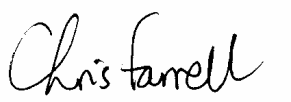
A Submission To The Economics and Statistics Administration

United States Department of Commerce

In response to the request for public comment published in the Federal Register dated Friday April 13th 2007 and in support of the efforts of the 'Measuring Innovation in the 21st Century Economy Advisory Committee'.

Submitted by Chris Farrell, Individual, in ten numbered pages (excluding this cover page) and dated Monday May 7th 2007.



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Re: Measuring Innovation in our 21st Century Economy.

I would like to thank the Economics and Statistics Administration of the Department of Commerce for inviting public comment on the challenges that measuring innovation presents. I have been following progress through the documents published on the website.

The Federal Register invites specific proposals. As there may be an important element of measuring innovation that is being missed, I am going to recommend that the Panel look closely at S-curves. I have not seen them mentioned in any of the documents, yet they have been accepted since the 1980's and are taught in many business schools. Their drawback, namely difficulty of measurement, may be the reason they have been overlooked. However recent work has lifted this constraint and – as far as I can tell – they are now capable of completely satisfying the innovation metric requirements set for the Panel.

S-curves have very practical outcomes. In particular, this metric can already estimate that the total innovation in the goods sector of the U.S. economy was 1.13 million utils in 2000, falling about 3 % to 1.10 million in 2001 (page 7 – figure 9). And for the service sector it rose to 1.03 million utils in 2001 (page 9 – figure 13). The page and figure references are to a paper entitled 'How To Measure Innovation Using S-Curves' that follows. It should assist the Panel in considering S-curves by putting them into a suitable framework with appropriate practical contexts.

One advantage of the new methods is that they use data already available from the Department of Commerce. The series known as Current Industrial Reports forms the backbone of the data plotted in the examples.

In addition I would like to comment on several of the specific questions that appear in the Federal Register whose answers do not fit easily into the context of the S-curve paper.

Category 1 – Improvements in National Accounts, specifically the potential inclusion of Total Factor Productivity.

The difficulty with TFP is to know what it measures. Whether it is calculated using Cobb-Douglas, KL or KLEMS it is still a 'residual', with the unavoidable and long-standing label that it is 'a measure of our ignorance' (*Abramovitz, M., Amer. Econ. Rev., May 1956, 46(2), pp 5-23*). The only way to be sure that TFP measures innovation is to obtain independent verification, which S-curves now provide. The result appears to be that TFP is always too small to contain measured innovation.

Category 2 – Identification of appropriate indicators.

(a) The use of market share is a good indicator, especially when it is combined with % of sales from products developed in recent years. The Product Development & Management Association uses something similar (plus dividing the 'new' products into categories of innovativeness) when it considers candidates for its annual Outstanding Corporate Innovator Award. But the problem for a metric that has to go beyond firm level is three-fold (a) the definition of innovation in a firm is inherently different than it is for a product – see category 3 comment (b) there is no known connection between these measures and economic growth (GDP) and (c) innovations may flow from suppliers and not truly rest with the company that puts the final product on the market, raising issues of multiple-counting.

(b) For the service sector I suggest that – rather than 'outputs and inputs' - data on investment in service equipment should be expanded. This will improve innovation measurement by the S-curve method. At the moment the National Economic Accounts do not break out (historical cost) equipment investment for the service sector by type of equipment for each service category. But this is needed to calculate an accurate innovation metric by the S-curve method – page 8.

Category 3 – Firm-specific data.

Innovation within the firm has a different character than innovation that filters up to higher levels of aggregation. Specifically (in the goods sector) a firm is very concerned about its cost of manufacture and directs innovation toward it. The extra profit of the low cost producer can be invested to increase its market share. But the product of an industry isn't sensitive to the market share of its producers – at that level, and above, it matters less who produced it than what is produced. You will see this quantified in the paper as (p/c) for the firm – page 9 – but as (p) for aggregation above firm level – page 7. In other words there are two metrics and their use depends on the level of aggregation being considered.

Category 4 – Data 'holes'.

