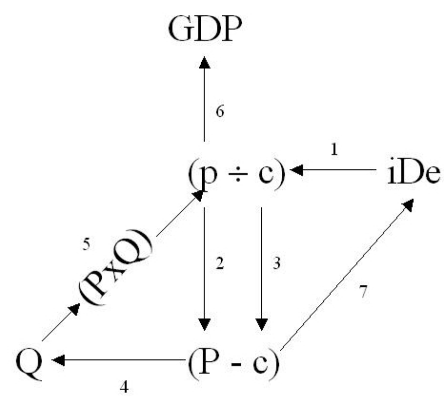
Innovation in Economics

Missing Pieces



The *Principia* of Economic Growth

Part I – Steps 1 to 5

Chris Farrell Ph.D.

Innovation Measurement

Tracking the State of Innovation in the American Economy

A Report to the Secretary of Commerce by

The Advisory Committee on Measuring Innovation in the 21st Century Economy

January 2008

Transmittal Letter from the Committee

January 2008

The Honorable Carlos M. Gutierrez
Secretary of Commerce
U.S. Department of Commerce
Washington, DC 20230

Dear Mr Secretary:

You charged this Committee with developing "new and improved measures of innovation" in three areas: how innovation occurs in different sectors of the economy, how it is diffused across the economy, and how it affects economic growth. As chair of the Advisory Committee on Measuring Innovation in the 21st Century Economy, I am pleased to present a report that is the culmination of nearly a year's worth of study and consideration by the members, and that we believe represents the most fundamental changes that can be made to advance our understanding of innovation.

While we recognize that the American economy is changing in fundamental ways – and that most of this change relates directly to innovation – our understanding remains incomplete. Indeed, data collection and measurement, while seemingly mundane, loom large in understanding these changes. Policymakers, investors, executives, managers, consumers and researchers require accurate and complete information in order to make informed decisions. The centrality of the need to advance innovation measurement cannot be understated.

The difficult work of improving our measurement systems is only just beginning. On behalf of the committee, I want to thank you for this opportunity, and I look forward to the improved information that will become available if the Committee's recommendations are implemented.

Sincerely yours,

Carl J. Schramm
Chair
Advisory Committee on Measuring Innovation in the 21st Century Economy

Transmittal Response – from inside Commercial Knowledge

Tracking the ‘state of innovation’ advantages any economy. The Chairman’s second paragraph is as cogent today as it was in 2008.

But in order to track innovation it must first be measured and measured rigorously. This requires overcoming certain fundamental impediments within Economics.

The first is its ‘quality change problem’, which stems from an inability to go beyond a list of attributes to enumerate the **actual** ‘quality’ (functional goodness) of a product or service in a single variable.

The second is the ‘measure of ignorance’ that arises each time Economics tries to account for economic growth at the macro level. This is known as Factor Productivity. Factor Productivity is often proffered as a proxy for innovation or technical change (or something?) [I].

Economics seems to accept these limitations. The Committee didn’t differ.

Nevertheless solutions **are** available and are presented in this book. They arise from a wealth of previously hidden commercial knowledge supported by otherwise neglected data.

The outcome is far-reaching. The impact of innovation on the economy is far more direct and profound than Factor Productivity – or any construct of current economics – is capable of delivering[II]. The residual has to evaporate, and it does.

If – as the transmittal letter opines, and this book affirms - the centrality of innovation cannot be understated in relation to changes in the American economy, then innovation also merits tabulation within National Accounting.

To supplement and support progressive presentations made to the Bureau of Economic Analysis since 2014, Technology Matters provides this research monograph.

Chris Farrell

[I] Factor Productivity is even more vague than phlogiston. Phlogiston was a late 18th century conjecture to explain the chemistry of combustion. It later gave way to oxygen, because oxygen did, and does. Factor Productivity may be said to be Economics’ phlogiston.

[II] Litmus tests for such capability have all failed, page 65-66 and page 99.

The Direct Economic Measurement of Innovation: Eight Steps in Commercial Knowledge[III]

Each **Step** uses otherwise neglected data, or interprets such data, to illustrate increasingly complex commercial activity that puts innovation into Economics. Its direct economic measurement becomes a talisman linking growth to original factors that are arranged with utmost simplicity to provide new possibilities for economic enhancement, including Going Beyond GDP.

[III] 'Over the longer term I would like to see economics researchers begin to incorporate more from the non-economics community', Griliches (1999).

Step 1 – Economic Growth Has Distinct Commercial Origins

In the late 1980s Innovation Practitioners thought measuring innovation might be solved by Richard Foster's pioneering work at McKinsey on functional, or engineering performance, S-curves. Together with other pioneering work, this time by Fisher-Pry at General Electric, whose market penetration S-Curves were finding success in technology forecasting, it seemed that economic growth would become explainable from product succession alone. However, this was not realized because each S-curve treatment used completely different variables and existing literature, then as now, could not provide an economic link between them. To overcome this, the following commercial and economic knowledge is brought together. It delivers a foundational equation that opens the door on the economics of industrial technology and productivity. The obvious is algebraically confirmed. Innovation drives growth in the American Economy.

Starting from S-Curves

An S-Curve describes economically driven growth, rapid at first, but necessarily slowing down as it approaches a temporal barrier, or permanent upper limit.

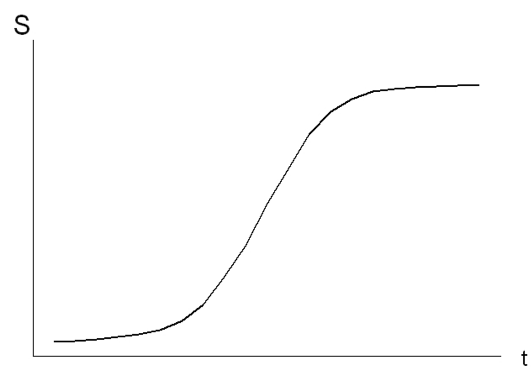


Figure 1 – Classic S-Curve

It's logical for growth to start fast and slow down[1], so many commodities fit this stretched S shape[2]. When a particular and deceptively simple commodity, such as tire cord, is examined in great detail, new economics can emerge from it.

Applied to Tire Cords

Motorists are generally unaware that the quality of their ride is highly dependent on reinforcements hidden in their vehicle's tires. Tire remnants shed by trucks are a common sight on the interstate highway system. Their carcasses usually have ribs sticking out. These are tire cords. Their S-curves can be studied because the Goodyear Tire & Rubber Company has data available over decades.

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[1] Its mathematical form is given by $S_t = S_\infty / (1+\exp(a-bt))$ where S_t is the value in year t while S_∞ is the value at the upper barrier or limit and a and b are constants.
[2] The International Institute for Applied Systems Analysis, IIASA, identified and collected hundreds.

For Understanding their Performance

In 1980 and in preparation for Richard Foster's seminal book Innovation, Foster (1986), Donald Merino, then Director of New Business Development at Celanese Corporation used Goodyear and Celanese data to construct graphs to Foster's request, Merino (1990). A version of these is presented in figure 2.

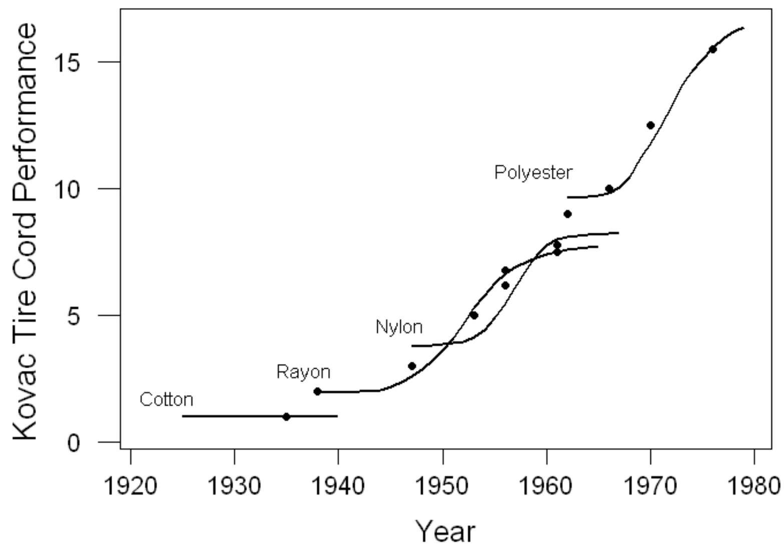

Figure 2 – S-Curves capture a rising engineering performance for tire cords

The most important factors determining tire cord performance are, in Merino's order, fiber tenacity[3] then fiber strength. But F.J. Kovac[4] of Goodyear differs by ranking 'resistance to bruise breaks' first, and 'uniformity/ flatspotting/ride comfort' second. Kovac's tire based definition prevails for figure 2.

Henry Ford's Model-T tires were reinforced with cotton fabric and there wasn't much that could improve it. For Rayon it was a different matter. Wood pulp dissolved into a thick liquid (called viscose) and spun into solid fibers provided plenty of scope in both chemistry and engineering to make 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 on a classic S-curve development path. Decades after the Model-T the tires on Ford's Taurus benefited from polyester's truly superior limit far above what the earlier fibers could achieve. And today's tires combine steel wire with polyester producing the ribbed carcasses seen on highways.

[3] Tenacity is a fiber term roughly translating as stiffness that's used for economic comparisons between cords, Skolnik (1972).
[4] F.J. Kovac wrote to Farrell in 1994 with his recollection of Goodyear research done c1969.

Tire cords provide an excellent source for developing an innovation metric, not least because their product performance evolves.

Over Generations

Annual data on tire cord production from the Goodyear Tire & Rubber Company is displayed in figure 3 for cotton, rayon and nylon.

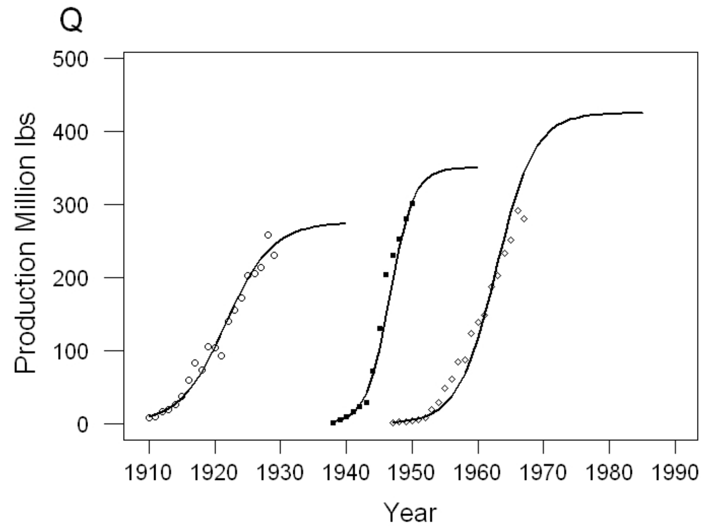

Figure 3 – Cotton, Rayon and Nylon each show early promise

Classic logistic growth curves fit early periods, for cotton from 1910 to 1929, for rayon from 1938 to 1950 and for nylon 1947 to 1967. But this orderly sympathy with the performances offered in figure 2 does not continue.

There is a more disruptive story, a succession, in which cotton, then rayon, then nylon, peak and decline, figure 4. Polyester and wire eventually win.

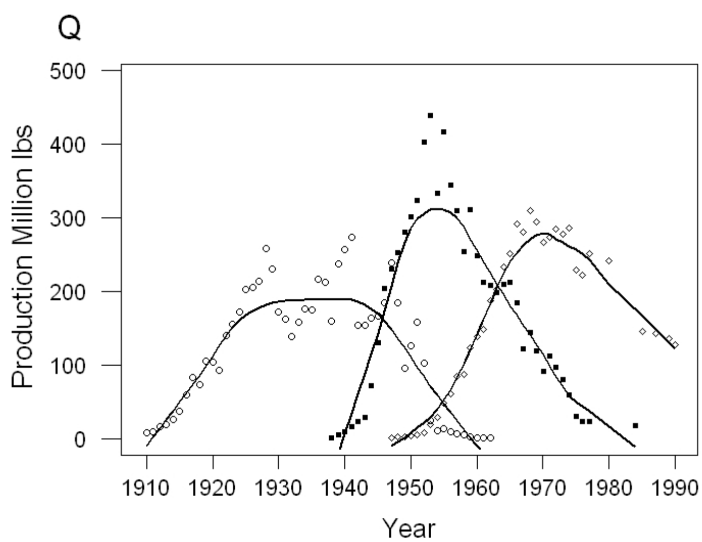

Figure 4 – Cotton, Rayon and Nylon succumb in turn to superior performance

Tire cord is evolving[5] by the process of creative destruction, Schumpeter (1942).

Over Product Life Cycles

Predicting the actual contour of the generally bell-shaped product life cycle, like those of the tire cords seen above, captured commercial interest in the 1960s. Academic research proposals had argued that, if a universal form could be discovered, some predictability relating to economic growth might ensue, Rink & Swan (1979). But the effort faded away after a critical summary by Dhalla & Yuspeh (1976). The principal impediment was lack of data beyond a single decade (but DINTEC™ has lifted that constraint, Appendix E, p84).

Meanwhile General Electric's Fisher & Pry (1970, 1971) had already proposed a substitution model to explain - if not a bell shape, then at least a rise and fall. Their simple idea applied to tire cords is that one pound of nylon substitutes for one pound of rayon so the upward S-curve for nylon, in a fixed market, exactly matches the downward one for rayon. Its straightforward mathematics is elegant[6] and became *de facto* for technology forecasting in the late 1970s and 1980s.

A Fisher & Pry symmetric pair fit for nylon versus rayon is shown in figure 5. But it accounts only for the descending portion of rayon's bell-shape. An extra and separate logistic is required to fit rayon's ascent leaving a disjoint at the top of the bell.

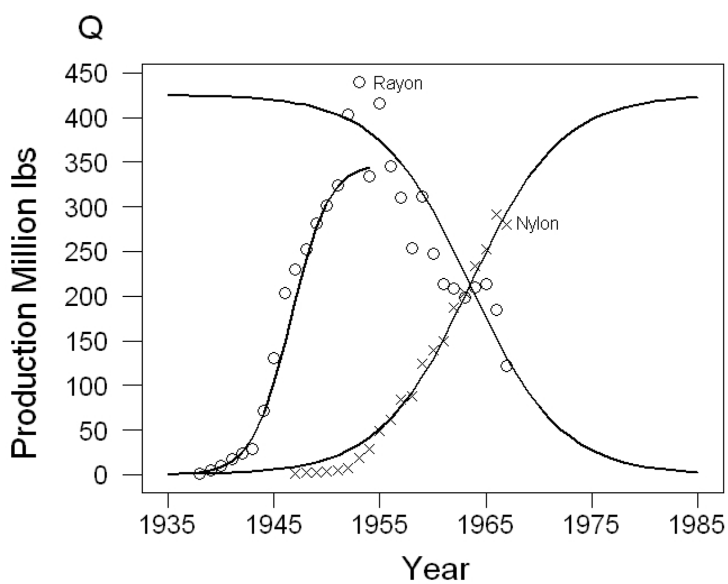

Figure 5 – A Fisher-Pry symmetric pair cannot account for Rayon's bell shape

[5] Evolution has featured in Economics before, Nelson & Winter (1982), but for firms. Unfortunately for that approach the firm has very little correspondence in nature. Products do.

[6] Stemming from fractional substitution. If f is the fraction of the market substituted at time t then f/(1-f) = exp(bt-a). So a plot of loge(f/(1-f)) against t has a as intercept and b as slope. Extrapolating the line forecasts future f.

That's an obvious limitation of the Fisher & Pry method, as is the presumption of pound for pound parity and therefore of substitution of rayon by nylon, which appears to deny a role for performance advancement.

Because some are better

Nylon reinforced tires develop flat spots overnight in very cold weather. When polyester came along its marketing focused on this weakness, something northern consumers had actually adapted to. So the Kovac performance definition used for figure 2 should not be applied before the arrival of polyester[7]. Instead the performance as marketed for nylon should be applied.

And nylon strength tells a different story. According to Skolnik (1972) and presented in figure 6, with ratios in Table 1, its fibers were far stronger than rayon.

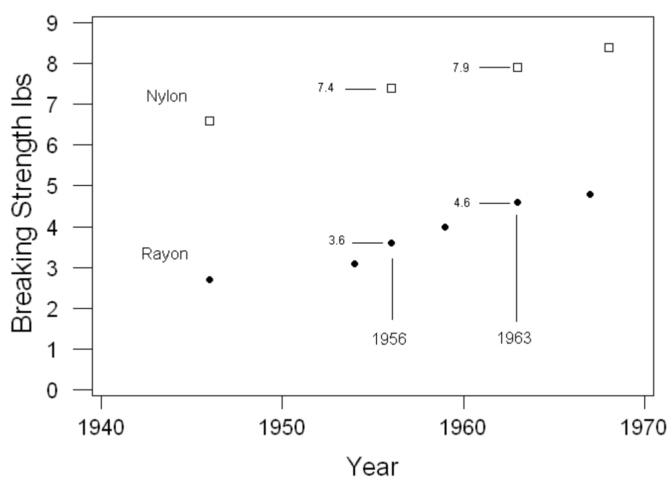

Figure 6 – Tire cord strength development

Table 1 – Strength Ratio Nylon/Rayon

1956	2.1
1963	1.7

Sears evidence supports this. In its Spring 1970 catalog it exclaims *'World's Fair Hell Drivers Choose nylon Guardsman ALLSTATE Tires for second straight year', 'fully 10% stronger'*.

Clearly fiber strength was winning sales for tires. And this needs to be taken into account by any modeling.

[7] Polyester excelled in radials. In 1970 these had penetrated 5% of the new car tire market, 36% by 1975.

Like in Nature, and in Pond Life

The Fisher & Pry model can neither match an integrated shape to growth and demise, nor account for the effect of performance advantage.

But because a fight for survival, like that between nylon and rayon for use in tires, is played out everywhere in nature ecology offers an outstanding alternative metaphor.

In pond water Protozoa compete for the same food source – bacteria. Such competitions have been studied in laboratory conditions, an option not available for manufactured goods such as tire cords.

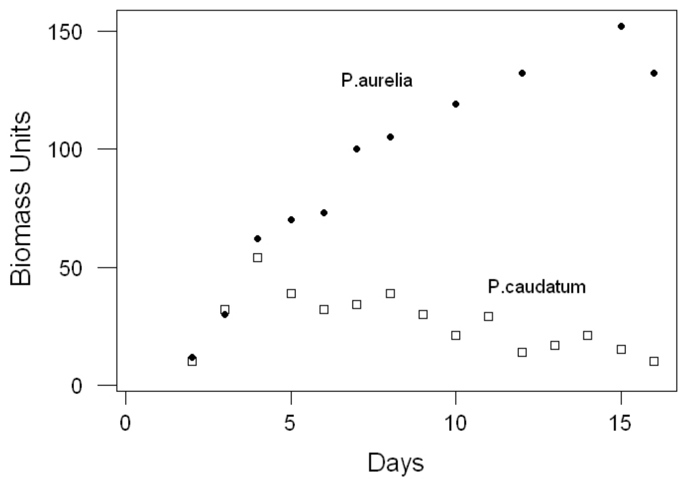

Figure 7 – The fight for bacterial food between two Paramecia in test tubes

Figure 7 shows the result of setting two species of unicellular Paramecia into simultaneous competition for a fixed bacterial food source in laboratory test tubes, Gause (1964). Protozoa seek bacteria like goods seek money so the graphical trajectories for nylon and rayon are indeed reflected by those of P. Aurelia and P. Caudatum despite their simultaneous laboratory start[8].

In explanation Gause used two logistic equations each one modified by a variable from the other and each requiring a multiplier[9].

Commerce is simpler. When a defender is unaware of the attack, as is usual, only the defender's logistic equation is modified by a variable originating from the attacker. The multiplier of this variable can be interpreted as an absolute performance advantage A that is 'cardinal' in economic parlance.

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[8] Experiments in which P. Caudatum (rayon) is allowed to thrive before P. Aurelia (nylon) is introduced have not been conducted as far as is known.

[9] This model originated with Lotka and Volterra for predators preying but was developed by G.F. Gause for competitors competing, Kingsland (1985) who suggested it be called the Volterra-Gause model instead.

Applied to tire cords, using the same equations as Gause, delivers figure 8, Farrell (1993),

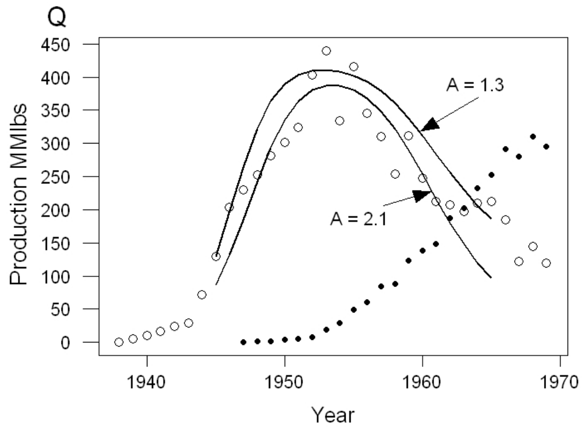


Figure 8 - The greater advantage A, the faster the demise of Rayon in the face of Nylon

As the attack parameter A increases rayon's bell shape tightens; it is further suppressed.

Gause's equations originated from two physicists A.J.Lotka and V.Volterra who derived them by separate argument. In particular Vito Volterra likened individual organisms to molecules governed by the kinetic theory of gases. But the experimental use of test tubes by Gause leads the mind to the gas laws[10] and to a macro analogy in which the paramecia exert a combined overall pressure. In commerce that competitive pressure[11] should be expressible as total competing quantity ΣQ[12].

(mathematical symbols Σ and $\propto$ are explained in the Glossary on p89)

Leading to a New Equation

When other factors are fixed the price of a commodity, such as tire cord, should increase in direct proportion to its performance, p, so we can write

$$P \propto p$$

[10] In the gas laws the pressure exerted by an ideal one is $p = RT/V$, where V is its volume, T its absolute temperature. R is a universal constant. For a particular gas $p = mR'T/V$, where R' is specific to the gas and m is its mass. So pressure is directly proportional to mass, or quantity of gas.

[11] Competitive pressure is a new concept that neither depends on firms, whose products are more fundamental than they are (evidenced, for example, by trademarks surviving mergers and acquisitions), nor on industry structure, whether monopoly or oligopoly, nor on factors perfect or imperfect within them. In any case perfect or imperfect are inadequate to describe competition as experienced by Innovation Professionals. Pressure, ruthless pressure, is far closer to actuality.

[12] In manufacturing the quantity produced is normally a little greater than the projected demand. This builds up inventory so that supply from production plus inventory from warehouses can always meet demand. Therefore competitive pressure ΣQ is the mixture of production and inventory that satisfies domestic consumption; in other words it is 'satisfied demand'. In Economics Q is normally expressed by division of value by a price index. But quantity is an independent variable throughout this exposition.

Another factor is competitive pressure. If performance[13] remains fixed price should decrease as competitive pressure increases most simply[14] expressed by,

$$P \propto 1/\sum Q$$

Combining proportionalities we obtain,

$$P \propto p/\sum Q$$

or

$$p \propto P \sum Q$$

If A connects Q and p then it could be the proportionality constant,

$$p = A\,P \sum Q$$

But it seems more likely, given the way the Lotka-Volterra model works in commerce (only the defender's logistic equation needs modification) that p of the attacker provides enough force by itself[15]. This can be incorporated by setting parameter A equal to one by definition so that

$$p = P \sum Q$$

Performance p can now be calculated from real price P and competitive pressure ΣQ using this simple equation. It can be verified[16] and clarified by calculating performance, for tire cords, and for other items of commerce[17] to see if it matches, or even goes beyond, their independently determined values.

[13] Known to economists as 'quality' or 'how good it is'. But quality has a different meaning in the innovation profession, Crosby (1986). This requires explanation. In manufacturing, quality is a condition of zero defects. A manufacture or service could therefore have very high commercial quality with attributes seen as 'not very good' to an economist. The pre-Crosby meaning of 'quality' in Economics is preserved throughout this exposition. Economists should be aware that their use of the term 'quality' might elicit puzzlement from innovation practitioners; the term performance will overcome it.

[14] Other ways to achieve this might be, for example, by multiplying by (K-ΣQ), where K is a constant >ΣQ, but Occam's Razor eliminates it for having more than the least assumptions.

[15] A stream of research since the 1970s supports this, Cooper & Kleinschmidt (1990). Of eight key factors underlying success, the first is 'a superior product that delivers unique benefits to the user'. In Foster's language this clearly corresponds to an 'Attackers Advantage'.

[16] Using regression analysis to find equations from data is standard economics. But it is more powerful to use argument to find the equation and preserve the data for its verification. This physics approach has a long history of producing fundamentals, and is adopted here.

[17] Converting nominal to real price by applying the Producer Price Index for all commodities WPU0000000 1967 base year or the Consumer Price Index CPI-U for all items, as appropriate.

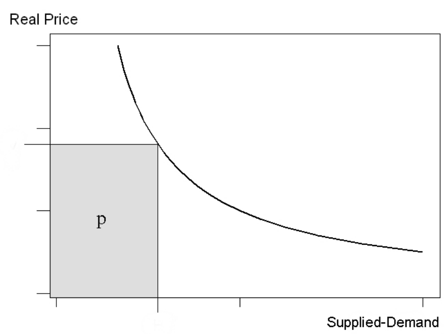
$$p = P\ \text{Sum} : Q$$

Where p is performance perceived by a purchaser at the time of purchase. P is the real price paid. Q is physical quantity whose sum across the market constitutes competitive pressure.

This previously unknown equation will be referred to as pPQ and verified – in **Step 2** - by testing its authenticity in a wide range of commercial situations where performance is either known or can be judged.

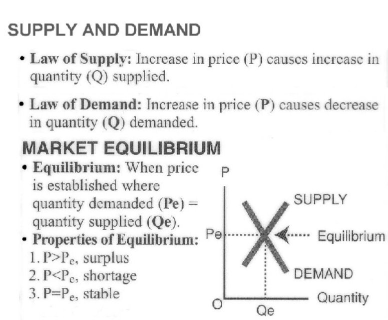
The Overlooked Connection Between Quality and a Specific Demand Curve

A plot of **P** against **Sum: Q** is a demand curve. This means that performance (or quality) is equal to the area of a rectangle whose top right hand corner touches a 'supplied demand' curve at the point of interest.



These supplied demand curves happen to have an elasticity of –1 at constant quality. In reality there exists a nest of them through which a price point moves while charting a state of dis-equilibrium due to 'quality change'. Real world commercial examples are provided for the 100W light bulb and for nails, on page 98.

This solution for 'quality change' has been hiding in plain sight for decades.



The above treatment should not be confused with price determination from crossover points between supply and demand curves. The didactic case, shown on the left for market equilibrium, is from a student quick reference guide.

In practice, quality change creates non-equilibrium conditions in markets that are – at best – stabilized by inventory control. Nothing about innovation or creative destruction is about equilibrium. Instead it needs the enumeration of 'quality' that is delivered by the single plot of P against Sum:Q (above).

Step 2 – Verifying the pPQ Equation

1. Can pPQ explain the known Performances of Tire Cords?

To apply pPQ to tire cords requires data on prices[18], adjusted for inflation (using the producer price index[19]), and the total quantity supplied to the domestic market each year. List prices are available from an industry newsletter Textile Organon though not for all fibers and not for all years. Figure 9 presents what is available.

The data for rayon follow an upward S-curve. The data for nylon show decline and recovery. Polyester's decline may indicate high early market acceptance. But with so few points the R,N,P data is just averaged between 1954 and 1969 as shown.

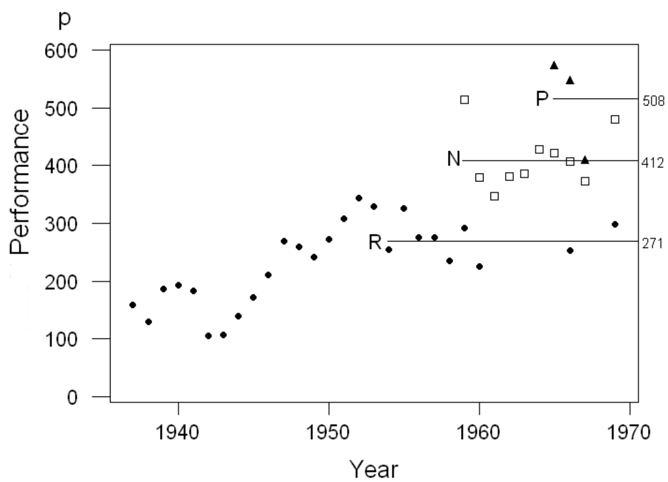


Figure 9 – Tire Cord Performance calculated from pPQ

Table 2 – Average performance of cords between 1954 and 1969

Rayon	271
Nylon	412
Polyester	508

[18] Shipment prices are used. This is valid where exports are small or export prices are parity.
[19] Performances are expressed in millions of 1967 constant dollars unless otherwise stated.

Ratios calculated from Table 2 can be compared with engineering ones from the three sources, Kovac (1978), Merino (1990) and Skolnik (1972) in Tables 3 and 4.

Table 3 - Performance Ratios Nylon/Rayon

	Kovac	Skolnik	pPQ
1954-69			1.5
1956	0.9	2.1	
1961	1.04		
1963		1.7	

Table 4 - Performance Ratios Polyester/Nylon

	Kovac	Merino	pPQ
1965-67			1.2
1966/1962	1.1		
1970/1966		1.25	

Skolnik's values are for tensile strength while Kovac's and Merino's are more complex as they put nylon at a secondary disadvantage due to flatspotting. The pPQ (which uses only economic data) gives an average value in the far right columns that lies satisfactorily between.

