INNOVATION METRICS FOR ECONOMIC GROWTH

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BUSINESS INNOVATION ANALYSIS

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Providing outsiders with insider knowledge on innovation

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How It Works

TechMatt™ Business Innovation Analysis solves the longstanding quality change problem in Economics to deliver rigorous[1] innovation metrics that connect innovation spending in firms to GDP, and the outcome of innovation to a nation's quality of life – the maintenance of which, in the face of globalization, requires policy interventions.

Introduction & Background Review

In the 1960's there was great interest in predicting the shape of the generally bell – shaped product life cycle[2]. Academic research proposals argued that, if a universal form could be discovered, some predictability relating to economic growth might ensue. The aim was never achieved and the effort was brought to a summary end in 1976[3].

Since then it has been innovation professionals who have made the key breakthroughs.

In the 1970's we discovered that the shape of a product life cycle is determined by the attack on an incumbent by its competitive successor. Two engineers Fisher and Pry, at the General Electric Company, put this into simple mathematical form (a pair of logistic S-curves, one going up the other coming down[4]) and this fueled a resurgence in industrial Technology Forecasting[5].

So an industrial research laboratory, not a University, gave Joseph Schumpeter's 'creative destruction' its first mathematical form. And that trend continued.

In the 1980's S –Curves of a different type emerged. Richard N. Foster of McKinsey & Co. plotted performance against cumulative R&D spending. Successive generations of tire-cord cotton > rayon > nylon > polyester gave a series of ever upward reaching performance S's delivering the first innovation metric.[6, 7]

So a consultant, using data from industrial clients Celanese and Goodyear made this breakthrough – but no University was involved.

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[1] Rigorous signifies the use of fundamental principles that stem from observation and are validated by data.
[2] Rink D.R. & Swan J.E., *Product Life Cycle Research: A Literature Review*, Journal of Business Research, (1979) 219-242.
[3] Dhalla N.K. & Yuspeh S., *Forget The Product Life Cycle Concept!*, Harvard Business Review, January – February (1976) 102-112.
[4] Fisher J.C. & Pry R.H., *A Simple Substitution Model Of Technological Change*, General Electric Research & Development Center, Report No. 70-C-215 (1970).
[5] My report, *Fillers in Plastics* (1982), for American Can Company's strategic technology planning process, was one such Fisher-Pry forecast.
[6] Foster R.N., *Innovation*, Summit Books (1986).
[7] For tire cord graphs see *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,* from www.techmatt.com/Farrell0308.pdf

By the late 1980's both the dynamics of creative destruction and the innovation involved were measurable[8] and I started to try and connect them in a synthesis that I thought could lead to understanding economic growth, like physicists understand other phenomena – using numbers and the simplest possible mathematics.

My intentions were

1. To assemble a five-decade multiple-product database, vastly more comprehensive than ever assembled before, from which the effect of innovation in the economy could be made to emerge.

2. To use new tools to tweeze it out – these tools being derived from actual innovation observed happening from factory floor, technical center and corporate office.

Certainly I was guided by University knowledge where it existed and where it fitted, but where it didn't I relied on the tacit knowledge that surrounded me daily. This kind of knowledge is highly interdisciplinary and is judged by results[9]. Using it I applied lateral thinking to observations of the following actual economic workings of industry to deliver many otherwise unachievable results[10].

Industrial Observation 1.

The price of an innovative product is dominated by two considerations (a) the advantage of the new product in the eyes of the purchaser and (b) the current price of similar competitive ones.

This can be expressed by the simple equation

$$P = F\ (p, C, I)$$

Where P is price of the innovative product, and p is its performance perceived by the purchaser and C measures competition[11].

The function F connects P with p, C and I – where I is an inflation index, accounting for changes in the value of money over time.

Discovering the form of F, C and I became the principal aims of this research, where the function F is universal and applies to both good and services, including public services.

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[8] Management of Technology courses www.iamot.org adopted S-curve explanations and taught them at many Universities.
[9] It must work, and be seen to work. This is the 'peer review' of industrial research.
[10] As illustrated on pages 16 and 2-5 at the end of this document and at www.techmatt.com
[11] By introducing the term '*quality competition'* Joseph Schumpeter partially anticipated this in *The Process of Creative Destruction, Chapter VII*, Capitalism, Socialism and Democracy, Harper (1975).

