 20% of output was (MOS) memory and 20% was MOS logic
chips. The balance was discrete and hybrid ICs and bipolars. By 1992, MOS memory
was only 10%. From 1988, Sony SC production seems to consistently account for

between 10-12% of production. Prior to 1986, the role SCs played in Sony was considerably smaller. It appears that either industry demand or the artificial prices of the STA or both spurred Sony to ramp up its SC production facilities. Data for 1986 is non-existent. In this year Sony switched from reporting statistics in October to March. One can imagine a smooth cyclical behavior of the I/P ratio which falls after 1984 and after 1990, but contrary to other firms *does not* peak and then decline in the 1996 recession. It would be interesting to see where this investment is being spent, and whether or not this simply adds to the glut in 1997 or is part of some grander re-invention of Sony semiconductors. It is difficult to say much about profit except to say that it seems as though, like many other firms, profits were lower than usual for the first three years of the STA and bounced back to something like a normal level in the 1989-91 period.

Rohm Investment/Production Ratio

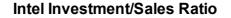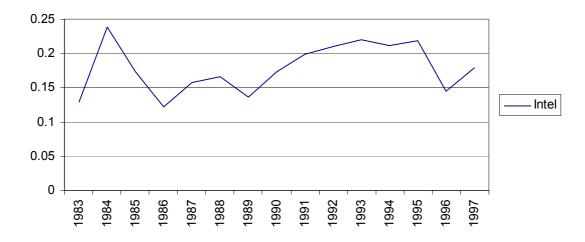|	Total Firm (1 million yen)			Stock of Capital		Actvity in Semiconductor Division only(mill y			
Rohm	Sales	Profits	after-tax P	Plants	Equipment	Production	Prod/Total	Investmen	Inv/Tot.sal
1980	20320	1294	629	n/a	n/a	n/a	n/a	n/a	n/a
1981	29800	3560	1509	n/a	n/a	n/a	n/a	n/a	n/a
1982	36811	7005	3134	n/a	n/a	n/a	n/a	n/a	n/a
1983	32857	1100	1641	2300	3095	n/a	n/a	n/a	n/a
1984	57769	5156	1834	2413	3337	70200	1.215	11000	0.541339
1985	87210	11862	5214	3779	7293	68200	0.782	7400	0.248
1986	84816	2907	1668	3809	8797	74100	0.874	6500	0.177
1987	93012	2896	1455	4295	7895	82000	0.882	4200	0.128
1988	103863	6080	2512	4108	5967	107900	1.039	15500	0.268
1989	127450	7594	4021	4472	8136	121000	0.949	14500	0.166
1990	142199	7750	3179	8489	14171	141500	0.995	12500	0.147
1991	165719	8107	4433	7889	14234	156600	0.945	17100	0.184
1992	178454	14669	6674	9102	13479	133300	0.747	13000	0.125
1993	152076	11354	5980	10656	10897	145300	0.955	13600	0.107
1994	164087	12593	6463	n/a	n/a	177300	1.081	17200	0.121
1995	195382	24052	10449	11739	7087	249400	1.276	21400	0.129
1996	231024	42371	20992	15892	16150	205800	0.891	20700	0.116
1997	232386	46247	23014	14561	15567	241500	1.039	15000	0.099
1998	272839	61352	30721	24240	16626	n/a	n/a	n/a	n/a

Rohm

In 1988, only 33% of Rohm's SC production was in integrated circuits, which makes it a very small player in the memory market. The balance of their production was in semiconductor devices (37%), printheads (13%), and resistors (17%). Initially, Rohm was primarily a producer or CMOS and application specific ICs (VCRs, audio, etc.), but

in 1986 it acquired a small American chip maker and began producing SRAM and EEPROM. Rohm, wasn't, and still isn't, a player in the DRAM market. As Rohm is primarily a SC company, the Production/Total Firm Sales is often times greater than one. These values are taken from different sources and we are comparing value of production of semiconductors to total sales. This is an important thing to keep in mind when looking at the firm's data as well. Rohm's investment pattern follows a path of its own. While dramatically reducing investment as all firms did during the post-1984 slump, Rohm quickly bounces back and after some investment overshooting in 1988 seems to keep a fairly steady ratio until the 1996 industry recession. Presumably, by staying clear of the DRAM market, Rohm has avoided at least some of its' vicious cycle.

Ricoh

Ricoh is and was primarily a producer of CMOS, ASICs and BiCMOS. Unfortunately data for the firm is scarce and truncated. The five years of data for investment and production produce the following I/P ratios from 1985-1989: 35%,13.6%,19.1%, and 50.8% respectively. Entering the SC industry in 1982, their small SC division has made little inroads in market share. Ricoh still makes a few ASIC chips, but it is obviously a marginal player in this industry who seemed to enter on the chip wave in the early to mid-eigthies.