(a) Much of the data needed to determine S-curves for the goods sector can be found in Current Industrial Reports. Although these are an excellent set of publications, their data has always had to be supplemented to find the innovation metric. These other sources include private ones, such as industry associations, and other government sources - including the Census of Manufactures, the Annual Survey of Manufactures, Foreign Trade publications, the Geological Survey and the Economic Research Service of the Department of Agriculture. To lapse into the colloquial for a moment let me say it has been a proverbial nightmare trying to unite data from these sources. They have different formats, different collection methodologies, and different categories. Without the help from individual analysts at each agency over the years, not to mention the support of numerous information specialists in Federal Depository Libraries across Illinois and

Indiana, the S-curve method would still be where it was in the 1980's. A unified approach would make it so much easier – perhaps in a publication that might be called 'Current Industrial Innovation Reports'.

(b) For the service sector the main data hole is identified in my response to category 2(b).

(c) For firms, data filed with the Securities & Exchange Commission formed the basis for the beer example in the paper – page 9. Determining an innovation metric from this source has its problems when there is a consolidated statement. Anheuser - Busch diversified into snack foods to the extent that after 1983 their statements were no longer useful for innovation assessment in beer. Diversification is a common strategy when traditional markets come under pressure, and sometimes exactly the point when a firm's innovativeness in its core business is most interesting to know. There also seems to be broad leeway in accounting practices between firms on where costs and expenses appear on the statements. A stricter common set of accounting practices would make the innovation metric a more reliable one.

My proposal is that S-curve methodologies, which are calculated from economic data, be adopted to provide the desired innovation metric. They offer the following advantages.

- S-Curves satisfy all four categories of need identified in the Federal Register.
- S-curves are already accepted, in their early form, as a measure of innovation. (And taught as such in business schools).
- S-curves can be aggregated to any level in the goods or service sector.
- S-curves can be used to determine the total degree of innovation in the economy.
- S-curves can be used to analyze the sources of innovation in the economy.
- S-curves can be calculated from economic data that is mainly already collected.
- S-curve data can be collated separately at minimal incremental cost.

I hope that the Panel will agree with me that S-curves are the best candidate for the innovation metric they seek.

Chris Farrell

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How To Measure Innovation Using S-Curves

A Responsive Commentary In Two Parts

Chris J. Farrell

In the 1980's practitioners of technology innovation thought the problem of measuring it had been solved by Richard Foster's pioneering work on S-curves. But the practical implementation of measurement was difficult in most cases, and impossible in others - so only a few iconic curves exist. The work was not forgotten. Since then not only have several refinements been made to his business advice, but also the measurement has been made much easier and extended to intangibles. This second development renews S-curves as an innovation metric. In Part I the history of the S-curve is reviewed leading to its new measurement from economic data. With this metric, innovation is connected to economic growth. Part II focuses on the firm and shows how the metric can be used to monitor company-wide innovation and warn of impending threat from competitive innovation implemented elsewhere. Responses to specific questions asked by the 'Innovation in the 21st Century Economy Advisory Committee' in the Federal Register are given in this paper and in the preceding letter. Also some quotations, taken from the transcript of the inaugural meeting, are placed next to their answers in this paper.

Part I – Innovation and Economic Growth

Richard N. Foster, a McKinsey & Co. consultant, wrote one of the best business books of the 1980's. In 'Innovation' he took a theory known simply as 'S-curves', and delivered some excellent practical advice for managing a mature corporation. Not surprisingly, the book cover heralds enthusiastic endorsements from nine prominent CEO's and chairmen of major corporations.

Tires Provide S-curve Data

Tire remnants shed by trucks are a common sight on the interstate road system. Their carcasses usually show ribs sticking out. These are tire reinforcements. From the Model - T to the Taurus, Foster took cord performance data and plotted it, figure 1.

On the vertical axis is an engineering measurement of tire cord performance from the Goodyear Company. On the horizontal axis is the total technical effort expended in engineering development to achieve it, as estimated by experts at Celanese, for four generations of cord.