2. Can the pPQ extend from Tire Cords to Tires?

Cords are an intermediate good sold to tire manufacturers. Tire data is available from the Census of Manufactures under SIC3011 111, Passenger Car and Motorcycle Pneumatic Tires, from which it hasn't proven possible to separate cars. Fortunately motorcycles represent less than 10% of the market. An enumeration of performance of both OEM (new car) tires and replacements, using the pPQ, is presented in figure 10,

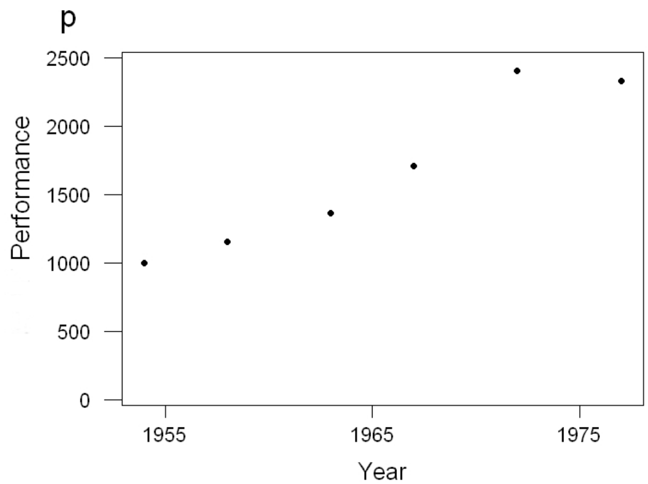


Figure 10 – Performance of tires incorporating mixed generations of tire cords

Table 5 – Tire Performance

1954	1000
1967	1700

After adjusting for generations (in 1954 rayon dominated tire cord usage but by 1967 nylon had reversed that) the overall cord improvement ratio from the pPQ is 1.4 whereas the improvement ratio for tires from Table 5 is larger at 1.7. An evolution to higher performing tubeless tires was occurring in this period.

Also noting the absolute pPQ performance of tires naturally exceeds their cord constituents (by a factor of ~ 4).

3. Can pPQ reproduce known Performances of Cement?

Cement also has a commercial history describable by simple measurement.

Table 6 – Performance of Cement

1954	888
1994	1628
2004	2449

Table 7 - Performance ratios from the PCA compared against pPQ
(pPQ ratios calculated from Table 6)

	PCA	pPQ
1994/1954	1.8-2.2	1.8
2004/1954	2.1-2.6	2.8
2004/1994	1-1.4	1.5

The Portland Cement Association in Chicago has been serving its industry members since 1916. Although it may seem a never changing gray powder to some, cement properties have improved very significantly over time and the Portland Cement Association has measured them using the same methods in 1954, 1994 and again in 2004. The primary use of cement is in concrete, which hardens slowly after molding. A set point, for a given composition, is the time to reach a certain % of potential strength after 28 days (78% in this case) and is shown in a series of graphs published by the Portland Cement Association PCA (1996) and Bhatty & Tennis (2008). This offers another opportunity to test the pPQ.

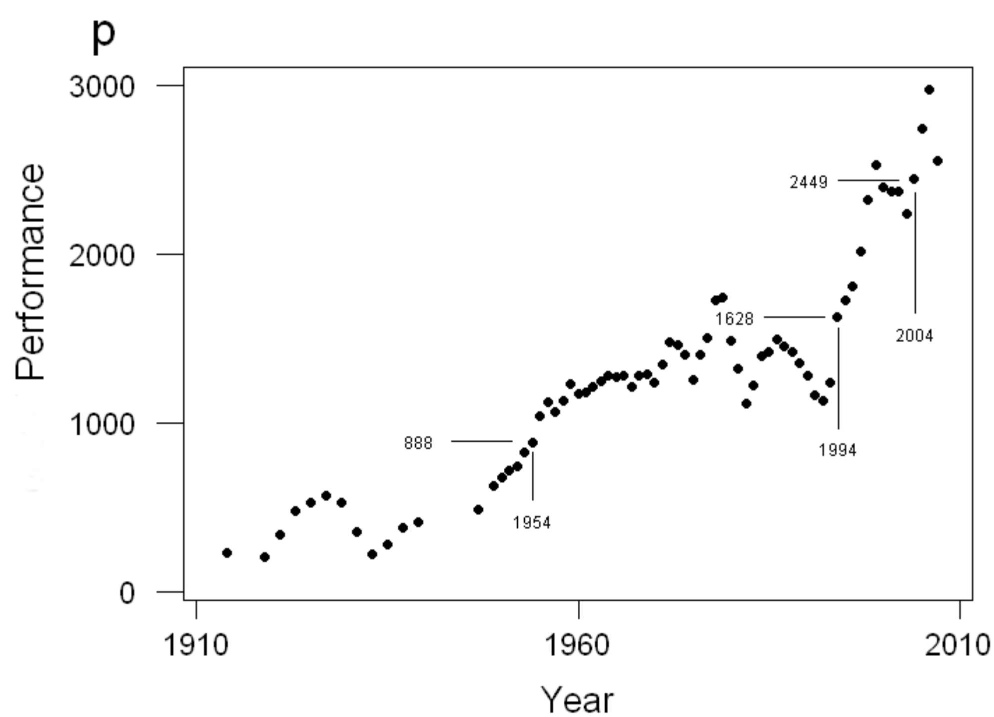


Figure 11 – Performance of Portland Cement

For cement competitive pressure is not only applied by cement itself but also, since the 1990s, by coal ash (itself cementitious) Over decades, the pPQ produces the jagged but rising performance shown in figure 11. Numbers for 1954, 1994 and 2004 are extracted to Table 6.

And from the comparison in Table 7 pPQ may be measuring a higher performance than PCA from 1994 onward. As coal ash F-grade tends to delay set, the perceived performance of cement in countering this would be increased. This is the first evidence, albeit slight, that the pPQ might be measuring something other than strict engineering. Consideration of concrete will endorse this.

4. There are special Cements. Can pPQ explain their Performance?

Cement is graded into five types. Type I dominates with >70% of the market. Though the aggregate performance of all five has been calculated so far it's worth singling out Type III, which is specially formulated to develop high early strength.

Since Type III is exposed to the same competitive pressure as other types pPQ performance is governed by Type prices. These can be found by dividing value by quantity from Census of Manufactures SIC 32410 12 for Type I and SIC 32410 14 for Type III, in Table 8,

Table 8 - Cement Type Prices, current$/short ton

	Price Type I	Price Type III
1982	48.8	52.9
1987	47.7	52.8
1992	48.8	54.0
1997	66.4	71.7
2002	67.9	71.2

Applying pPQ, Type III's price - and therefore performance - is no more than 10% greater than Type I. But PCA tests in the 1990s show that the time taken to reach 4000psi strength was halved if Type III was used in preference to Type I. And this requires explanation.

Type III is used primarily for casting pipes, tiles, posts, boxes and the like, in standard molds. Its shorter set allows quicker mold re-use but is balanced against employing more molds to increase the overall output. In contrast, Type I is for construction where molds, or forms, are unique and custom constructed for the job on site. While a shorter set time is also preferable for Type I it's generally not necessary to pay 10% more for it. Therefore the pPQ interpretation stands.

5. Can pPQ accommodate the use of Cement in Concrete?

Prior to the late 1950s laborers used rotary on-site batch mixers to make concrete. The ready mix truck changed that and created a whole new industry. The pPQ can calculate the performance of ready-mix concrete. Cement and concrete are very heavy so, in this case, there is geography of competitive pressure. But for pPQ they are presumed localized together. Data from the Annual Survey of Manufactures, for industry SIC3273, is shown in figure 12.

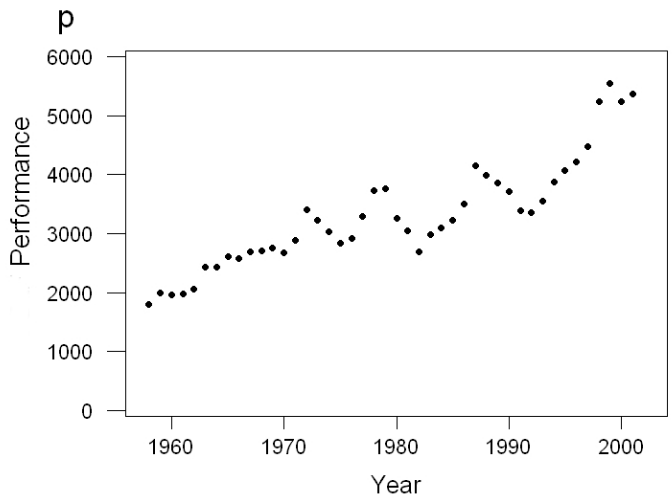


Figure 12 – Performance of Ready-Mix Concrete

As might be anticipated the absolute performance for concrete is far greater than for cement, just as tires perform better than cords, and just as any final product should when compared to an intermediate component.

And on closer inspection figure 12's data has two segments. The first starts from 1958 and extends to 1990. But from about 1990 the data rises faster. The same appears to happen in figure 11 for cement. According to the PCA, Collins (2004),

> *'the performance of Portland has been enhanced with advances in additional materials that are added to concrete mixtures like mineral admixtures (fly ash, slag, silica fume, and natural pozzolans) and chemical admixtures (retarders, accelerators, water reducers, etc). Portland cement is a great material that can be made better with the addition of other materials in a concrete mixture'.*

In other words the performance of concrete enhances the perception of cement, an influence possibly captured by the pPQ when it outstrips PCA slightly in Table 7.

Tire cords and cement both show significant performance improvement over decades. But it would also be good to find a commodity whose engineering performance did not change and see if pPQ agrees. Incandescent light bulbs present just such a challenge.

6. Can pPQ explain the known Performance of Light Bulbs?

Lack of improvement in light bulb efficiency has been investigated several times by governments resulting in some disclosures on engineering performance. In particular from a Federal Trade Commission report, Rogers (1980), we find that

> *'For a standard 100-watt lamp, the efficiency has increased from 16.3 lumens per watt in 1947 to 17.1 lumens per watt in 1976'.*

This amounts to a measly 5% in 30 years and is perfect for our purpose. The performance, using prices extracted from Sears catalogs for an inside frosted 100-watt bulb, under competitive pressure from all bulbs 15 to 150 watts to occupy the same fitting, is calculated from pPQ and featured in fig 13.

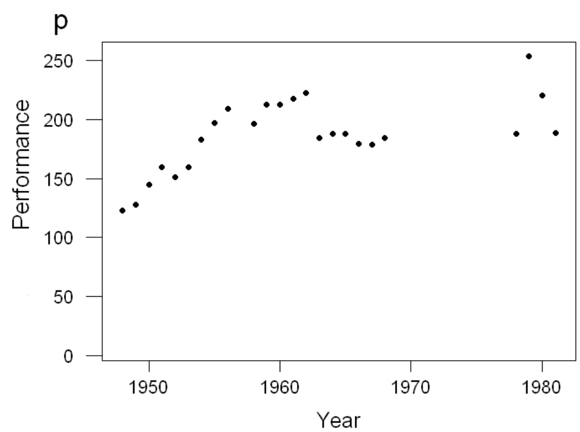


Figure 13 – Performance of Sears inside frosted 100W light bulb

Far from flat lining as expected from Rogers (1980) an upward S-curve is very prominent. And between the first point in 1948 and the average value of the last four points 1978-81 pPQ shows a 70% improvement!

Going back to Rogers (1980) we find the efficiency numbers come from the General Electric Company and are said to be standard, most likely their best, and equipped with coiled-coil filaments, for which there was indeed little improvement from introduction.

Coiled-coil means a double helix. Unlike DNA (in which two helices wrap around the same axis but are displaced from each other along that axis) this double helix is a helix wrapped on an axis that is itself a helix, a description showing the extreme difficulty of making them commercially. GE would have wanted to keep that to itself.

Sears sold Westinghouse's bulbs - not GE's - and even as licensee Westinghouse would not be selling GE's leading edge. This is somewhat given away by Sears in 1940 when they extol Westinghouse's improved 'non-sag filaments'. This refers to GE's Pacz Patent 1,410,499 issued in 1922 and a generation behind the coiled-coil.

In selling Westinghouse bulbs Sears lagged behind GE's leading edge according to pPQ. This would have been of interest for the Federal Trade Commission to explore had such analysis been available in 1980.

For components such as tire cords cement and light bulbs it's relatively simple to assign measurable attributes. For final consumer goods that's not so easy. Televisions provide a suitable example.

7. Does the pPQ capture Television's Wow factor?

The television set is a home entertainment product. Such consumer goods carry intangibles that can't be specified in engineering terms, that's advertising's province.

But applying pPQ produces an extraordinary outcome, figure 14.

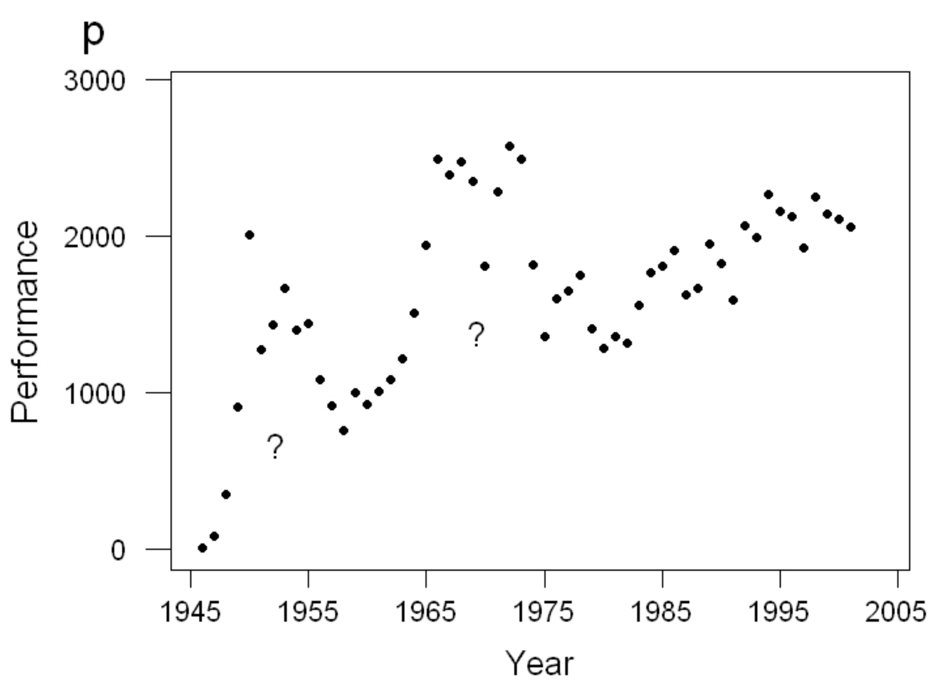


Figure 14 – Performance of all Televisions

An S-curve is clearly inadequate to describe performance of television, which is dominated by two massive surges.

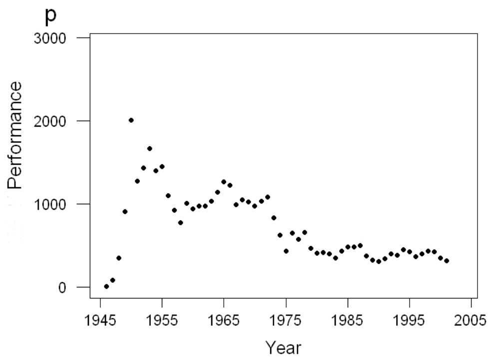


Figure 15 – Performance of B&W Television

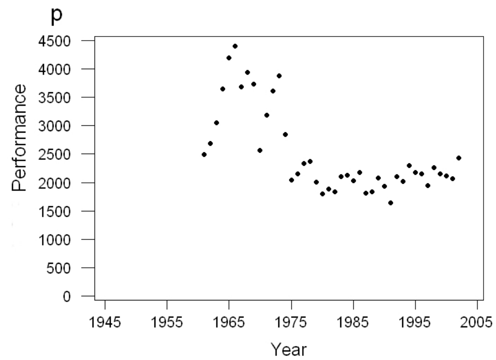


Figure 16 – Performance of Color Television

But when Black & White and Color televisions are treated separately, in figures 15 and 16, each is responsible for one of the surges in figure 14.

The story of television is often told, of inventors and corporate R&D. But what is usually forgotten is Madison Avenue[20]. Advertising was spectacularly successful at the introduction of television. At the beginning of Black & White early adopters invited excited friends and neighbors to view it in their home. Shops with a television in their window attracted an outside crowd. The wow factor was huge. And the wow was repeated when color was introduced. For consumer products pPQ is capturing a purchaser's perception of performance - not just engineering factors.

It does this using the two variables, competitive pressure and price, shown separately for televisions in figure 17.

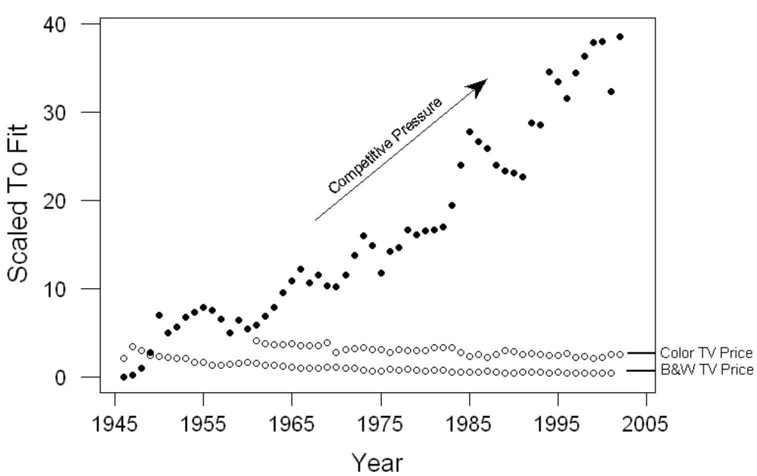


Figure 17 – Components of the television's pPQ

An upward surge in competitive pressure ΣQ in the mid-1950s and the mid-1960s can explain the performance surges, while price generally decreases monotonically. Popularity evidenced by increased quantity sold is very consistent with wow (let's get one) being the underlying factor.

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[20] Noting that most advertising revenue is spent to promote the market share of a particular brand.

This challenge shows pPQ is sensitive to, and can enumerate, the enthusiasm that often accompanies the introductory phase of brand new technology.

8. Does pPQ agree with Economics' Television Price Index?

Televisions have attracted attention in Economics for their price index. When a market basket of televisions is compared year to year it's necessary for those televisions to be the same so that the component of price change due to changes in the purchasing power of the dollar can be isolated. Because televisions are changing rapidly this provides a challenge. Fortunately certain televisions may not change substantially year to year. By identifying them a step-by-step constant quality index can be constructed.

However this is much easier using pPQ because if p is held constant then,

$$P \propto \frac{CPI}{\sum Q}$$

where CPI is the consumer price index for all items. And there is pretty good agreement with the 'matched-pair' index offered from an analysis of Consumer Reports data by Gordon (1990)[21] when anchored to a base year (1967 in this case).

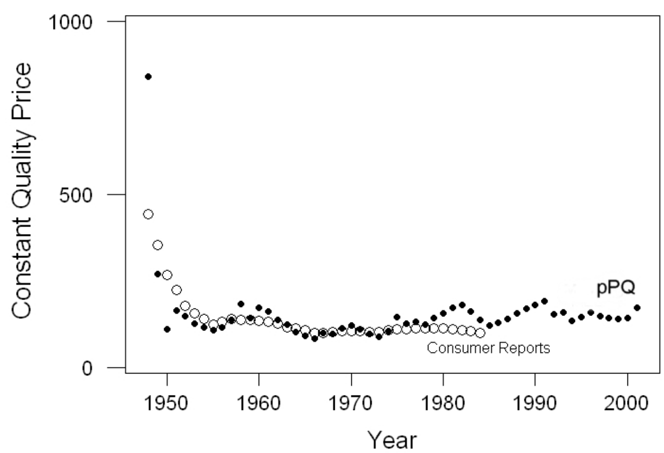

Figure 18 – Constant Quality Prices for Televisions by two methods

Although the 'matched pair' method is capable of effectively freezing quality at a base year it cannot track change. Only the pPQ can do that.

9. Does pPQ register Yuppie taste for luxury goods like Fountain Pens?

Of the three technologies for writing ink to paper the oldest is capillary action to a nib in a quill or fountain pen. The others convey ink by roller - in a ballpoint pen, or by pores in a marker. All have competed with each other in the second half of the twentieth century. Their pPQ performances can be compared, figure 19.

[21] The agreement is lessened after about 1978 for Gordon's energy and repair cost inclusion index.

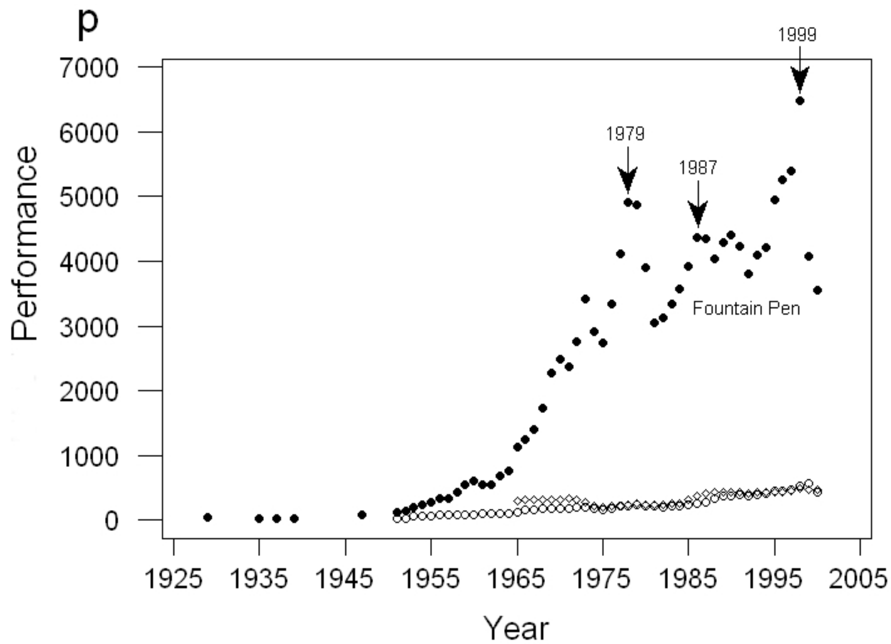

Figure 19 – Performance by Technology; capillary (solid), ball (circle), porous (diamond)

The fountain pen's upward trajectory stands out. Rapid performance improvement occurs from 1950 - peaking in 1979 - only to collapse and then rise to greatest height in 1999 - only to collapse again, while ballpoint and porous point pen performances show steady growth. With no known 'wows' what can explain it?

According to the Los Angeles Times, Hillinger (1986), quoting Fred Krinke of the Fountain Pen Shop,

> *'You would be surprised at the growing number of businessmen, doctors and attorneys using expensive fountain pens instead of ballpoint pens'*

A full-page advertisement in Pen World provides a vital clue, Waterman (1989). Its header shows a 30-something man dressed for success in establishment surroundings. He is leaning on pile of leather bound books while an oil painting hangs on the wall behind him. Five lines describe his biography.

> *'I was born the second son. I graduated second in my law school class. And finished second in the Cannes-Marrakesh Rally (twice). Recently, however, I acquired a Waterman. How delightful to feel first, at last'*.

He embodies the classic Young Urban Professional (Yuppie) stereotype first commented on in 1980 but existing prior. To enhance the perception of their very expensive pens makers exploited this. But vanity is easily abandoned and the dip in pen performance enumerated by pPQ in 1980 corresponds to recessions, one from January to July 1980 (-2.2% GDP) and the other from July 1981 to November 1982 (-2.7% GDP).

Even the Black Monday stock market collapse of 1987 may be reflected in pPQ's fountain pen performance.

Yet the 1990s were a time of economic boom and the pen, particularly the Mont Blanc, became an overt emblem of executive spending authority; only to collapse in 1999.

Separating pPQ's variables provides further insight, figure 20.

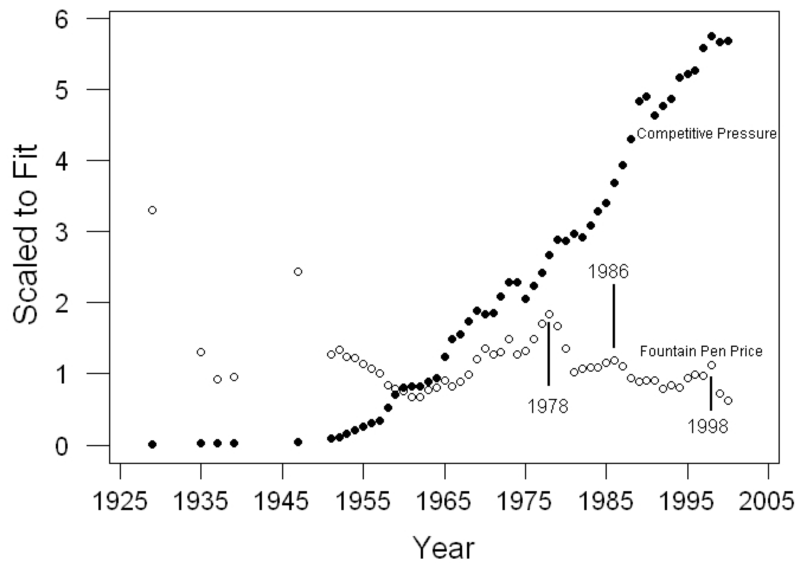

Figure 20 – Components of the Fountain Pen's pPQ

The collapses of 1980 and 1999 have a similar cause, a decrease in average pen price, most likely due to the most expensive pen category in each case. What probably made 1999 different from 1980 was not economic (the next event was the dot com crash of 2000) but executive concern surrounding Y2K, or the millennium bug[22].

Yuppie vanity and executive concern are sociological factors. Their invocation to understand fluctuations in **p** for pens is a powerful reminder that **p** is measuring far more than engineering specification. It is clearly going beyond price to what is actually valued. This makes **p** suitable for Going Beyond GDP to values, as expanded upon on page 92.

10. Does pPQ agree with Economics' Automobile Price Index?

For televisions closely matched pairs provided a way to track price without quality change. For automobiles, as pioneered in 1961 by Zvi Griliches, hedonic methods provide another means[23]. Resulting constant quality price indexes are compared with pPQ's in the following two figures.

[22] Time Magazine's cover story in January 1999 was placarded by 'The End of the World, Y2K insanity! Will computers melt down? Will society? A guide to Millennium Madness'

[23] The hedonic method connects product prices, P_t, for a given year with their quality attributes a_{jt} in an equation of typical form $\log P_t = \alpha a_{1t} + \beta a_{2t} + \ldots \omega a_{nt}$ where multipliers α, β … ω are determined by →

Firstly, in figure 21, the constant quality index of Griliches (1971) is presented on the same axes as the pPQ price for constant automobile performance. His hedonic index agrees with pPQ's over a short range 1953 to 1961.

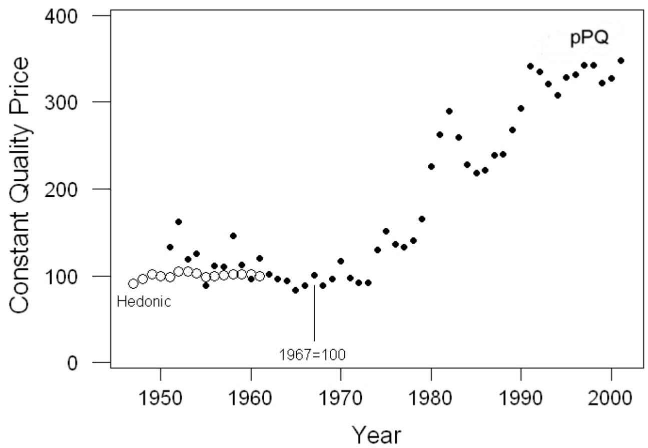

Figure 21 – Constant Quality Prices for Automobiles using Hedonic and pPQ methods

Secondly, in figure 22, the hedonic index prepared by Gordon (1990) is compared with pPQ's for data up to 1983. The agreement is good from 1955.

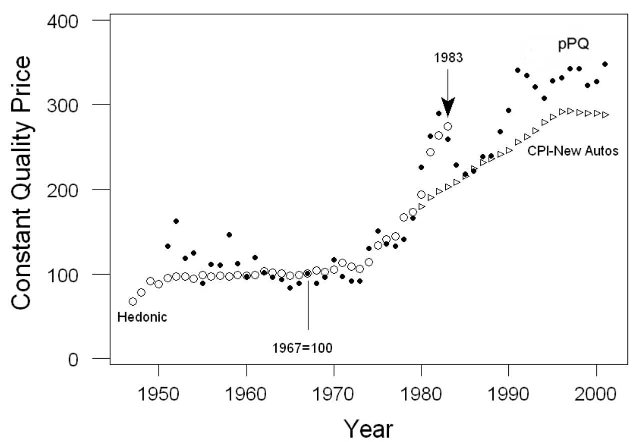

Figure 22 – Constant Quality Prices for Automobiles using Hedonic, pPQ and CPI

But the pPQ disagrees with the quality adjusted CPI for new autos from 1981. Auto CPI appears to over-adjust for quality change. Quality adjustment made on attributes that are perceived transparently by purchasers, such as ones made compulsory by regulation, may explain the difference[24].

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regression of the prices against attribute values. Once the equation is established the attributes can be reverted to find a price differential not due to quality change. A systemic weakness of hedonic analysis is that consumers don't purchase $a_1,a_2 \dots a_n$. They buy on perception that may diverge from what $a_1,a_2 \dots a_n$ is capable of specifying.

[24]The pPQ doesn't employ an attribute list to characterize quality. It is sensitive to all factors considered by purchasers without having to identify them in detail.

By their nature constant quality price indexes cannot enumerate actual quality or actual performance. The pPQ can, as already demonstrated for televisions, and next for automobiles in figure 23.