Intel Investment/Sales Ratio

Intel*	Total Firm ($mill)		Total Prop	Actvity in Semiconductor Division only($mill)			
	Net Sales	Profits		Sales	Sales/Tota	Investment	Inv/Tot.Sal
1980	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1981	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1982	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1983	1122	not avail	not avail	1122	1	145	0.129
1984	1627	not avail	not avail	1627	1	388	0.238
1985	1365	422	1338	1365	1	236	0.173
1986	1265	404	1364	1265	1	155	0.123
1987	1907	863	1536	1907	1	302	0.158
1988	2875	1369	1898	2875	1	477	0.166
1989	3100	1406	2249	3100	1	422	0.136
1990	3913	1991	2814	3913	1	680	0.174
1991	4779	2463	3644	4779	1	948	0.198
1992	5844	3287	4648	5844	1	1228	0.210
1993	8782	5530	6313	8782	1	1933	0.220
1994	11521	5945	8516	11521	1	2441	0.212
1995	16202	8391	11792	16202	1	3550	0.219
1996	20847	11683	14262	20847	1	3024	0.145
1997	25070	15125	18127	25070	1	4501	0.180
1998	n/a	n/a	n/a	n/a	n/a	n/a	n/a

*this table is somewhat redundant to be as consistent as possible in reporting the data. Handoutai Nenkan data is taken directly from company reports and essentially all Intel production/sales are semiconductors.

Intel

Intel has seen spectacular growth in worldwide sells, particularly in its microprocessors

sales in which it is clearly the market leader. Developing the 8088/8086 chip in 1978,

followed by the 286 in 1982 and the 386 in 1985, Intel has maintained its lead in MPU technology. They were, however, also producers of EPROMs and DRAM during the eighties. We see from the graph above that Intel also seems to have suffered from the 1984 worldwide fall in chip prices. Sales fell from $1,627 million in 1984, and remained low for 1985 and 1986, picking up again in 1987 when the PC revolution began to take hold and shortly after Intel released the 386 chip. Its' investment/sales ratio began to rise after a setback in '85-'86 and has remained on a fairly slow but steady rise until the most recent dip in semiconductor demand starting in about 1995.

Motorola Investment/Sales Ratio

Motorola	Total Firm ($mill)		Total Prop	Actvity in Semiconductor Division only($mill)			
	Net Sales	Profits		Sales	Sales/Total	Investment	Inv/Tot.Sal
1980	not avail	not avail	not avail	n/a	n/a	n/a	n/a
1981	not avail	not avail	not avail	n/a	n/a	n/a	n/a
1982	not avail	not avail	not avail	n/a	n/a	n/a	n/a
1983	not avail	not avail	not avail	1122	n/a	n/a	n/a
1984	not avail	not avail	not avail	2240	n/a	400	n/a
1985	5443	2037	3419	1728	0.317472	325	0.060
1986	5905	2249	3779	1807	0.306012	250	0.042
1987	6727	2656	2444	2198	0.326743	350	0.052
1988	8250	3210	2854	3035	0.367879	435	0.053
1989	9620	3715	3337	3319	0.34501	536	0.056
1990	10885	4003	3778	3692	0.339182	548	0.050
1991	11341	4096	4194	3915	0.345208	n/a	n/a
1992	13303	4908	4576	4480	0.336766	n/a	n/a
1993	16963	6612	5547	not avail		n/a	n/a
1994	22245	8485	7073	not avail		n/a	n/a
1995	27037	9492	9356	not avail		n/a	n/a
1996	27973	8983	9768	not avail		n/a	n/a
1997	29794	9791	9856	not avail		n/a	n/a
1998	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Motorola

Motorola is obviously a huge player in the semiconductor market with 1996 sales of $8.1 billion, placing it fifth in the world. However, Motorola is a much more diversified producer of semiconductors than, say, Intel or AMD, as well as being a producer of a

wide range of electronic goods. Semiconductor sales account for roughly a third of Motorola's total company sales which include cellular phones, modems, and a variety of other communication devices. This share has remained fairly constant as has its' investment/sales ratio, which is lower than Intel's and has less fluctuation over time. Profits during the STA period remain fairly stable though it does appear they were a larger percentage of total sales than in the nineties. Investment/sales ratio swings seem smaller but appear to follow the industry movement fairly well, falling in the post-1984 period, and then rising some in '86-'87 but remain remarkable flat throughout the remainder of the STA. Investment data for its semiconductor division is not available after 1990.

TI Investment/Sales Ratio

TI	Total Firm ($mill)		Total Prop	Actvity in Semiconductor Division only($mill'			
	Net Sales	Profits		Sales	Sales/Tota	Investmen	Inv/Tot.Sal
1980	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1981	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1982	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1983	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1984	5741.6	1552	2577.1	2660	0.463	472	0.082
1985	4924.5	853.3	2775.6	1941	0.394	281	0.057
1986	4974	938.6	2889.7	2065	0.415	220	0.044
1987	5816.2	1406.6	3026.7	2665	0.458	350	0.060
1988	6294.8	1477.2	3073.7	3240	0.515	435	0.069
1989	6522	1432	3641	3269	0.501	536	0.082
1990	6567	1240	4217	2574	0.392	548	0.083
1991	6784	1122	4361	2753	0.406	n/a	n/a
1992	7440	1720	4434	n/a	n/a	n/a	n/a
1993	8523	2249	4620	n/a	n/a	n/a	n/a
1994	10315	2844	4895	n/a	n/a	n/a	n/a
1995	11409	4008	4880	n/a	n/a	n/a	n/a
1996	9940	2794	6712	n/a	n/a	n/a	n/a
1997	9750	3683	7414	n/a	n/a	n/a	n/a
1998	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Texas Instruments (TI)

TI was fifth in worldwide sales in 1987 and still remains in the top-ten. TI first started out in the ASIC chip market, but in 1989 it entered the memory market and began producing SRAM as well as DRAM. They continued their specialty in specific

application chips however. Although the data is only for a limited number of years, we see than SC sales were anywhere from forty to fifty percent of total firm sales during this time. Profits slumped in the post-84 period but then bounced back in 1987. Its I/P ratio drops some in the wake of the first industry recession, but then continues on a steady rise throughout the late eighties. As the investment data ends in 1990, we cannot say whether or not TI followed the same decline as many Japanese firms did in the 1990s.

