



## Andy's acceleration and Moore's momentum

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..... Most advances in integrated circuit manufacturing and design result from the efforts of some of the most clever engineers and scientists on the planet. Yet, that is not the whole story of economic progress. Advances in the technical frontier do not find their way into users' hands without deliberate actions by the managers of the firms who sell chips.

That last observation seems uncontroversial until you consider that ephemeral economy-wide business conditions and strategic priorities shape these managers' actions.

That raises a couple of questions because business conditions were exceptionally good in the 1990s and they are not now. Did those good conditions accelerate the translation of technical advances

into new products? Has this acceleration slowed recently?

These big questions are more than a single column can tackle. But I can use Intel's behavior to illustrate the answer, because there is more data on Intel than on any other company. The answer may surprise you.

### The product line

Figure 1 presents Intel's product line pricing in the last decade. These data come from "Moore's Law, Competition and Intel's Productivity in the Mid-1990s," a paper written by Ana Aizcorbe, an economist at the US Department of Commerce's Bureau of Economic Analysis. See [http://www.bea.gov/bea/working\\_papers.htm](http://www.bea.gov/bea/working_papers.htm). (These are Dr. Aizcorbe's data, but

she is not responsible for this interpretation. Do not blame her if I get it wrong.)

Each line on the graph represents a new product in a popular Intel product line. The line begins at the introductory price (shown in log scale) and declines over time, ending at the retirement price. The line's average steepness represents the rate of decline in the product's price over its life. In the 1990s, most of the lines represent versions of the 486 or Pentium processors. (The Celeron product line is not represented.)

Notice that after 1995 the lines are steeper and closer together. In other words, after 1995 the life of any particular product shortens, experiencing a faster drop in price and replacement.

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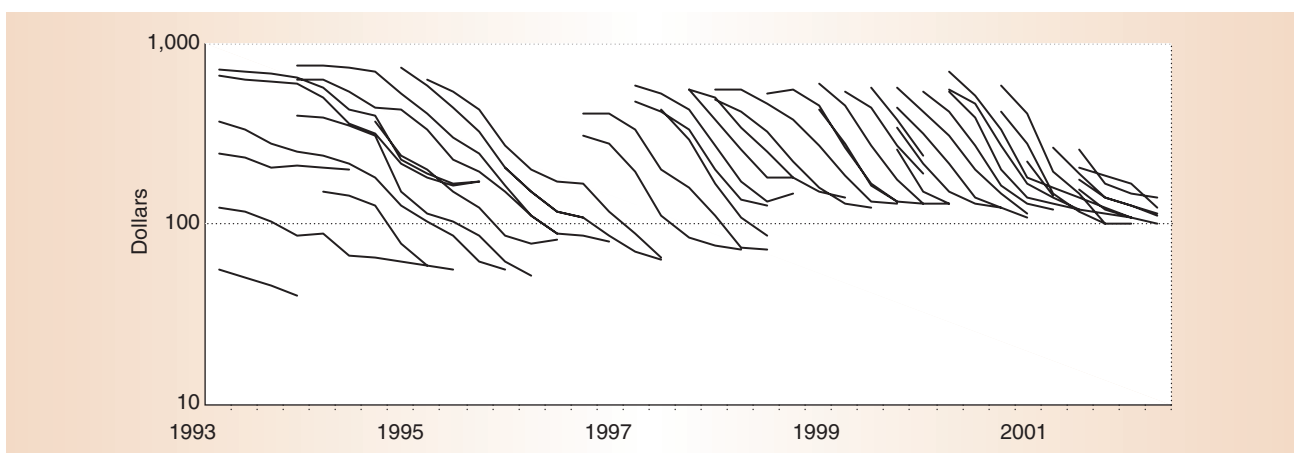


Figure 1. Price contours and product cycles for Intel desktop microprocessors (1993 to 2002).

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If this were a typical industry, the changes after 1995 would be easy to explain. In typical industries, firms alter their designs more frequently when it becomes necessary to match rivals or cheaper to introduce a design improvement.

However, this is not a typical industry. Neither of those explanations holds up to scrutiny.

