

Transition of Memory (DRAM) Market: From Oligopoly to Monopoly

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Abstract

(The DRAM market has been competitive and dynamic right from the days of its formation. It has seen transition (in technology & market structure), booms, exits, turmoil, and shocks like any other market. However, the frequency of accruing these events has been higher vis-à-vis other markets.

Currently the market has seen severe financial distress, already one major player has filed for bankruptcy, and (the market) is poised to see re-structuring/ evolution. This paper attempts to consider the possibilities of transition of oligopolistic structure to monopolistic structure with comprehensive, exhaustive and multi-dimensional exploration.)

Key Words: Industry Economic Transition, Memory (DRAM) Market, Oligopoly, Monopoly, Economic features of Market, and Market Dynamics

(A) Introduction

The DRAM Memory market has been amongst very dynamic markets; where fierce competition has been one of the salient features of the market. It evolved over the time, different factors and events impacted the health and shape of the market and it adopted different features over the period of time. The market has been seeing many business cycles, shocks, booms, entries, exits with relatively high pace and frequency.

Market had evolved different kinds of economic features at different stages of time. With time, market became very competitive, and then due to certain series of events it adopted oligopolistic (explained latter) nature.

In below table, the top suppliers in the market in 1995 and 2010 are compared; the red indicates players who have exited the market over the period of time.

Table 1

1995		2010	
1 Samsung	15.6%	1 Samsung	37.6%
2 NEC	10.9%	2 Hynix	20.7%
3 Hitachi	10.0%	3 Elpida	16.0%
4 Hyundai	9.3%	4 Micron	12.7%
5 Toshiba	8.2%	5 Nanya	4.3%
6 Texas Instruments	8.1%	6 Powerchip	3.0%
7 LG Semicon	5.9%	7 ProMOS	1.6%
8 Micron	5.8%	8 Winbond	1.3%
Others	26.2%	Others	2.9%

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As mentioned before, the market has seen many events in a span of 35 years, with certain downturns and recoveries; a quick snapshot of past 35 year history is depicted in the diagram below. It explains the business cycles of the market; it indicates 6 major downturns of the market, indicated in different colors. These downturns vary in their severity and magnitude, 2000-03 being the worst downturn where revenue was down by almost 80% and average selling price (ASP) was down by 90%. In terms of time span also, it lasted longest, for 11 quarters. Currently, also, industry is seeing potentially **the 7th** downturn in 2011 and 1Q 12, where ASP for the mainstream fell significantly and sharply.