National SC Investment/Sales Ratio

Nat'l SC	Net Sales	Profits		Sales*	Sales/Tota	Investmen	Inv/Tot.Sal
1980	not avail	not avail	not avail	n/a	n/a	n/a	n/a
1981	not avail	not avail	not avail	n/a	n/a	n/a	n/a
1982	not avail	not avail	not avail	n/a	n/a	n/a	n/a
1983	not avail	not avail	not avail	911		278	0.305159
1984	not avail	not avail	not avail	1152		401	0.34809
1985	not avail	not avail	not avail	837		117	0.139785
1986	1478	381	1361	981		95	0.09684
1987	1868	549	1385	994		63.9	0.064286
1988	1432	461	622	1432	1	154	0.107542
1989	1647	368	697	1648	1	278	0.168689
1990	1675	424	702	1675	1	182	0.108657
1991	1702	408	527	1702	1	110	0.06463
1992	1718	470	519	1718	1	183	0.106519
1993	2014	634	577	2014	1	n/a	n/a
1994	2295	959	668	2295	1	n/a	n/a
1995	2833	1130	1308	2833	1	n/a	n/a
1996	2623	1062	1349	2623	1	n/a	n/a
1997	2537	885	2940	2537	1	n/a	n/a
1998	n/a	n/a	n/a	n/a	n/a	n/a	n/a

*All of NSC sales are semiconductors yet there is a discrepancy between the company
reports and the Handoutai Nenkan data for years prior to 1988. It is possible that NSC
switched its reporting period at this time. Handoutai Nenkan discontinued
reporting NSC data in 1992.

National Semiconductor (NSC)

National Semiconductor has a long history, dating back to 1959, being founded (like

Intel) by former employees of Fairchild Semiconductors. In fact, in 1987 they bought out

Fairchild Semiconductors.   NSC recently acquired Cyrix, a long-time maker of microprocessors and math co-processors, and sold its logic, memory and discrete business under the Fairchild name.   However, in the mid- to late eighties they were producing mostly CMOS, BiCMOS, ASIC, ECL, SRAM, and EEPROM chips. We can see from the above graph that National SC's investment along with investment/sales ratio plummets in the wake of the 1984 downturn, and stays at a fairly low level (only once rising above 15%) in the next seven years or so. Nonetheless, the short sample of the trend generally matched the Japanese firms, as NSC's I/P rises after the 1984 downturn and then recovers during the late eighties, falling again in 1990. If we look at profits for NSC, it appears that they are much lower as a percentage of sales than other firms. Profits as a percentage of sales for NSC are around 25% during the first STA while other firms such as   AMD are over 40%.   Naturally this is an imperfect measure of profitability. Ideally, some rate of return on investment would be compared. However, matching the timing of investment expenditures with profits is difficult, if not impossible given the huge amounts of plants and equipment investment as well as R&D investment (often not reported) and the variation over time. Perhaps we can speculate that profits in NSC product markets were not as high as those that CPU makers concentrated on.

AMD Investment/Sales Ratio

	Total Firm ($mill)		Total Prop	Actvity in Semiconductor Division only ($mill)			
AMD	Net Sales	Profits		Sales	Sales/Total	Investment	Inv/Tot.Sal
1983	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1984	n/a	n/a	n/a	1122	n/a	308	n/a
1985	n/a	n/a	n/a	796	n/a	243	n/a
Apr-86	576	228	784	829	n/a	102	n/a
Apr-87	632	258	832	n/a	n/a	n/a	n/a
Dec-87	997	435	1143	997	1	138	0.138
Dec-88	1126	464	1248	1125	0.999112	133	0.118
Dec-89	1105	461	1262	1104	0.999095	160	0.145
Dec-90	1059	381	1449	1059	1	310	0.293
Dec-91	1227	568	1531	1226	0.999185	135	0.110
Dec-92	1514	768	1684	1500	0.990753	n/a	
Dec-93	1648	859	1998	n/a		n/a	
Dec-94	2135	859	2465	n/a		n/a	
Dec-95	2468	1051	2947	n/a		n/a	
Dec-96	1953	512	3327	n/a		n/a	
Dec-97	2356	778	3799	n/a		n/a	
Dec-98	n/a	n/a	n/a	n/a	n/a	n/a	n/a

*all data are year-end (December) as taken from *Handoutai Nenkan* and as a result
it conflicts for the early years of the data set when AMD reported on March 30th
There are also apparently some discrepancies in some of the sales data

Advanced Micro Devices (AMD)

AMD is most well-known for being the market follower in CPUs, developing its

AMD386 in 1991 and AMD486 in 1993, patterned after the technological innovations of

Intel. AMD is, however, also a producer of EPROMs, EEPROMs, telecommunication equipment and other programmable logic chips. We can see from the graph above that AMD's investment/sales ratio plummeted in the post-84 period, and again in 1990. During the STA period AMD's I/S ratio was flat. Post-1991 data for investment was unavailable.