First, while I am willing to believe that competitive pressure on Intel increased over the 1990s, it is a bit hard to understand why 1995 was such a special year for that. AMD's lawsuit victory occurred prior to 1995, but that was not as important as events in 1997, when AMD introduced the K6 and then Cyrix followed with its design. This pressured Intel to retire the Pentium MMX and introduce the Celeron in 1998 (which is not even on the graph). Even then, arguably, only Intel's upgrade to the first Celeron design, which arrived in 1999, had much market impact. There was more to these events than I am saying, to be sure, but for now all I am saying is that the timing of the increase in competition does not explain the graph.

Second, it also strains credulity to think that the capital investment associated with designing upgrades declined for Intel during this time. It did not for anyone else.

It is no secret that manufacturing chips requires extraordinary care and precision, and that it depends on hitting several moving technical targets that would be hard to hit even if they were not moving. Micron levels always shrink. Design complexity always grows. New materials are always being introduced. Even the basic physics of heat dissipation have changed in the last decade. I could go on and on.

Today, new fabrication plants are extremely expensive, at several billion dollars. Indeed, companies didn't build new plants in the late 1990s unless the plant produced several designs, often from different firms. It was too expensive for any single firm, except Intel. By the end of the decade, Intel became practically the only firm with sufficient volume to build a plant entirely for one design. More to the point, with only this key difference, Intel still

faced the same trends in design and production costs that everyone else faced.

My instincts tell me to look elsewhere. Let me offer an interpretation that is quite distinct from the typical explanation for most typical industries.

### **An engineering and design achievement**

Intel had an enviable market position in the 1990s. Intel and Microsoft together controlled the most popular design for the most popular personal computers. Moreover, user demand had not yet been sated; there were many more opportunities to sell upgrades to a standard PC.

Andy Grove became CEO of Intel just as this era began. A more conventional CEO might have thanked his lucky stars (as well as his predecessors) for the extraordinary market position and just milked it with a safe strategy. *Safe* in this case would have meant cautious investments in new capacity and stringent budgets for R&D. *Safe* would have let demand grow on its own, as Intel had in the past.

However, Grove resisted coasting. No single decision alone made a difference, but Intel initiated several related investments in 1991 and afterward. This is a long story, but let me summarize pieces of it. (For more information, see Annabelle Gawer and Michael Cusumano's *Platform Leadership*, HBS Press, 2002.)

Intel reorganized designers and production engineers to plan for several generations of backward compatible upgrades. The firm also accelerated its already aggressive fabrication building and equipment purchases, aiming to stay close to the production technical frontier while not sacrificing its upgrade plans for designs. It also accelerated its aggressive moves into designing motherboards and other facets of the PC. The marketing campaign efforts—"Intel Inside"—also started early in Grove's reign. Altogether this strategy was expensive and risky.

It also was not obvious. There were many calls in the early 1990s to design RISC (reduced instruction set computer), and not the CISC (complex instruction set computer) that Intel had traditionally done

and would need to do to continue to make backward compatible chips. Moreover, investments took a long time, sometimes several years, to have an effect in the market place. Any strategy was a gamble.

One additional, big idiosyncrasy existed. Intel was in a mass market with historically volatile demand. Until the 1990s most industry curmudgeons, as well as many venture capitalists with memories, thought the microprocessor market was an extremely risky market, subject to wild ups and downs about every three or four years. Until the early 1990s, that is what every firm experienced and what every Wall Street analyst forecast.

Had this historical pattern held, Intel would have had a big slice of a shrinking pie—that is, if the PC market experienced a steep decline in demand starting in 1994 or 1995, as it had from 1989 to 1991. Grove's aggressive investments would have produced financial losses. I have always wondered if Grove would have survived as CEO had this happened.

Of course, no such decline happened. The mid-1990s were the most favorable demand conditions the integrated circuit industry had ever seen, microprocessors included. PC demand began growing after 1992 or 1993, depending on how you count it. Growth continued over the next few years at astronomical rates, fueled by the browser wars, the expansion of global markets, and the dot-com boom. In other words, after the downturn of the early 1990s, the industry never experienced another major downturn until the dot-com crash. That was about eight or nine years of uninterrupted double-digit growth without a decline.

While it helps to be good, sometimes it is better to be lucky. It is even better to be good *and* lucky, which is what Intel was in this instance.

More precisely, growth in demand supported high sales volumes at high prices. High margins covered many mistakes and rewarded aggressive investment. It spread costs over large volumes of profitable sales. That paid off the loans and any other debts Intel had made in the early 1990s. The internal rate of return for more investment