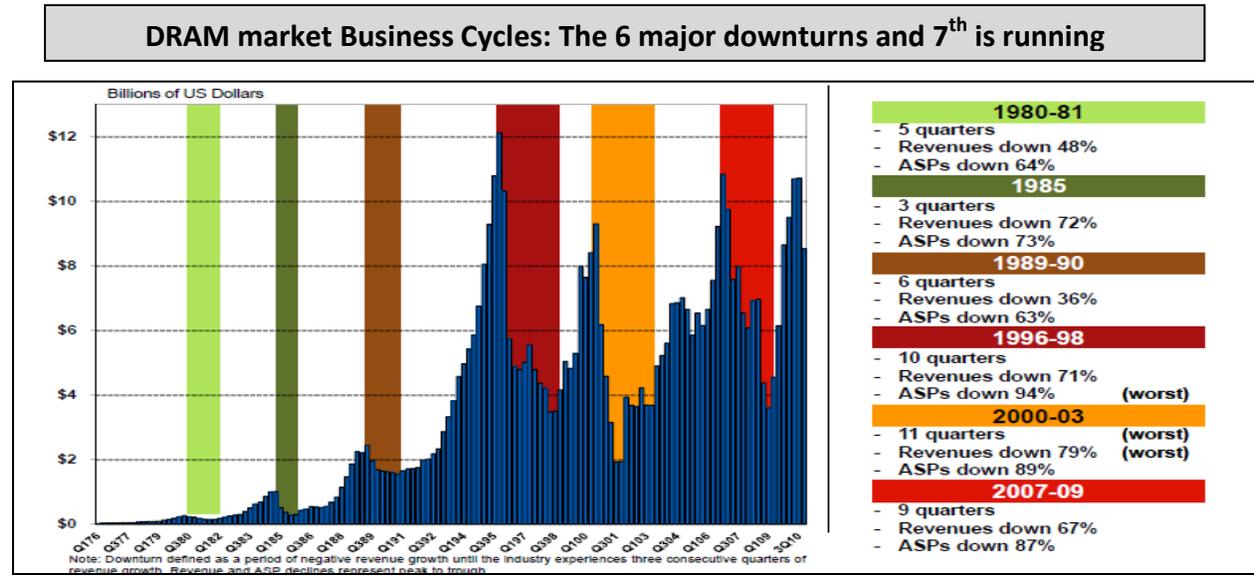


Diagram 1

The graph plots industry revenue in billions of US dollars on Y axis and the time horizon in quarters on X axis.

As it can be seen the market has been aggressive and prone to changes, the current 7th downturn has also impacted the nature of market and caused some structural changes in the DNA of the market. Already, one of the big players, Elpida, has filed for bankruptcy in February'12. The market share is concentrated among a few strong players and hence there is change in the market structure as a result of this new development.

This paper attempts to explore the possibilities, where market sees an economic transformation from **oligopolistic** tendency to **monopolistic** tendency. It further analyzes different channels through which this may happen, and test their likelihood through economic analysis and reasoning.

(B) Economic features of the DRAM market

- i. Oligopolistic structure from supplier's side: There are 4 big players in the industry consisting of almost 90-95% of the output; the inherent features of oligopolistic structure will be discussed later.

- ii. Market is sufficiency (supply-demand gap) sensitive: Demand is more volatile and, supply is slow to respond and static in nature. The sufficiency is majorly driven by the demand volatility.
- iii. Few giant buyers: From the consumer side, there are a few giant buyers (4-5 PC manufacturers).
- iv. Continuous technology innovation (DDR, DDR2 then DDR3) and product replacement.
- v. It's a global market, so macroeconomic risk exposure: Coming from exchange rate fluctuations, economic shocks, economic performance.
- vi. Contract and spot market coexist: Spot comprises of smaller portion (about 10-15%) of the total market.
- vii. Existence of dominant player: one player is dominant in terms of technology and market share (but not the first mover).

(C) Economic Structure of current DRAM Market

The current DRAM market resembles oligopolistic outlay, with few suppliers, and a certain level of price and quantity competition.

What is **oligopoly**?

Oligopoly is a market structure with a few enterprises (≥ 2), with a homogenous or differentiated product, where the firms are continuously informed about market conditions, with some barriers to entry. In oligopoly a firm takes decisions considering the interdependency of decisions among the firms. **Duopoly** refers to a special case where there are just 2 firms in the market.

There are different Economic theoretical models defining oligopoly behavior, and satisfying these attributes: Barriers to Entry, ≥ 2 player, price/quantity competition. These models are:

(1) Cournot Model

- Features: ≥ 2 player, quantity competition
- Firm have separate demand function (dependent at quantity produced by competitor)
- Simultaneous quantity game
- Certain Nash Equilibrium with no incentive for deviation

(2) Bertrand Model

- Features: ≥ 2 players, true price competition, demand function dependent at quantity produced by competitor
- Nash Equilibrium is at zero profit and equal market share level
- Deviation from equilibrium price will either lead to losses or loss of market share to 0

(3) Stackelberg Model:

- Features: ≥ 2 players, Price/quantity competition
- One player has first mover advantage, and demand function dependent at quantity produced by competitor

Considering the empirical evidences, the DRAM market has shown volatility in Operating Profits (OPs) and there has been a price competition. DRAM market satisfies all the specific features given in the **Bertrand model with repeated game** (as players/producers interact repeatedly).