5. POSSIBLE INDICATORS OF COLLUSIVE BEHAVIOR

In order to meet the market share targets, Flamm (1996) feels the Japanese government `put pressure` on firms to hold production down. According to Flamm, by late 1987 `regional allocation` of production was put in place. This occurred at a time when demand for chips was on the rise due to a recovery in the computer industry (Flamm, 1996). If such a regional allocation took place during the this time, and cartels and quotas shares are usually based on historical level, one could posit that market shares of either production or investment levels would be roughly constant during this time. Another way of interpreting this could mean that the variation of each firms market share over time would have been lower during the period of the STA. This could reflect some sort or `collusive harmony` presumably guided by MITI. Tables 4 (production) and Table 5 (investment) present the largest 8 or 9 Japanese firms and their respective percentages of the total investment or production of those eight firms.

In Table 4b, we see the variances of these market share as segments of the entire 17 year period. It appears that variance has fallen during the first STA with variances of the three largest firms (NEC, Hitachi, and Toshiba) is very low during this time. This

may imply that the FMV values on DRAM facilitated collusion among the main producers of DRAM. This results are far from robust. First of all the data is scarce. Second, several of the firms have very low variance in the late nineties as well. This may be more the result of industry specialization among firms getting settled into their niche market (whether it be ASICs, CPUs, DRAM, EPROM,etc) rather than collusion. One really can do no more than speculate with such data as it exists.

For completeness, Tables 5a and 5b present similar market shares and variances with investment data. Here, the variances are so wide and varied, even speculation is impossible. These tables demonstrate again the difficulty in explaining the movements in investment over time, much less extracting some residual which might hope to measure any effects of the STA.

6. POSSIBLE METHODOLOGIES FOR FUTURE RESEARCH

None of the above rumination answers the question of how the STA may have effected investment within the industry, but the two theories on investment behavior are a potentially useful guide to proper research in that endeavor. What is really needed is a appropriate theory of investment theory as it apples to the very unique semiconductor industry. This is, of course, a very difficult task. Tobin`s Q requires the firm`s total asset value. This is not really appropriate for multi-product firms where we are only concerned with the investment in semiconductor activity. A neoclassical/Jorgenson approach needs labor costs, other factor costs, and the cost of capital which would be hard to obtain reliably. Furthermore, this method would use a large number of degrees of

freedom which this sparse data set cannot afford. A more simple flexible accelerator model which only required investment and sales might be ideal. This method is still severely restricted due to the short time series and small cross-section. One might pool the data, but that is dangerous given the product differentiation across firms as well as the rapidly changing nature of the industry which essentially creates a new product every three to four years. The empirical challenge is apparent, but the question(s) it could answer would be significant. Did the STA cause Japanese firms to cutback on investment and the US to increase theirs and result in higher profits for both? Perhaps more importantly, if the STA cause such restraint in Japanese investment, did this lead the Japanese firms to rest on their DRAM laurels (and excessive profits) but lead them to fall behind in next generation of chips as Nagaoka (1992) implies?

References

Dixit, Avinash K. and Robert S. Pindyck (1994), <u>Investment under Uncertainty</u>, Princeton University Press, Princeton, N. J.

Flamm, Kenneth (1996), <u>Mismanaged Trade?: Strategic Trade Policy and the Semiconductor Industry</u>, Brookings Institution Press, Washington, D.C.

Greaney, Theresa (1996), "Import Now! An analysis of market share voluntary import expansions (VIEs)," *Journal of International Economics*, vol.40 149-163.

Irwin, Douglas, A. (1994), <u>Managed Trade: The Case against Import Targets</u>, The AEI Press, Washington, D. C.

Krishna, Kala, Suddhasatwa Roy, and Marie Thursby (1996), "Implementing Market Access," Working Paper.

Nagaoka, Sadao (1992), "An Economic Analysis of Trade Friction: Economic Effects of the Dumping Control and the Result-Oriented Trade Policy." *Japanese Economic Studies: A Journal of Translations,* Fall 39-88.

Nakamura, Hiroshi (1995), "Does a Minimum Share Target Really Increase Competition in an Importing Country?", Stanford PhD. Dissertation.

Parsons, Craig (1997), "Some Possible Hypotheses for the Effects of the 1986 Semiconductor Trade Agreement on Firm Level Investment", mimeo.

Reitzes, James D. (1991), "The Impact of Quotas and Tariffs on Strategic R&D Behavior," *International Economic Review,* November 1991.

Sumita, Makoto, and Hitoshi Shin (1996), Japan's Semiconductor Industry in the 21st Century," *Nomura Research Institute Quarterly.* Spring 20-43.

Tyson, L. D'Andrea (1992), <u>Who's Bashing Whom?: Trade Conflict in High-Technology Industries,</u> Institute for International Economics, Washington, D. C.