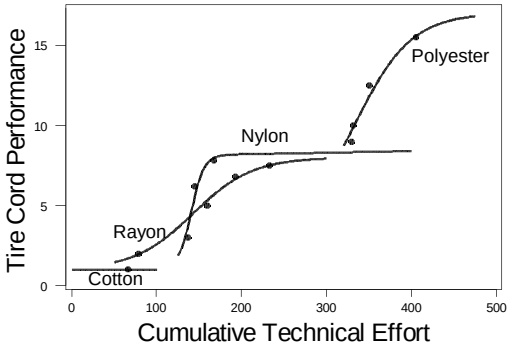


Figure 1 – Engineering sequence of tire cord innovations.

S-Curve Analysis

The Model – T tires were reinforced with cotton fabric. There isn't much you can do to improve it, so the curve is flat. Rayon, however, is a different matter. Wood pulp is dissolved into a thick liquid

(called viscose) that is spun into solid fibers. There is plenty of scope here in both chemistry and engineering to make a better fiber for tire reinforcement, and its graph heads upward. Eventually it flattens out because a barrier is reached in the basic chemistry of Rayon. In the meantime Nylon rapidly catches up, and can even surpass, Rayon - displaying the classic S-curve development path. Then comes polyester with a truly superior limit, far above what the earlier fibers could achieve. It dominates, while cotton becomes extinct and rayon heads in the same direction.

Foster used these S-curves to warn companies dependent on products near the limit of their technological growth – at the plateau of the S-curve. By puncturing the delusion of continued prosperity he showed how to act to counter the hidden threats to survival from the next upward S, and his book is still available through Amazon.

Toward Innovation Measurement

That engineering development is capable of delivering a series of innovative improvements, each of which drives out its incumbent, each of which strives for an ever-higher performance limit is familiar. But it is unfamiliar, and new, to measure innovation using the performance of the products of such evolving technologies. With twelve data points over six decades it is hardly comprehensive, but it points a way.

Intangible Performance

Tire cords are intermediate goods, steps in the stream of commerce leading from raw materials to finished consumer goods. They are sold business to business and so it is relatively easy to codify their performance in an engineering specification. Indeed, it is the basis on which their sale takes place. However, consumer purchases are made by a personal perception of performance - often involving lifestyle aspiration and other imponderables.

Today it is easier to measure R&D spending as a component of innovation but I think our challenge is also how to determine – how to quantify – non-technical, intangible aspects of innovation.

Setting aside the fate of a particular company for the moment, when the data for all companies is re-plotted against time, in figure 2, the overall upward drive of innovative performance is very apparent. It was about sixteen fold from the Ford Model –T to the Taurus – whoever was making the cords. Taken together figures 1 & 2 show that performance is an excellent candidate for an innovation metric.

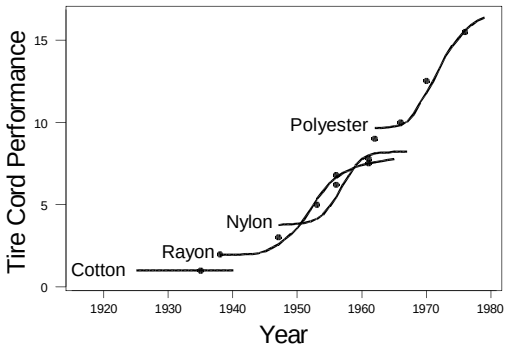


Figure 2 - Upward historical sweep of tire cord innovation.

This challenges the practicality of S-curves dependent on engineering measurement - fine for intermediate goods, but final products are the ones that contribute to economic growth as expressed in the gross domestic product, GDP and these sell on perception, not engineering fact.

Captured By Price

If consumers perceive advantage in a product they will pay more for it, neatly capturing both engineering and imponderables. But, because price is influenced by other factors – such as competition – it has proven very difficult to extract the performance component of it from price statistics. But this has been achieved recently. The rest of this document uses the new methods. It takes price statistical series, extracts product performance (as perceived by the purchaser) from them and displays them as S-

curves, a measure of innovation.