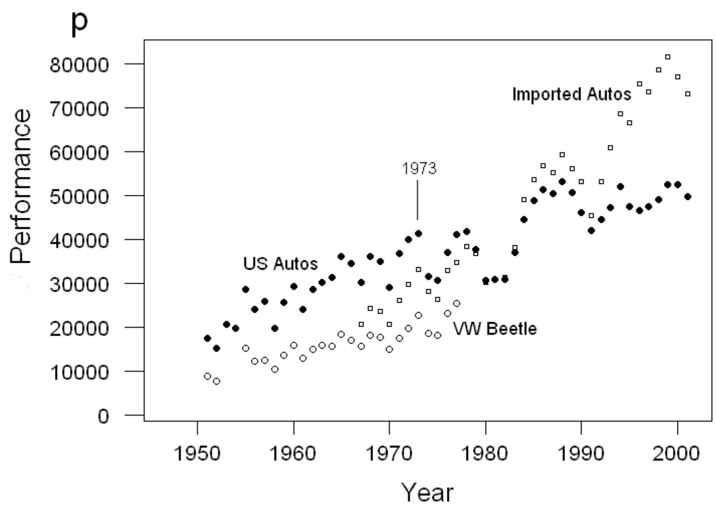


Figure 23 - Performance of Domestic and Imported Autos

pPQ performance of US produced automobiles rises until the 1973 OPEC oil crisis. Although consumer perception recovered from the shock and growth continued, imported cars, starting with the VW Beetle introduced in 1949, recovered better and then overtook the perceived performance of US produced by the mid -1980s.

11. Does pPQ's performance fit an icon, like Volkswagen's Beetle?

The VW Beetle was studied because it's an icon with performance not expected to change much.

But according to the pPQ its performance rose from 8,900 in 1951 to 25,400 in 1977, an almost 300% increase, figure 24. This requires exploration.

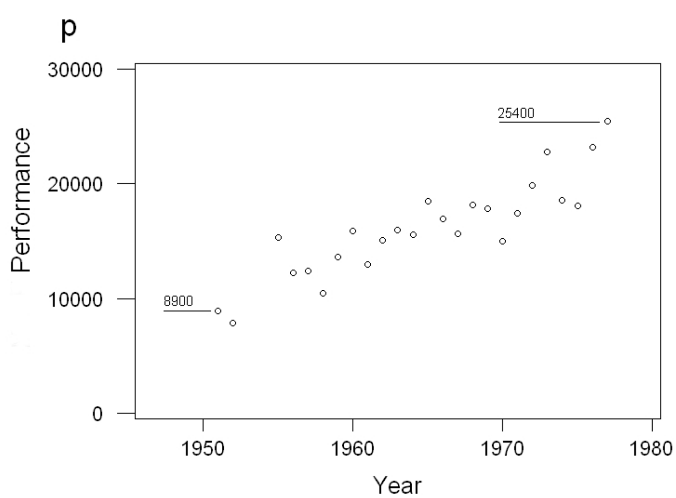


Figure 24 – Performance of the iconic VW Beetle

To restore old cars to their original condition Beetle enthusiasts need a list of all the changes by model year. This is provided in Britain, Meredith (1994). Fortunately he points out most of the features exported to the United States. And he lists 142 changes between 1954 and 1977, an average of almost 7 per year. Many are minor and noticeable only to mechanics but others are substantial. A flavor of these is given in Table 9,

Table 9 – Sellable Changes to the VW Beetle (1955-1960)

1955	Flashing turn signal, Reinforced bumpers, Increased luggage space
1956	Tubeless tires
1957	Big windows
1959	Fixed door handles, Steering wheel redesign, Improved seating, Sound proofing
1960	Steering improvement

It turns out the only iconic unchanging feature of the Beetle is its ageless curves. Over time much else is new and improved.

12. Does pPQ match Marketing and Innovation information on Refrigerators?

Every consumer performance S-curve goes up and down in response to many factors, both tangible and intangible, some revealed in the above challenges, where insider knowledge is usually required to interpret them. Sometimes trade magazines can help, as for refrigerators.

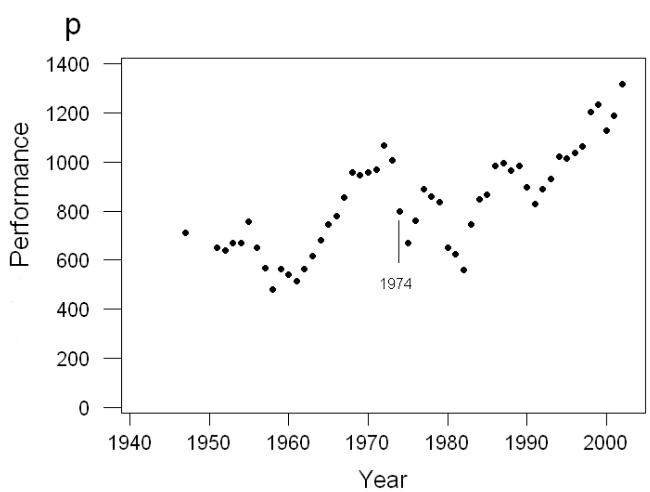


Figure 25a – Performance of Refrigerators

The performance S-curve produced by pPQ is unusually complex, figure 25a. The portion from 1974 is generally rising but it's from 1947 to 1973 that's startling and is separated for further consideration in figure 25b.

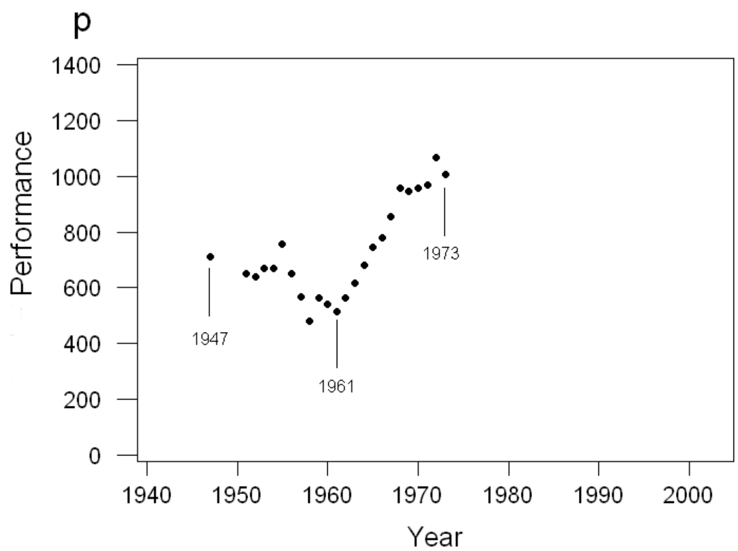


Figure 25b – A complex portion of Refrigerator performance

In the trade magazine 'Electrical Merchandising' there is no hint of a performance decline from 1947 to 1961. In fact the nominal performance is definitely increasing from providing one door to providing two bigger ones.

The context is further complicated because the refrigerator price index shown in figure 26 has a yawning discrepancy prior to 1960 between matched models from Consumer Reports, Gordon (1990), and from the pPQ.

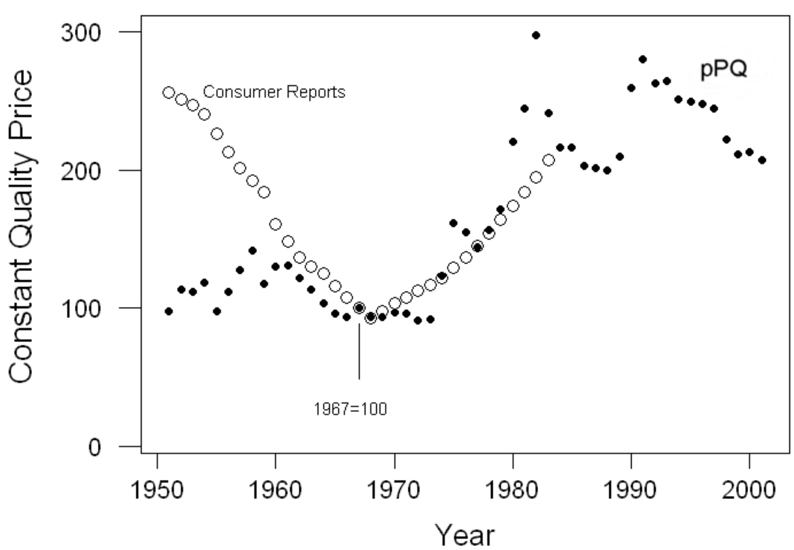


Figure 26 – Constant Quality Prices for Refrigerators using Matched Model and pPQ methods

This arises because the matched model method is eliminating price differential due to quality change that purchasers didn't care about having.

The likely cause is instructional. In the 1950s refrigerators were the most adopted of all appliances[25]. Unimpressed, even frustrated, by new features (re-purchasers wanted the same again when one broke) the perceived performance declined as seen in figure 26. In his merchandising column, Farr (1958), Mort Farr dubbed this 'was-is' and recommended selling new features (automatic defrosting, for example) more effectively.

Then an innovation hit the market. And it didn't come from the market leader but from fifth placed Norge who invested $3MM in new production equipment (about four times the usual incremental improvement figure), Staff Reporter (1958), to introduce a 'Swing 'n Serve' refrigerator whose adjustable shelves swung out from a post with a crisper that did the same. This new feature stimulated sales of all refrigerators because dealers that didn't carry Norge had to start selling what they had against it as Farr recommended. The result was pPQ performance climbing very rapidly from 1961 in response to the stimulus provided by the arrival of this specific innovation.

The Norge refrigerator is a classic instance of product development and its management done well.

Smartphones – Entry Point to a Digital Economy

The service sector uses equipment - procured from the goods sector - to provide what consumers cannot, or choose not to, provide for themselves. The digital economy provides access to these services, or new services, using software. This is fundamentally innovative and its preeminent enabling equipment is the Smartphone.

The Smartphone was introduced to market outside the temporal reach of the DINTEC™ (1951-2001) database. However, with the caveat that the data is less well vetted and of shorter span than needed for full comprehension, the following figures present what can currently be provided by a pPQ treatment.

[25] By 1958 the % wired homes having a Refrigerator was 97.3%, a Radio 96.8%, an Iron 89.5%, a Washer 88.5% and a Television 86%.

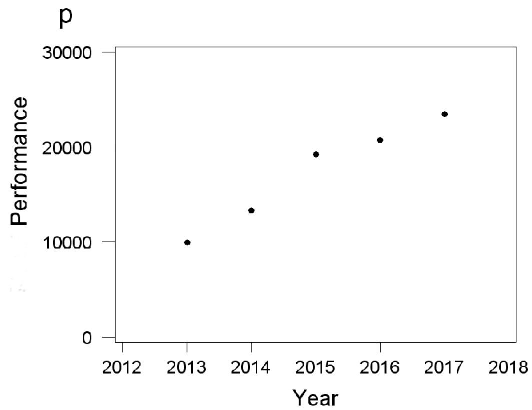


Figure 27a – Perceived Performance of Smartphones

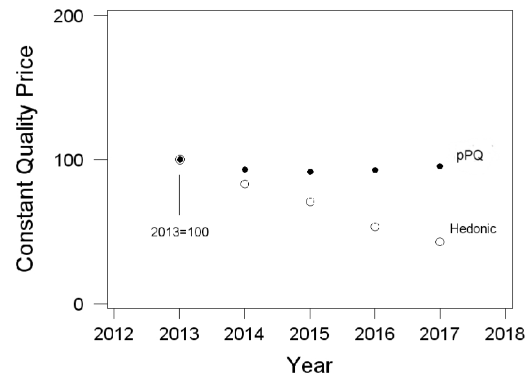


Figure 27b – Smartphone Price Indices

The performance of Smartphones, as perceived by their purchaser at the time of purchase, enumerates as shown in figure 27a. Prices are J.D.Power's from Aizcorbe, Byrne & Sichel (2019) with competitive pressure from Statista (Hamburg). It's no surprise that performance rises.

However, the price index situation **is** surprising, figure 27b. The hedonic index, Aizcorbe et al. (2019) drops rapidly while pPQ's hardly at all. This indicates that the attributes used in the hedonic analysis are not a good proxy for consumer perception. Such divergence has already been seen for automobiles and refrigerators.

To clarify the situation other digital equipment, such as Mini & Mainframe computers, Gordon (1990), and IBM PC Desktop computers, Nelson, Tanguay & Patterson (1994) are considered in figure 27c and figure 27d, where the same pattern of deviation across the whole timeframe is observed using DINTEC™ data.

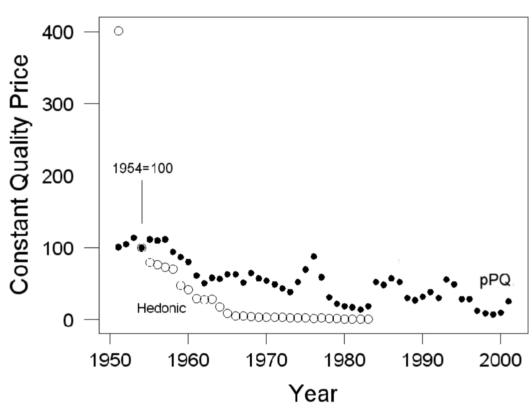


Figure 27c – Mainframe & Mini Computer Price Indices

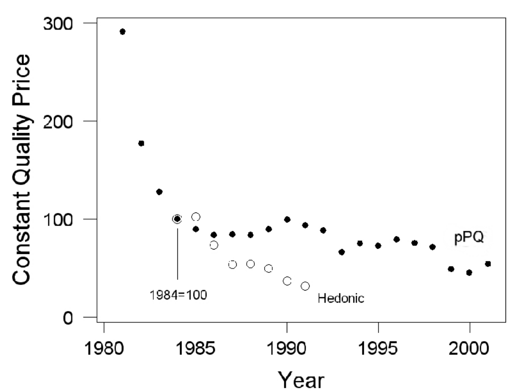


Figure 27d – IBM PC Desktop Computer Price Indices

The likely reason is Moore's Law, an empirical rule on the density of transistors doubling every two years – an extraordinary rate. While it enhances what computer components can achieve it does not track customer response when they are assembled into devices. For that reason the current hedonic method is not working for these high-tech goods.

Adam Smith and the Price of Nails

In his insightful generalizations that constitute ‘The Wealth of Nations’ Adam Smith provides a section whose title is ‘Effects of the Progress of Improvement Upon the Real Price of Manufactures’. He intones that *‘It is the natural effect of improvement, however, to diminish gradually the real price of almost all manufactures’*.

Sichel (2011-2021) provides the real price of nails from 1695. This data is averaged and smoothed from 1776, the year of Smith’s publication, to 2010, and shown in figure 27e.

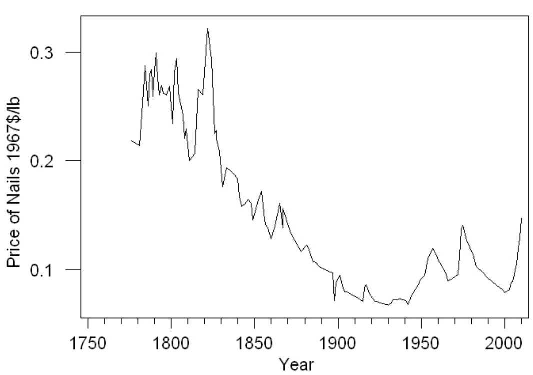


Figure 27e – Four Generations of Nail Technology

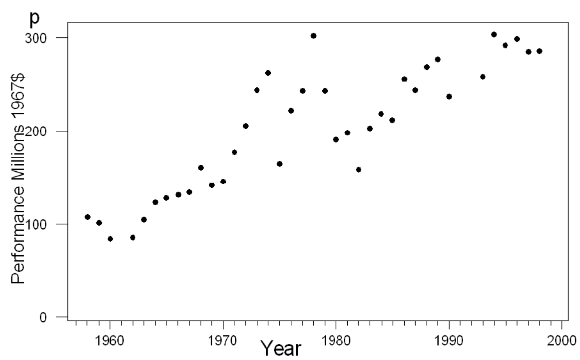
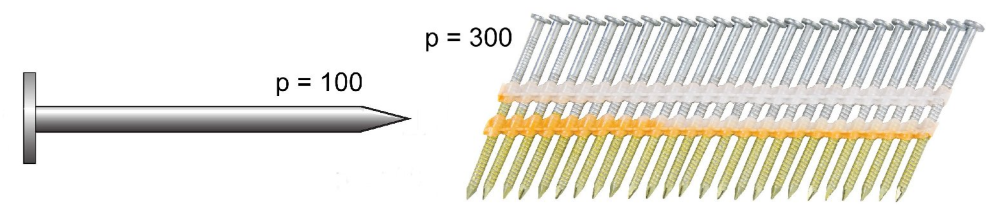


Figure 27f – pPQ Performance of Nails from 1958



The real price of nails does indeed decrease, even as nail manufacture improves from forging to drawn wire, from 1776 to the mid 1940s. Then real price rises. In this modern period hammering declined in favor of the nail gun. It was introduced in 1950. To adapt, nails were collated into strips and magazines.

Sichel’s empiric estimate found a delivery rate rising from 6 nails per minute to 20 nails per minute, about a three-fold improvement.

When the pPQ is applied to nail data from DINTEC™ the performance of nails adapted to work in the evolving nail gun does indeed rise from about 100 to about 300 in figure 27f. Sichel’s estimate affirms this at two points but without the intervening market detail that allows a confident re-phrasing of Adam Smith to better-fit modern innovation,

‘The natural effect of improvement is to cause the real price to vary in balance with the output of manufacture’.

In symbols, ‘real price’ is either a balance between ‘improvement’ and ‘output’, P = p/Q - or ‘improvement’ is a balance between ‘real price’ and ‘output’ - p = PQ.

Step 3 – Resolving a Paradox

The Price of Light Quandary – Hangs a Question Mark over Price Indices

William Nordhaus published two papers in the late 1990s in which he analyzed the price of light. At **Step 2**, and for Sears light bulbs, performance was described in lumens per watt. But Nordhaus explores light in terms of ¢ per 1000 lumen hours. His results for a constant provision of 1000 lumen hours are reproduced in figure 28, Nordhaus (1997).

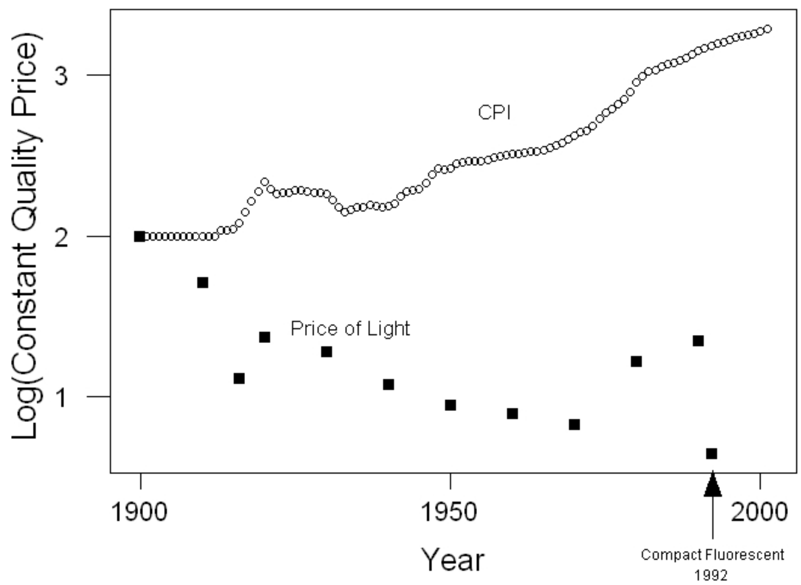


Figure 28 – The Price of Light in the age of electricity moves opposite to CPI (1900=100)

His price of constant quality light lowers as the standard Consumer Price Index rises! He interprets this paradox as another example of a long suspected upward bias and cites several other affirmative studies, Nordhaus (1998)[26]. Since the upward path of the CPI graph in figure 28 is about 3% per annum (1900-2001) and the downward path of price of light is about – 1.8% (1900-1992) the total disparity is very substantial, about 4.8%.

Even with a ~ 1% bias more extreme conundrums become apparent. Historical documents tell us what household income was enjoyed in previous centuries in the coin of the day. Converting to understandable modern money involves assumptions but it's still clear that under a 1% bias our forebears would have been on starvation diets by today's standards. Yet Pieter Bruegels's wedding scenes painted in 1569 show delightful feasts, Gordon (2005). Ancestor goods were inferior to ours but eminently affordable to

[26] Consumer Durables 3.2 – 5.9%, Heart Attack Treatment 5.5%, Pharmaceuticals 3%. Since these are not the only industries where successful R&D occurs, bias must be widespread across the economic landscape. This is astounding and compounded by Nordhaus (1998) who also points out that the sheer volume of work needed to eliminate bias makes it logistically unlikely to have occurred in published indexes. This was after the Boskin Commission had given a lower estimate of about 1%, Gordon (2000).

them. Hulten (1997) attempted to resolve this in colonial context but was stymied by the ‘impossible topic’ ‘quality change’, Griliches (1999). As will be seen in Appendix D removal of bias must be accompanied by separate ‘quality’ enumeration [67(p83)].

Starting with constant quality over time, such as for light in figure 29 (using the formula from p25) and then progressing to actual historical quality improvement over five decades in figure 30 (using the formula on p13) the pPQ provides what has previously been missing.

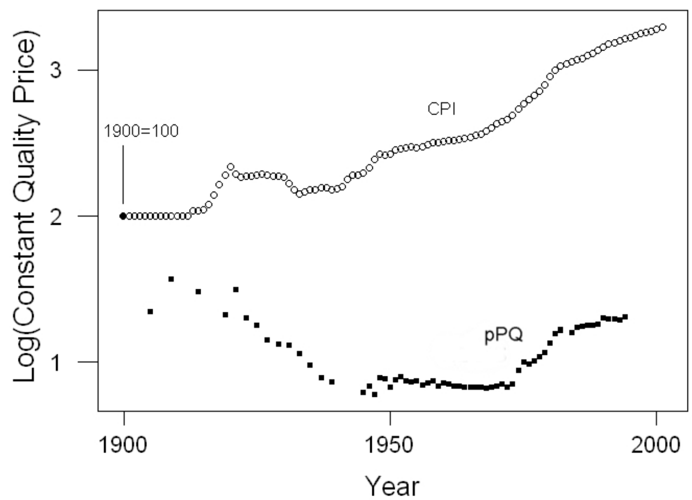


Figure 29 – The price of constant quality incandescent light compared to CPI

Figure 29 generally reproduces Nordhaus’s Price of Light from figure 28.

But why keep performance constant in an equation capable of calculating it? The resulting performance of compact fluorescents is shown in figure 30 along with the average for all incandescent bulbs between 15 and 150 watts also calculated from pPQ.

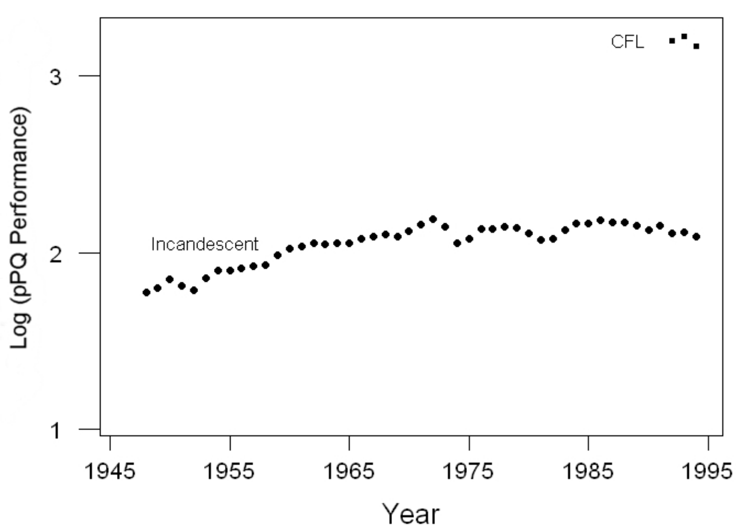
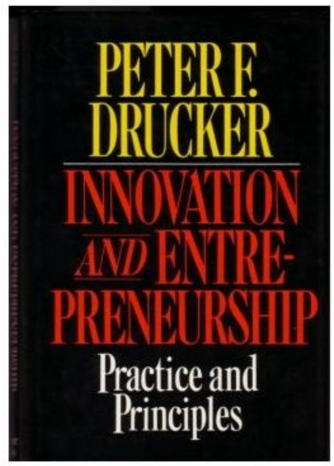


Figure 30 – Performance of Incandescent and Compact Fluorescent

The pPQ shows compact fluorescents have about a ten-fold improvement in performance over contemporary incandescent ones. Nordhaus shows only a five-fold decrease in the lumen-hour cost of a compact fluorescent bulb compared to an incandescent two years earlier. Clearly pPQ is measuring something with perceived value far beyond the delivery of lumen-hours.

And this renews a larger paradox. Price is not the only determinant of economic reality. *'What products do for the customer'* – their quality in Economic parlance – is just as important, Drucker (1985), yet – as he points out – it's missing from economic analysis.

Every economics book points out that customers do not buy a 'product', but what the product does for them. And then, every economics book promptly drops consideration of everything except the 'price'. What the product does for the customer is never mentioned again ..



pPQ delivers that missing piece. Not only does p from pPQ provide reasonably good matches to known historical performances of intermediate type commodities, tire cords, cement and light bulbs - at **Step 2** - but it also makes sense when applied to intangibly affected consumer goods. Now – in **Step 3** – it makes sense of the 'Price of Light'.

Step 4 – The Algebraic Mechanism of Economic Growth

The previous steps have established that '*what a product (of technology) does for the customer*' is enumerated by the simple algebra,

p = P Sum: Q

where P is its real price and Q is the competitive pressure exerted upon it (equal to the sum of the **physical quantity** constituting its market); where p is defined in the Glossary. It is closer to 'quality' than it is to 'utility' but is neither. Specifically, it does not depend on identifying attributes - or their weights – and is cardinal.

The next question is whether this simple algebra can be extended to GDP.

Gross Domestic Product is the total output of goods and services produced by labor and property located in the United States, valued at market prices. The commodity value supplied by the ith market and summed over N markets to represent the economy, is

$$\mathrm{GDP} = \sum_{i=1}^{N}(P_u^i Q_u^i + V_E^i - V_I^i) \text{ or } \mathrm{GDP} = \sum_{i=1}^{N}(P_u^i Q_u^i) + V_E - V_I$$

where subscript U signifies shipments from US manufacturers to US markets, I signifies imports as intermediates or as final products that create pressure, and E signifies exports.

Because P = p/Sum:Q, and with the appropriate subscripts for the ith market we obtain,

$$P_U^i = p_U^i \Big/ \left(Q_U^i + Q_I^i\right) \quad \text{therefore,} \quad \mathrm{GDP} = \sum_{i=1}^{N} p_U^i \left(Q_U^i \Big/ \left(Q_U^i + Q_I^i\right) \right) + V_E - V_I$$

summed over all N markets[27]. In the absence of foreign trade $V_E = V_I = Q_I^i = 0$ and the equation simplifies to,

$$\mathrm{GDP} = \sum_{i=1}^{N} p_U^i$$

Now GDP is determined exclusively by the aggregated market performances of products of technology. Foreign trade GDP is also determined entirely by the aggregated market performances of products of technology when appropriately adjusted by Qs and Vs.

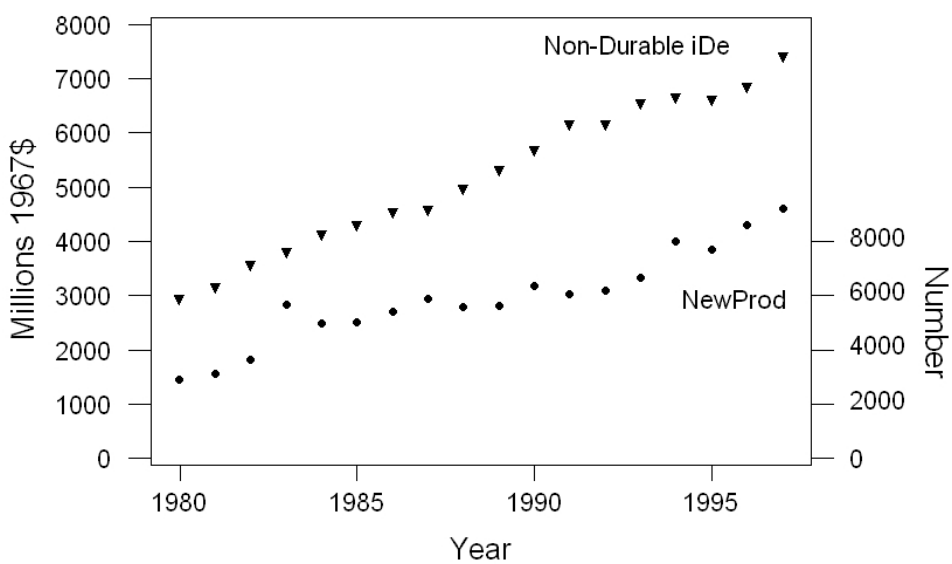
'*What a product (of technology) does for the customer*' goes algebraically to GDP for the country. This outstanding result makes innovation the source of economic prosperity, as has often been opined, but never proven, until now.

---

[27] This monograph uses N=11 (plus 1 pilot). Methodology details are provided for the manufacturing sector in Appendix A, starting on page 71, and for the service sector in Appendix C, on page 83.

To create products that do *more for a customer* starts from many new ideas that are evaluated against specific requirements. These include assessing whether customers will recognize the improvement and pay the asking price for it, and the existence of, or the possibility to develop, the technology necessary to deliver the article at a cost that is less than that price[28].

The above requirements are satisfied within more algebra. The resulting formulae govern the execution of what is known to practitioners as the innovation funnel, in **Step 5**.



Extra insight

←

The output of new product introductions in consumer-packaged goods rises in tandem with the overall input from idea development expense across the innovation funnel. It implies a substantially fixed ratio between incoming product concepts and outgoing commercial success.

---

[28] This process leads to what is known as 'Creative Destruction', Schumpeter (1942). Incumbent products die as newer ones replace them. **Step 5** constitutes its first-ever algebraic explanation in terms of innovation.

Step 5 – The Innovation Funnel – Commercially Vital but Absent From Economics

Ideas are the ultimate intangibles. They drive economic growth but not before they've passed through an entrepreneurial funnel to become innovations. Innovations have unique commercial elements. To acquire them, ideas have to pass in stages through a well-established Innovation Funnel described in detail by Stevens & Burley (1997)[29] (but tacitly known well before).

It is common to confuse ideas, inventions and innovations. Professional use is clear[30].