Additionally readers may be interested in each of the firm's webpage addresses below:

NEC: www.nec.com, Hitachi: www.hitachi.com, Toshiba: www.toshiba.co.jp
Fujitsu:www.fujitsu.com, Mitsubishi: www.mitsubishielectric.com,Matsushita:
www.mec.panasonic.com, Sanyo: www.sanyo.com, Sharp:www.sharp.com,Oki:
www.oki.com, Sony: www.sony.com, Ricoh: www.ricoh.co.jp, Rohm: www.rohm.com
Intel: www.intel.com, Motorola: www.mot.com, TI: www.ti.com, NSC: www.nsc.com
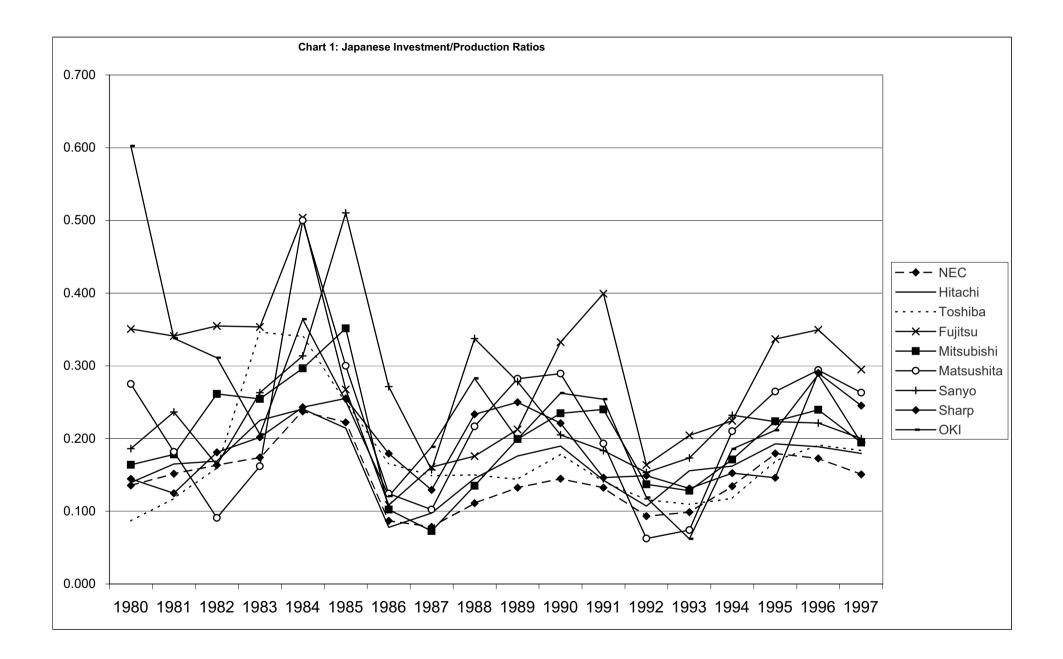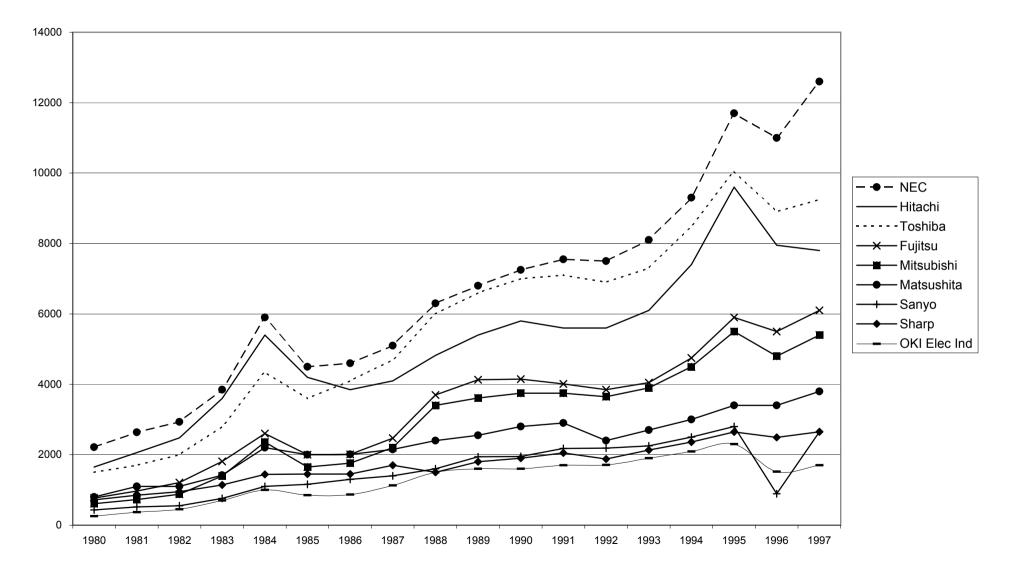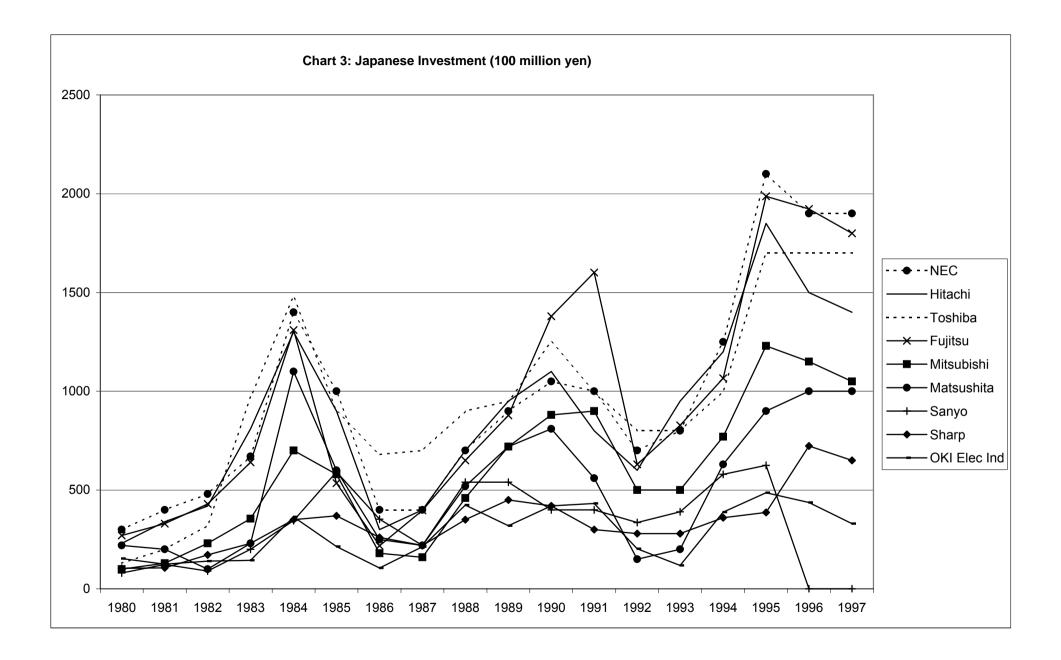AMD: www.amd.com