The Example of Pens

If you started school in the 1950's you will have needed a fountain pen (and blotting paper). For your parents it was a steel-nib pen with inkpot - but today we have ballpoints, and no blotting paper or inkpots.

In figure 3 we see shipments of fountain pens increasing from the 1920's to a peak in about 1960 then going into rapid decline, but not disappearing, and then making a slow comeback since about 1980.

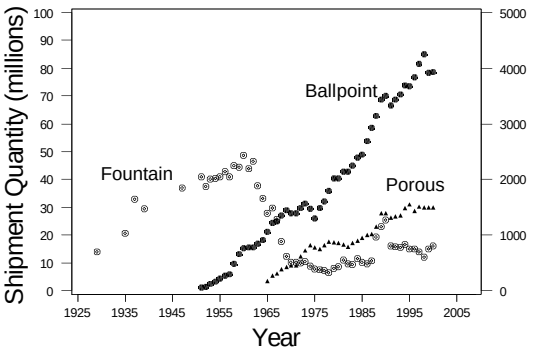


Figure 3 – Quantities of pens showing the fate of the fountain pen as other technologies invade.

The decline was caused by the success of an innovative new ink delivery technology that replaced the nib with a rotating ball – the ballpoint pen. Then another innovative ink delivery technology, using a rigid porous wick, produced pens that joined the fight for consumer preferences with some success.

These innovations can be measured by creating their S-curves from price series using the new methods.

Pen S-Curves Found Using Economic Data

The S-curve for fountain pens, calculated from market data, is shown in figure 4. Annual performance from 1951 provides a very rich picture of innovation. Note that it continues to increase <u>after</u> the start of the market share decline in 1960, with most of the improvement <u>after</u> 1960. This is the era of the status pen – where the cachet of the label is the perception of performance. The innovation is not in the engineering (there is not much actual improvement in these pens) but in creating the perceptions surrounding their purchase and use.

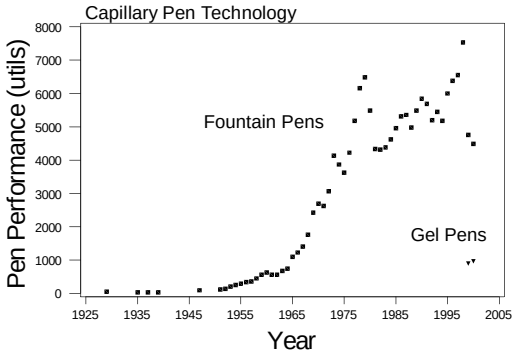
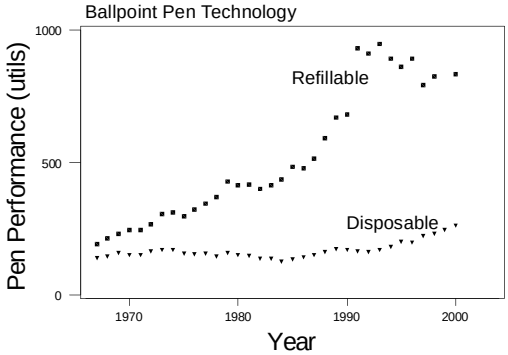
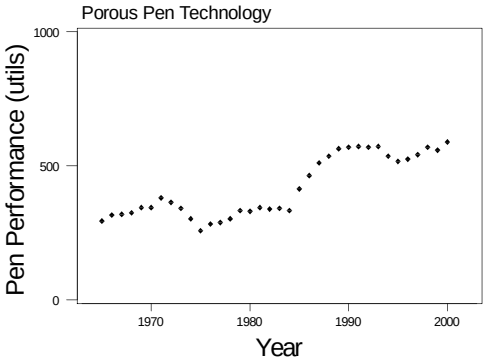


Figure 4 – S-curve for fountain pens, calculated from economic data.

The fountain pen S-curve after about 1975 is driven upward almost entirely by non-technical factors, yet the curve captures them. Intangible factors contribute to GDP just as much as engineering does. The huge dip in performance seen in 1982 was due to the collapse of this luxury market in the recession.





Figures 5 (upper) and 6 (lower) – S-curves for pens with innovative ink delivery technologies. They challenged the fountain pen, and won.