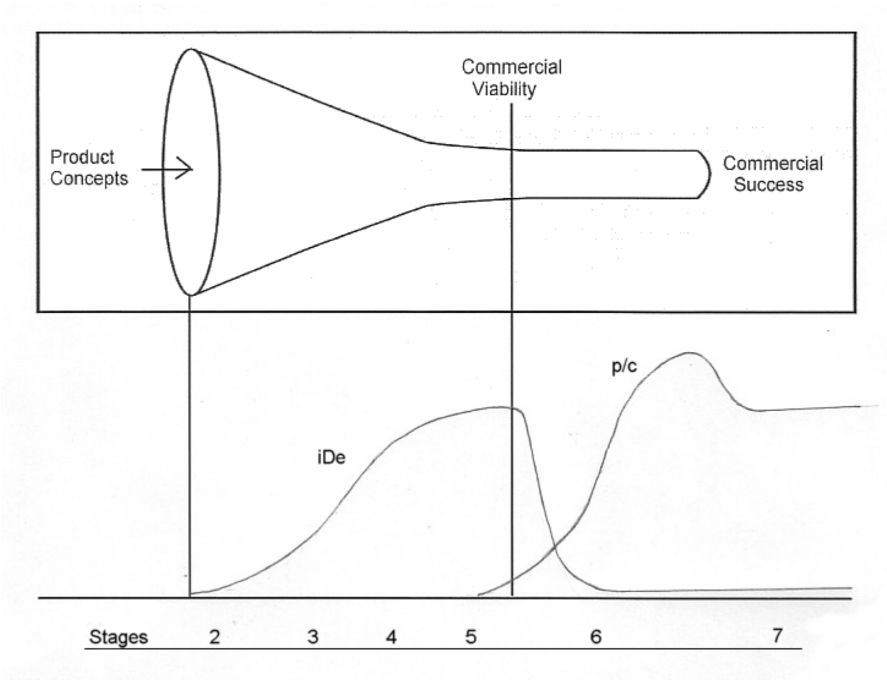


Figure 31 - The funnel admits ~300 'shaped ideas', or new product concepts, for every eventual commercial success. Substantial spending on iDe[31] drives Stages 2 to 6.

For commercial viability of the products of new technologies only two conditions are required. One is for price the other is for cost[32]. From these two an innovation metric (p/c) is derived, as follows,

(a) Price

The first condition can be determined from pPQ, which associates price with performance and competitive pressure.

[29] The stages are 1. Ideation 2. Explorations 3. Small Projects 4. Significant Project 5. Major Development 6. Commercial Launch 7. Commercial Success.

[30] Ideas are ideas. Inventions are ideas that are 'non-obvious to one of ordinary skill in the art' (in patent law parlance) and reduced to elemental practice; no commercial success is presumed. It is for innovations.

[31] 'Idea Development Expense' relates to conventional categories of R&D. It is the sum of company sourced Applied Research and Development (Appendix A). It is primarily STEM activity.

[32] Neither condition requires a patent. Patent counting does <u>not</u> characterize innovation.

In a simple market, with two competing products,

For the first product,

$$p_1 = P_1(Q_1 + Q_2)$$

For the second product,

$$p_2 = P_2(Q_2 + Q_1)$$

Competitive pressure is the same, so,

$$p_1/P_1 = p_2/P_2$$

Making the essential point that, for market penetration, it’s not necessary for performances or prices to be equal. It’s the ratio that matters. Incumbents rarely appreciate this allows inferior products to succeed against them if their price is lower, or that consumers will even accept a necessary degree of aggravation for less outlay.

The price point is set by assessment in relation to competing entities and **not**, as commonly thought, by adding margin to cost. Opening price may need to be below cost.

(b) Cost

For the second condition the unit cost of delivered performance must be less than the achievable price point in the near future. This assures eventual and necessary profit.

Cost includes direct production labor and the materials and energy needed for manufacture plus the indirect labor of management and administration, of sales, marketing and R&D. In annual report parlance this is cost of sales COS (minus depreciation if included) plus Sales General and Administrative SG&A.

Commercial Viability

Using this cost+ definition[33], the commercial viability of a firm’s new product can be expressed by the ratio $\left(p/c+\right)$ where $c+$ must be less than P[34], or $c+ < P$ so that,

$$\left(p/c+\right) > \left(p/P\right)$$

---

[33] c^+ is the unit cost a firm’s price must exceed. It is greater than the underlying commodity cost. Commodity cost c excludes overheads. It is composed of materials, energy and direct production labor.
[34] Projected for full-scale production, at Stage 5 for realization at Stage 7.

but from pPQ,

$$\left(\frac{p}{P}\right) = \sum Q$$

so that,

$$\left(\frac{p}{c+}\right) > \sum Q$$

for each commodity provided by a firm to a market. By this inequality competitive pressure $\sum Q$ takes on another meaning. It constitutes an innovation boundary IB that can be expressed graphically as shown in figure 32.

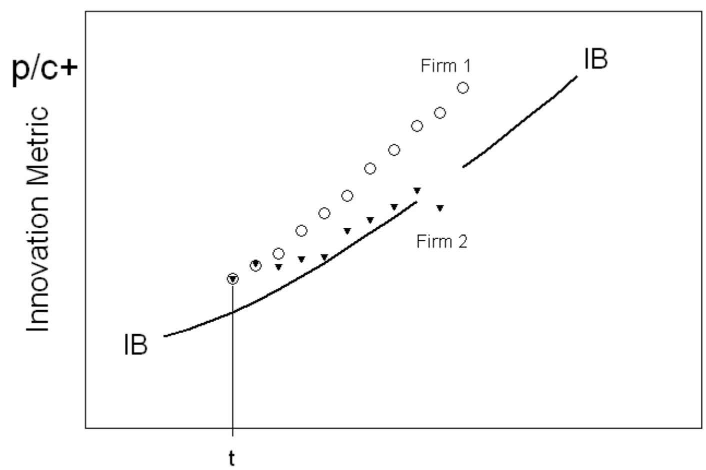


Figure 32 – Firm 1 innovates successfully above the boundary, Firm 2 does not [35,36]

where the trajectory of $\left(\frac{p}{c+}\right)$ for two commodities each introduced by a different firm in year t is shown. The first remains above IB while the second veers into it when c=P. This vital transition marks the onset of creative destruction, Schumpeter (1942), which is the fundamental mechanism of economic growth in an economy. And where $\left(\frac{p}{c+}\right)$ is the metric that controls it. Therefore

> Innovation is
>
> **The prospering of new technology in a market**,
>
> enumerated by the commercial metric $\left(\frac{p}{c+}\right)$.

[35] With t =1963, Firm 1 is Anheuser-Busch, Firm 2 was the Falstaff Brewing Company, Farrell (2007).

[36] Noting that survival is systemically easier for products than firms. This arises because a firm's cost is always greater than a commodity's, c+>c. As often happens a commodity survives by being transferred into stewardship of a firm with a lower cost structure and eventually, perhaps, to a smaller firm serving a niche market that tolerates a higher price. As a corollary, products tend to have longer survival times than firms.

Interpreting Innovation Funnel Schema

The graphic below the funnel in figure 31 imagines how iDe spending effects the innovation metric (p/c) during development.

The earliest stage is inexpensive There is nothing but ideas, (p/c) = 0. The explorations phase will require mock-ups crafted from existing parts. They will possess some kind of functional representation, so p is larger, but will be very expensive to create. As development proceeds functionality will increase and unit cost will decrease across planned milestones and putative (p/c) will rise. The most expensive stages are ahead. These usually involve unforeseen and unique issues seen in the context of multiple designs coming together. They often relate to interactions between particular machine and material characteristics. Sometimes these are unprecedented and require original applied science to resolve. At the very least, flaws have to be removed or ameliorated, very preferably without increasing unit cost.

The interdisciplinary requirements, invariably unavailable from open literature, and the urgency for resolution, make this world of the innovation professional one of the most fascinatingly rich and challenging technical spheres imaginable. It is also one of the least known about.

Products of the developing technology may enter test markets or niches where high unit costs can be tolerated, at least for a while. (p/c) may peak for early adopters (the wow factor described at **Step 2**, p23-24). Once fully commercial (p/c) will increase slowly as improvements, especially those lowering cost or renewing attributes, are implemented.

The development knowledge acquired by iDe spending stays with the firm and becomes part of its core competency.

Note on Definition

For some it may be worth recalling the working definition of innovation adopted by the 'Measuring Innovation in the 21st Century Economy' committee, Commerce (2008) and page 95, but which remained unrefined throughout viz.

Innovation is,

'*The design, invention, development and/or implementation of new or altered products, services, process systems, organizational structures, or business models for the purpose of creating new value for customers and financial returns for the firm*'.

By convolving this to '**The prospering of new technology in a market**' the single metric the committee chairman opined – no doubt based on its awkward definition - would likely never exist, and anyway be transient and error prone, is comprehensively proven otherwise within this book.

Innovation Tracked in the 20th Century

Year	Durable Goods Sum:(p/c)	Non-Durable Goods Sum:(p/c)	All Goods Sum:(p/c)
1951	35.7	79.3	43.2
1952	34.7	80.7	42.6
1953	39.7	83.9	47.3
1954	41.4	83.3	48.6
1955	50.9	87.6	57.2
1956	52.2	88.5	58.4
1957	51.2	87.7	57.5
1958	63.6	89.7	68.1
1959	74.0	93.6	77.4
1960	74.0	89.6	76.7
1961	71.8	89.4	74.9
1962	79.6	95.2	81.3
1963	86.7	92.4	88.2
1964	92.9	96.0	92.9
1965	100.0	94.0	99.3
1966	99.2	93.6	98.3
1967	**100.0** (131.8)	**100.0** (27.4)	**100.0** (159.2)
1968	110.5	102.7	109.2
1969	118.6	100.2	115.4
1970	109.2	101.2	107.8
1971	122.5	109.4	120.3
1972	132.0	117.5	129.6
1973	142.8	118.1	138.5
1974	123.2	118.4	122.4
1975	108.2	117.9	109.9
1976	119.2	124.1	120.0
1977	131.5	126.4	130.6
1978	142.9	125.6	139.9
1979	140.5	134.3	139.5
1980	123.6	132.5	125.2
1981	118.7	133.4	121.3
1982	109.2	142.6	115.0
1983	126.3	149.9	130.4
1984	138.9	156.5	142.0
1985	143.3	158.1	145.9
1986	152.0	170.6	155.2
1987	156.8	181.1	161.0
1988	158.3	183.9	162.7
1989	162.0	192.3	167.3
1990	154.3	192.7	161.0
1991	146.1	190.9	153.9
1992	155.8	194.2	162.4
1993	147.6	198.2	156.3
1994	151.6	223.6	164.0
1995	159.8	216.2	169.5
1996	163.9	223.0	174.1
1997	191.1		
1998	198.9		
1999	208.3		
2000	204.7		
2001	209.4		

1967 values in brackets are absolute in billions of quantils

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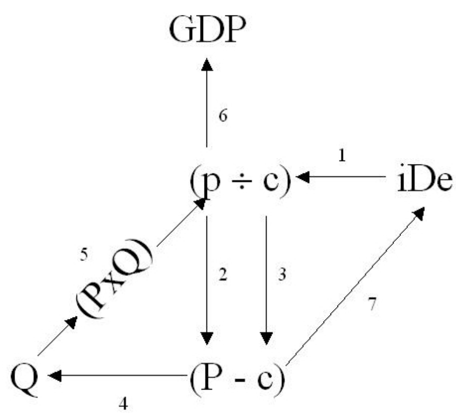
Missing Pieces



The *Principia* of Economic Growth

Part II – Steps 6 to 8

Appendices, References, Glossary, Supplements

Chris Farrell Ph.D.

Step 6 - Innovation and Creative Destruction in Firms

Although products are first and fundamental to pPQ firms play a key role. They create and steward. That is vital not least because of the legal shelter provided to entrepreneurs navigating the contrary financial odds of the product innovation funnel. Established firms must navigate market changes to survive and prosper.

The impact of market growth and innovation on established firms is illustrated for beer.

Success and Failure in providing Beer for 20-somethings

The demographics of beer consumption changed dramatically from 1965 to 1985. Table 10 shows the rising percent of males between the ages of 25 and 29 for those years,

Table 10 – Changing Beer Consumption Demographic

	1965	1970	1975	1980	1985
%	6.0	6.9	8.1	8.9	9.4

This 20-something cohort raised the innovation boundary for beer shown in figure 33.

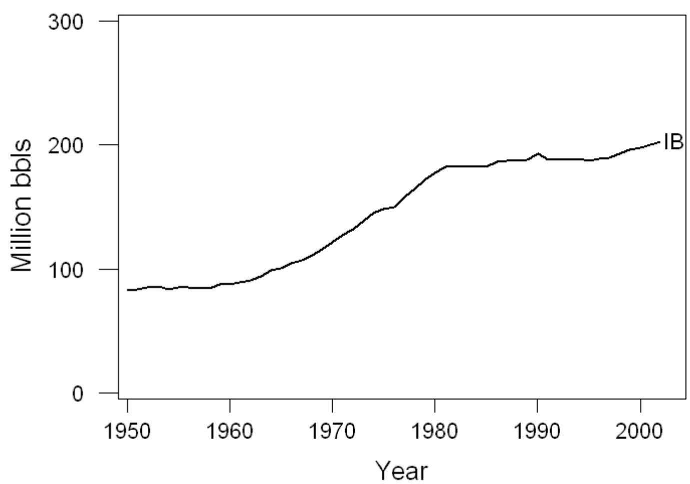


Figure 33 - The Innovation Boundary for Beer rose significantly from 1960 to the early 1980s

How beer firms innovated to avoid that boundary (some did not avoid it) provides many interesting instances. The fate of five, treated in reverse alphabetical order, is next.

Old Milwaukee

Schlitz's innovation metric rose away from the innovation boundary until 1973. After that it leveled out on the way to colliding in 1979. Quotes from annual reports explain why.

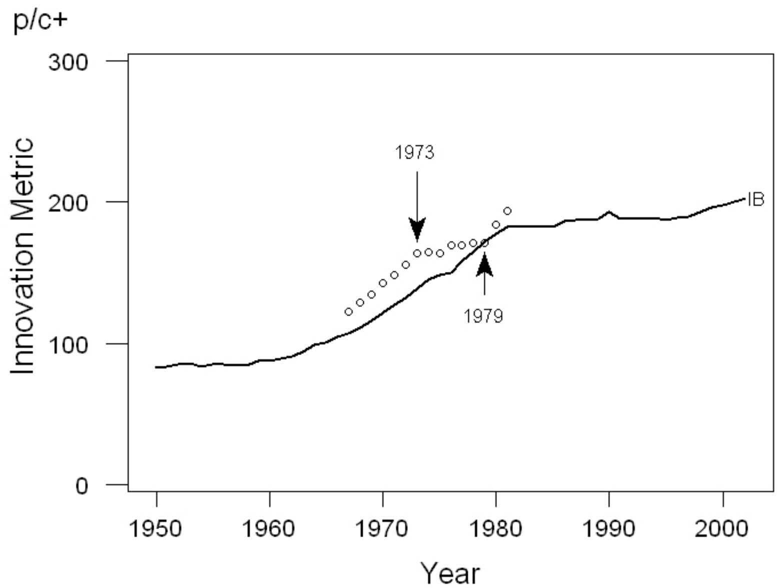


Figure 34 – Schlitz hits the Innovation Boundary in 1979

1. The Schlitz approach to long-range volume growth has been to build large efficient plants, Schlitz (1973),
2. Most of our production facilities are relatively new and highly efficient, Schlitz (1974),
3. A premium plus brand Encore was with drawn from test markets, Schlitz (1974),
4. We will continue to aggressively support our four national brands. The Schlitz brand in 1978 will emphasize quality and its appeal to all beer drinkers. The market is becoming more segmented, Schlitz (1978),
5. How packaging costs, beer pricing, and sales volume balance in conjunction with our marketing programs will determine our progress, Schlitz (1978),
6. We successfully test marketed an exciting fifth brand Erlanger – our superior-tasting entry into the super premium category, Schlitz (1979).

Schlitz had a strong and successful focus on manufacturing technology (1, 2). In 1972 they had capacity of 22 million barrels and produced 19 million (about 85% efficiency). Their output peaked in 1976 at 24 million barrels but declined to only 20 million barrels by 1978.

By then they had installed 32 million barrels of capacity and so were operating at only 63% efficiency. This is referred to in (5) as the ‘sales volume’ factor and it raised their unit production cost. That would have been fine had their product portfolio’s performance been significantly increased.

But by focusing on ‘appeal to all drinkers’ they missed the segmentation opportunity, despite recognizing it (4). A new product didn’t do well (3) and if Erlanger could have made a difference it came too late (6).

In terms of (p/c+), Schlitz focused on future reduction of c+ without producing enough p in the meantime to realize the gain. Too much supply with too little ‘Wow’.

Schlitz held on after 1979. But they sold their highly efficient Syracuse brewery to Anheuser-Busch in 1980 and were taken over by Stroh’s in 1982.

Blue Ribbon

Pabst was doing well until 1972 when its innovation metric started heading down toward the Boundary, figure 35, for which management offered the following explanation in 1980.

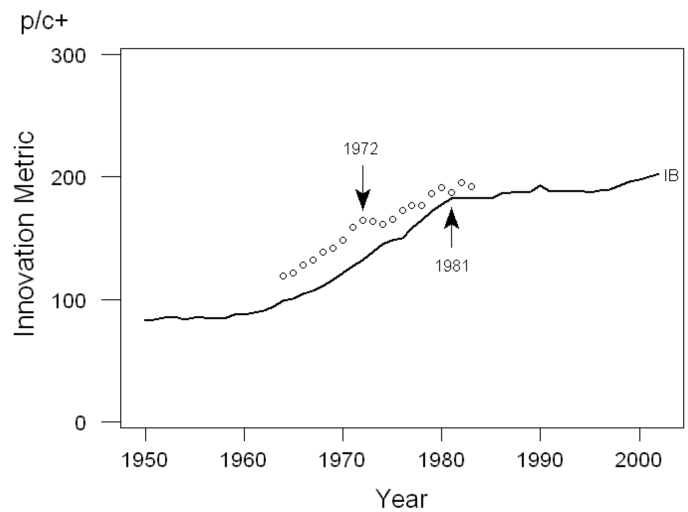


Figure 35 – Pabst just misses the Innovation Boundary in 1981

Competitive pressures have not permitted selling price increases to offset the higher costs of raw materials, packaging, labor and other expenses, Pabst (1980).

This assessment seems to have been done in nominal dollars[37] and indicates that increasing unit costs since 1974 were being accepted rather than fought. But with the resignation of CEO A. J. Amendola in January 1981 and his replacement by F.C. DeGuire the situation changed, because unit production costs were lowered in 1981 and again in 1982.

[37] Nominal dollars are current in the year under consideration.

Then Pabst made a series of maneuvers including acquisition of Olympia and swapping selected breweries with Heileman and Stroh's.

1. With 18 brands in its house of fine quality products, Pabst positioned itself better than ever before to compete in the brand segmentation arena of the brewing industry, Pabst (1984).

2. Pabst embarked on a planned cost-control program to reduce too-high production costs, a move expected to yield significant savings in 1984, Pabst (1984).

In terms of (p/c+), Pabst came close to the Innovation Boundary in 1981 but bounced back by expanding its brands, and therefore p, while also getting c+ under better control.

It's the Water

At least the **Olympia** Brewing Company recognized the need to innovate beyond its flagship beer.

1. Perhaps the most significant market trend in recent years has been the decline in classic beer sales in favor of specialty products. Low-calorie light beers, super-premiums and imports now account for an increasingly significant share of the market. In an effort to serve that demand, we plan to test-market as many as three new malt beverage products later this year, Olympia (1977),

2. Introduced in January, Olympia Gold became a best seller in the light beer category, though it trailed the market leader in most areas, Olympia (1977).

Olympia's innovation metric (p/c+) continued toward the Boundary, figure 36a.

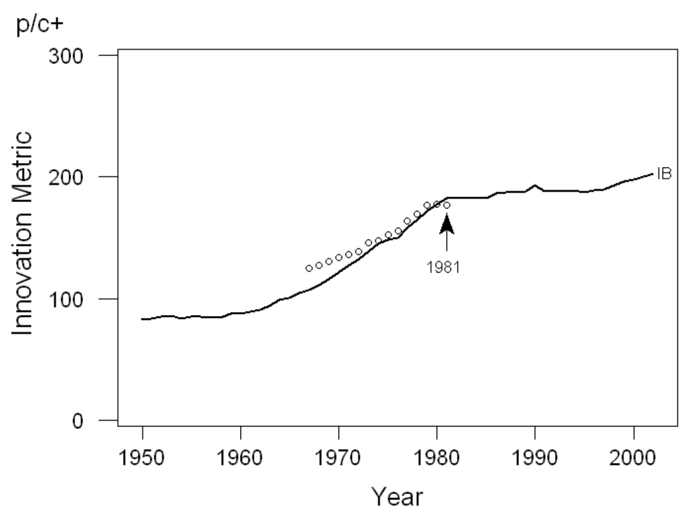


Figure 36a – Olympia slips under the Innovation Boundary in 1981

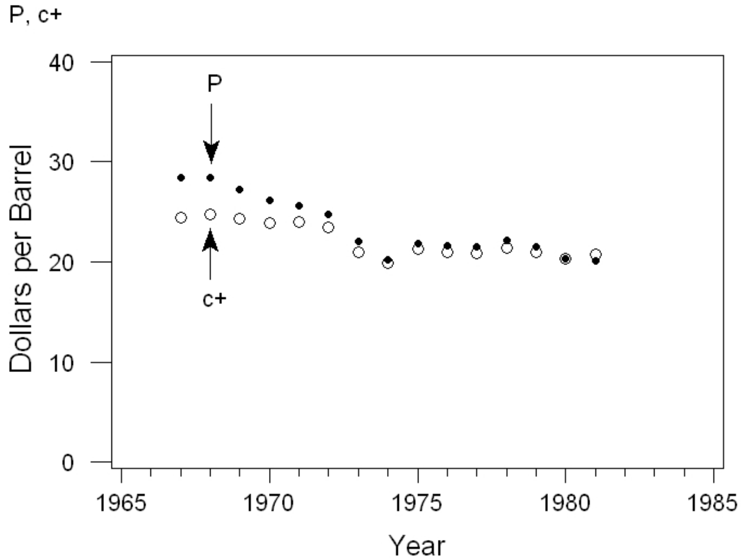


Figure 36b – Competitive Pressure from all brands pushes Olympia's price below cost

Heileman acquired Olympia in 1982.

The Champagne of Beers

The Innovation Boundary diagram for **Miller** is quite different from those presented so far, figure 37.

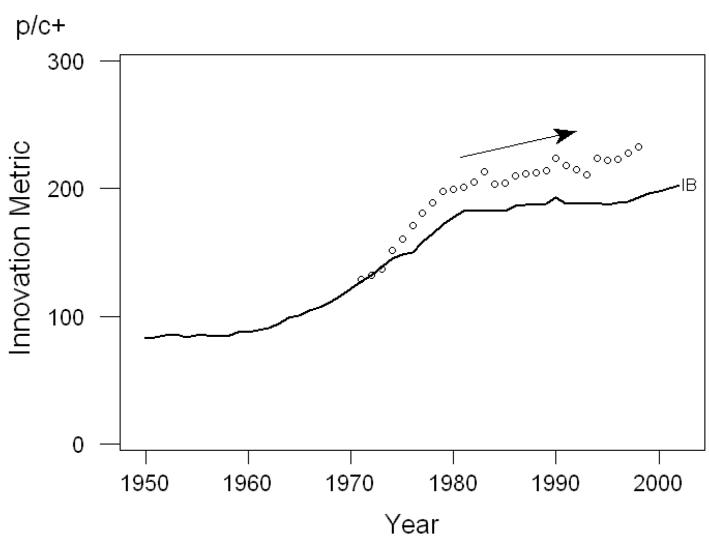


Figure 37 – Miller gains on the Innovation Boundary after the early 1970s

Miller's metric (p/c+) starts in 1971 after a planned interim by Philip Morris who had acquired Miller in 1969,

1. 1971 was the year for repositioning the Miller Brewing Company. A new advertising campaign was launched successfully, and the first major new

product in Miller's history, Miller Malt Liquor, was introduced in many markets. There was a substantial decline in operating income due to planned increases in marketing costs and severe increases in manufacturing costs, Morris (1971),

2. Miller High Life Beer is a quality product and one of only three premium beers sold in all fifty states. A leading international advertising agency developed a new advertising campaign around the theme, 'If you've got the time, we've got the beer', Morris (1971). The momentum of Miller High Life's growth has permitted a proportionate reduction in marketing costs per barrel, Morris (1974),

3. Our new Lite brand – a low calorie, low carbohydrate beer – was successful in its test markets last year and will be introduced nationally in 1975, Morris (1974),

4. Lite, which dominates the lowered calorie segment, continued its success story[38]. Lowenbrau[39] further solidified its position in the super-premium category, Morris (1979).

Prior to the advertising campaign (2.), and since 1903, Miller High Life had been 'The Champagne of Beers'. The new slogan redirected its appeal from the imagined champagne lifestyle of those who didn't need to work, to a real reward for those who did. The beer remained the same, just the perception of its performance changed. Sales increased.

And in 1985 Miller tested a new beer, its Genuine Draft. By cold-filtering yeast out, using technology licensed from Sapporo, the characteristics of a draft beer could be achieved in a can or bottle. It was distributed nationally the following year.

All this contributed to Miller's rising (p/c+) presented in figure 37.

This Bud's For You

Innovation at **Anheuser-Bush** has kept its metric well above the boundary for a very long time, figure 38.

[38] Aided by the memorable slogan 'Everything you always wanted in a beer. And less'

[39] Brewed in the USA under license.

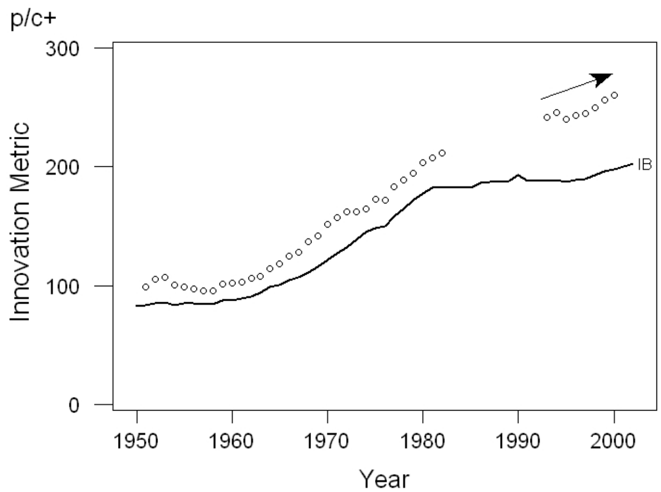


Figure 38 – Anheuser soars above the Innovation Boundary after divesting non-beer businesses in 1992[40]

1. Apart from Anheuser-Busch's impressive portfolio of beers, including Budweiser, Bud Light, Michelob, Busch and O'Doul's, each appealing to a certain market segment and contributing to p, the following two statements show they also developed a unique approach to controlling c,

2. Anheuser-Busch Incorporated utilizes wholesaler and ABI owned branch warehouses to build inventory in early spring to support peak summer sales. By using controlled environment warehouses and stringent inventory monitoring policies the quality and freshness of the product are protected, while maximizing the utilization of production facilities throughout the entire year, Busch (1993),

3. Operations of Manufacturers Railway and St Louis Refrigerator Car, our subsidiaries which provide railroad, truck cartage and warehousing services at some of our breweries[41], continue to be profitable, Busch (1972).

This complete control of the transit and storage of beer keeps c as low as possible. Together with their portfolio this gives Anheuser-Bush an elevated (p/c+) trajectory.

Innovation and Market Share

The beer market is served by many other competitors than these five. It's generally presumed that innovation will be proportional to market share but this isn't exactly the case. Consider the simple binary market from p42 where

$$p_1 = P_1\left(Q_1 + Q_2\right)$$

[40] Data for the years 1983 to 1992 did not meet the requirement of this study that more than 90% of sales be beer related. In 1982 the number was 92%. But in 1983 it dropped to 81% because of diversification into food products that could not be subtracted. This lasted until 1992.
[41] Delivery costs were included in SG&A in 1951, and presumably since.

the first brewer's market share f_1 will be

$$f_1 = Q_1 \big/ (Q_1 + Q_2)$$

so that,

$$p_1 = P_1 \left(Q_1 \big/ f_1 \right) = V_1 \big/ f_1$$

where V_1 is the shipment value of the brewery. The performance of their beer is counter-intuitively inversely proportional to their market share, a finding that challenges conventional presumption. It also answers another unresolved question from Commerce, Commerce (2007).

Creative Destruction of Firms, but not their Beers

The creative destruction wrought by beer drinking on brewers responding to the demographic upheaval between 1965 and 1985 is demonstrated when productions are combined in figure 39. The barrels of beer shipped by successful Miller and Busch rises from 29.4 million in 1971 to 134.4 million in 1998. The combined output of unsuccessful Schlitz, Pabst and Olympia peaks at 47.4 million barrels in 1976.

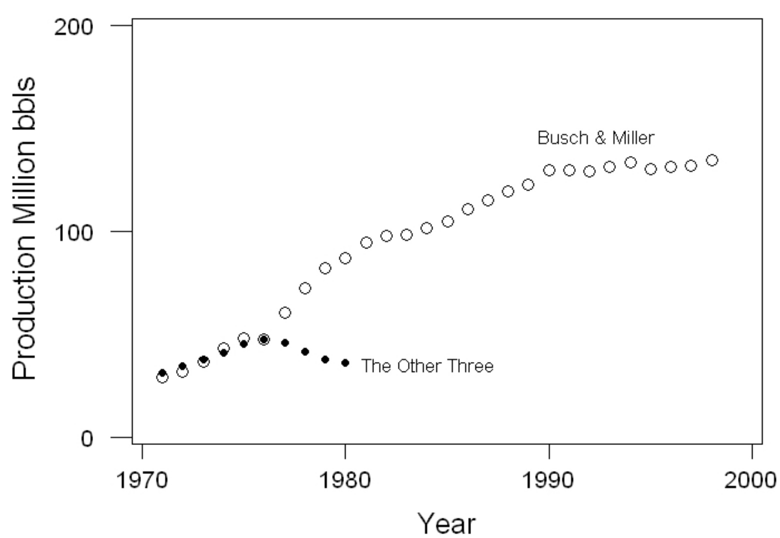


Figure 39 – Brewers innovated or died[42], but their brands survived

Pabst eventually sold all its breweries but retained recipes and trademarks. MillerCoors currently brews Schlitz, Pabst and Olympia for them. Pabst's new business model

[42] By monitoring innovation trajectories of firms against innovation boundaries, such as in figures 34 –38, investors may have an advanced tool for determining what equities to buy and when to sell them.

provides economy of scale offered by new equipment administered by a lean corporate staff. Virtual brewing of strong established brands is innovative; it reduces c+ while maintaining p.