Chart 1: Japanese Investment/Production Ratios

Legend:
- NEC
- Hitachi
- Toshiba
- Fujitsu
- Mitsubishi
- Matsushita
- Sanyo
- Sharp
- OKI

Chart 2: Japanese Production

Chart 3: Japanese Investment (100 million yen)

Table 1: Worldwide Production of SCs (jpn firms:100 Million Yen or US firms:1 million dollars)

Jpn Firms	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
NEC	2215	2640	2935	3850	5900	4500	4600	5100	6300	6800	7250	7550	7500	8100	9300	11700	11000	12600
Hitachi	1650	2060	2480	3600	5400	4200	3850	4100	4820	5400	5800	5600	5600	6100	7400	9600	7950	7800
Toshiba	1500	1700	2000	2800	4350	3600	4100	4700	6000	6600	7000	7100	6900	7300	8500	10050	8900	9250
Fujitsu	770	968	1212	1810	2600	2000	2010	2470	3700	4130	4150	4010	3850	4050	4750	5900	5500	6100
Mitsubishi	610	730	880	1395	2360	1650	1760	2200	3404	3613	3750	3750	3650	3900	4500	5500	4800	5400
Matsushita	800	1100	1100	1420	2200	2000	2010	2150	2400	2550	2800	2900	2400	2700	3000	3400	3400	3800
Sanyo	430	520	550	760	1100	1160	1300	1400	1600	1940	1950	2180	2190	2250	2500	2800	890	2650
Sharp	720	850	950	1140	1440	1450	1450	1700	1500	1800	1900	2050	1880	2133	2362	2649	2492	2650
OKI Elec Ind	254	370	450	700	1000	850	870	1130	1500	1600	1600	1700	1710	1900	2090	2300	1518	1700
SONY	n/a	n/a	n/a	n/a	600	350	*	850	1250	1400	1600	1900	1900	2000	2100	2300	2200	2400
Ricoh	n/a	n/a	n/a	n/a	215	200	220	157	197	300	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Rohm	n/a	n/a	n/a	n/a	702	682	741	820	1079	1210	1415	1566	1333	1453	1773	2494	2058	2415

US Firms[a]	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Intel	n/a	n/a	n/a	1122	1627	1365	1265	1907	2875	3100	3913	4779	5844	8782	11521	16202	20847	25070
Motorola	n/a	n/a	n/a	n/a	2240	1728	1807	2198	3035	3319	3692	3915	4480	n/a	n/a	n/a	n/a	n/a
TI data from Tsurumi	n/a	n/a	n/a	n/a	2660	1941	2065	2665	3240	3269	2574	2753	n/a	n/a	n/a	n/a	n/a	n/a
National SC from Tsu	n/a	n/a	n/a	911	1152	837	981	994	1432	1648	1675	1702	1718	n/a	n/a	n/a	n/a	n/a
AMD from Tsurumi	n/a	n/a	n/a	n/a	1122	796	829	997	1125	1104	1059	1226	1500	n/a	n/a	n/a	n/a	n/a

Source: Nihon Handoutai Nenkan (Japan Semiconductor Yearbook), various years

*SONY switched from reporting accounts in October to March and so data is available for this year
** Sanyo switch from November reporting to March on 1996.
a- US firms figures are actually sales of semiconductors.

Table 2: Plants and Equipment Investment in Semiconductors (Jpn firms:100 Million Yen, US firms: 1 million dollars)

Jpn Firms	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
NEC	300	400	480	670	1400	1000	400	400	700	900	1050	1000	700	800	1250	2100	1900	1900
Hitachi	230	340	419	810	1300	900	300	400	700	950	1100	800	600	950	1200	1850	1500	1400
Toshiba	130	200	320	970	1480	900	680	700	900	950	1250	1000	800	800	1000	1700	1700	1700
Fujitsu	270	330	430	640	1310	535	218	397	650	878	1380	1601	630	828	1066	1987	1923	1800
Mitsubishi	100	130	230	355	700	580	180	160	460	720	880	900	500	500	770	1230	1150	1050
Matsushita	220	200	100	230	1100	600	250	220	520	720	810	560	150	200	630	900	1000	1000
Sanyo	80	123	90	200	345	592	353	220	540	540	400	400	336	390	580	625	197*	530*
Sharp	104	106	172	230	350	370	260	220	350	450	420	300	280	280	360	387	723	650
OKI Elec Ind	153	125	140	144	364	214	105	213	424	319	420	432	203	118	388	486	437	330
SONY	n/a	n/a	n/a	n/a	350	200	*	300	450	600	700	700	400	400	400	430	500	700
Ricoh	n/a	n/a	n/a	n/a	50	70	30	30	100	100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Rohm	n/a	n/a	n/a	n/a	110	74	65	42	155	145	125	171	130	136	172	214	207	150