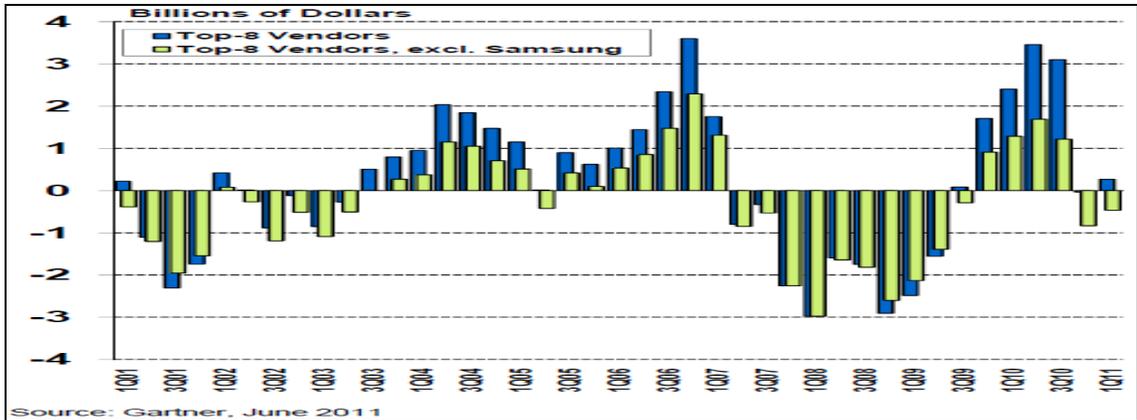


Diagram 2

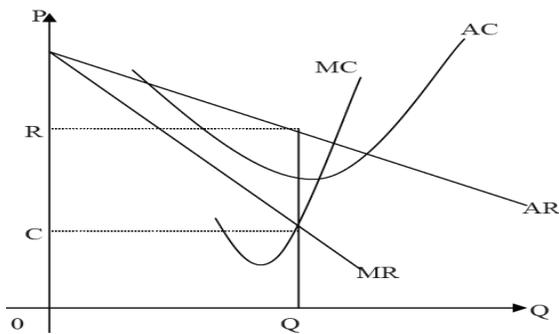
The evidences of the price competition can be drawn from the above graph, it shows the OP of top 8 vendors for past 11 years, the average OP has been -6%.

(D) Possibilities of Transition from Oligopoly To Monopoly

What is monopoly?

A market with these attributes: Single producer, high initial fixed investment, economies of scale, price discrimination and supernormal profits. Good has no close substitute. Here monopolists (producer) act as a price maker.

Interpretation of Diagram (Diagram 3)



- Here quantity is decided by interaction of Marginal Revenue(MR) with Marginal Cost (MC), but the price charged is decided by corresponding value of Average Revenue (AR) at that quantity
- So, RC times OQ is the profit generated in long run

Micro economic theory, suggests **two possibilities** under which oligopolistic market can behave as a monopoly or can achieve a transition to monopoly.

- (1) **Collusion of all players** (producers) in market and they achieve monopolistic outcome (and share gains).
- (2) **Exit of Players** from market and only one player left with clear cost advantage to defer entry. (i.e. one player gain 100% market share by either merger and acquisitions or by beating the competitors out of the market, compelling them to exit).

Economic Perspective and Likelihood of Possibility No. 1

It has been stated earlier that the DRAM market resembles features of Bertrand Model; assuming there are 3 players (for simplicity, $n=3$). **Demand** is, $Q = a - \min(p_1, p_2)$, where p_1 is the price by firm 1 and p_2 is the price by firm 2, Q is the market quantity and $a > 0$ (constant term). **Cost** function for both firms is given by $C(q_i) = c \cdot q_i$, where q is the quantity by firm and $c > 0$ (constant term, $a > c > 0$)

Now, if it were a monopoly market the solution would have been at

$$\text{Max}_Q \{(a - Q) \cdot Q - c \cdot Q\}$$

Which will result (the solution to above maximization exercise) monopoly price (p_m) = $(a+c)/2$, and monopoly Profit (π_m) = $(a - c)^2/4$.

If all 3 producer can collude and charge monopoly price $p_m = (a+c)/2$, then they can share profit of $(a - c)^2/12$ each, respectively. Now, these producers have this **strategy**: play (charge) $p_i = p_m = (a+c)/2$ (the monopoly price) as long as the other producer has played p_m in all prior periods, play $p_i = c$ (which is marginal cost i.e. no profit) forever otherwise. In this case all the 3 will have to charge $p=c$ hence will be making 0 profits.