Decoupling Brewer Innovation from their Supply Chain

Bringing ideas through the funnel to launch new beer products requires substantial technical skills. Suppliers may have spent a significant fraction of overall iDe on that. The innovation metric of the brewer is therefore defined as (p-p')/c, where p is the beer's market performance while p' is the performance of the beer's incoming ingredients.

Unfortunately annual reports do not separate what has been spent on development but include it in Sales, General and Administrative (SG&A), which can only be used as a proxy. Plots of (p-p')/c against SG&A, for all five brewers, are presented in figure 40.

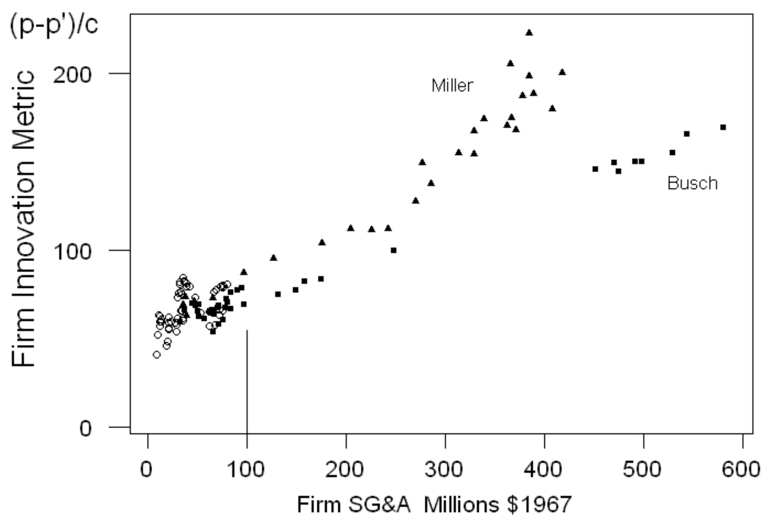


Figure 40 – The winners separate from a metric cluster

They cluster together until a SG&A of about 100 million ($1967) when the winners separate, with Miller outperforming Anheuser-Busch. Miller may have achieved this by employing more innovation professionals. In 1998 Miller reported 86 to Anheuser-Bush's 77, Bowker (1998). The number of professionals employed by the other three in the cluster is not in the public domain.

Firm level innovation metrics can deliver otherwise invisible insights. Further examples – including how to empower strategic management - are given in Appendix F, page 84.

From Firms to Markets

The foregoing analysis applies to firms within markets in industries across the economy. Some feature highly disruptive technology advancement[43]. This is less so for beer whose market innovation metric is shown below from Appendix A, p81.

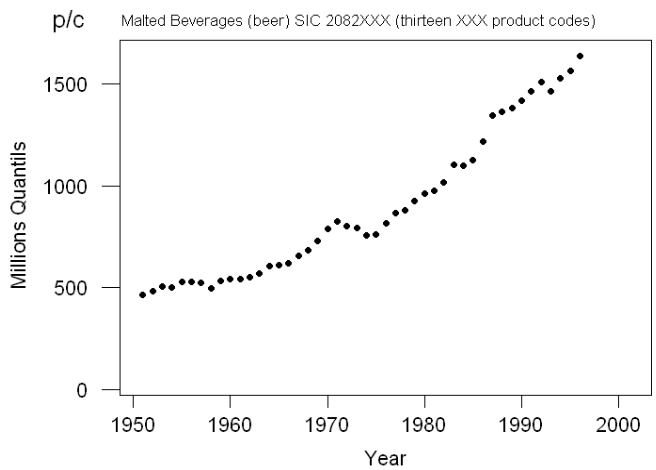


Figure A13

The private economy consists of a very large number of markets.

But National Accounting is tabulated by industry and commodity.

Since innovation metrics can only be enumerated by market, new treatment methodologies are required. These are described in detail in Appendix A.

The knowledge described in the previous **six** steps will be applied to establish the missing link between iDe and the Innovation Metric, in **Step 7**.

[43] For example, and from DINTEC™, the leading woven carpet firm made a successful transition to tufted technology (Bigelow-Sanford), while the primary tufted carpet innovator was enjoying enormous initial success. It then foundered, not least because of an overstuffed innovation funnel (Barwick). Then other firms started to take over (Galaxy). Other markets are featured in Appendix A and illustrated in figures A5 to A14, p77 – p82.

Step 7 – iDe Innovation and Economic Growth

In **Step 7** cause and effect between company sourced iDe and resulting innovation metric will be put beyond reasonable doubt by matching their congruent rising shapes when displaced according to product development time. This is a decisive step towards reclaiming an otherwise seemingly abandoned specific origin for economic growth.

It begins by,

1. Dividing iDe into Durable and Non-Durable, and

2. Summing Innovation to fit this division,

The methodologies for 1. and for 2. are in Appendix A. They lead to the following results, for

(a) Durable Goods

Congruent Shape

When durable iDe and its corresponding innovation metric Σ(**p/c**) are plotted separately. They show congruent rising scallops. iDe rises to 1969, falters then rises again to 1986, dips and rises again to 1997, where is also falters, figure 41.

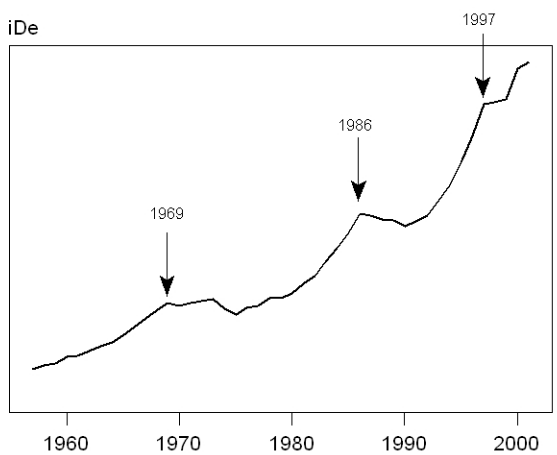


Figure 41 – iDe

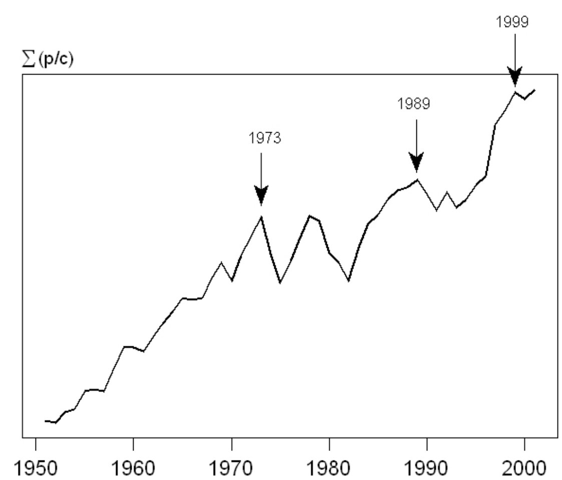


Figure 42 – Aggregated Innovation Metric

Σ(**p/c**) rises to 1973, collapses, recovers, collapses again[44], then rises to 1989, falters and rises to 1999, where it falters again, figure 42.

---

[44] If the leveling of iDe due the moon landing in 1969 had its effect on Σ(**p/c**) in 1973 a smooth response would be expected. In fact Σ(**p/c**) plunges. In **Step 2**, p23-24 the 'wow' of consumer reaction to the novelty of television is clearly registered in **p**, twice – once for b&w and again for color. Therefore it's likely that negative perceptions surrounding the oil crisis contribute. A partial recovery and another collapse follow

Table 11 – Endpoints for Corresponding Trends in iDe and Σ(**p**/**c**)
Durable Goods

iDe	Σ(**p**/**c**)	Latency δ
1969	1973	4
1979	1982	3
1986	1989	3
1997	1999	2
2001	?[45]	?

until the effect of iDe starts to impact the economy again. Recessions are discussed in this context on pages 58-59.

[45] Key DINTEC™ sources for enumerating Σ(**p**/**c**) end in 2001 but an alternative method is available for future investigators to extend the range, Appendix B.

And not only are their shapes congruent rising scallops they are also shifted. 1969 in iDe corresponds to 1973 in Σ(**p**/**c**). 1986 in iDe corresponds to 1989 in Σ(**p**/**c**) and 1997 in iDe corresponds to 1999 in Σ(**p**/**c**). The latency δ between Durable iDe and Durable Σ(**p**/**c**) is 4, 3, 3 and 2 years respectively, Table 11.

Matching Segments

When single points are plotted, instead of lines invisibly connecting them, segments can be identified. These are shown in figure 43.

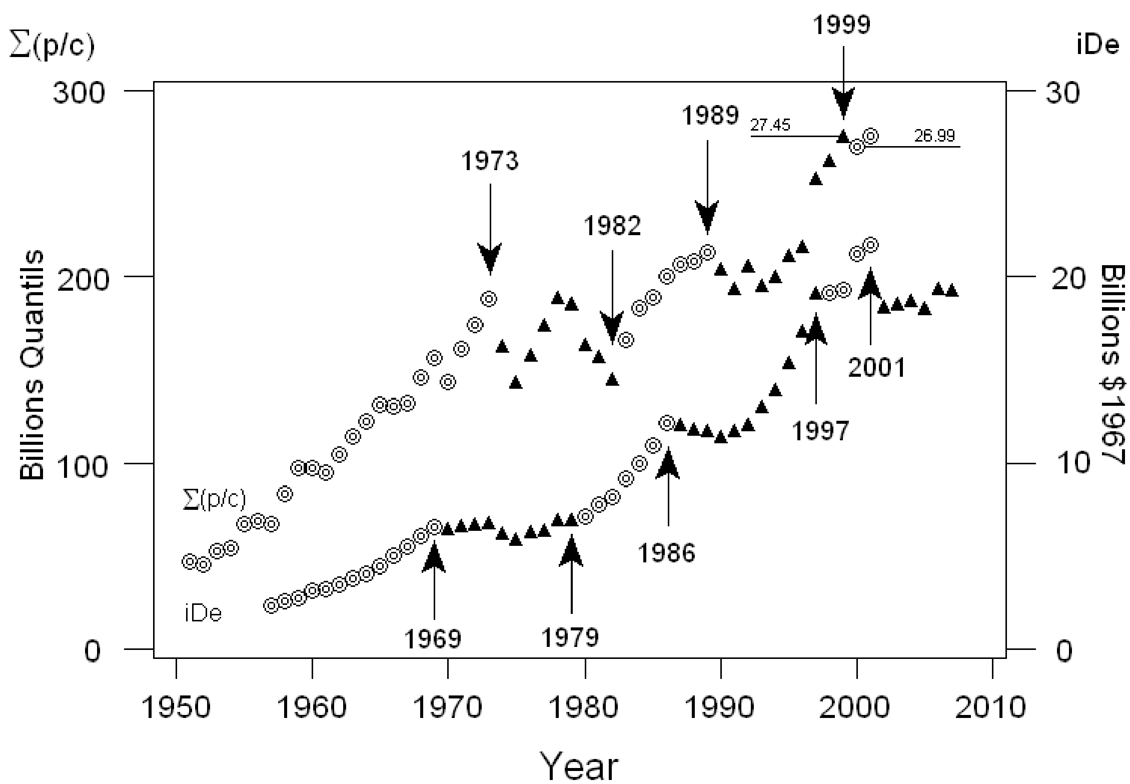


Figure 43 – iDe is cause: Σ(**p**/**c**) is effect

To reliably identify segments all points are covered by an opaque overlay then uncovered in sequence from the earliest. If a point appears to belong to an existing trend the next one is revealed until a new trend has appeared. The last point of the old trend marks the end of a segment. The resulting major trends are given corresponding symbols, triangle or double circle, in figure 43.

Durable iDe, which is extended to 2007 in figure 43, shows a remarkable drop in 2002. This permits prediction. If Σ(**p**/**c**) can be extended from 2001 a latent response should be found in it (for how - see footnote [45 (p56)]).

The strength of correspondence between iDe and $\Sigma(\mathbf{p/c})$ also passes the following tests,

1. Are latency periods δ consistent with what is known about product development timeframes?
2. Is there an alternative cause?
3. Is the shape of $\Sigma(\mathbf{p/c})$ due to a dominant surrogate?
4. Is the iDe shape distorted by supercomputing?

1. Consistent Timeframes?

Development times are available for Business to Business products[46] from a 1995 survey, Griffin (2002). In this study the product development process was divided into nine activities. Seven of these correspond to the innovation funnel. The average overall time was about 27 months. In addition 50% of firms surveyed were being successful in reducing their product development times. Although the survey did not separate durable and non-durable goods both conclusions are nevertheless consistent with the latency periods δ of Table 11.

2. Alternative Cause?

Columns in figure 44[47] indicate nine recession periods - from 1951 to 2001. The arrowed dates are $\Sigma(\mathbf{p/c})$ trend endpoints from Table 11.

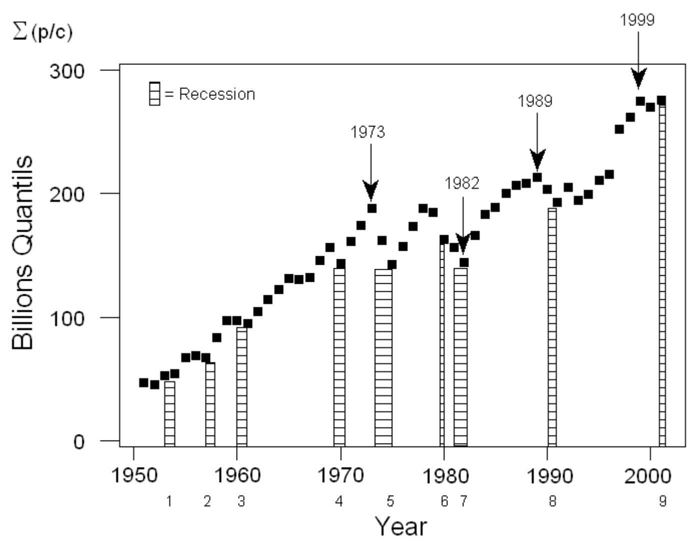


Figure 44 – Potential Influence of Recession on $\Sigma(\mathbf{p/c})$

Fluctuations in $\Sigma(\mathbf{p/c})$ are clearly associated with at least three of the recessions 5, 6-7 and 8. Downturns will negatively influence purchaser decision to buy and **p** will be suppressed by this perception. This is due to the sociology of purchase, shown already, for example, by consumer reaction to fountain pens in **Step 2**, 9.

[46] Intermediate goods.
[47] Peak to trough as defined by NBER.

If the perception induced by recession is evened out as short-term consumer anxiety the stability seen in iDe, a future-directed activity, clearly connects to Σ(**p/c**) with latency δ.

3. Dominating Surrogate?

Concrete is the dominant durable surrogate. Therefore total surrogate Σ(**p/c**) was re-plotted with it removed (not shown). The key transitions seen in figure 43, 1973, 1982, 1989 and 1999 remain unchanged. The scallop between 1989 and 1999 is sharper (bottoming at 1991) but general upward shaping is maintained.

4. Supercomputing?

Because the rush to supercomputing produced so many company failures its company sourced R&D was removed from consideration against Σ(**p/c**) in figure 43. But if supercomputing iDe is put back in the key iDe transitions at 1969, 1979, 1986 and 1997 remain intact despite the portion from 1986 to 1993 being somewhat flattened.

The Connection Between Lower (input) and Upper (output) Segments in These Graphs has Profound Significance for the Origin of Economic Growth

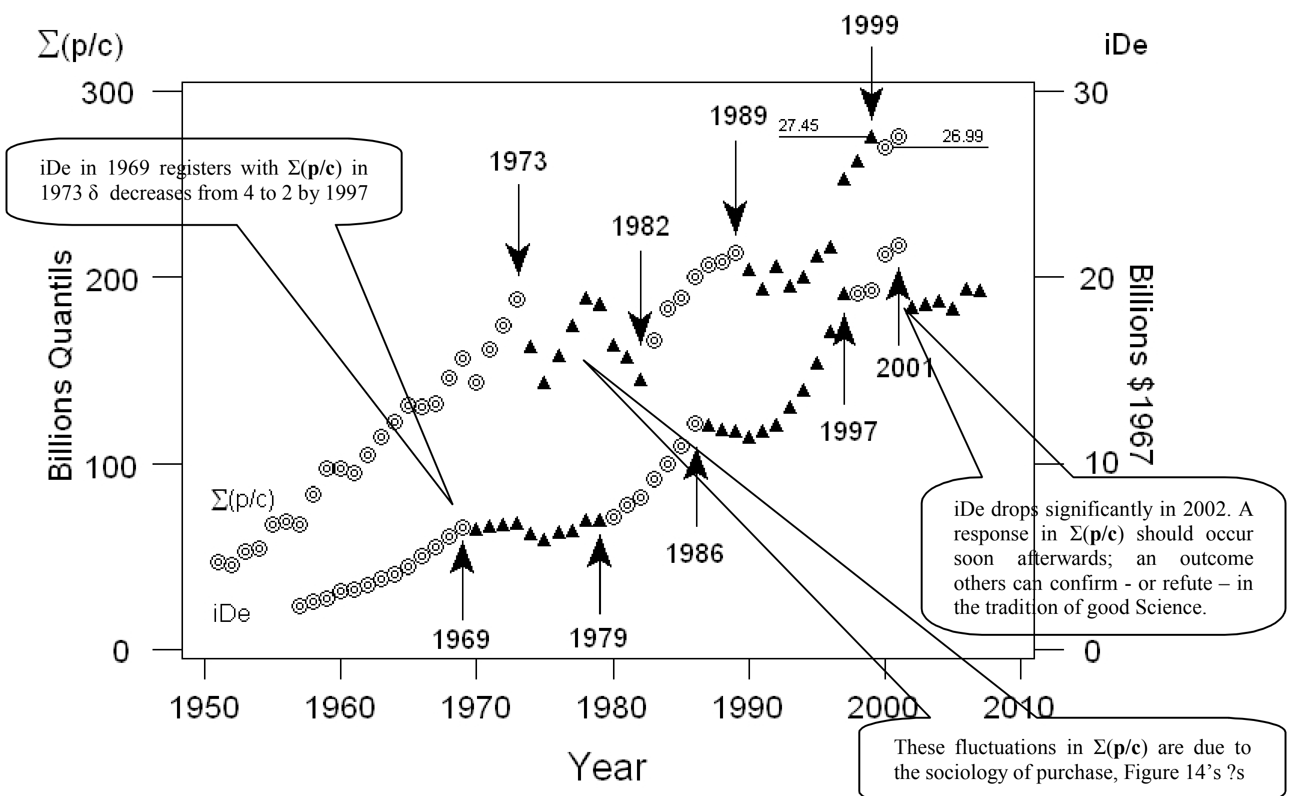


Figure 43 – iDe is cause: Σ(**p/c**) is effect

And for,

(b) Non-Durable Goods

Trends are unmistakably different for Non-Durable Goods in figures 45 and 46 than they are for durable goods in Figures 41 and 42. Less expensive goods are less economically sensitive and that clearly produces a credibly different and distinct growth behavior.

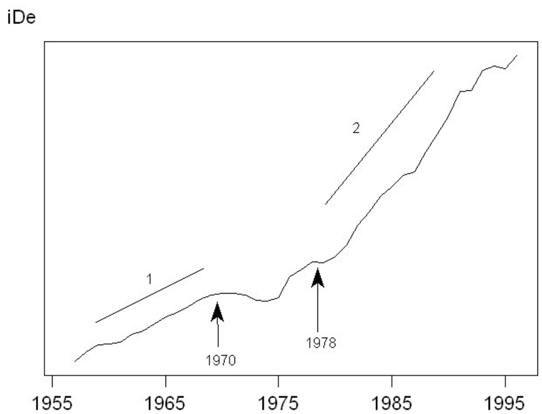


Fig 45 - iDe

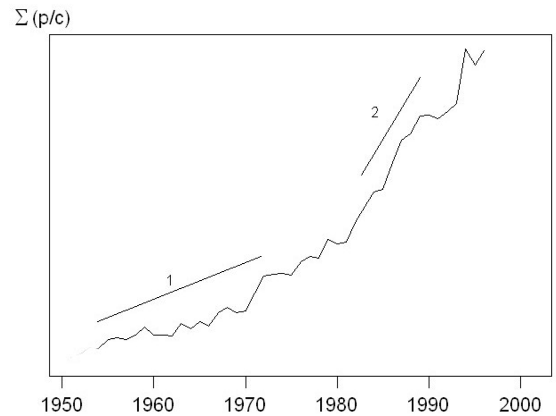


Fig 46 - Aggregated Innovation Metric

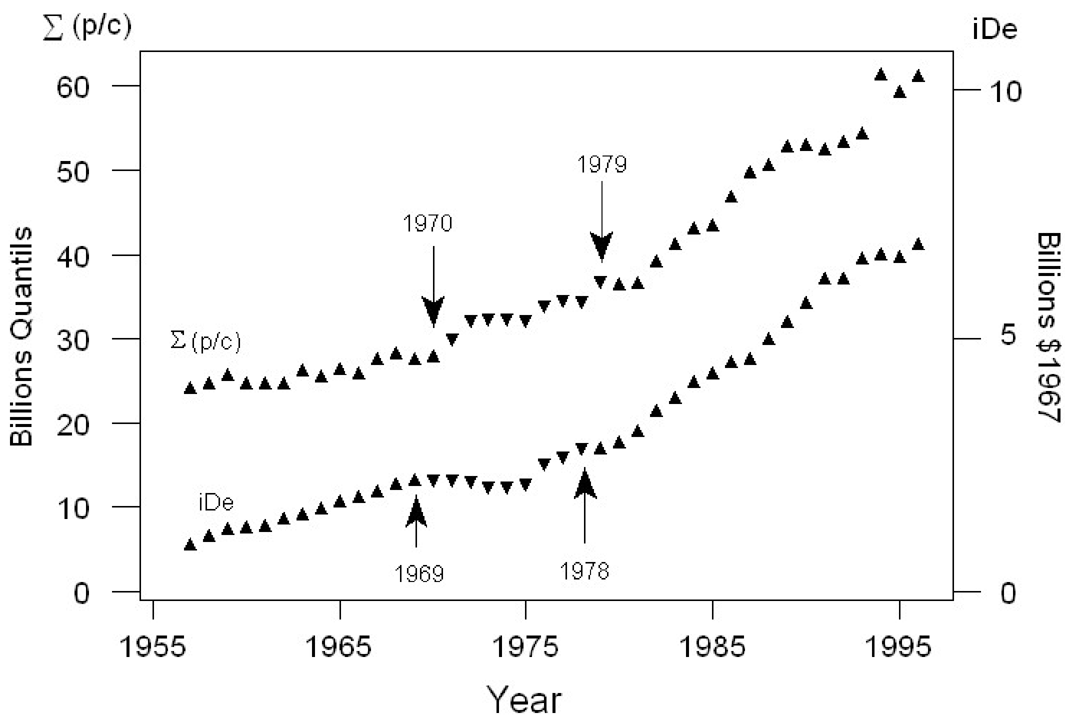


Figure 47 – iDe is cause: Σ(**p/c**) is effect?

Non-durable growth is best characterized by three slopes seen in iDe and in its corresponding Σ(**p/c**).

iDe grows in a uniformly linear manner until 1969 in a first slope – though it did so exponentially for durable goods – and it then stalls in 1970. This stall, which is shown by inverted solid triangles continues until a recovery from 1976 to 1978 when it joins a third linear slope that is distinctive from 1979.

This uniform linearity contrasts sharply with that seen for durable goods, whose rise in iDe occurs in exponential leaps.

Non-durable goods's Σ(**p/c**) rises uniformly to 1970. It then shifts upwards and continues to 1979. It joins a third linear slope that is distinctive from 1980.

Both iDe and Σ(**p/c**) show three slopes that are clearly related to each other in growth rate and chronology.

Innovation measurements for non-durable-good markets are fewer than are available for durable-good-markets[48]. This makes the latency period δ less certain. The best estimation is provided in Table 12.

Table 12 – Endpoints for Corresponding Trends in iDe and Σ(**p/c**)
Non-Durable Goods

iDe	Σ(**p/c**)	Latency δ
1969	1970	1
1978	1979	1

[48] Only three non-durable markets qualified for inclusion in determining Σ(**p/c**). Other non-durable markets set aside for want of complete or self-consistent data were Softwood Plywood SIC 2436XXX, Man-made Fibers SIC 2823XXX with 2824XXX, Analgesics SIC 28342XX, Soaps and Detergents SIC 2841XXX, Recorded Media SIC 3652XXX and Glass with Plastic Bottles SIC 32210XX with 30850XX.

1. Alternative Cause?

In the case of durable goods the graphs of iDe and Σ(**p/c**) are clearly shifted by a $\delta > 1$. For non-durable goods the latent period δ is less distinctive. This makes it possible, though unlikely, that another factor temporally common to both iDe and Σ(**p/c**) is both cause and effect in Figure 47[49].

2. Ethical Drugs

Ethical drugs, which are non-durables, have development times extended by regulatory approval and this might be thought to contribute to very long δ latency. This is certainly true for the base chemicals. However formulations from them are the norm. By comparing patterns of new-drug applications with those that are not for new drugs the approval time for the latter in the 1980s was about one year, on average, Austin (2006).

The Slowdown in Whole Manufacturing Innovation Σ Σ(p/c)

By adding Σ(**p/c**) for Durable-Goods to Σ(**p/c**) for Non-Durable Goods the innovative output of the Manufacturing Sector can be enumerated. When the logarithm of Σ Σ(**p/c**) is plotted annually it divides into two distinct growth eras, figure 48.

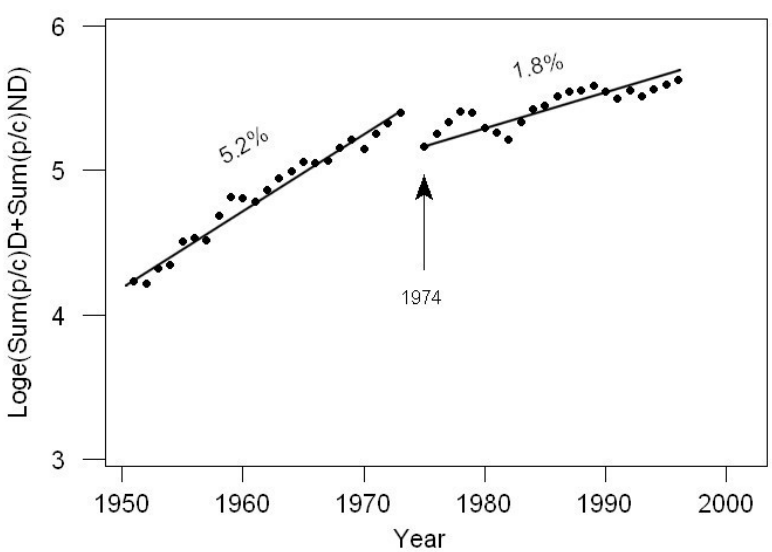


Figure 48 – There was a Great Slowdown in Innovation

[49] Non-durable goods are inherently easier to develop than durable goods. So it is not surprising that their δ is found to be inherently less.

One extends from 1951 to 1973 and shows an exponential growth rate of 5.2% per annum the other extends from 1974 to 1996 with a reduced rate of 1.8%. This mirrors the 'Productivity Slowdown', to explain which several hypotheses have been advanced. The R&D one seems to have foundered after 'Productivity Puzzles and R&D: Another Non-Explanation', Griliches (1988), due to data constraint, Griliches (1994). Lacking that data he offered a thought experiment instead.

Productivity Thought Experiment

To direct economic attention to its 'impossible topic' quality change, Griliches challenged his audience to think about the space program, Griliches (1999). '*Should GDP be unaffected whether Apollo landed and safely returned to earth, or not*?' he asked.

Apollo 11 landed and safely returned to earth in 1969 the year after which durable goods iDe stalled, figure 43, and the same year for non-durable goods iDe doing the same, figure 47. Latency δ delayed the transition to lower growth rate to 1974, figure 48. Apollo definitely impacted GDP growth around the world.

Television assured that landing a man on the moon became an international talisman an unbeatable zenith in technology prowess. To paraphrase Ralph Waldo Emerson's famous Revolutionary War Commemoration line 'a shot heard around the world' this time it was 'a moonshot seen around the world'.

Nordhaus (1981) characterized a simultaneous international depletion of innovation as implausible. The mass media impact surrounding Apollo 11 makes it highly possible.

Actual Innovation Productivity

Plots of Σ(**p/c**) against iDe reveal actual innovation productivities, figures 49 and 50, with notable features. Of these it might be tempting to imagine Durable Goods heading toward a limit. But it's more likely that Durable Goods are ever more sophisticated and require more spending to deliver in historically reducing δ latencies, Table 11, p56.