Such an equation would also provide the lens of the 'macroscope' sought by the Industry Studies initiative at the Sloan Foundation[12] when re-focused to

$$p = G\,(P, C, I)$$

Where the fundamental and universal innovation metric, p, can now be calculated from P, C and I [13].

If p were expressed in engineering units, it would correspond to the original measurement of innovation used by Richard Foster in his pioneering work in the 1980's.

But because the attributes of engineering merit are often changed by innovation[14] this equation calculates p from market evaluation, and from engineering merit only to the extent that the end - user perceives value in it. It transcends engineering and neatly integrates all factors that enter a purchasing decision into p, overcoming the weakness of relating the innovative performance of products or services to attributes, such as is done in hedonic[15] and most factor, and indicator analyses[16]. All attributes – intangibles and behaviorals – are included without tying them to individual choice or identifying factors individually.

And because every buyer makes an implicit benefit assessment of well – being for themselves or for their loved ones or for their communities at point of purchase, the aggregate of their perceptions is a measure of well – being; very simply captured by $\sum p$, providing the perception surrounding the continued use of older durable goods and equipment within their service lives is also included. This allows quality-of-life or social well - being to be enumerated.

This analysis hinges - not a theory of price, as is found in Economics, but on an explanation of price. The distinction between these two is essential and is perhaps best understood by looking at an economic text on the theory of price. George Stigler's 'Theory of Price' reached its fourth edition in 1987, five years after he won the Nobel

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[12] Gomory R.E., *Industry Studies: An Observational Science*, Industry Studies Annual Meeting (2005). For a number of years the Sloan Foundation required their researchers to incorporate factory inputs. Sloan wanted academic research that would explain actual economic workings of industry. They wanted economists to develop a 'macroscope' capable of doing this http://web.mit.edu/ipc/sloan05/gomory.pdf

[13] Thus overcoming the longstanding impediment to Economics - no methods for calculating the goodness of a good or service – its so-called 'quality change problem'.

[14] Christensen C.M., *Exploring The Limits of the Technology S-Curve Part I & II*, Production and Operations Management, **1**, No4 (1992) 334 –366.

[15] Hedonic methods survey product prices, P_i, in conjunction with attributes a_{ij}. An equation $\log_e P_i = \alpha a_{i1} + \beta a_{i2} + \ldots$ is derived by regression of prices against attributes. Subsequent innovation will have produced new values of the attributes a_{i1} , a_{i2} ... and by substituting these back into the equation the probable effect on P_i can be estimated. When subtracted from the P_i 's actually observed the effect of 'quality improvement' on price can be adjusted out for calculating price indices, such as the consumer price index. Although the hedonic equation $\log_e P_i = \alpha a_{i1} + \beta a_{i2} + \ldots$ appears to be similar to P = F (p, C, I) it completely misses the effect of competition on price. This, and the inherent limitations of attributes for capturing innovation, is exactly what the complementary equation P = F (p, C, I) so elegantly overcomes.

[16] Any indicator that relies on surveys falls into this category, with attributes implicit in the questions.

Prize in Economics. The book contains 79 graphs - but their lines are imaginary, none connect any data points. It has 24 tables of numbers, but only one uses actual data, other numbers are made up. This is theory[17].

Explanation, on the other hand, is dominated by data that simple equations - preferably one - must explain. And if you can explain you can predict, so confirmation includes making a prediction and verifying it. The forms of F, G, C and I within TechMatt™ Business Innovation Analysis meet all the explanation objectives[18].

Industrial Observation 2.

Competition requires two adjectives to describe it. These are (a) ruthless and (b) relentless.

If you have ever shared the duty of protecting your company from the effects of competition, these terms will resonate with you[19]. But if you have been taught to think of competition as 'perfect' (or imperfect) in the abstract of an Economics class, then ruthless and relentless will need to be seen as 'extremely imperfect', a new sub-category.

At first it may seem impossible to quantify competition using these two new adjectives.

However, ruthless is a characteristic of a single organization whereas relentless is dependent on many. Therefore C must contain both one and many, an important clue to how it may be mathematically represented.

TechMatt™ Business Innovation Analysis provides a way to express C that has been verified and validated against actual data.