Using this strategy, there is incentive for deviation, as soon as, one of the producer slash prices marginally below p_m , it will capture all demand, and hence slightly less than monopoly profit of $(a - c)^2/4$ (assuming epsilon difference from monopoly profit) the others will be having zero demand and hence zero profit (this is one period game).

For $n=3$, deviation profit $(a - c)^2/4 > (a - c)^2/12$

For $n=4$, deviation profit $(a - c)^2/4$ is even larger than the collusion profit of $(a - c)^2/16$

So, as n increases the incentive for deviation from collusive outcome increase even further. Even if we extend it to multi-period game, we will realize that there will be certain incentive for producer to deviate from collusion and charge slightly less price to gain market share and those deviation incentive will be higher for higher n .

There can always be incentive for players to deviate from collusive outcome (monopolistic output) and make extensive gains. **Strong penalties** need to be imposed for deviation from p_m . These strong penalties are difficult to conceive in a set-up where one firm is quite dominating in terms of cost advantage/market share. Hence possibility of collusion in this DRAM market is difficult to conceive. The first possibility is ruled out on these grounds.

Economic Perspective and Likelihood of Possibility No. 2

One player outperforms others in terms of (a) Cost advantage (production cost efficiency) (b) Captures market through product innovation (c) Institutional Barriers by Regulatory authorities (d) Exit of financially weak firms in some odd economic conditions. In fact the market **ground reality** resembles this possibility well.

- i. Samsung has come up as front runner in terms of cost advantage due to better and advance production technology (a. factor is there)
- ii. It has been forging ahead in terms of product innovation; one step ahead in its technology and product portfolio (b. factor is there).
- iii. The DRAM industry has seen a tough phase from 2007-09, most of the firms have seen huge negative operating profits, most of the firms have not recovered their losses so far, which occurred during that period. In second half of 2011, again market is going through the similar kind of **financial distress**. Prices have seen more than 50% fall, and remaining below cash cost for almost all firms. Only, two players, Samsung and Hynix are capable of bearing this distress. (The reason d. is also there).
- iv. The current financial distress already has caused the demise of Elpida (market share of 13%), it has filed for the bankruptcy, and seeking for re-structuring or liquidation as possibilities, it will be acquired by Micron.

Theoretically, all the evidence are supporting a possible revolution in terms of transition of the market structure i.e. going into monopoly from the current oligopolistic structure. Now, to support this argument even further, some of **empirical evidence** is analyzed.

Empirical Evidence

- i. There are already 5-6 small players, who have exited from the market in the 2007-09 distress.
- ii. Samsung has been cost efficient (lowest per unit production cost), also, it has been front runner in terms of innovation and advanced technology product-line.

Company	Tech. Node	1Q09	2Q09	3Q09	4Q09	1Q10	2Q10	3Q10	4Q10	1Q11	2Q11E	3Q11F	4Q11F
Samsung	90nm												
	80nm 6F2	9%	5%	3%	3%	3%	3%	2%	2%	1%			
	68nm 6F2	66%	61%	52%	42%	34%	24%	12%	1%				
	56nm 6F2	25%	33%	45%	51%	49%	42%	29%	32%	25%	17%	13%	12%
	46nm 6F2	0%	0%	0%	5%	14%	31%	52%	58%	59%	51%	37%	25%
	35nm 6F2					0%	0%	5%	8%	15%	32%	49%	64%
Hynix	90nm												
	80nm	4%	3%	3%	2%	1%	1%	1%	1%	1%	0%	0%	0%
	66nm	82%	70%	62%	58%	49%	38%	21%	17%	11%	4%	4%	4%
	54nm	14%	27%	35%	40%	48%	49%	51%	41%	38%	37%	23%	15%
	44nm					2%	12%	28%	41%	50%	58%	68%	73%
	38nm 6F2									0%	1%	4%	8%

Table 2 shows the % of total production under various technology nodes. Samsung in 2009 had 68 nm technology and was dominant, in H1 2010 56nm, in H2 10 46nm and in H2 11 with 35 nm technology node, it will be dominant (lower the technology node, better it is).