Eight pen categories (some S-curves not shown separately but included) define an industry group and its aggregated pen performance S-curve is shown in figure 7.

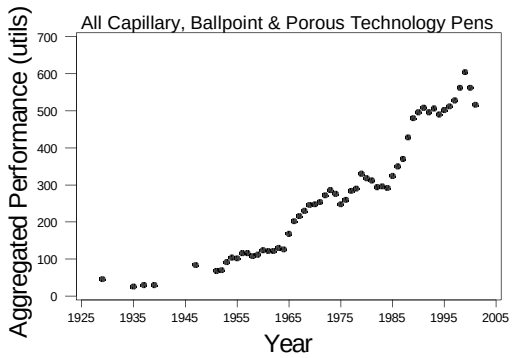


Figure 7 – The S-curve for all the pens taken together as an industrial group.

Aggregation To The Goods Sector Level

If an S-curve is produced for the goods sector, then the question can be asked 'where are we in innovation?'

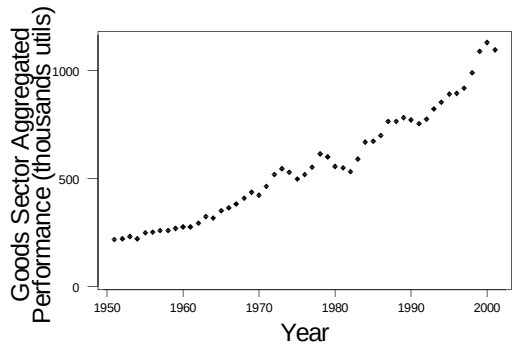


Figure 9 – An (estimate) of S-curve innovations aggregated to the goods sector level can answer the question 'where are we now on the innovation metric?'

Even with the limited data available in the current

I look forward to the day when we are receiving quarterly economic updates, and one of those numbers, that we look at in addition to GDP, in addition to inflation, in addition to employment, happens to be the innovation metric.

Connecting S-curves to GDP

The price of pens captures all the value added from raw materials to their final purchase and this contribution to GDP from a single industry group can be calculated from the aggregated S-curve in figure 7 using a mathematical operator F (whose derivation - which includes additional factors - is beyond the present commentary).

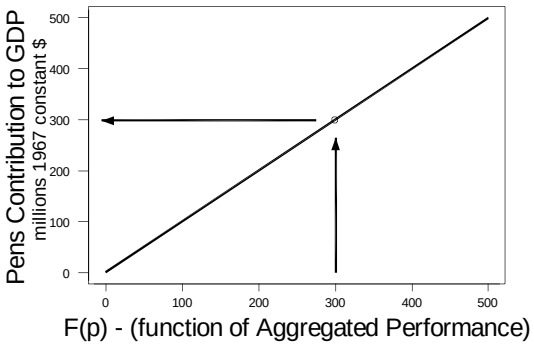


Figure 8 – Using F, aggregated performance can be transformed to GDP – it drives economic growth.

And S-curves can continue to be aggregated, if data is available, to the sector level.

database DINTEC (described later) such an S-curve can be approximated, as in figure 9, and it would certainly have raised concern about the dip in 2001.

Taking the logarithm reveals the underlying innovative growth rates – seen below in figure 10.

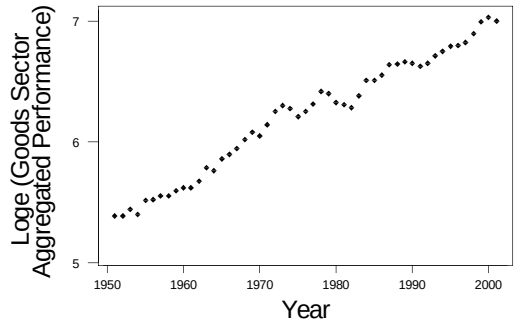


Figure 10 – The slope of this graph gives the growth rates of the aggregated performance of all goods.