The resulting equation contains parameters that, in the limit of a monopoly, still give competition C a positive value[20]. This surprises convention because competition is supposed to be absent from a monopoly. In fact it is truer to say that monopolists choose not to compete with themselves. Competition is not so much absent as virtual, and thereby dormant. This paves the way to measuring innovation in public services. Public Services are essentially monopolistic and being able to determine their virtual C allows p, their innovation metric, to be enumerated also.

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[17] Stigler G.J., *The Theory of Price*, The Macmillan Company, (1947). The effect of theory in Economics is seen as an impediment by some *'their professional research downplays innovation because it is impossible to quantify and not conducive to mathematical models'* - Fact & Comment, Forbes Magazine, 6th October (2008) - but Economists do not participate in its primary literature (patents) or attend its establishments (Technical Centers, Factories & Corporate Offices). The Sloan Foundation has recognized this and has tried to overcome it in University settings. But industry insiders – innovation professionals – are better positioned because they inhabit innovation. When their new tools are transferred to Universities, this may indeed be expected to positively influence future academic research on the economic workings of industry.

[18] And by precedent set by R. Hooke F.R.S. - F (p, C, I) has an anagram form of *bceeeeffiiiimoprrsssttuuv*

[19] Joseph Schumpeter's *'ever present threat'* is a symptom of this. *The Process of Creative Destruction, Chapter VII*, Capitalism, Socialism and Democracy, Harper (1975).

[20] In this limit relentlessness will relent and ruthlessness will become benign, but C still contributes to p.

Industrial Observation 3.

The products of an industry are determined by the very long run happening in a very short time.

This is an essential characteristic in an era of rapid technological change.

Microeconomics currently treats activity in a firm as either short – run, or long –run.

But to a purchaser, able to choose between the products of competing firms, the very long run has occurred in a very short time.

In the automobile industry 224 innovations were introduced between 1954 and 1974[21], close to one a month. For a single company and for a single car, the Volkswagen Beetle, there were at least 151 lesser improvements between 1954 and 1974[22], one every six weeks.

Because Development is an activity that anticipates the market 'the very long run can occur in a very short time'.

Properly identifying an inherent condition like this is an essential pre-cursor to the following corollary.

Inflation without bias is found from the change in general price, not from the general change in prices.

A market basket is currently used to determine a general change in prices, such as the consumer price index (CPI). Market baskets originated in the 18th century when innovative change was miniscule over long periods of time[23]. Today, because the very long run occurs in a very short time, goods in such a basket change from month to month. Comparing like with like is an almost impossible task – and that introduces bias.

The Boskin Commission estimated total bias for 1995-6 to be about 1.1%, of which 0.6% was attributed to innovation[24]. Although small in absolute terms, when compared to the CPI rise of 3% the relative error is much larger ~ 20%. This is too large to be useful for measuring innovation.

For measuring innovation without introducing significant circular error, TechMatt™ Business Innovation Analysis provides an inflation index free of innovation bias.

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[21] Abernathy W.J., Clark K.B., & Kantrow A.M., *Industrial Renaissance*, Basic Books Inc., (1983), Table D.1 lists 631 automobile innovations 1893-1981.
[22] Meredith, L., *Original V.W. Beetle*, Bay View Books, (1994). Lists of model changes for enthusiasts.
[23] Diewert W.E. *The Early History Of Price Index Research*, Essays in Index Number Theory, Volume I, Chapter 2, Elsevier (1993).
[24] Gordon R.J., *The Boskin Commission Report and its Aftermath*, Working paper 7759, National Bureau of Economic Research (2000).

This was achieved by switching from 'general change in prices' to 'change in general price', which is the total value in a basket divided by total quantity[25]. This eliminates bias. It also eliminates the need to compare like to like and is therefore more suited to eras of rapid technological change.

With the numerator money, the denominator goods - not only does this correspond to Milton Friedman's assertion that 'inflation is always and everywhere a monetary phenomenon' but it also quantifies the Economist definition that 'inflation is too much money chasing too few goods'.

The problem is that there is no current means for measuring the denominator, total quantity. Unfortunately in the 1920's Irving Fisher could not find a way to add bushels of grain to tons of metal to heads of cattle[26] and this left its mark on Economics. Since then macro-quantity has always been calculated by dividing actual value by a price index, producing an awkward derivative with no unit behind it.

By adapting concepts from Industrial Design and bringing them to bear on this problem a new universal unit of quantity, the quantil, is created.