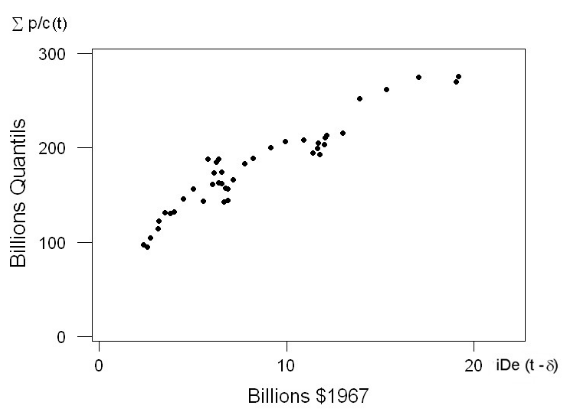


Figure 49 – Innovation v iDe Durable Goods

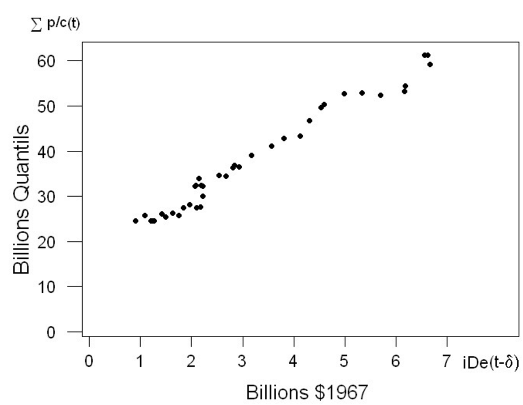


Figure 50 – Innovation v iDe Non-Durable Goods

Extrapolating the linear trend of Σ(**p/c**) (only the first fifteen points (1957-71) for Durable Goods, all points for Non-Durables) back to zero iDe produces non-zero Σ(**p/c**)s. This may represent manufacturing technology inherited from past eras and opens a window to economic history – during which planned spending on innovation using Science and the scientific method for the purpose of industrial success contributes only in modern times.

A linear fit is appropriate for the early Durable Goods data. But what's even more interesting is to explore the later trend. There is a very simple fit to <u>all</u> the Durable Goods data to 2001 taking the curvature into account

$$\Sigma\left({}^{p}\!/_{c}\right) \approx \sqrt{\text{iDe}} \text{ x } 60$$

This predictive formula has no upper limit on Σ(**p/c**). And there isn't one in sight for Non-Durable goods, figure 50. Both correspond to 'Science The Endless Frontier' as coined by Vannevar Bush, Bush (1945).

There are many factors, institutional, organizational, political and strategic, behind successful iDe and its impact on Σ(**p/c**). The measurement of the effectiveness of this suite of factors, in figures 49 and 50, is fundamental and reflects the underlying ecological imperative (described at **Step 1)**.

What starts between products cascades up into firms, to industries, to sectors, to economies, to nations and ultimately affects civilization, MacGregor (2011).

Step 8 – Implications for Economic Growth

Neo-Classical Factors

Neo-Classical Growth Theory asserts that economic growth can be parsed into factors. The two most important ones are capital and labor. Others are energy, materials and services[50]. But despite many attempts, measures of these inputs have never been enough to explain the key measure of output, which is GDP. At least another factor is at work. This is generally agreed to be technology and, since it's implicitly realized that innovation is commercialized technology, the remaining factor could be, or is, innovation.

Since Σ(**p/c**) passes the litmus test for an independently derived innovation metric[51] the sufficiency of the remainder - multi-factor productivity KLEMS – in relation to innovation can be rigorously tested using the data plotted below from page 93.

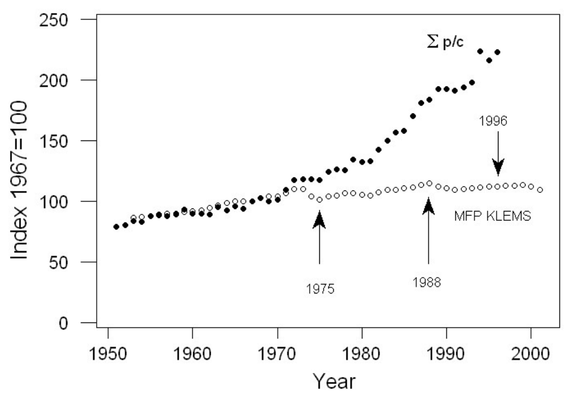


Figure 51 - Non-Durable Σ(**p/c**) compared to MFP KLEMS

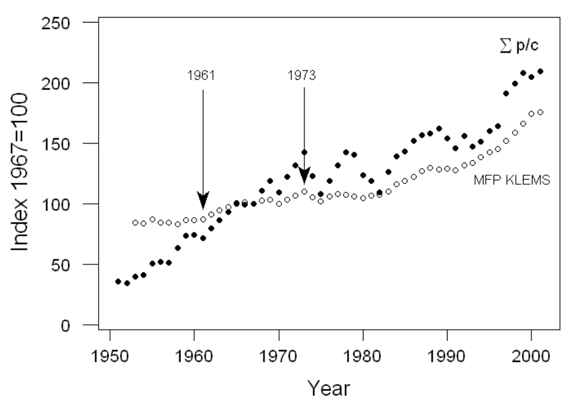


Figure 52 – Durable Σ(**p/c**) compared to MFP KLEMS

For non-durable goods MFP rises to a slight maximum in 1988 (114.5) but is essentially quiescent for some twenty years from 1975 (101.6) to 1996 (111.9), figure 51. This is

[50] Collectively dubbed KLEMS. The Bureau of Labor Statistics measures these inputs and publishes their factor productivity; referred to as MFP KLEMS in figures 51 and 52, Commerce (2004).
[51] The litmus test is whether or not it fits Innovation Funnel constructs.

completely at odds with innovation spending. In the same period iDe soars from 2.14 billion dollars in 1975 to 6.85 in 1996, figure 47. As already established in **Step 7**, Σ(**p/c**) corresponds well with that spending.

And the response of MFP to innovation spending limps for durable goods during the period 1961 to 1973 when MFP only rose from 87.1 to 109.9 while iDe rose from 2.4 billion in 1957 to 6.5 in 1969 (the dates accounting for a four year latency period δ), figure 43. As already established in **Step 7**, Σ(**p/c**) rises appropriately in response to iDe spending. Furthermore – and in contrast to the treatments in **Steps 5 and 6** - there is no sense in which, when MFP reaches a specific value, creative destruction ensues.

Multi-factor productivity MFP fails the above tests and is therefore insufficiently related to innovation. It must be measuring something else.

Factor Productivity belongs within Neo-Classical Growth Theory.

The principal protagonist of today's more conceptual New Growth Theory characterized '*the study of research and development or productivity at the level of the industry or firm*' as '*complementary to, but different from*' such theories, Romer (1994). Those different complements are now provided, in this book.

A Paradigm of New Factors

The connections between major variables established in the preceding **Steps** can be expressed heuristically by three algebraic expressions; a division, a subtraction and a multiplication, arranged in a parallelogram, linked as follows,

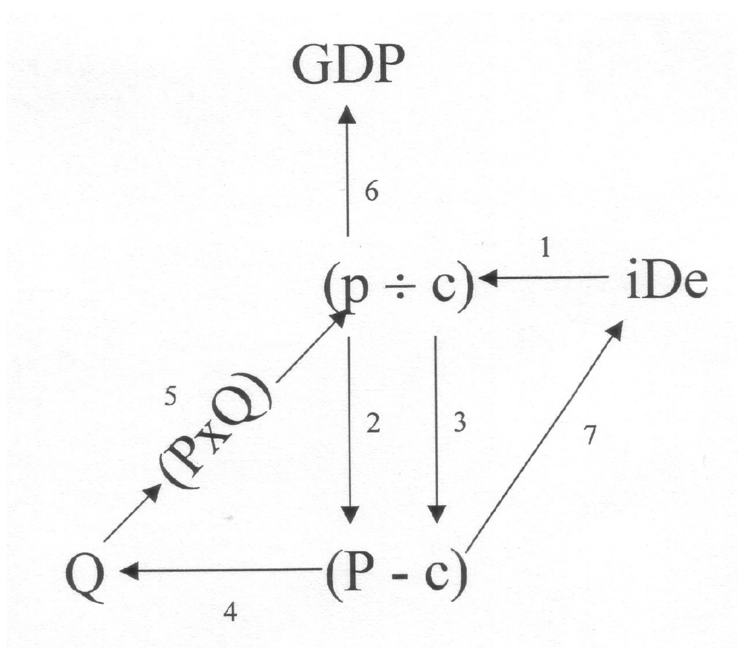


Figure 53 – The Innovation Parallelogram

1. Spending on iDe[52] raises the innovation metric (**p/c**); by

2. increasing the numerator p through product development, for which a higher price can be asked,

3. and/or by reducing the denominator c through technology development.

4. Greater profit (P-c) enables more production, a higher Q,

5. that pPQ multiplies by P to quantify p,

6. that translates into greater GDP (its full algebra is on page 39).

7. Meanwhile previous profit (P-c) spent on iDe is coming to fruition, completing the parallelogram.

Although this illustration is for a single product from a single firm in a single market[53] the model is nevertheless comprehensive.

Innovation parallelograms can be viewed as a mosaic of tiles that the customary divisions of industries by commodities are representing. Each tile depicts a market that is expanding from the economic growth mechanism within, where the economy is a dynamic stack of such mosaics.

Parallelogram factors are quite different than those invoked by Neo-Classical Growth Theory, in which capital and labor are primary. In the parallelogram labor is secondary (appearing as a component of c) and capital is tertiary (giving rise to greater production capacity for Q, see Appendix E, p84). Primary growth factors operate through the iDe - (**p/c**) link that's completely absent from the incumbent Cobb-Douglas treatment.

Nevertheless, and in the words of Alan Greenspan, Greenspan (2007) *'It is conceivable that by 2030 economists will have devised a new means of measuring an economy's productivity directly, rather than through its proxy output per hour'*. This single productivity is exactly what the innovation parallelogram's iDe - (**p/c**) link already offers. What might thwart economists for another decade - without outside help – is the input isn't contemporary; it's in the past viz. GDP/iDe(t- δ).

The current upside down productivity indicator 'R&D Intensity' - as reported, for example, by the National Science Foundation – embodies compromised thinking. True

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[52] iDe is company sourced Applied Research and Development funds applied to the Innovation Funnel, noting that federal funds may stimulate companies to seek commercially interesting outcomes from their own iDe spending. The link 1. - between iDe and (**p/c**) - includes latent period δ. These delays are different for durable and non-durable goods – Tables 11 and 12. Because only the iDe portion of R&D has direct effect, the indicator R&D Intensity (=R&D/GDP)% (which is an invert productivity) is fundamentally inadequate and should be supplemented - or replaced - by true productivity GDP(t)/iDe (t-δ) evaluated by sector.

[53] For instance a new-to-the-world product creating a new market protected by a strong patent monopoly.

productivity from Innovation Funnel economics is far more powerful as it empowers evidence-based action.

Significance for National Accounting

National Accounting treats R&D as capital. The argument is that intangible knowledge can enhance future production making it eligible – like capital spending on manufacturing equipment - for addition to current GDP. From the same argument R&D is accumulated in a separate account from which past knowledge is retired to obtain a current intangible stock. But National Accounting tabulates no way for conversion from intangibility to tangibility, which is required to cause economic growth.

The innovation funnel provides this means. Because it is absent from academic economics, page 41, National Accounting's methodology naturally combines success and un-success in R&D, Aizcorbe, Moylan & Robbins (2009), figure 54.

Here is how it should work. iDe is an **expense**. It pushes new ideas into viable products through the funnel. Successful products or services then contribute to economic growth by the Innovation Parallelogram market mechanism. Unsuccessful products and services – that are in the majority - are held back in originating firms as core competency. They may then arise Phoenix-like in the future, or they may be licensed to other firms in an openness of the funnel that is a developing characteristic of the 21st Century economy. In every case additional iDe spending is the key that unlocks any potential.

iDe has more merit than R&D for inclusion in National Accounting. The iDe to (**p/c**) link provides the otherwise missing piece in the puzzle of GDP growth[54].


BEA BRIEFING

Toward Better Measurement of Innovation and Intangibles

By Ana M. Aizcorbe, Carol E. Moylan, and Carol A. Robbins

Innovative property

Expenditures for technological and creative property are larger than those for computerized information, representing about a third of total spending on intangible assets, according to the Corrado, Hulten, and

11. These measures of R&D investment are based on R&D expenditures, which implicitly treat both failed and successful activity as capital forming

forms of entertainment and, more broadly, nontechnological spending for new product development.[10]

10. BEA considers the scope of R&D investment to include both technological and nontechnological activity as long as the purpose is to increase the stock of knowledge, including knowledge of man, culture, and society that is used to devise new applications. This definition of R&D is from the Organisation of Economic Co-operation and Development (2002, 30, paragraph 63). BEA considers R&D in the social sciences and the humanities to be nontechnological R&D.

The portion of spending on innovative property that involves technological R&D, which accounts for about half of the business spending in this class, is currently measured in the BEA R&D satellite account.

and obligations for R&D allow the measurement of R&D performed by private business, private nonprofit institutions serving households, and government entities. Data on R&D performed by others at the government's expense and data on R&D performed by the government for its own use are both available.[11]

Figure 54 –Treating failed and successful activity together is weak. It overlooks the critical importance of the Innovation Funnel in weeding out what will actually determine future economic growth.

[54] That's link 1 of the Innovation Parallelogram, which is the Innovation Funnel. In economic parlance, GDP is the endogenous variable of the innovation parallelogram while (p/c) is the endogenous variable of the innovation funnel. Other variables are exogenous. All are influential in proportion to their place in each system or sub-system, respectively.

Significance for Policy

Neo-Classical Growth Economics measures neither technology nor innovation and therefore leaves an unaccountable gap that may be filled by one or the other, or both. This presents an obvious weakness when trying to frame vibrant economic policy.

But once the data constraint, Griliches (1994), is lifted from Economics and the neglected numbers brought to light the situation changes. The direct economic measurement of innovation delivers a set of factors from which it is possible to frame such policy.

Plots of the metric shown in figures 49 and 50, once they are part of National Accounting, can be extrapolated. Using reasonable assumptions it is possible to estimate, with some degree of confidence, how much innovation spending will be necessary to achieve a given goods GDP in a future year. Policy can then be constructed to achieve it.

Such capability bestows global economic advantage.

Last Word from an Innovation Practitioner

In ten years since the advisory committee's report on innovation measurement, Commerce (2008), Economics is not close to taking this 21st century step. It still hasn't cracked its 'impossible topic' 'quality change', Griliches (1999), without which Economics' existing paradigms and constructs are not conducive to incorporating innovation.

For success the following adjustments need consideration,

1. Physical quantity not derived from price but independently and universally,

2. Competition as market pressure that is manifest by physical quantity, while firms create and steward advantaged product offerings in those quantities,

3. The economy divided into these markets rather than by their commodities,

4. Innovation Funnel economics controlling micro and macro economic growth,

5. Capital and labor not presumed primal.

With at least these provisos and using tacit knowledge available within the professional community of non-economists that practice innovation commercially, economic growth is explained from neglected numbers to ground breaking conclusion.

Appendices, References and a Glossary

Appendix A

Surrogate Methodology

The surrogate method provides a way for a small, but data intensive, sample to represent something much larger; the manufacturing economy. In the geometric tile analogy presented on page 67 certain tiles are allowed to expand to fit where other tiles may be missing. It requires several elements. The first element co-opts the conventional divisions of Research and Development and reconfigures them to fit the innovation funnel. The second element identifies all endpoints of innovation funnels operating within the manufacturing sector when goods are separated into durable and non-durables[55]. The third element matches a small number of markets, or tiles, for which detailed data on innovation metrics is available to these divisions. The fourth element aggregates these surrogates to produce two economy-wide innovation measures, one for durable the other for non-durable goods.

First Element – Reconfiguring Research and Development

Surveys conducted by the National Science Foundation contain data on R&D spending in three categories, Basic Research, Applied Research, and Development. Their focus on scientific research has roots in a politically influential essay 'Science, the Endless Frontier', Bush (1945), but doesn't fit the innovation funnel particularly well. Funnel activity is about turning ideas into commercial products and about technology rather than Science[56]. Funnel iDe leading to the innovation metric (**p/c**) is closely aligned with company sourced Applied Research and Development (but not with Basic Research)[57]. It is a constant fraction of total company sourced R&D, Figure A1.

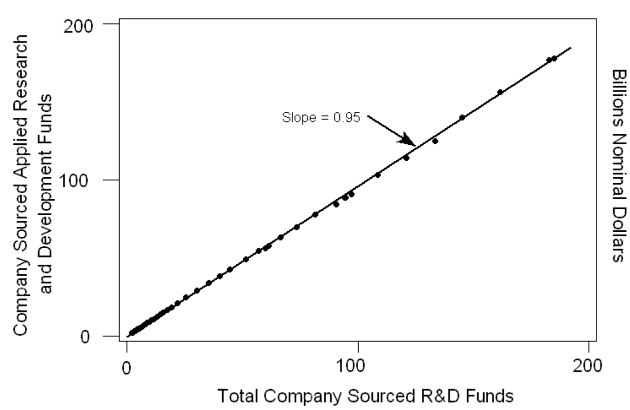

Figure A1 – Company sourced iDe is a constant fraction of total company sourced R&D (1951-2001)

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[55] R&D on goods for export is deemed essentially 'free'.
[56] Where technology is the means for producing new and useful objects, where Science expands frontiers of use (the limits on S-Curves), and where the scientific method has advanced both.
[57] Federal funds stimulate companies to seek commercially interesting outcomes with their own funds. iDe is company-only money spent primarily on STEM (Science, Technology, Engineering and Mathematics).

With these inclusions and exclusions understood iDe and R&D will be used interchangeably.

Company sourced R&D is available in broad industry classification from 1957[58]. Despite missing data Durable Goods R&D can be separated out[59]. Within it there is a prominent and singular drop in Machinery R&D from 1992 to 1993. This is attributable to High Performance Computing firm failures when Massive Parallel Processing gave way to Vector Multi-Processing technology. Forty-three vendors went out of business and nine merged with others, Strohmaier et al (1999). To keep the durable goods development success rate steady[60] estimated supercomputing development expense, Figure A2, was subtracted from Durable R&D and Total R&D from 1976 to 1992.

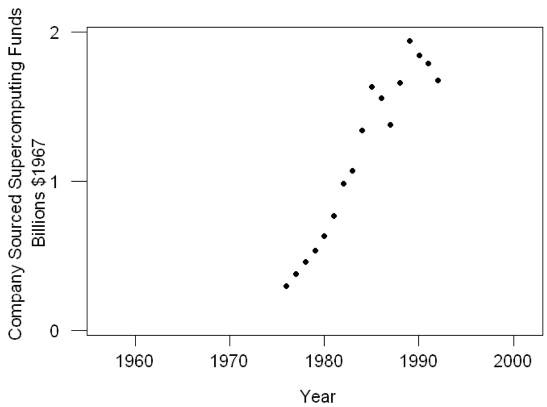


Figure A2 – Estimated Company iDe for Supercomputers

For Non-Durable Goods missing data is more serious at about 28%. Therefore Non-Durable Goods R&D was obtained by subtraction of Durable Goods and Service Sector R&D from the Grand Total. Even this is somewhat problematic because some Service Sector data is also missing between 1958 and 1980. It was put back by linear interpolation between 1957 and 1981.

Second Element – End-points for Manufacturing R&D

Innovation operates in markets. Markets are not divisions within the National Income and Product Accounts (NIPAs). A beauty of the surrogate method is they don't need to be. Only outputs from markets, the end-points of R&D, are required. From the NIPAs, major end-points for durable goods R&D in order of importance belong in the following categories - Producers Durable Equipment, Personal Consumption Expenditures, Intermediates to Construction, Intermediates to Services, Government Equipment and Intermediates to Government[61]. Major end-points for non-durable goods R&D in order of importance belong in the following categories - Personal Consumption Expenditures, Intermediates to Services, Intermediates to Government and Intermediates to

[58] With a transition from SIC classification to NAICS classification from 1999.
[59] About 4.5% of data remains missing for durable goods, constituting small but distributed errors.
[60] The innovation funnel treatment implicitly assumes this. See page 40 for supporting data.
[61] Excluding Defense whose quantities are too small to constitute a competitive pressure.

Construction. Each category's value is available or can be closely estimated from 1951 to 2001. Transport wholesale and retail margins can be backed out to provide factory or port values. The resulting numbers include imports and exclude exports and are suitable for matching to market combinations available from DINTEC™.

Because the economy has interconnecting chains that mix durable and non-durable strands their separation requires justification. Referring to the Benchmark Input-Output Accounts 'The Use of Commodities by Industries' table (for 1992) shows industries classifiable as durable benefiting from intermediate commodities both durable and non-durable, Lawson (1997). Summing the value of intermediate manufactured commodities to durable industries shows 83% of them are durable. Non-durable industries benefit from manufactured intermediate commodities that are 82% non-durable. Therefore, although separating durable and non-durable end-points for R&D is not exact it is a good approximation.

Third Element – Matching Innovation Metrics with R&D Endpoint Categories

From 1993 to 2003 a database dubbed DINTEC™ - Data on INnovation Technology and EConomics was compiled. It contains annual core market data between 1951 and 2001[62] for ten durable goods markets and four non-durable ones representing well over a hundred commodities at the seven-digit SIC level with ninety-seven qualifying as surrogates. The factory gate or port value of domestic supply (shipments – exports + imports) and the innovation metric (**p/c**) for shipments from US producers is available for each DINTEC™ market and many commodities within them[63].

The procedure for matching innovation metrics with R&D endpoint categories begins by seeking surrogates for each category from available DINTEC™ markets. The result for durable goods is shown in Table A1 and for non-durable goods is in Table A2,

Multipliers between putative durable or non-durable surrogate markets and the value of each R&D end-point category are found from 1951 to 2001 by linear regression[64]. Any negatively signed term in the resulting equation is eliminated and the regression repeated until all signs are positive. The sum of all equation output is plotted against total R&D endpoint value to assure no large deviation. For durable goods eight surrogate markets provide a set of fits. For non-durable goods three surrogate markets provide a fit to the sum of all R&D end-point categories between 1951 and 1996. Beyond 1996 no combination of non-durable surrogate markets provide a reasonable fit.

Whether such small surrogate sampling can validly represent such a large economy can be explored with 'The Use of Commodities by Industries' table in the Benchmark Input-Output Accounts. In 1992 the number of durable goods commodities intermediate to any given durable good industry is large. On average a single durable good industry sources

[62] DINTEC™ stops in 2001 because the Department of Commerce discontinued the enabling data it had collected since the 1940s. It has not re-instated that data collection since.

[63] Noting that the price of domestically destined products is taken equal to shipment price.

[64] With the exception of durable intermediates to construction; concrete provides a unique singular fit.

Table A1- Multiplier Matrix for Durable Matches

R&D Endpoints	Nominal 1992 Value (billion)	Surrogate Markets							
		Carpets 227X0XX	Concrete 32730XX	Light Trucks 336112	Office Machines (Words) 357XXXX	Office Machines (Data) 357XXXX	Home Computers	Refrigerators 36321XX	Pens 39510XX
Producers Durable Equipment (Investment)	368.0	25.0		0.994	2.22	2.54	9.36		
Personal Consumption Expenditures	290.2	19.9		1.9	1.09			5.48	2.0
Intermediates to Construction	180.9		14.8						
Intermediates to Services	169.5	4.34		1.62	0.226				27.6
Government Equipment (Investment Non-Defense)	46.2			0.462		0.297			10.5
Intermediates to Government	14.6	0.44		0.098		0.0728			3.17
Multipliers α =		49.68	14.8	5.07	3.50	2.91	9.36	5.48	43.27

Table A2- Multiplier Matrix For Non-Durable Matches

R&D End-points	Nominal 1992 Value (billions)	Surrogate Markets		
		Frozen Vegetables 20372XX	Beer 2082XXX	Interior Paint 2851XXX
Personal Consumption Expenditures	778.2	44.8	16.3	116
Intermediates To Services	115.4			
Intermediates To Government	93.7			
Intermediates To Construction	42.6			
Multipliers α =		44.8	16.3	116

intermediates from about 60% of all durable good industries. A set of eight single surrogate markets is therefore far more representative than might be expected. A single non-durable industry sources non-durable intermediates from a similar 55% of the non-durable total. But with fewer surrogates covering the non-durable sector their conclusions will carry less weight.

Fourth Element – Aggregation of Innovation Metrics

The innovation metric's unit is physical quantity and differs from market to market. For aggregation an intermarket-invariant unit is required, but not provided, within Economics.

For his quantity theory of money Irving Fisher added bales of cotton, sacks of rice, cars of fruit, feet of lumber, cases of shoes and tons of coal by fixing a base year price for each. In future years, bales, sacks, cars, feet, cases and tons could each be expressed in constant base year dollars and summed, Fisher (1922). Today a quantity index can be obtained from a base year by dividing nominal value by a price index with that base year. Physical quantity became a dependent variable by adoption.

But competitive pressure treats quantity as inherently independent. Aggregations will require a missing piece of the economic puzzle transferred from architecture. This is a unit dubbed the quantil[65]. The innovation metric (**p/c**) for shipments is presented in quantils for the eleven surrogates in figures A4 – A14.

[65] Further detail on the quantil from Appendix A and other details from content referred to in Appendices A – E are confidential. The Department of Commerce has negotiated access to it from Technology Matters.