Because this result is based on a very small, though approximately representative, sample of

the goods sector interpretation should be suspended until a more comprehensive set of data is in place. However, the growth does seem to fall into four general regions (1951-1961), (1961-1973), (1973-1984), (1984-2001) with the fastest growth (1961-1973) and the most recent rate (1984-2001) slower than that. The average growth rate (1951-2001) is 3.3%. Despite the approximations the ultimate potential and power of the S-curve methodology is very apparent. And it is even more powerful for analyzing where growth is coming from.

Pen Mightier Than Computer?

Specific economic growth can be illustrated by comparing individual products. For example the S- curves for fountain pens and (home) personal computers, in figure 11. They have broadly similar performance growths with one being driven by intangibles, the other by utility. But their impact on economic growth is quite different, as seen when they are aggregated into their industrial group. PC's belong to office machines – an historical series of innovative products starting with the manual typewriter and progressing to the electric and e-typewriters, stand-alone word processors and most recently, the personal computer.

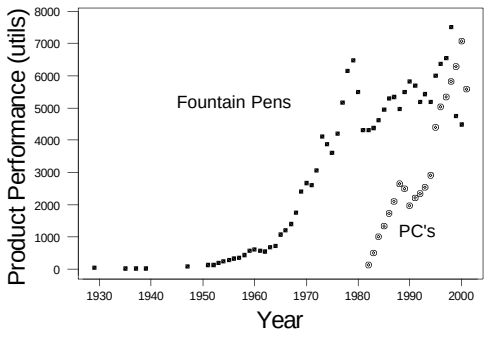


Figure 11 – Comparative S-curves for a pen and a computer.

In the next we see that the performance of the pen group has increased at only 1.1% over time while the office machine group contributes at a growth rate of 4.3%. This is because, despite its performance, the fountain pen has a tiny share of the pen market (compare the left and right hand axes of figure 3), while the PC currently holds a lion's share in office machines.

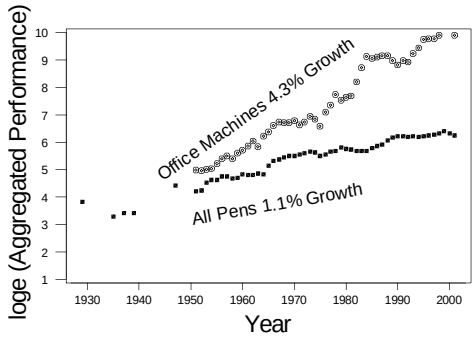


Figure 12 – Comparative innovative growth for two industrial groups. The goods sector grew at an average of 3.3% in the same period.

This S-curve example indicates that economic growth derives from products with fast growing performance on their way to a high limit (notice that fountain pens are rounding into their S-curve limit but PC's are still heading up) while capturing a large share of their market. Analyzing data using the new S-curve method should provide means for identifying where investment might best be directed to achieve these aims, and perhaps how policy could be framed to invigorate it.

The goods producing part of our economy is very heavily measured and represented and dissected. But services, as you know, dominate our economy.

Aggregation To The Service Sector Level

The service sector depends on the goods sector, and imports, to provide it with the equipment it needs to provide its services. Since 1962 the general office has been transformed by innovations in machines - from the typewriters to word processors, from the adding machine to the spreadsheet. Innovation in these, and other, service equipment can also be captured by S-curves and aggregated to assess the performance of the private service industry - remembering that equipment is durable and may be up to twelve years old. Once this is accounted for, the aggregated S-curve for the private services sector is shown (1962 - 2001) in figure 13. Taking the logarithm again reveals the underlying innovative growth rate of 5.2% - well above that for the goods sector.

The Service Sector (continued)

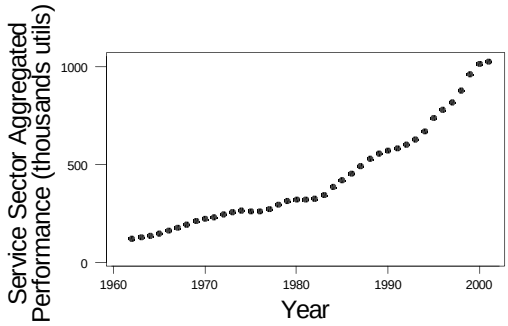


Fig 13 - An (estimate) of S-curve innovation for the private services sector (aggregated with accounting for durability).