US Firms	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Intel[a]	n/a	n/a	n/a	145	388	236	155	302	477	422	680	948	1228	1933	2441	3550	3024	4501
Motorola	n/a	n/a	n/a	n/a	400	325	250	350	435	536	548	n/a	n/a	n/a	n/a	n/a	n/a	n/a
TI	n/a	n/a	n/a	n/a	472	281	220	250	600	600	909	n/a	n/a	n/a	n/a	n/a	n/a	n/a
National SC	n/a	n/a	n/a	278	401	117	95	63.9	154	278	182	110	183	n/a	n/a	n/a	n/a	n/a
AMD[b]	n/a	n/a	n/a	n/a	308	243	102	138	133	160	310	135	n/a	n/a	n/a	n/a	n/a	n/a

Source: Nihon Handoutai Nenkan (Japan Semiconductor Yearbook), various years

*SONY switched from reporting accounts in October to March and so data is available for this year
** Sanyo switch from November reporting to March on 1996.
a- Intel figures are for the entire firm and includes non-semiconductor investment
b- `84-87 figures are from Tsurumi and Tsurumi (1991)

Table 3: Investment to Sales Ratios

Jpn Firms	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
NEC	0.135	0.152	0.164	0.174	0.237	0.222	0.087	0.078	0.111	0.132	0.145	0.132	0.093	0.099	0.134	0.179	0.173	0.151
Hitachi	0.139	0.165	0.169	0.225	0.241	0.214	0.078	0.098	0.145	0.176	0.190	0.143	0.107	0.156	0.162	0.193	0.189	0.179
Toshiba	0.087	0.118	0.160	0.346	0.340	0.250	0.166	0.149	0.150	0.144	0.179	0.141	0.116	0.110	0.118	0.169	0.191	0.184
Fujitsu	0.351	0.341	0.355	0.354	0.504	0.268	0.108	0.161	0.176	0.213	0.333	0.399	0.164	0.204	0.224	0.337	0.350	0.295
Mitsubishi	0.164	0.178	0.261	0.254	0.297	0.352	0.102	0.073	0.135	0.199	0.235	0.240	0.137	0.128	0.171	0.224	0.240	0.194
Matsushita	0.275	0.182	0.091	0.162	0.500	0.300	0.124	0.102	0.217	0.282	0.289	0.193	0.063	0.074	0.210	0.265	0.294	0.263
Sanyo	0.186	0.237	0.164	0.263	0.314	0.510	0.272	0.157	0.338	0.278	0.205	0.183	0.153	0.173	0.232	0.223	0.221	0.200
Sharp	0.144	0.125	0.181	0.202	0.243	0.255	0.179	0.129	0.233	0.250	0.221	0.146	0.149	0.131	0.152	0.146	0.290	0.245
OKI	0.602	0.338	0.311	0.206	0.364	0.252	0.121	0.188	0.283	0.199	0.263	0.254	0.119	0.062	0.186	0.211	0.288	0.194
SONY	n/a	n/a	n/a	n/a	0.583	0.571	*	0.353	0.360	0.429	0.438	0.368	0.211	0.200	0.190	0.187	0.227	0.292
Ricoh	n/a	n/a	n/a	n/a	n/a	0.350	0.136	0.191	0.508	0.333	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Rohm	n/a	n/a	n/a	n/a	0.157	0.109	0.088	0.051	0.144	0.120	0.088	0.109	0.098	0.094	0.097	0.086	0.101	0.062
Mean	0.232	0.204	0.206	0.243	0.344	0.304	0.133	0.144	0.233	0.230	0.235	0.210	0.128	0.130	0.171	0.202	0.233	0.205
Variance	0.026	0.007	0.007	0.005	0.018	0.016	0.003	0.006	0.014	0.008	0.009	0.009	0.002	0.002	0.002	0.004	0.005	0.005

US Firms	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Intel				0.129	0.238	0.173	0.123	0.158	0.166	0.136	0.173	0.198	0.210	0.220	0.212	0.219	0.145	0.180
Motorola				n/a	0.179	0.188	0.138	0.159	0.143	0.161	0.148	n/a	n/a					
TI				n/a	0.177	0.145	0.107	0.094	0.185	0.184	0.353	n/a	n/a					
Nat`l SC				0.305	0.348	0.140	0.097	0.064	0.108	0.169	0.109	0.065	0.107					
AMD				n/a	0.275	0.305	0.123	0.138	0.118	0.145	0.293	0.110	n/a					
Mean				n/a	0.217	0.243	0.190	0.117	0.123	0.144	0.159	n/a	n/a					
Variance				n/a	0.005	0.005	0.000	0.002	0.001	0.000	0.011	n/a	n/a					