- iii. The economic indicator for measuring the industry concentration, the “**Herfindahl–Hirschman Index (HHI)**”, also, confirms our analysis. HHI is a measure of industrial concentration, it shows how the competitiveness in the industry is moving, despite the structure of market. It can take a value between 0 to 10000, 0 indicating high level of competition (perfect competition), the ideal world, value 10000 indicating perfect monopoly (other extreme). It uses the market share distribution of the industry and quantifies the level of concentration at every point of time.

It can be seen the overall HHI is increasing, meaning the concentration in the industry is increasing, and level of competitiveness is reducing. With Elpida acquired by Micron, the index will jump further, indicating higher level of concentration.

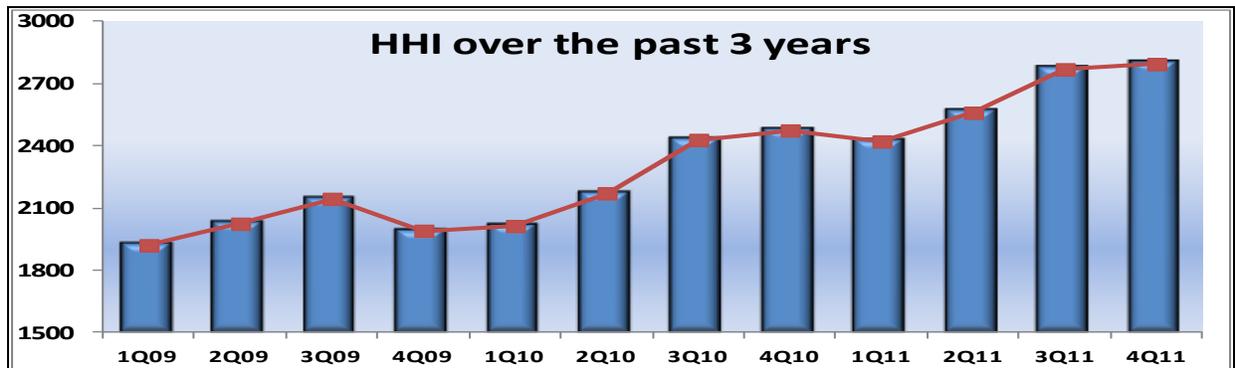
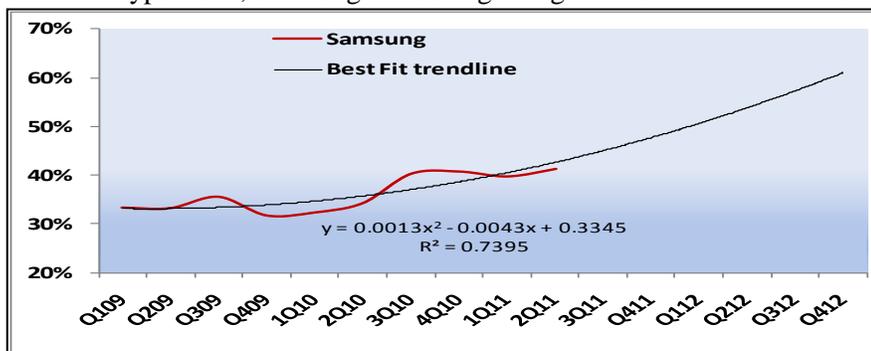


Diagram 4

iv. The analysis of Samsung’s market share dynamics over the past 3 years, throws good evidence in favor of this hypothesis, Samsung has been gaining the market share constantly in the past 4 years.



This diagram (diagram 5) shows the market share of Samsung over the past 3 years, with red line. There is best fit polynomial trend line which indicates, with this

momentum, Samsung will capture almost 60% of the market in beginning of Q1 13. Similar analysis for the market share of Hynix reveals a less convincing picture.