The general price can then be determined from a market basket by dividing its total value by its total quantity. The litmus test is that the bias must lie within the plausible Boskin Commission range of 0.8 – 1.6%, compared to the CPI for 1995-96, and it does[27].

And the function G becomes simpler when I is substituted for the CPI in the equation p = G (P, C, I), strongly indicating a movement towards the way things really are[28].

These three new observational tools were brought to bear on the problem of explaining economic growth in the following four research phases.

I. Data Collection & Collation

II. Validating the Metric Equations

III. Aggregating the Metric; Explaining GDP

IV. Disaggregating the Metric; Innovation in Firms

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[25] 'general change in prices' is taken from James Tobin's '*Inflation*' entry in the McGraw-Hill Encyclopedia of Economics, Second Edition p 530-542. The rearrangement to 'change in general price' better suits eras of rapid technology change.

[26] Fisher I., *The Purchasing Power of Money* (1922). Reprinted by Augustus M. Kelley (1971), especially Chapter IX, Sec. 3, page 196.

[27] Document www.techmatt.com/InflationIndex_2.pdf shows biased and unbiased indices graphed together.

[28] *'you know you are getting somewhere when the equations start looking beautiful and you know numbers are taking you closer to the secret of how things are'* words of Tom Jericho, a fictional Alan Turing, written by Tom Stoppard for the movie Enigma (2001).

I. Data Collection & Collation

The data cloud DINTEC™ (Data on INnovation, TEchnology & EConomics) covers the period 1951-2001[29].

Five decades of annual data were needed because (a) stochastic fluctuations confuse interpretation of short period data and (b) foreign trade in manufactured goods becomes significant only after the mid – 1970's – so a database with this midpoint allows the effects of foreign trade on innovation to be deciphered.

The primary source was the Census of Manufactures published every five years. Data for intervening years was taken from the Annual Survey of Manufactures and Current Industrial Reports. These were supplemented by data from industry sources and associations such as The Almanac of the Canning, Freezing, Preserving Industries, Can Manufacturer's Institute, Frozen Food Institute, Carpet & Rug Institute, Portland Cement Association, Association of Home Appliance Manufacturers, Motor Vehicle Manufacturers Association, Ward's Automotive, Consumer Electronics Association, Dealerscope Merchandizing, Business Technology Association and the Writing Instrument Manufacturers Association. Additional data came from the Geological Survey and the Economic Research Service of the Department of Agriculture.

Foreign trade data was obtained from the Department of Commerce, Foreign Trade Division publications. R&D data was obtained from the National Science Foundation.

Annual reports of individual companies were obtained from specialized libraries, including the Hicks collection at Purdue University and the Angelo Bruno collection at the University of Alabama, as well as from the collection at Northwestern University.

Data collected relate to production and shipments, manufacturing labor and materials costs, number and size of establishments, number and size of companies, and industry structure - with prices from Sears and other catalogs, and the Bureau of Labor Statistics.

Data was collated by rearranging it so that products that compete with each other can be brought into the same group. For example, using the seven-digit SIC (Standard Industrial Classification), the following selections each create a competing industrial group.

- Processed Vegetables - SIC 20332XX (seventeen XX product codes) and 20372XX (fourteen XX product codes).
- Malted Beverages (beer) – SIC 2082XXX (thirteen XXX product codes).
- Carpets – SIC 227X0XX (nine X0XX product codes).

[29] Because of the lack of detailed data on service sector industries, DINTEC™ specializes on the manufacturing sector but the metric equations developed and validated will also apply to the service sector - as the underlying mechanisms are congruent.

- Paints – SIC 28511XX (twenty-two XX codes).
- Cement – SIC 32410XX (seven XX product codes).
- Refrigerators SIC 36321XX (fifteen XX product codes).
- Motor Vehicles NAICS 33611X (two X product codes).
- Televisions SIC 36512XX (eight XX product codes).
- Office Machines SIC 357XXXX (eighteen XXXX product codes).
- Truck Trailers (reefers) SIC 37151XX (three XX product codes), (vans) SIC 37151XX (four XX product codes).
- Pens SIC 39510XX (seven XX product codes plus un-coded gel pens).
- Tire Cords SIC 22960XX (five XX product codes)
- Electric Lamps SIC 36411XX (three XX codes)

Precision data collation gave DINTEC™ a scope of about one hundred and fifty products at the seven-digit SIC level. DINTEC™ also includes engineering performance data on tire cords, electric lamps and cement - from various industry sources. These are intermediate products where performance from the purchaser perspective is determined more by engineering specification than not.