Table 4a: Market Share of Japanese Production among 'Big 9'*

Firm	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
NEC	24.14	23.37	22.03	22.39	21.02	20.96	20.44	20.18	19.75	20.03	20.49	21.02	21.08	20.95	21.71	23.68	24.25
Hitachi	18.83	19.75	20.6	20.49	19.62	17.54	16.43	15.44	15.68	16.02	15.2	15.7	15.87	16.67	17.81	17.12	15.01
Toshiba	15.54	15.93	16.02	16.51	16.81	18.68	18.84	19.22	19.17	19.34	19.27	19.34	18.99	19.14	18.65	19.16	17.81
Fujitsu	8.85	9.65	10.36	9.87	9.34	9.16	9.9	11.85	11.99	11.46	10.88	10.79	10.54	10.7	10.95	11.84	11.74
Mitsubishi	6.67	7.01	7.98	8.96	7.71	8.02	8.82	10.9	10.49	10.36	10.18	10.23	10.15	10.13	10.2	10.33	10.39
Matsushita	10.06	8.76	8.13	8.35	9.34	9.16	8.62	7.69	7.41	7.73	7.87	6.73	7.03	6.76	6.31	7.32	7.31
Sharp	7.77	7.57	6.52	5.46	6.77	6.61	6.81	4.8	5.23	5.25	5.56	5.27	5.55	5.32	4.91	5.36	5.1
OKI	3.38	3.58	4.01	3.8	3.97	3.96	4.53	4.8	4.65	4.42	4.61	4.79	4.94	4.71	4.27	3.27	3.27
Sanyo	4.75	4.38	4.35	4.17	5.42	5.92	5.61	5.12	5.63	5.39	5.92	6.14	5.85	5.63	5.19	1.92	5.1
Sum	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

*these figures are a % of the sum of the above nine firms as calculated from data in Table 1.

Note: SONY is not included due to a break in their accounting data.

These figures do not account for all production of Japanese firms although it is over 85%.

Table 4b: Average Market Share and Variance during selected sample periods

	Mean	Variances						
Firm	81-97	81-97	83-97	84-97	86-91	87-91	87-96	92-97
NEC	21.62	2.13	1.80	1.76	0.18	0.09	1.27	2.17
Hitachi	17.28	3.64	1.66	2.69	0.72	0.24	0.66	1.05
Toshiba	18.14	1.93	0.53	0.87	0.07	0.04	0.05	0.32
Fujitsu	10.58	1.00	0.89	0.89	1.29	0.73	0.46	0.31
Mitsubishi	9.33	1.85	0.99	0.97	1.26	0.63	0.28	0.01
Matsushita	7.92	1.05	0.85	0.83	0.44	0.21	0.45	0.15
Sharp	5.88	0.87	0.48	0.44	0.66	0.59	0.30	0.05
OKI	4.71	0.32	0.31	0.31	0.08	0.02	0.23	0.58
Sanyo	5.09	1.01	1.14	1.14	0.10	0.09	1.46	2.40

Table 5a: Market Share of Japanese Investment among 'Big 8'*

Firm	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
NEC	19.91	21.85	20.95	16.55	17.49	19.61	16.72	14.76	14.88	15.29	14.36	15.17	18.12	17.87	18.76	19.74	18.39	19.33
Hitachi	15.26	18.57	18.29	20.00	16.24	17.65	12.54	14.76	14.88	16.14	15.05	12.13	15.53	21.22	18.01	17.39	14.52	14.24
Toshiba	8.63	10.92	13.97	23.96	18.49	17.65	28.42	25.83	19.13	16.14	17.10	15.17	20.71	17.87	15.01	15.98	16.45	17.29
Fujitsu	17.92	18.02	18.77	15.81	16.37	10.49	9.11	14.65	13.82	14.91	18.88	24.28	16.31	18.50	16.00	18.67	18.61	18.31
Mitsubishi	6.64	7.10	10.04	8.77	8.75	11.37	7.52	5.90	9.80	12.23	12.04	13.65	12.94	11.17	11.55	11.56	11.13	10.68
Matsushita	14.60	10.92	4.37	5.68	13.74	11.77	10.45	8.12	11.05	12.23	11.08	8.49	3.88	4.47	9.45	8.46	9.68	10.17
Sharp	6.90	5.79	7.51	5.68	4.37	7.26	10.87	8.12	7.44	7.64	5.75	4.55	7.25	6.26	5.40	3.64	7.00	6.61
OKI	10.15	6.83	6.11	3.56	4.55	4.20	4.39	7.86	9.01	5.42	5.75	6.55	5.26	2.64	5.82	4.57	4.23	3.36
Sum	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: SONY and Sanyo are not included due to inconsistencies in their accounting data.

Table 5b: Average Market Share and Variance during selected sample periods

Firm	Mean 80-97	Variances 80-97	80-85	86-91	91-97	86-97	87-91
NEC	17.76	5.12	4.10	0.66	0.52	3.89	4.27
Hitachi	16.25	5.86	2.90	2.45	6.95	6.07	5.70
Toshiba	17.71	23.25	31.11	30.35	3.93	18.16	9.81
Fujitsu	16.63	11.56	9.13	26.42	1.52	13.58	8.42
Mitsubishi	10.16	5.08	3.15	9.04	0.60	4.86	4.14
Matsushita	9.37	9.79	17.87	2.59	7.74	6.47	6.87
Sharp	6.56	2.70	1.42	4.69	1.79	3.45	1.92
OKI	5.57	3.87	5.84	2.87	1.39	3.24	3.45