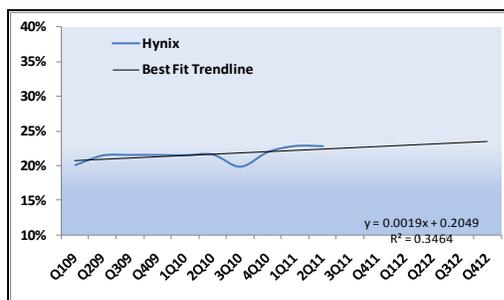


Diagram 6

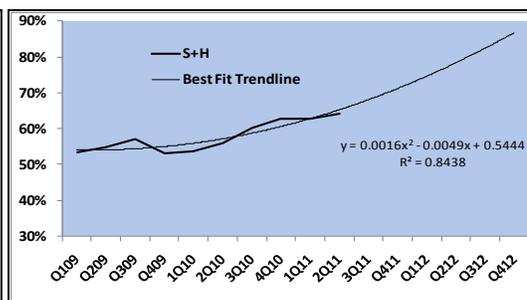


Diagram 7

Diagram 6 explains similar best fit for Hynix’s market share analysis, where it is showing slight gains. It is showing a kind of stability around 20-22% market share. Diagram 7 shows similar best fit polynomial trending for combined share of Samsung and Hynix. It reveals that they both

will be holding around 85% of the market by end of Q4 12. Hence they both will be having full control over the market like a monopoly entity.

- v. Elpida’s crisis: Elpida holds about 13% market share and have 2 fabs, Hiroshima and Raxchip (holds 65% share in it). The demise may potentially have impact on market share distribution of the other players and also concentration of negotiation power with the survivors.

Exit Year	Company	Prior Year's Share & Share of Overall	Peak Share and Year	Notes
1995	Intel	0.3% (0.5%)	82.9%, 1974	Exited the mainstream business in early 1980s and slowly phased out of the DRAM business.
1998	Texas Instruments	6.2% (17.5%)	25.7%, 1976	Sold its DRAM operations to Micron Technology.
1998	Motorola	0.6% (1.5%)	8.9%, 1982	Sold its DRAM operations to Infineon (then Siemens) after the downturn in 1996.
1999	LG Semicon	7.9% (78.2%)	7.9%, 1998	Taken over by Hyundai Electronics Industries, creating Hynix.
2000	NEC	8.8% (19.9%)	17.1%, 1986	Merged its DRAM operations with to form Elpida Memory.
2000	Hitachi	4.8% (16.9%)	19.0%, 1985	Merged its DRAM operations with NEC to form Elpida Memory.
2001	Toshiba	6.4% (11.7%)	19.3%, 1988	Sold its commodity DRAM operations to Micron, still retaining some specialty DRAM production.
2002	IBM	0.6% (0.3%)	7.8%, 1993	Originally a supplier to IBM's captive market, the company saw a slow exit from the industry.
2002	Mitsubishi	1.8% (8.3%)	13.9%, 1986	Merged DRAM business into Elpida.
2004	Mosel Vitelic	2.9% (100%)	2.9%, 2003	Withdrew from the market while its previous foundry partner ProMOS picked up its sales.
2009	Qimonda	9.5% (27%)	15.4%, 2003	Qimonda moves into bankruptcy
2011	Powerchip	1.5% (3%)	4.3%, 2006	Withdrew from the branded market.

Table 3

The table above shows major players’ exit from the market in past 20 years. The latest addition to above table is Elpida. With demise of Elpida there will be only 3 major players remaining and negotiation power of top players will be stronger.

(E) Conclusion

The theoretical and empirical evidence support the possibility 2. The DRAM market is heading towards monopoly in upcoming future. There will be one entity either Samsung, or Samsung dominated, which will be behaving like a monopolist and market will contain monopolistic features. The empirical evidence indicates that Samsung can create this kind of scenario by end of 2013. If Samsung and Hynix were to merge then this scenario can arise in beginning of 2013. In fact, if the current market distress prolongs, and if producers continue to see operating profit losses (i.e. prices below cash cost) for long period then this transition can happen even earlier, due to possibilities of merger and acquisitions. The financial health and liquidity situation for many of these firms (except Samsung and Hynix) is getting worse with time; with stiff competition coming up in terms of new advanced production technology (lower nm density switch), these bleeding firms would not have funds for investing in technology up-gradation. The result would be a vicious-cycle of depletion of profitability and loss of market share, hence extinct of these firms from the market.

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