II. Validating the Metric Equations

Using a standard price index the fundamental equations P = F (p, C, I) and p = G (P, C, I) were validated. Various mechanistic forms for F, C and G were tested against DINTEC™ data to calibrate parameters and obtain good fits with P and p[30].

An unbiased I was found from DINTEC™ separately, using quantils. Producing bias equaling that given in the Boskin Commission's Report validated it. The fundamental equations were then tested and validated using I.

III. Aggregating the Metric; Explaining GDP

GDP is the sum of the value of all final products sold (excluding imports but including exports) so

$$GDP = \sum F\ N$$

Where N is the number at each price level in a distribution. Therefore once F had been determined in Phase II, the sum to GDP was a question of doing advanced algebra. The outcome took the form

$$GDP = H\ (\sum \sum p,\ \delta)$$

[30] Econometric methods that rely on admitting variables when they reduce the overall residual variation were not used. Determinative methods were used instead.

Where H is a function, $\sum\sum p$ is the innovation metric aggregate, and where $\delta << \sum\sum p$. In other words the innovation metric $\sum\sum p$ dominates economic growth but is not the sole factor[31]. This was verified using data from DINTEC™ capable of sampling the manufacturing sector approximate to its real size[32].

IV. Disaggregating the Metric; Innovation in Firms

The performance, p, is calculated for products generally made by multiple competing firms. Corporate annual report data[33] in DINTEC™ allows this metric to be disaggregated to the firm level – where creative destruction, the originating mechanism of economic growth, operates. Firms must produce products at prices that cover their costs with a profit margin, if they are to expand. Firms forced into loss by competition contract and disappear. This is creative destruction.

Therefore the innovation metric at firm level is p/c, where c is the unit cost of production. Firms increase p, and decrease c, by spending money to develop new technologies and to improve old ones[34].

A firm buys innovation when it purchases from suppliers so its development spending strictly increases (p-p′), where p′ is the performance incoming from its supply chain. Using this insight DINTEC™ was used to establish the following aggregative four-link chain sequence from development spending to GDP.

<Level>		Firms			Industries		Economy		
<Metric>	D	→	(p-p′)/c	→	$\sum p$	→	$\sum\sum p$	→	GDP

Graphs of (p-p′)/c against D were obtained for multiple firms in the Malted Beverage Industry SIC 2082. Note that D is considered alone - in contrast to the received wisdom that always pairs D with R in *R&D* - without such a distinction and separation, a rigorous connection to GDP cannot be made[35].

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[31] Innovation measured by $\sum\sum p$ far exceeds total factor productivity (where TFP = GDP/$K^{\alpha} L^{1-\alpha}$ - with K capital, L labor, α constant). So GDP = H ($\sum \sum p$, δ) eclipses Cobb-Douglas and similar *a priori* equations.

[32] A graph of GDP against H for the whole of the goods sector is available www.techmatt.com/GDPH.pdf

[33] Concentrating on the beer, carpet, cement, office machine and fast-food (service sector) industries.

[34] Thereby protecting them from creative destruction by others, so an aggregated index of p/c may be called a 'Schumpeter' index. It is also a direct productivity meeting the requirements set by Alan Greenspan in his *'Age of Turbulence'* (The Delphic Future, p 473). The causal effect of Development spending on this index, for durable and non-durable goods contributing to GDP, can be seen in the graphs at www.techmatt.com/Index_D.pdf

[35] Unfortunately the conventional wisdom that co-joins R with D into *R&D* also includes the very common - but inaccurate – notion of *'R&D Investment'*. R is investment but D is immediate project specific expense. Accounting them together is deceptive, as is another common idea that R is science and D is engineering. Development is a highly interdisciplinary craft. And for success it has many co-factors. Among these are many types of innovative activity, including innovative management itself. They all belong within D in TechMatt™ Business Innovation Analysis and contribute to economic growth along its metric chain.

For success development spending must be at least enough to put this graph into the ascendant [36].

Armed with this, individual firms can measure (a) their total innovation metric (p/c) - as well as (b) the innovation metric (p-p′)/c they contribute. If you get what you measure then both (a) and (b) will be increased by spending wisely on D [35, 36], invigorating the streams of commerce, contributing to GDP and to everyone's economic prosperity.