Part II – Innovation and the Firm

Innovation in the individual manufacturing firm is fundamentally different than it is for products.

The performance of their beer was below Anheuser's, but in the 1960's it was catching up, figure 15.

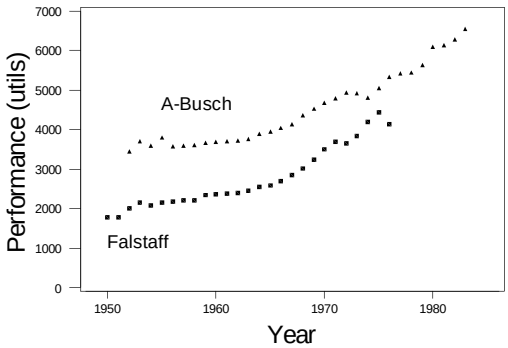


Figure 15 – Falstaff beer raises the perception of its quality and starts to catch up with Anheuser in the 1950' and 1960's.

But in manufacturing technology (p/c) Falstaff was falling behind, figure 16.

The ultimate goal of innovation is competitiveness.

Firms are in competition with each other and if one firm fails the product will still be made, but not by them. Because the manufacturing costs of surviving firms must lie below the market price, a good measure of innovation in the individual firm is the performance of products divided by their unit cost of manufacture or (p/c) – where p is calculated in the same way as before.

Fierce Competition in the Beer Industry

No one can drink Falstaff beer today but in the 1950's it wasn't far behind Anheuser-Busch in popularity, see figure 14.

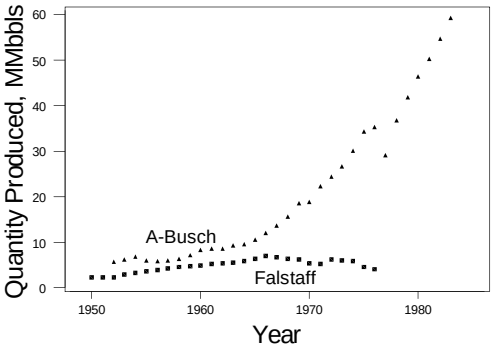


Figure 14 – The popularity of Falstaff peaked in 1966 and then went into decline.

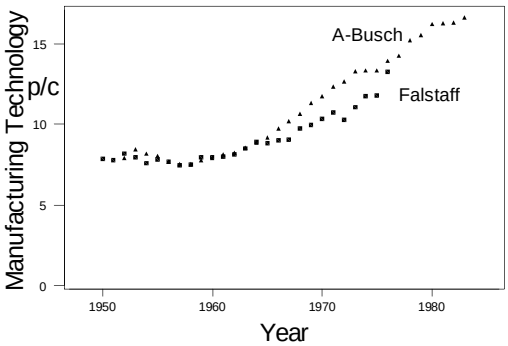


Figure 16 – Although Falstaff is increasing the public's perception of the performance of its beer; its manufacturing technology is falling behind.

The criterion for survival is that a company's innovative manufacturing technology (p/c) must be held greater than a certain parameter. This parameter maps out a danger zone. In the next figure it is cutaway to show Falstaff falling into it from 1972 –75. It bounced back in 1976 but it was too late.

With S-curve methods to track innovative progress perhaps they could have done in 1966 what they finally did in 1976, and prospered today.

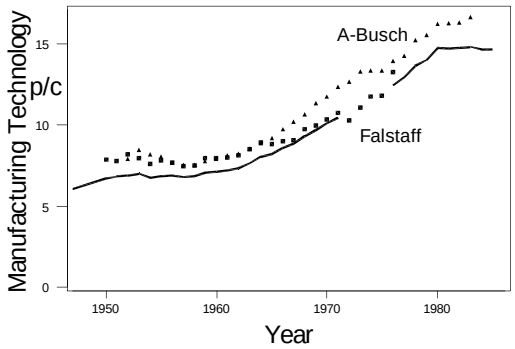


Figure 17 – Falstaff's manufacturing technology heads for the danger zone after 1964 and rides into it in 1972.