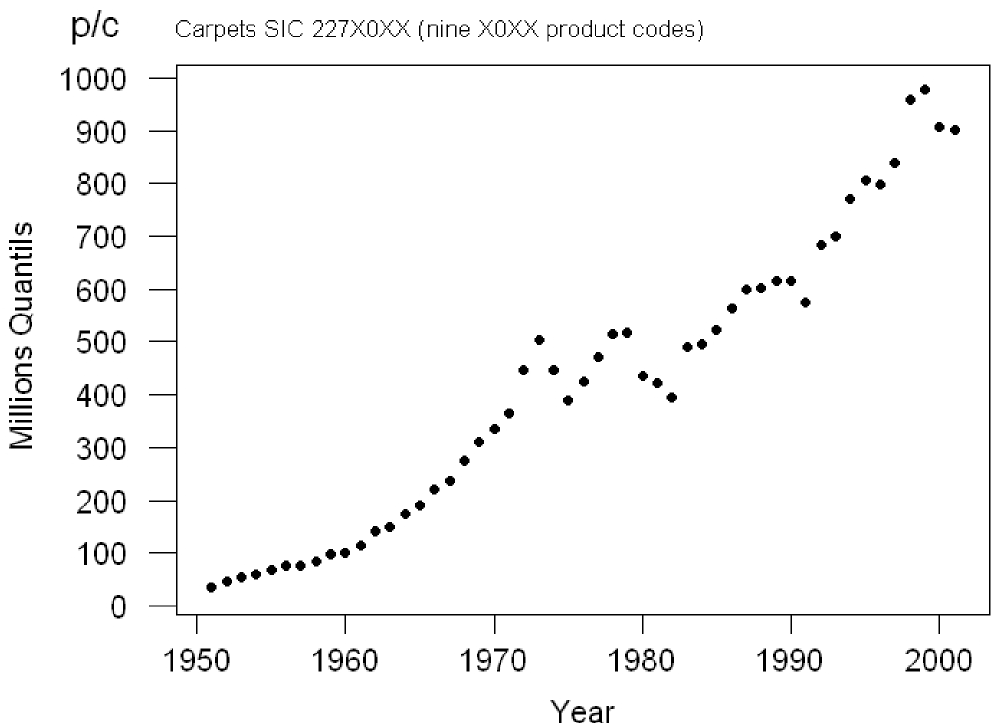


Figure A4

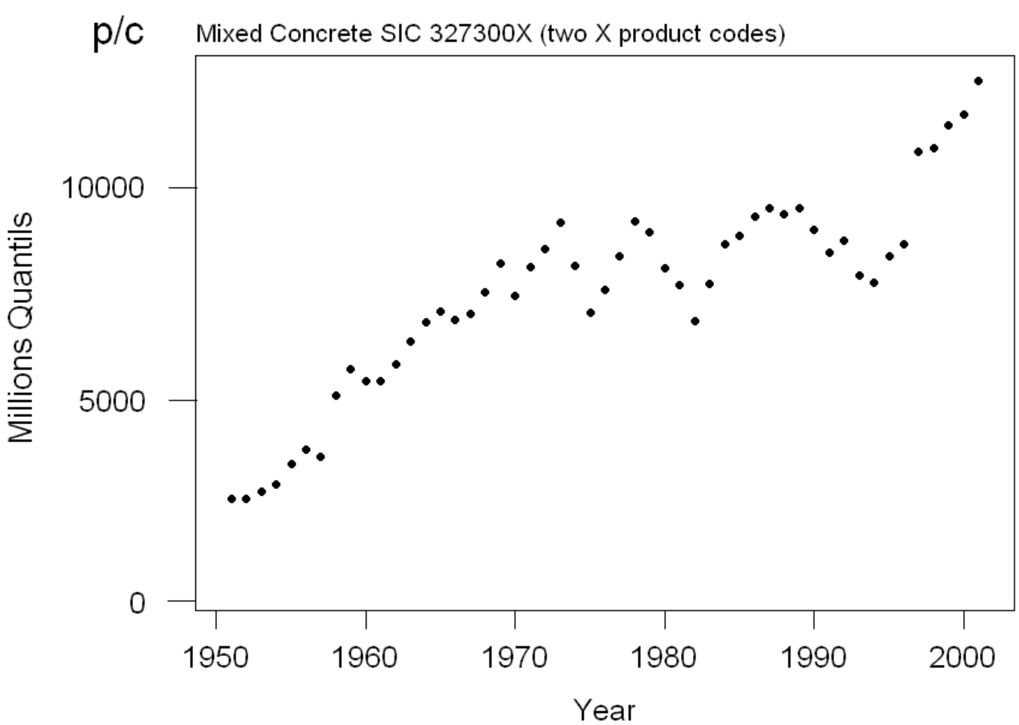


Figure A5

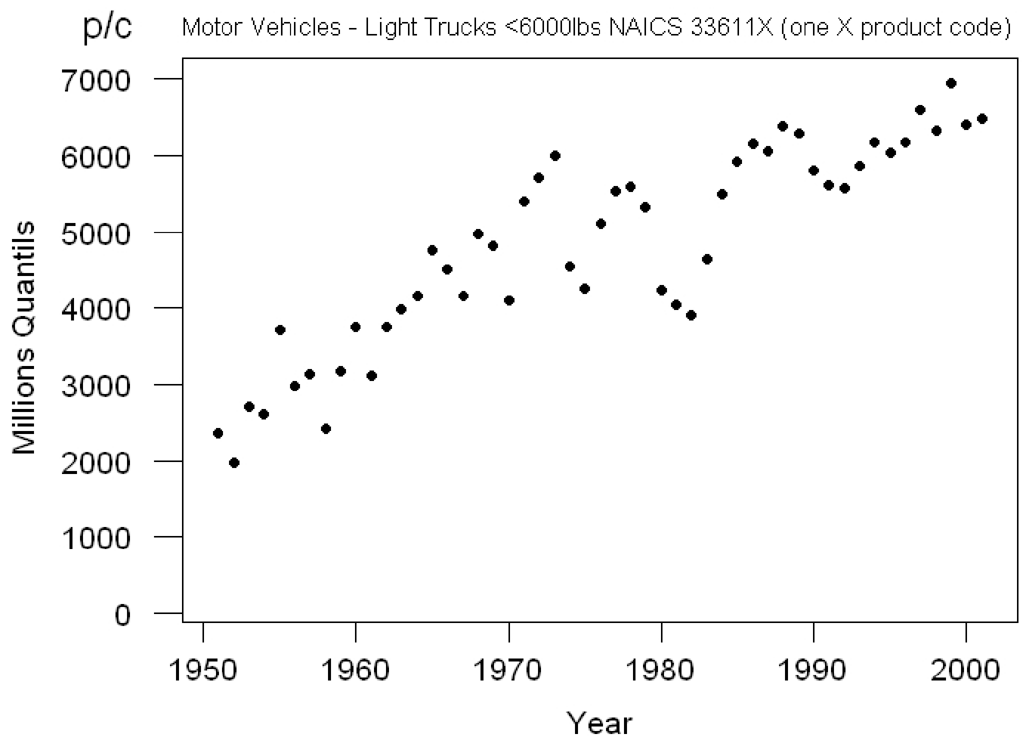


Figure A6

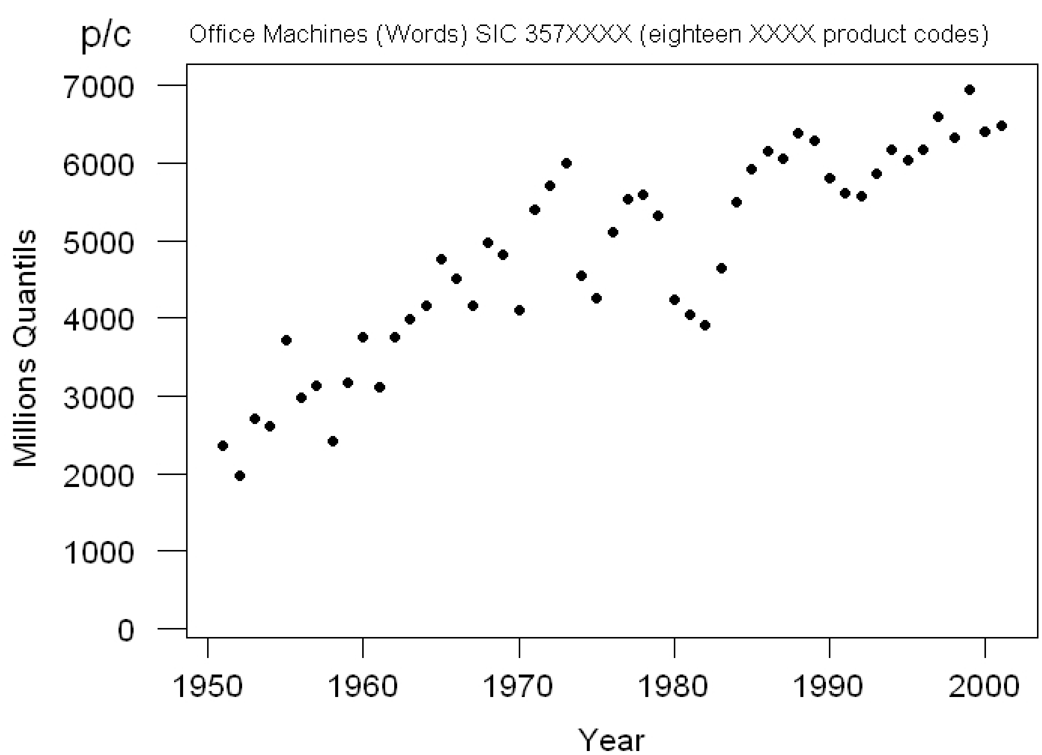


Figure A7

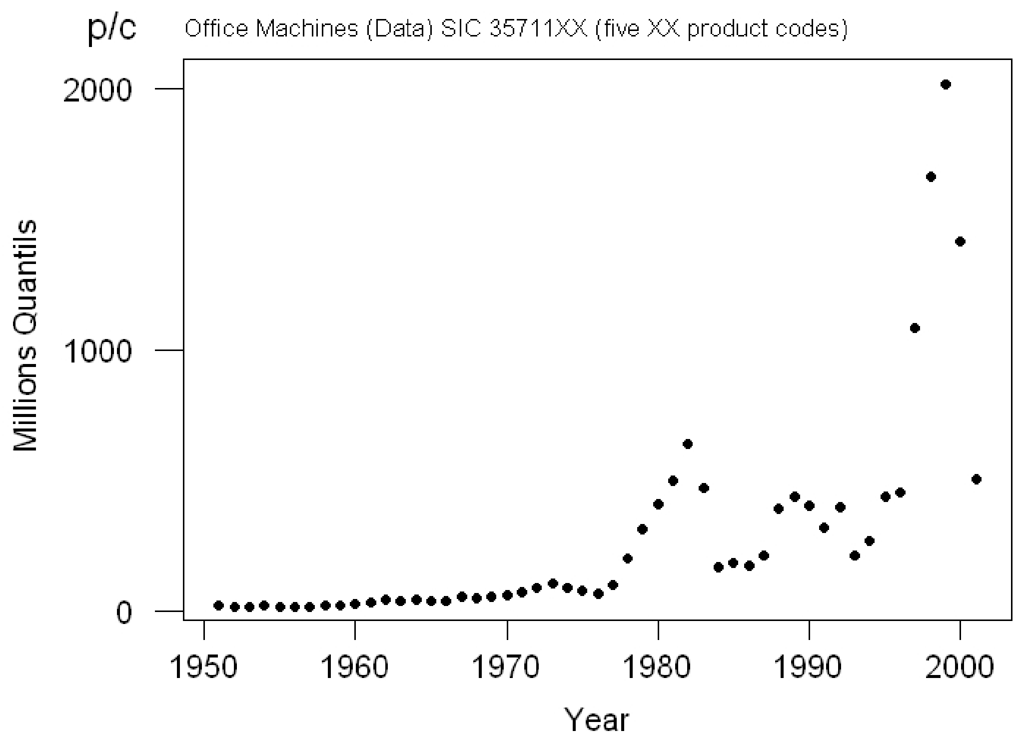


Figure A8

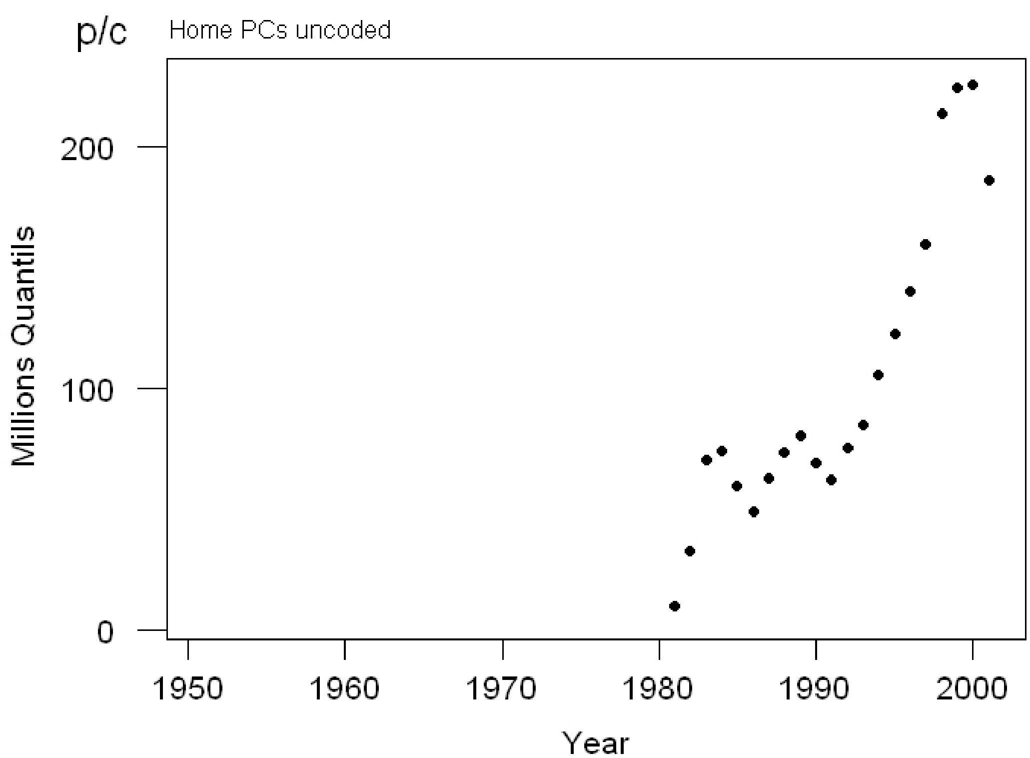


Figure A9

The computing innovation in Figures A8 and A9 contributes significantly to the multipliers in Table A1 on page 74. When Robert Solow stated *'You can see the computer age everywhere but in the productivity statistics'* he was looking at the wrong productivity, a conclusion entirely consistent with Alan Greenspan on page 67.

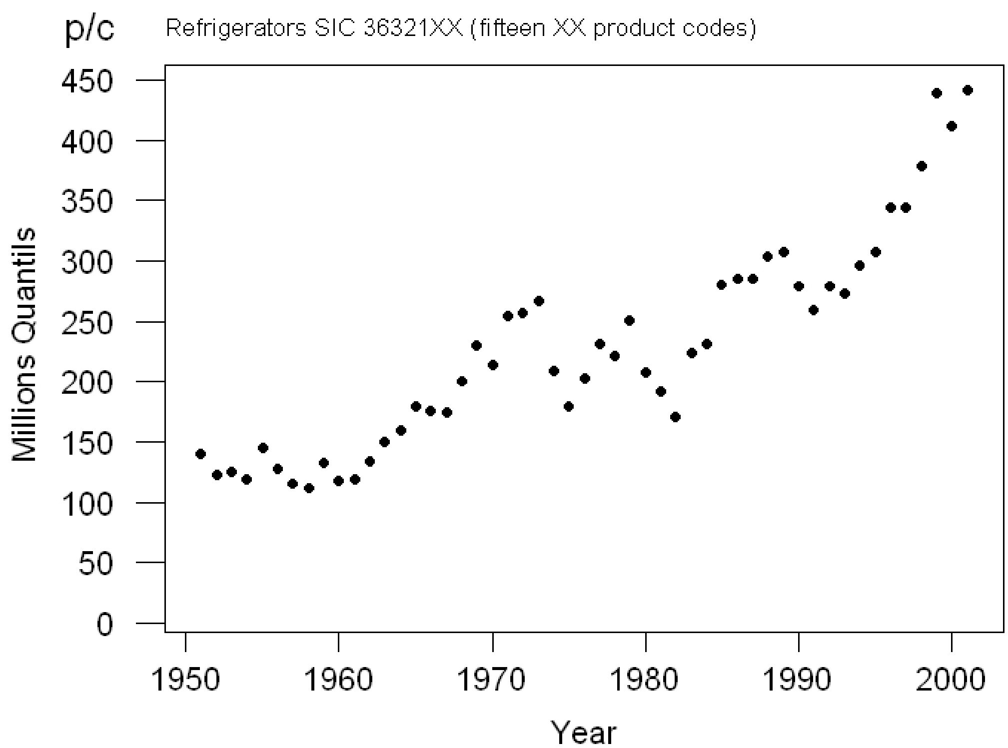


Figure A10

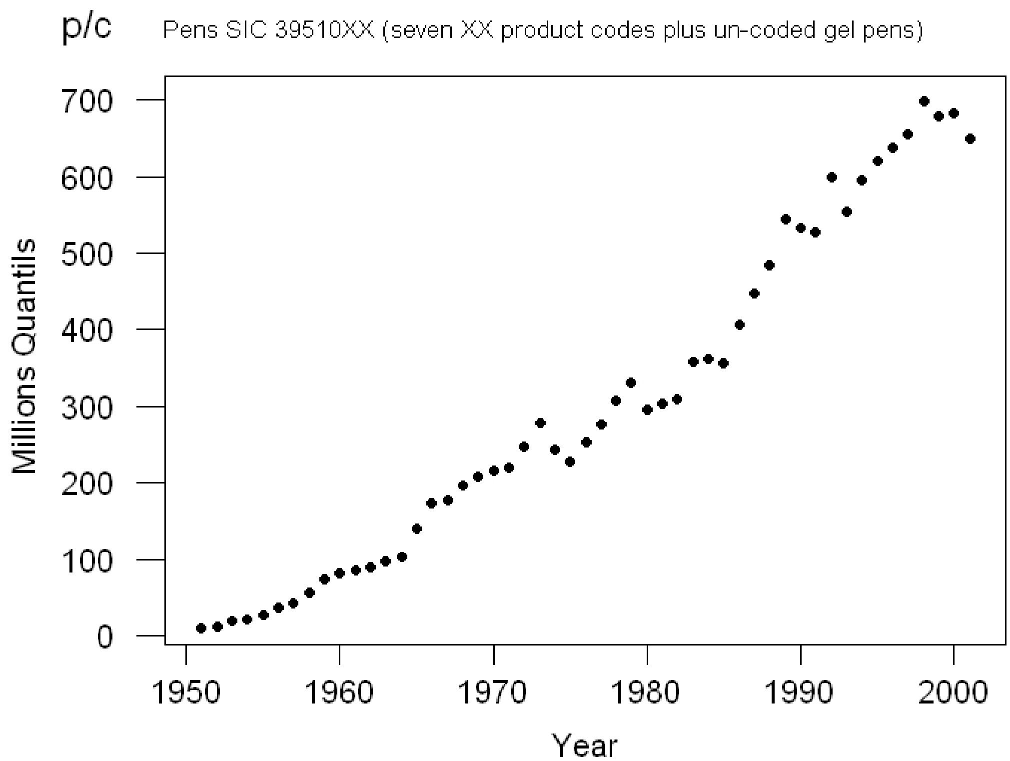


Figure A11

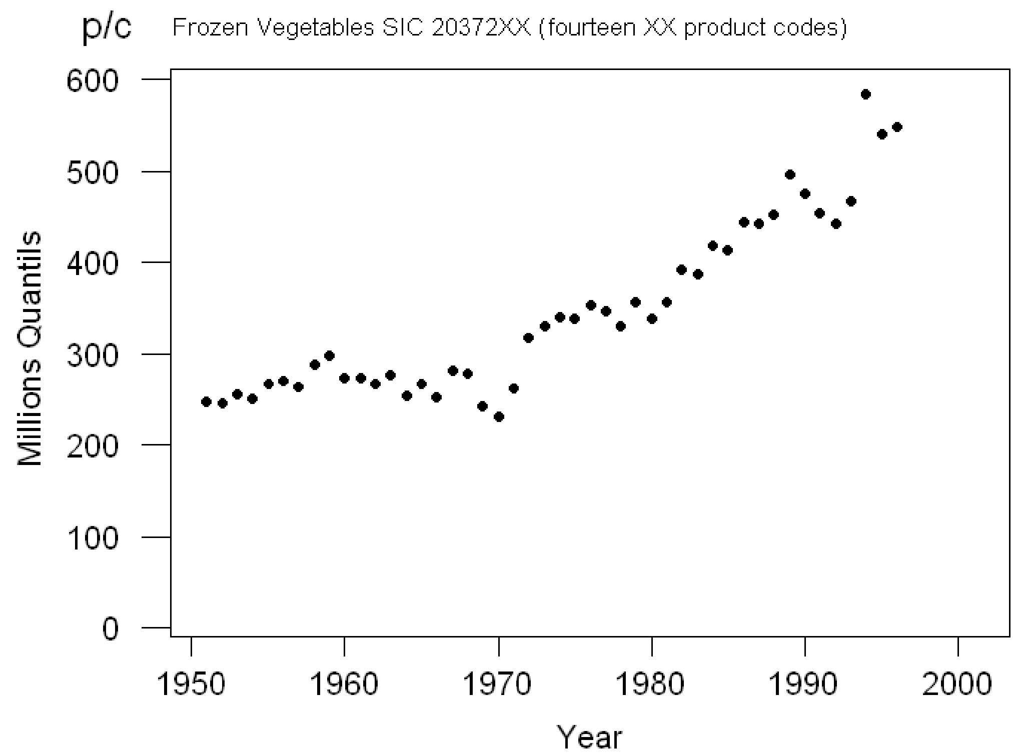


Figure A12

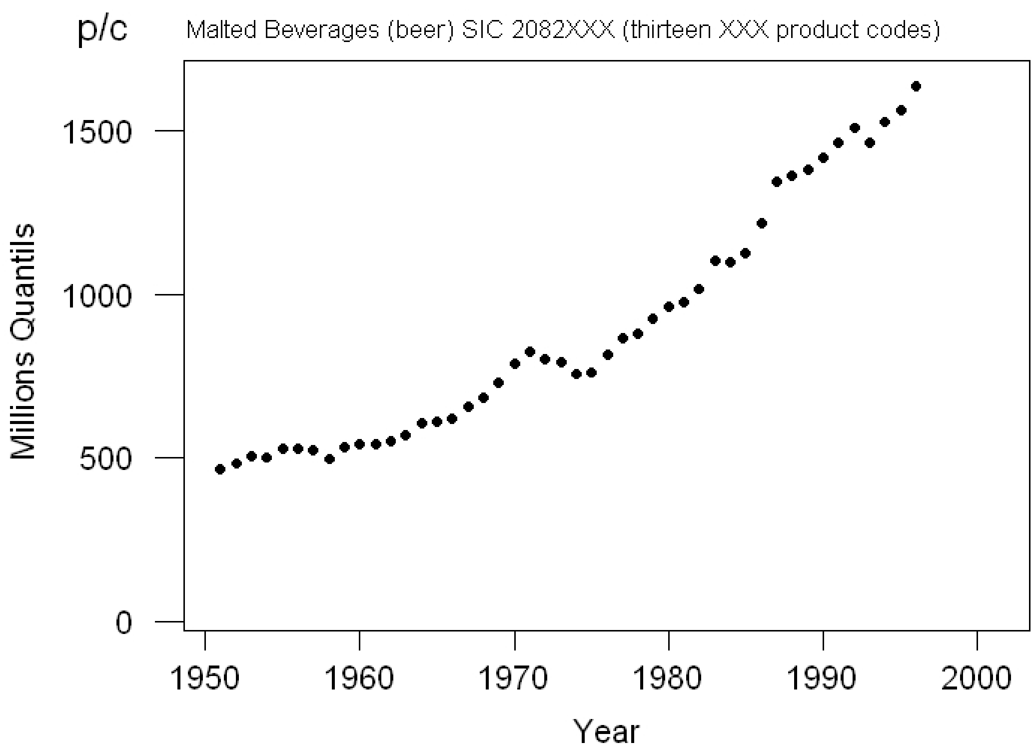


Figure A13

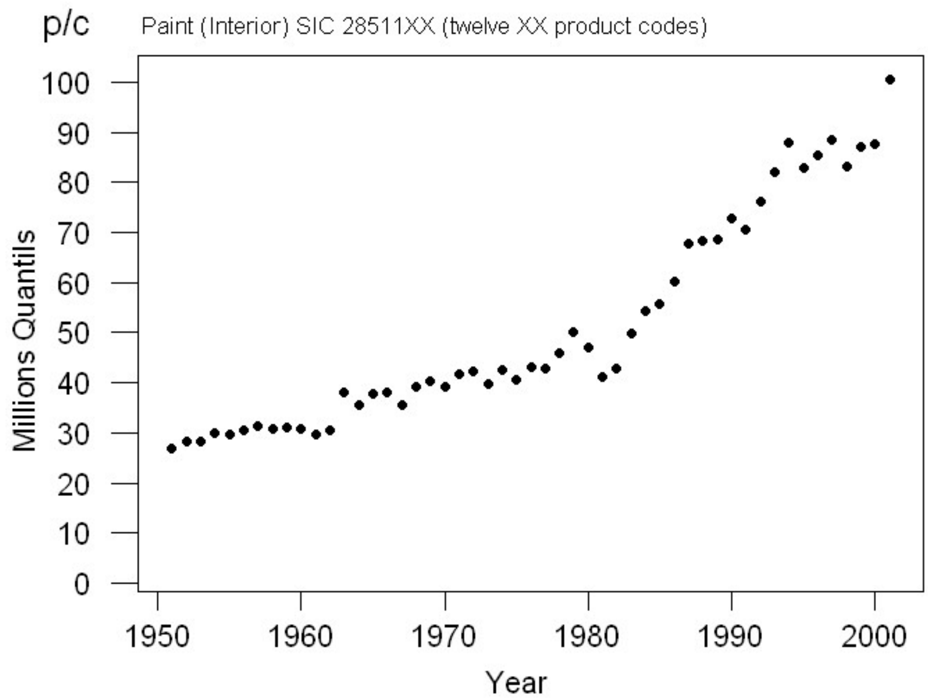


Figure A14

The aggregate Innovation Metric Σ(**p/c**) for Durable Goods is created by multiplying each durable surrogate (**p/c**) by the appropriate multiplier in Table A1 and adding them together, and similarly for Non-Durable Goods from the multipliers in Table A2. These aggregates are plotted in figures 41 - 43 and 45 - 47.

Appendix B [65 (p76)]

An Alternative Method to Enumerate (p/c)

Physical quantity constitutes the most common data held by manufacturers but its appearance is rare in Economics. This Appendix shows how the calculation of innovation metrics can be achieved with numbers that are gathered across the economy.

Appendix C [65]

Application to the Service Sector

Using a Fast Food Industry example this Appendix illustrates how pPQ can be applied when 'data holes' are filled, Commerce (2007). This methodology is essential for understanding innovation in services, including within the digital economy.

Appendix D [65]

Applying the Surrogate Method to an Unbiased Experimental Price Index

Because the pPQ provides a method of calculating quality change it follows that bias from quality change can be eliminated. This Appendix shows how (Figure D2).

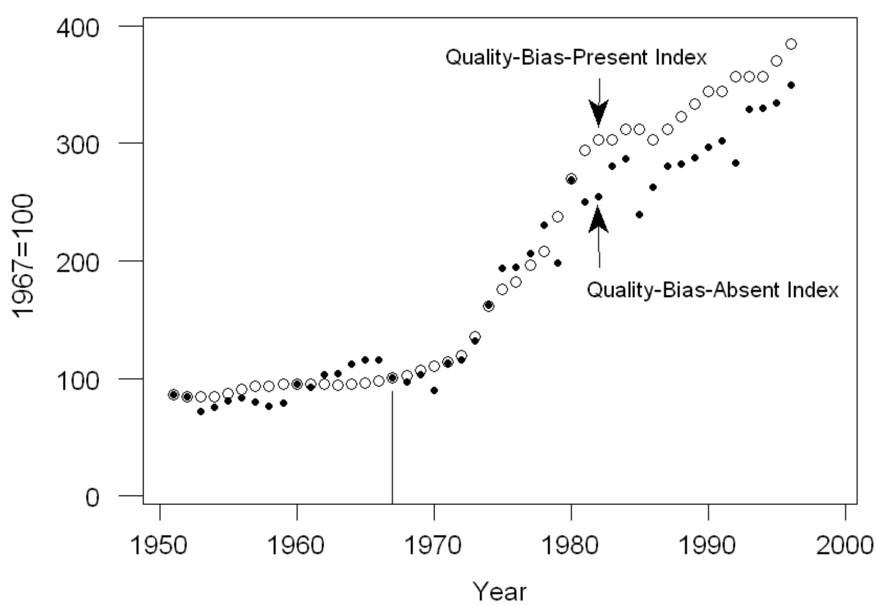


Figure D2 – The PPI index is upwardly biased compared to this experimental one from ~1980[67]

The upward bias in the PPI by this method is ~ 0.6%/year from 1980.

[67] For those interested in Public Policy a Quality-Bias-Absent index would need to be combined with a separate adjustment for quality improvement, using ∑**p**. Such a composite would put Social Benefits more in tune with living reality.

Appendix E [65]

The Universal Product Life Cycle

Using a simple mathematical transform applied to quantity growth data from DINTEC™ a universal product life cycle emerges. To explain economic growth tangible capital spending must be divided into a new category.

Appendix F

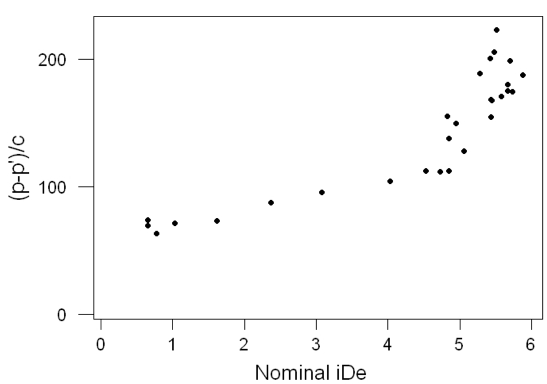
Steering Firm Innovation

If you get what you measure, and if a CEO wants to stimulate firm innovation, current metrics are inadequate to the task.

A primary one is % of current sales from products developed in the last five years, which contains no notion of how good these products actually are - when it is well known that superior ones are essential ([15] page 12).

Another is the old maxim - market share - a measure whose limitations are exposed at **Step 6**, page 51-52.

Their deficiencies are overcome by the innovation metrics presented throughout this book with the further example presented below.



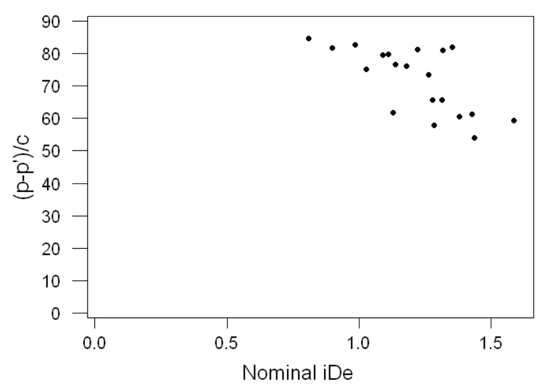


Figure F – Innovation Performances at the Miller Brewing Company (left) and at Pabst (right)

For innovation health the innovation metric needs to rise - as it does for Miller, but not for Pabst. Subsequent to this, Pabst necessarily re-invented itself, page 52 – 53.

Such pictorials can steer a firm toward greater growth and profitability better than any other.

References

Aizcorbe, Moylan & Robbins (2009), Toward Better Measurement of Innovation and Intangibles, Survey of Current Business, January, 10-23.

Aizcorbe, Byrne & Sichel (2019), Getting Smart about Phones: New Price Indexes and the Allocation of Spending Between Devices and Service Plans in Personal Consumption Expenditures, table 6 last line, table 2 line 5, NBER Working Paper 25645.

Austin (2006), Research and Development in the Pharmaceutical Industry, Congressional Budget Office.

Bhatty & Tennis (2008), U.S. and Canadian Cement Characteristics: 2004, Portland Cement Association, Chicago.

Bowker (1998), Directory of American Research and Technology, 32, ISBN 0-8352-3934-9

Busch (1972, 1993), Anheuser-Busch Annual Reports to Shareholders.

Bush (1945), Science The Endless Frontier, A Report to the President by Vannevar Bush, Director of the Office of Scientific Research and Development, July, United States Government Printing Office, Washington.

Collins (2004), Personal Communication from Terry Collins on Improvements in Cement by e-mail 22nd September 2004.

Commerce (2004), Multifactor Productivity in U.S. Manufacturing and in 20 Manufacturing Industries, 1949-2001, Bureau of Labor Statistics, Feb. 10.

Commerce (2007)[71], Innovation Measurement, Federal Register, 72, No 71, Friday April 13th, Notices, 18627 – 18628. Proprietary exclusion, p18628, col 3. Market share, p18627, col 3, item 2. 'Data Hole' p18628, col 1, item 4.

Commerce (2008), Innovation Measurement - Tracking the State of Innovation in the American Economy, A Report to the Secretary of Commerce by The Advisory Committee on Measuring Innovation in the 21st Century Economy.

Cooper & Kleinschmidt (1990), New Products: The Key Factors in Success, American Marketing Association, Chicago.

Crosby (1986), Quality is Free, McGraw-Hill.

[71] In innovation professional parlance this constituted requirement definitions. They were unmet in the report, Commerce (2008), not least because commercial knowledge was by definition explicitly excluded from consideration.

Dhalla & Yuspeh (1976*),* Forget The Product Life Cycle Concept, Harvard Business Review, January –February, 102-112.

Drucker (1985), Innovation and Entrepreneurship, HarperCollins.

Emerson (1837), Concord Hymn.

Farr (1958), Why Not Try Selling Refrigerators? Electrical Merchandising, April, 24, McGraw-Hill.

Farrell (1993), A Theory of Technological Progress, Technology Forecasting & Social Change, 44, 161-178.

Farrell (2007, 2008), How To Measure Innovation in the Products and Services of Firms and Use it to Explain GDP Growth for the Second Half of the 20th Century, submitted to Commerce (2008) in 2007 and, Measuring Innovation, Royal Economic Society Newsletter, Interview, Issue no. 142, July, 20-21 (2008).

Fisher (1922), The Purchasing Power of Money, Reprints of Economic Classics, Augustus M. Kelley, Publishers, New York 1971.

Fisher & Pry (1970, 1971), A Simple Substitution Model Of Technological Change, General Electric Research & Development Center, Report No. 70-C-215 (1970) or, A Simple Substitution Model of Technology Change, Technology Forecasting and Social Change, 3, 75-88, (1971).

Foster (1986), Innovation, The Attackers Advantage[72], Summit Books.

Gause (1964), The Struggle for Existence, Chapter V, Competition For Common Food in Protozoa, Hafner Press, MacMillan.

Gomory (2008), Industry Studies: An Observational Science, Alfred P. Sloan Foundation.

Gordon (1990), Measurement of Durable Goods Prices, 6.0 Computer Processors and Peripherals, 188-240, 7.5 Household Refrigerators and Refrigerator-Freezers, 249-270, 7.9 TV Sets, 300-309, 8.0 New and Used Autos, 321-382, University of Chicago Press.