Post-Script

The TechMatt™ Business Innovation Analysis toolbox has know-how with immediate practical importance in Commerce, and fundamentals already needed by Academia and Government. So that others can use and build from its leading edge, its formulae, methods, scholarship and its DINTEC™ database may be granted to the public domain by reimbursement of the private research investment that has produced it.

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more at
www.techmatt.com

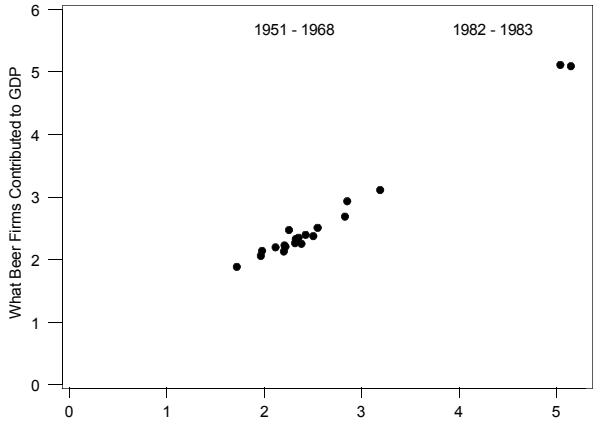
[36] Success correlates with the slope of the innovation metric plot. Creative destruction will eliminate the low performers and replace them with stronger ones, causing overall GDP to continue to rise (Appendix).

Appendix

Actual Innovation Metrics[37]

Creative Destruction and economic growth in a group of seven U.S. Beer Firms

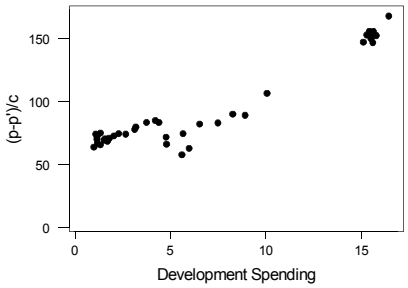
Contribution to GDP - $\sum p$ is beer industries aggregate innovation metric



$H (\sum p, \delta)$ – billions $

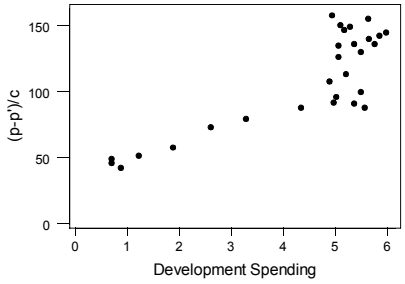
Successful Firm

Anheuser - Busch



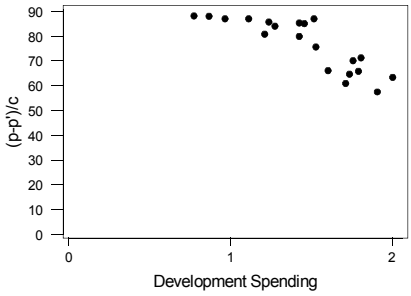
Successful Firm

Miller



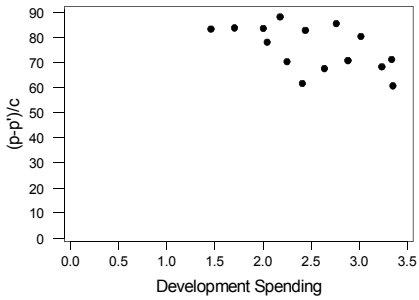
Unsuccessful Firm

Pabst



Unsuccessful Firm

Schlitz



[37] For further examples see *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,* from www.techmatt.com/Farrell0308.pdf

TechMatt™

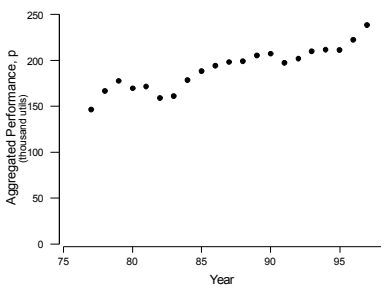
Business Innovation Analysis

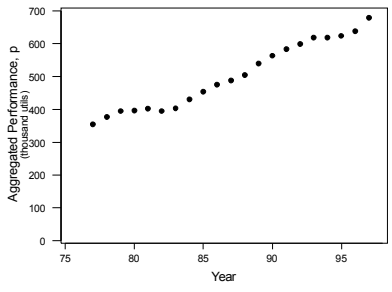
- Captures innovation by looking at what purchasers are willing to pay for 'new & improved' products or services,
- Takes this price or fee and extracts the effect of competition to leave the underlying innovative performance or utility being delivered,
- Aggregates these performances upwards from firm to industry to sector to the whole economy,
  - where delivering GDP validates the economic rigor of this approach.