Instead Falstaff had to shut its breweries but cleverly wrung the last value from its name by becoming a 'virtual' beer – brewed for the brand owner by Pabst - an end-game ploy that stretched until 2005. In the meantime Anheuser-Busch, who soared above the danger zone did so with some very innovative practices. Among them was brewing at capacity in the slow winter months and storing it in refrigerated warehouses until the summer. In that way they could meet demand not only without risking investment in new capacity, but also because unutilized capacity raises manufacturing cost.

The progression of annual snapshots in these figures gives rare insight into how competitive innovation works as the ultimate engine of economic growth. The firms that survive take the products of their better technology forward; those that don't are absorbed or disappear. The economist Joseph Schumpeter aptly called it 'creative destruction'.

A Word on Data

Data used in this commentary comes from a database called DINTEC (Data on INnovation, TEchnology & EConomics). At its core is market data from combined public and private sources for more than 140 products at the seven-digit SIC (Standard Industrial Classification) level. In the following list X's are selections that create a competing industrial group.

Dinner-plate Vegetables - SIC 20332XX (seventeen XX product codes) and 20372XX (fourteen XX product codes) plus eight un-coded fresh vegetables.

Malted beverages (beer) – SIC 2082XXX (thirteen XXX product codes).

Carpets – SIC 227X0XX (nine X0XX product codes).

Paints – SIC 28511XX (twenty-two XX codes).

Cement – SIC32410XX (seven XX product codes).

Refrigerators SIC 36321XX (fifteen XX product codes).

Motor Vehicles NAICS 33611X (two X product codes).

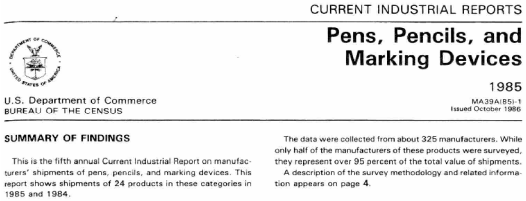
Televisions SIC 36512XX (eight XX product codes).

Office Machines SIC 357XXXX (eighteen XXXX product codes).

Truck Trailers (reefers) SIC 37151XX (three XX product codes), (vans) SIC 37151XX (four XX product codes).

Pens SIC 39510XX (seven XX product codes plus un-coded gel pens).

The following illustrates some of the data sources used to deliver the pen examples. Top – Current Industrial Reports MA39A. Bottom – Writing Instrument Manufacturers Association datasheet.



CURRENT INDUSTRIAL REPORTS

Pens, Pencils, and Marking Devices

1985

U.S. Department of Commerce
BUREAU OF THE CENSUS

MA39A(85)-1
Issued October 1986

SUMMARY OF FINDINGS

This is the fifth annual Current Industrial Report on manufacturers' shipments of pens, pencils, and marking devices. This report shows shipments of 24 products in these categories in 1985 and 1984.

The data were collected from about 325 manufacturers. While only half of the manufacturers of these products were surveyed, they represent over 95 percent of the total value of shipments. A description of the survey methodology and related information appears on page 4.

MECHANICAL HANDWRITING INSTRUMENT INDUSTRY STATISTICS
Annual Estimates Compiled by Writing Instrument Manufacturers Association, Inc.

	1951		1952	
	Estimated Number of Units Shipped	Estimated Total $ Value at Manufacturers' Prices (Exclusive of Tax)	Estimated Number of Units Shipped	Estimated Total $ Value at Manufacturers' Prices (Exclusive of Tax)
Fountain Pens	41,033,972	$ 45,127,081	37,378,744	$ 42,253,086
Ball Point Pens	52,831,167	13,496,605	68,192,148	18,204,989
Mechanical Pencils	70,559,080	27,042,691	63,801,600	24,427,062
Desk Sets	2,063,859	4,568,966	2,211,942	5,139,576
	166,488,078	$ 90,235,343	171,584,434	$ 90,024,713

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