Gordon (2000), The Boskin Commission Report and its Aftermath, NBER Working Paper 7759.

Gordon (2005), Apparel Prices and the Hulten-Bruegel Paradox, NBER Working Paper 11548.

[72] The 'Advisory Committee on Measuring Innovation in the 21st Century Economy', Commerce (2008), showed no recognition of functional performance metrics, including Foster's, Farrell (2007, 2008).

Greenspan (2007), The Age of Turbulence: Adventures in a New World, Penguin Press, Chapter 25 The Delphic Future, p 473.

Griffin (2002), Product Development Cycle Time for Business-to-Business Products, Industrial Marketing Management, 31, 291-304.

Griliches (1971), Hedonic Price Indexes for Automobiles: An Econometric Analysis, in Price Indexes and Quality Change, 55-87, Harvard University Press.

Griliches (1988), Productivity Puzzles and R&D: Another Nonexplanation, Journal of Economic Perspectives, 2, 9-21. Griliches 'gave up' on R&D.

Griliches (1994), Productivity, R&D, and the Data Constraint, The American Economic Review, 84, No1, 1-23.

Griliches (1999), NBER Panel on Research on Price Index Measurement: Agendas for the Next Twenty Years. Transcribed remarks from Zvi Griliches, July 21st.

Hillinger (1986), A New Chapter in Story of the Fountain Pen, Los Angeles Times, September 22nd.

Hulten (1997) – comment appended to Nordhaus (1997), p 67 –70.

Kingsland (1985), Modeling Nature, Episodes in the History of Population Ecology, University of Chicago Press.

Kovac (1978), Tire Technology, 5th Edition, Goodyear Tire & Rubber Company.

Lawson (1997), Benchmark Input Output Accounts for the U.S. Economy, 1992, Survey of Current Business, November, 66 – 82.

MacGregor (2011), A History of the World in 100 Objects, Viking Penguin.

Merino (1990), Development of a Technological S-Curve for Tire Cord Textiles, Technology Forecasting & Social Change, 37, 275-291.

Meredith (1994), Original VW Beetle, BayView Books.

Morris (1971, 1974, 1975), Philip Morris Annual Reports to Shareholders.

Nelson, Tanguay & Patterson (1994), A Quality-Adjusted Price Index for Personal Computers, Journal of Business & Economic Statistics 12, No1, 23-31.

Nelson & Winter (1982), An Evolutionary Theory of Economic Change, Harvard University Press.

Nordhaus (1981), Economic Policy in the Face of Declining Productivity Growth, Cowles Foundation Discussion Paper No 604.

Nordhaus (1997), Do Real output and Real Wage Measures Capture Reality? The History of Lighting Suggests Not, in Bresnahan T.F. & Gordon R.J., The Economics of New Goods, 58, 29-66.

Nordhaus (1998), Quality Change in Price Indexes, Journal of Economic Perspectives, 12, No 1, Winter, 59-68.

Olympia (1977), Annual Report to Shareholders.

Pabst (1980, 1984), Annual Reports to Shareholders.

PCA (1996), Portland Cement: Past and Present Characteristics, Concrete Technology Today, 17, No.2.

Rink & Swan (1979), Product Life Cycle Research: A Literature Review, Journal of Business Research, 219-242.

Rogers (1980), Staff Report on the Development and Structure of the U.S. Lamp Industry, Bureau of Economics, Federal Trade Commission.

Romer (1994), The Origins of Endogenous Growth, J. Economic Perspectives, 8, No. 1 Winter, p 3-22. Romer 'gave up' on R&D.

Schlitz (1973, 1974, 1978, 1979), Annual Reports to Shareholders.

Schumpeter (1942), Capitalism, Socialism and Democracy, Chapter VII, The Process of Creative Destruction, Harper.

Sichel (2011 - 2021), The Price of Nails since 1695: A Window into Economic Change, NBER Working Paper 29617, completes the earlier 2011 and 2017 versions.

Skolnik (1972), Tire Cords, Kirk-Othmer Encyclopedia of Chemical Technology, 2nd Edition, 20, 328-332.

Staff Reporter (1958), '7.5% of the Market ...That's Norge's Goal', Electrical Merchandising, January, 289-290, McGraw-Hill.

Stevens & Burley (1997), 3000 Raw Ideas = 1 Commercial Success! Research Technology Management, May-June, 40, 3, 16-27.

Strohmaier et al (1999), The Marketplace of High-performance Computing, Parallel Computing, 25, 1517-1544, Elsevier.

Waterman (1989), Pen-World, v3, Number 1, Fall.

Short Glossary of Key Terminology

$\sum q$ or $\text{Sum}:\text{q}$ is the sum of all items in category q.

$\sum_{i=1}^{N} p^i = p^1 + p^2 ......+ p^N$ signifies that N discrete items are added from category p.

$\propto$ denotes that the symbol or expression to its left is proportional to the symbol or expression to its right. It's a precursor to establishing an equality, while ≈ means it's approximately equal to, and > means it's larger than.

Cobb-Douglas names an equation that multiplies growth factors raised to powers, such as for KLEMS. Take logarithms and the powers transform to multipliers, differentiate and the multipliers become growth rates. This elegant mathematics has obscured its fatal lack of mechanism.

Competitive Pressure is the physical quantity supplied to a domestic market from all sources – production, inventory and imports; shipments minus exports plus imports.

Core Competency is all know-how relating to past and present product offerings held by a firm, whether or not they have traversed the innovation funnel successfully. This intellectual capital is given by the formula on page 90 with adjusted N and L.

DINTEC™ contains comprehensive Data on INnovation, TEchnology and EConomics. De-fragmented over ten calendar years from neglected sources, such as Current Industrial Reports and trade or industry publications, it is divided into markets - so as to include competition effects. It covers five decades and empowers everything in this book.

Factor Productivity. Productivity is output divided by an input. If all input factors have been called out and mathematically expressed – such as in Cobb-Douglas - and the result is equal to output then Factor Productivity = 1. Unfortunately, when output is GDP and for all otherwise satisfactory input combinations, this Factor Productivity has always been effectively > 1 and varies over time. This implies a missing factor or factors. Factor Productivity is still 'a measure of our ignorance'.

Hedonic methodology tries to estimate what the price of a good would have been in a given year if its quality had been frozen at a previous year. Such a method is used to distinguish what portion of current price is due solely to inflation and is applied to adjust price indexes. It is based on attributes derived from specifications and sources, such as Consumer Reports, and is imperfect for good reasons, for more see [23 (p27)].

iDe is an acronym for idea development expense that arises from company sourced Applied Research and Development funds. It is guided by input from marketing research on psychological and sociological factors that will affect product acceptance. Its commercial effect is latent for a distinct period δ in Tables 11, 12 on pages 56, 61.

Innovation is the outward expression of new technology prospering in a market.

Innovation Boundary is the limit at or below which prospering ceases and the disruptive element of creative destruction sets in due to competitive pressure from superior offering.

Innovation Funnel. Turns ideas into innovations. It's the centerpiece of economic growth.

Innovation Metric is the outcome from successful technology and is enumerated by the ratio of performance to unit cost. Values by category are tabulated on page 93.

Innovation Parallelogram diagrams the simple economic arithmetic surrounding the commercialization of ideas through the Innovation Funnel.

KLEMS – Capital, Labor, Energy, Materials and Services are multiple factors – presumed total, which under Cobb-Douglas treatment become a Factor Productivity.

Perceived Performance expresses whatever a purchaser hopes for in a product at the moment of purchase into a single variable enumerated by the pPQ. It deviates from functional performance in its measure of psychological and sociological affects.

Price Index is the value of a selection of items purchased on one date compared to the value of an identical selection at an earlier date. The idea is to characterize any decline in the purchasing power of money, of which more is usually needed on the later date. It was introduced when there was little or no improvement in items over long periods. Today, in an era of rapid technological change, quality has to be kept artificially constant between the two dates to meet the identity criterion. Quality corrections are highly problematic.

Quality (in Economics) is the functional goodness of a consumer product, but see [13(p12)].

Quantil is a universal unit of physical quantity that is invariant across markets.

Science is knowledge gained by the scientific method - the most reliable of all ways - while Engineering is Science applied to design in categories; chemical, electrical, mechanical etc. Reverse engineering can often extract technology from objects.

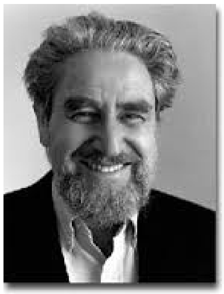
Scientific method provides cumulative evidence of reality from critical observation of revelatory situations that occur naturally, or are deliberately created in laboratories. The method's unique character is truth that evolves under its own scrutiny.

Technology is the know-how needed to make and (or) use objects. For more see [74(p99)]. It is equal to the area beneath the iDe input curve to the year of interest, t

$$\text{Single Object} = \int_{\text{Start}}^{t} \text{iDe}(t)\,dt \qquad\qquad \text{Market (of N Objects)} = \int_{t-L}^{t} \left(\sum_{j=1}^{N} \text{iDe}_j \right)(t)\,dt$$

with iDe as in figure 31 — where L = average longevity of market survival

Acknowledgements



To Harvard economist Zvi Griliches (1930-1999) who exhorted colleagues to seek more and better data through his seminal paper *'Productivity Puzzles and R&D: Another Non-explanation'* and in his American Economic Association Presidential Address *'Productivity, R&D and the Data Constraint'*. He knew what had to be explained but did not have the means. A bound copy of Zvi's 1957 University of Chicago Ph.D. thesis *'Hybrid Corn: An Exploration in Economics of Technological Change'* honors his influence from my bookshelf.

To energy economist Nebojsa Nakicenovic, of the International Institute for Applied Systems Analysis whose peer review of my 1993 paper *'A Theory of Technological Progress'* and our subsequent correspondence primed me to take Griliches's data pleas more literally than others have.

To Richard N. Foster, former Director of McKinsey & Co., who shared research data from his foundational book *'Innovation'*. His S-curves[72 (p86)] were absolutely crucial for validating pPQ.

To Rias Van Wyk, leading authority on Strategic Technology Analysis and Director of Technoscan® for his response to the opening paragraph of my 1993 paper and for his continued support and then guidance in writing up the further decades of intermittent personal research now revealed within these pages.

To the American Can Company (as it was) for fourteen years spent at their Barrington Technical Center where I learned the craft of an Innovation Professional. For the opportunity to create many aspects of a new multi-layer plastic injection blow molded technology whose purpose was pre-empting oil companies from creatively destructing its steel food can business. It was commercial for just twenty years because no oil company did. For involvement in American's foresighted technology strategy process where I learned about the Fisher-Pry method whose mathematics seeded this exposition.

To Cambridge University's tuition atmosphere from which I learned that original thinking leading to elegance and simplicity imbues the best Science. To Cambridge protein crystallographer Max Perutz (1914-2002) who exemplified the seemingly intractable can be made otherwise and is worth a lifetime of effort.

To librarians at Northwestern University Library, Illinois State Library, Harold Washington Chicago Public Library and the University of Chicago Library for their willing and able help with DINTEC™.

To everyone involved in producing Current Industrial Reports and to the many industry associations who collected and made available their data resources.

Beyond GDP Note

Most attempts to go beyond GDP quote the famous 1968 speech by Robert Kennedy against counting prices without considering the human impact of what's being bought. But no capable alternative has yet emerged. However, and unlike price, perceived performance can be conceived negatively. It can reflect unintended societal damage from technology. This simple conceptual distinction opens a new door for going beyond GDP. A net sum - subtracting the adverse in proportion to its burden, such as for CO_2 emission - can guide us to a better future than any other economic measure. This net-GDP 'Quality **in** Life' can even fall as GDP itself rises! The methodologies presented in this book provide a new foundation that supports thinking along lines that focus on the net gap.

Thoughts on the Role of Science

How does Science contribute to economic growth? In 1978 I started to write 'Fruits of Science' an historical account of how Science has led to so many good things for mankind. Even in the present I had hoped my thesis on a novel method to force elongation on polyethylene's otherwise folded chains might lead me to one.

Then I joined the American Can Company and observed that a transition from any Science to any new product is a mammoth undertaking. Factors that might have been easy to get separately under control in a laboratory must now be handled in unique and unanticipated combinatorial situations. Only then can new technology be made viable.

Science is available to everyone everywhere. It raises the limits on S-curves or creates new ones, for which technology is developed nationally. To harvest that fruit a system focused on the innovation funnel is paramount. Cultivating the requisite talent in light of metrics now described in this book is essential.

Chris Farrell is a practitioner and innovation professional with twenty-five years industrial experience in developing and managing the creation of new products and their manufacturing technologies. Developments from his many patents have been commercialized and won awards.

He received his B.A. in Natural Sciences from Cambridge University (Christ's College) and his Ph.D. in Physics from Bristol University, where his work on polymer chain dynamics vitalized an important stream of research. He served on the Board of Directors for the Product Development and Management Association and on the Industry Relations Advisory Board of Northwestern University. He has published technical papers and articles in both academic and popular presses.

Innovation Tracked in the 20th Century

Year	Durable Goods Sum:(p/c)	Non-Durable Goods Sum:(p/c)	All Goods Sum:(p/c)
1951	35.7	79.3	43.2
1952	34.7	80.7	42.6
1953	39.7	83.9	47.3
1954	41.4	83.3	48.6
1955	50.9	87.6	57.2
1956	52.2	88.5	58.4
1957	51.2	87.7	57.5
1958	63.6	89.7	68.1
1959	74.0	93.6	77.4
1960	74.0	89.6	76.7
1961	71.8	89.4	74.9
1962	79.6	95.2	81.3
1963	86.7	92.4	88.2
1964	92.9	96.0	92.9
1965	100.0	94.0	99.3
1966	99.2	93.6	98.3
1967	**100.0** (131.8)	**100.0** (27.4)	**100.0** (159.2)
1968	110.5	102.7	109.2
1969	118.6	100.2	115.4
1970	109.2	101.2	107.8
1971	122.5	109.4	120.3
1972	132.0	117.5	129.6
1973	142.8	118.1	138.5
1974	123.2	118.4	122.4
1975	108.2	117.9	109.9
1976	119.2	124.1	120.0
1977	131.5	126.4	130.6
1978	142.9	125.6	139.9
1979	140.5	134.3	139.5
1980	123.6	132.5	125.2
1981	118.7	133.4	121.3
1982	109.2	142.6	115.0
1983	126.3	149.9	130.4
1984	138.9	156.5	142.0
1985	143.3	158.1	145.9
1986	152.0	170.6	155.2
1987	156.8	181.1	161.0
1988	158.3	183.9	162.7
1989	162.0	192.3	167.3
1990	154.3	192.7	161.0
1991	146.1	190.9	153.9
1992	155.8	194.2	162.4
1993	147.6	198.2	156.3
1994	151.6	223.6	164.0
1995	159.8	216.2	169.5
1996	163.9	223.0	174.1
1997	191.1		
1998	198.9		
1999	208.3		
2000	204.7		
2001	209.4		

1967 values in brackets are absolute in billions of quantils

Answers to Innovation Questions

The Advisory Committee on Measuring Innovation in the 21st Century Economy missed bringing innovation to the forefront in economic growth in 2008[73]. However the requirements written for it by a Federal Agency remain a blueprint and a litmus test for the economic comprehension of innovation that has remained un-addressed until now.

In what follows these requirements – in 25 Questions - are extracted from their source in the Federal Register and answered by indexing to knowledge presented in this book.

[73] The Committee's effectiveness was thwarted by the following condition 'The department will not accept comments accompanied by a request that part or all of the material be treated confidentially because of its business proprietary nature or for any other reason', Commerce (2007). Most commercial knowledge is proprietary and some of it still is, including DINTEC™ (which contained the necessary data then as now) and certain content of Appendices A-E, where indicated [65 (p76)].

25 Questions from the Federal Register 76 FR 18627

DEPARTMENT OF COMMERCE
Economics and Statistics Administration
Innovation Measurement

SUMMARY: The Department of Commerce is seeking public comment on issues related to the measurement of innovation. This request supports efforts of the Measuring Innovation in the 21st Century Economy Advisory Committee as it prepares recommendations for the Secretary of Commerce on new or improved measures of business innovation.

The committee is charged with developing innovation metrics that inform policy decisions and enable policymakers and the business community to better monitor innovation. Among other things, the Committee's work should build on the way firms assess the effectiveness of their own innovative activities. The recommendations should not only focus on measuring innovation and inputs, but should also focus on the results and output of innovation. Furthermore, the recommendations should allow for analysis at industry, sector, national, and international levels and will cover the following four major categories

1. Improvement of the underlying architecture of the U.S. System of National Accounts to facilitate development of improved and more granular measures of innovation and productivity. Our national accounts are the main source of information about the growth of our national output, usually measured by the gross domestic product or GDP. Total Factor productivity (TFP), which measures growth of output per unit of input for the economy as a whole and for individual industries, is not included in the national accounts. Is the concept of TFP sufficiently related to innovation to warrant the inclusion of economy-wide and industry level TGP in the system of national accounts? ([1]). If so, what is the most effective way to incorporate the concept into national accounts? ([2]). Are there ways to disaggregate the innovation component of TFP to differentiate innovation from other productivity drivers? ([3]).

2. Identification of appropriate economy-wide and sector-specific indicators that could be used to quantify innovation and, or, its impacts. Are there measures that accommodate economy-wide (or macro-economic) and sector-specific notions of innovation? ([4]). What elements of innovation could serve as a foundation for statistical series? ([5]). To what extent would the collection of better data on service sector outputs and service inputs used by all firms improve innovation measurement? ([6]). Is market share growth a good indicator of innovation? ([7]). If so, would estimates in the change in U.S. firms' shares of regional, national, and global markets be useful innovation measures? ([8]). Could, or should, collaborative connections between entities be captured? ([9]). Since a characteristic of markets is that the benefits of innovations flow, at least in part, to buyers, are there ways to identify the flow of innovations across ► firms and sectors? ([10])

Answers at Question Marks Numbered ([1-10])

([1-3]) The contribution of innovation to the American Economy has risen far more rapidly and successfully than TFP is capable of determining, figures 51 & 52 on page 65. By the definition of technology – bottom of page 90 – and as enumerated in figures 57 to 60 on page 99, TFP isn't capable of determining technology either. Both deficiencies result from an overlooked flaw in the Cobb-Douglas foundation, page 89.

([4]) Yes. Sector and Economy wide innovation summations are in figures 42, 46, 48-52.

([5]) The necessary foundation is comprehensively presented in **Steps 1 & 2**, pages 5-34.

([6]) Better data collection is essential. This is addressed in **Appendix C**, page 83.

([7-8]) No. Not unless integrated with another factor, pages 51,52.

([9]) No. But the effect will be reflected in the metric for each entity, figures 11, 12.

([10]) Yes. The metric numerator **p** benefits buyers; its denominator **c** benefits firms.

3. Identification of firm-specific data items that could enable comparisons and aggregation. Current corporate innovation measurement appears to be done primarily on either a project or portfolio basis. Are these measurement practices sufficiently widespread and uniform to make data collection on either of these bases practical? ([11]). Is it possible or necessary to collect information on company culture, incentive structures, and organizational change? ([12]). If customer satisfaction is an important measure of an innovative firm, how can that be captured? ([13]). How important is it to distinguish between types of innovation (i.e. radical versus incremental)? ([14]). What data would be needed to differentiate the characteristics of innovative firms within industry sectors from non-innovative firms? ([15]). What are the most important measures of the underlying process of how innovation and productivity advances are initiated or stimulated? ([16]). Could or should an understanding of innovation from the consumer perspective be developed? ([17]). Could data items from SEC filings be used to enhance understanding of innovation in public companies? ([18]). Are there proxies for relative innovative success (e.g. percent of total revenue attributable to new – or significantly improved to the point where they could be considered new – products, services, or processes introduced within the last five years into markets where a firm has a growing market share) that would provide insight into relative innovative strength? ([19]). Is two years long enough? ([20]).

4. Identification of specific 'holes' in the current data collection system that limit our ability to measure innovation. Some specific types of data holes were identified during the meeting, including lack of data on firm formation, intellectual property licensing costs as a type of purchased input, and insufficient product detail. What should be the prioritized list of specific data items needed to fill the holes? ([21]). Limitations on our ability to link and coordinate across various data sets were also mentioned as a hole or deficiency of our current data collection system. Are there cost-effective ways of building on existing data sets to develop more information on innovation drivers and their link to success? ([22]). How could data sharing and cooperation among federal agencies be improved insofar as such agencies maintain data series related to the measurement of innovation? ([23]). Could existing private and, or, foreign data be combined with existing official statistical series in order to better measure innovation? ([24]). Are there changes that could be made to make such combinations possible or easier? ([25]).

Answers at Question Marks Numbered ([10-25])

([11,19,20]) Use the metric **(p-p')/c** on page 53 and in **Appendix F,** page 84.

([12]) Not necessary. Sales General and Administrative, SG&A, is within $\mathbf{c}^+$, pages 42,43.

([13,17]) With **p**. It uniquely captures a customer's satisfaction at the time of purchase.

([14]) Not. Radical innovations tend to boost **p** while incremental ones tend to lower **c**.

([15]) The gap between **p**/**c** and IB **Step 5**, pages 41-44 exampled in **Step 6**, pages 45-54.

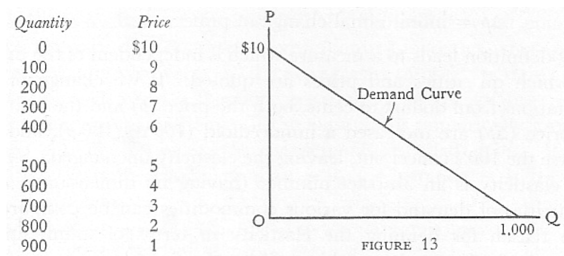
([16]) The primary factor is **iDe** introduced from page 41 and footnote 31 onwards.

([18]) Firms should be required to report multi division data separately in SEC filings.

([21,22-25]) DINTEC™ is the pre-eminent source for this. To operationalize between agencies requires knowledge supplied in **Appendix B**, page 83.

Supplement on Demand Curves

The simplest kind of demand curve is an imaginary illustration of a particular point, like this one from Stigler's influential The Theory of Price (1947).



But when **actual** data is used to create demand curves they do not look anything like it. Whereas theoretical demand curves invariably slope downward, implying that prices decrease as demand increases, this is not necessarily the case. It is especially not so in the presence of active corporate R&D, whose main function – increase in quality - will reverse the slope. This is shown for the 100w light bulb in figure 55 and for nails adapted for use in a nail gun in figure 56.

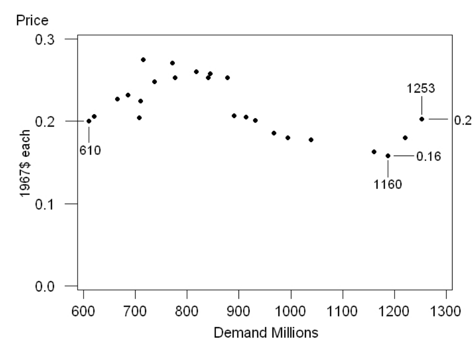


Figure 55 - Price-Demand Curve for a 100W light bulb

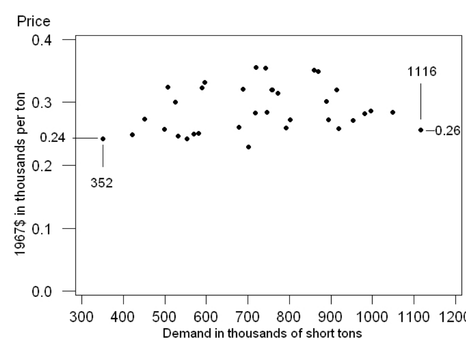


Figure 56 - Price-Demand Curve for nails

To determine quality multiply ordinate by abscissa point by point, real price by competitive pressure Sum:Q (which equals satisfied demand).

For the 100w bulb, quality starts at (.2x610) = 122 and ends at (.16x1160) = 186, in figure 13. For nails it starts at (.24x352) = 85 and ends at (.26x1116) = 290, in figure 27f.

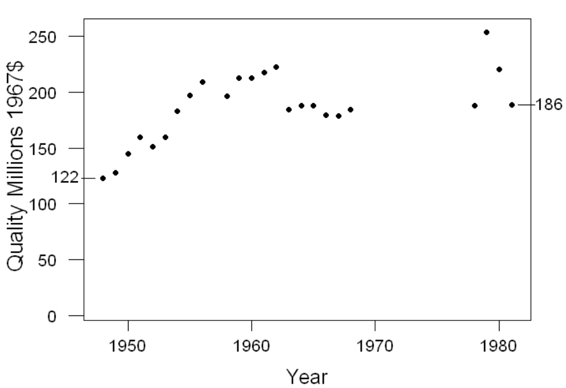


Figure 13 (page 22) – Quality of single inside frosted 100W light bulb

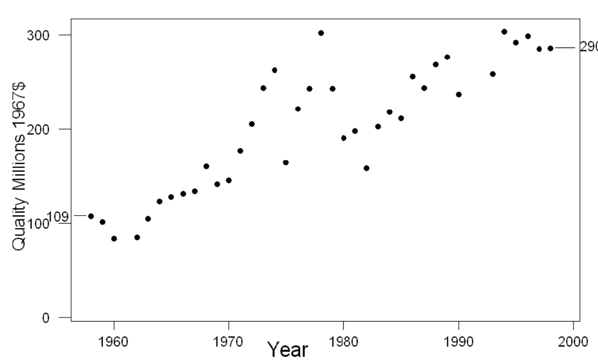


Figure 27f (page34) – Average quality of all nails

On The Matter of Technology

The definition of technology[74] in the Glossary can be enumerated using its formula,

$$\text{Group Technology (n markets)} = \int_{t-L}^{t} \left(\sum_{j=1}^{nN} iDe_j \right)(t)\,dt$$

Comparative data is available for three non-durable groups SIC 26, 28, 30 and for four durable groups SIC 33, 34, 35, 37. Products from Chemical and Allied Products SIC 28 feature in this book - in figure A14 - as do products from Industrial and Commercial Machinery including Computer Equipment SIC 35 - in figures A7 and A8.

Their Group Technology is plotted with the corresponding MPF KLEMS in figures 57 and 58 where L=15 years. The cessation of supercomputer development in firms that failed due to technology switch is seen in figure 58 from 1992, but not in MFP KLEMS.

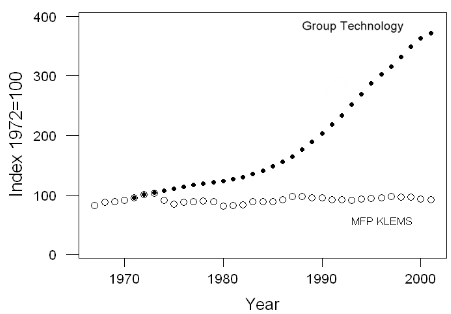


Figure 57 - Group Technology & KLEMS SIC 28

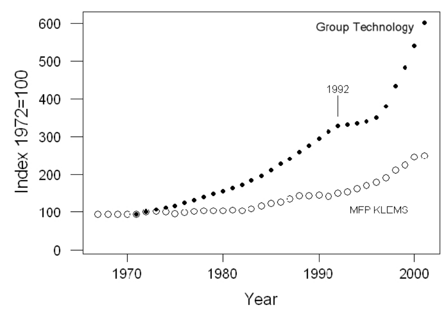


Figure 58 – Group Technology & KLEMS SIC 35

In a single market nails and staples, page 34, manufacturing technology for L=17 years rises in figure 59 while MFP KLEMS is quiescent in figure 60.

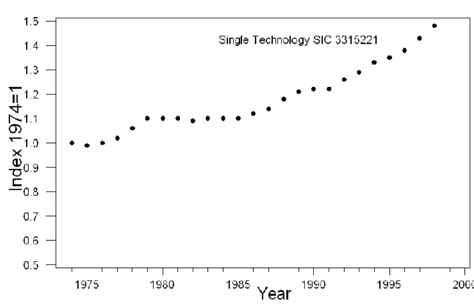


Figure 59 - Manufacturing Technology Nails & Staples

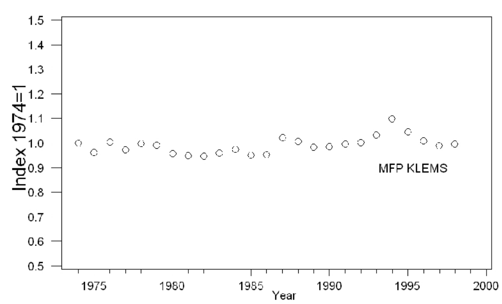


Figure 60 – MFP KLEMS Nails & Staples

Total Factor Productivity can measure neither innovation nor technology, including for computers in Figure 58. This puts Robert Solow's now famous remark into focus[75]. If neither technology nor innovation is measurable in Economics then neither can be productively associated with computing as illustrated on page 79.

[74] Its definition is synthesized from a citation in the Oxford English Dictionary that 'his technology consists of weaving, cutting canoes, making rude weapons and in some places practicing a rude metallurgy' and from Webster's 'the totality of the means employed to provide objects necessary for human sustenance and comfort' cast into the reality of current practice where technology can be parsed into five basic know-hows.

[75] '*You can see the computer age everywhere but in the productivity statistics*', Solow (1987).

Page References to the Four Laws and Five Equations of Economic Growth

1st Law – The perceived performance of a good or service at the moment of purchase is equal to its real price multiplied by the market's competitive pressure.

2nd Law – GDP is equal to the adjusted sum of the perceived performances of all final goods and services.

3rd Law – The penetration of a good or service into a market occurs when its ratio of perceived performance to price equals the incumbent.

4th Law – Innovation in a product or service is equal to its perceived performance in its market divided by its unit cost of delivery.

1st Law	$p=PQ$	Part 1 p13
2nd Law	$GDP = \sum_{i=1}^{N} p_U^i$	Part 1 p39
3rd Law	$p_1/P_1 = p_2/P_2$	Part 1 p42
4th Law	Innovation = p/c	Part 1 p43

Leading to a True Productivity = Output to GDP(t) / iDe(t – δ)

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