Innovation in the U.S. Economy 1977 - 1997

This graph shows innovation in Construction….

….and here is innovation in Manufactures.



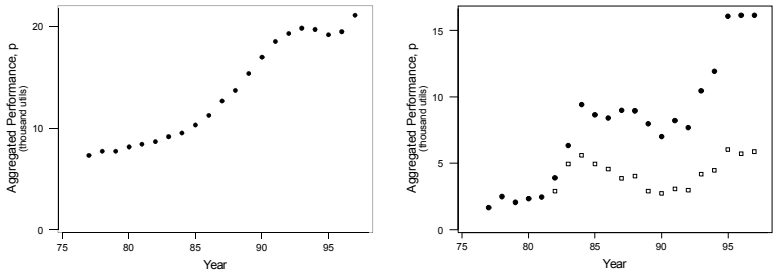


Innovation in the U.S. Economy 1977 - 1997

For domestic manufactures, here is innovation in Pharmaceuticals,

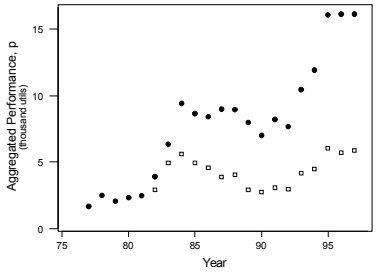
and here it is for Office Machines,

including Personal Computers.



Innovation in the U.S. Economy 1977 – 1997

Innovation in Office Machines (solid circles) and in Personal Computers (open squares)



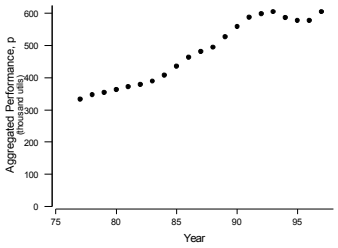
Surprisingly, innovation in Personal Computers increases at first and then goes **down**.

According to Brittanica's Book of the Year *'users began questioning whether the billions of dollars they had poured into computerized information systems over the years were really worth the investment'*

Revealing unexpected innovation insights is a rich capability of
TechMatt™ Business Innovation Analysis.

Innovation in the U.S. Economy 1977 - 1997

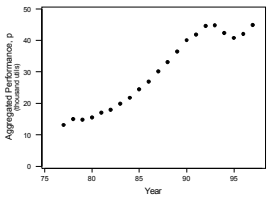
Here is innovation in Services,



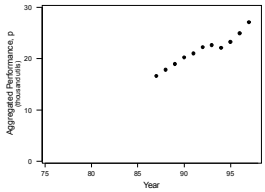
Innovation in the U.S. Economy 1977 - 1997

Within Services here is innovation in,

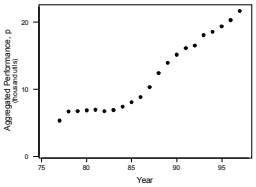
The Legal Profession,



Radio & TV,



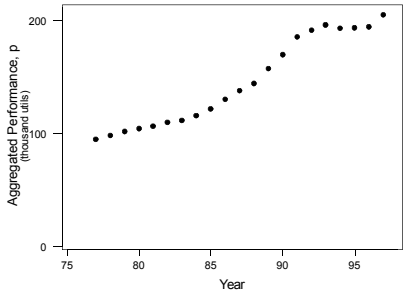
Motion Pictures.



Innovation in the U.S. Economy 1977 - 1997

And as a final example here is innovation in (local) Public Services,

this innovation is dominated by Education.



Innovation in the U.S. Economy

- The foregoing examples show aggregates of innovative product or service performances,
- They arise from a more visceral level where competition drives individual innovations,
- All of this can be explored here

supplemented by

- Department of Commerce paper
- Royal Economic Society interview

Department of Commerce paper www.techmatt.com/Farrell0308.pdf
Royal Economic Society interview www.techmatt.com/RESInterview.pdf