From Experience: Linking Product Innovation to Business Growth

by

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Business processes that create new products and services often extend far enough into the future to exceed learning horizons.[1] Business outcomes are so widely separated in time from the decisions that cause them that participants lose track of the details that have determined their current state of affairs. Furthermore, the market inertia built into existing product lines can sometimes perpetuate the financial success of a business enterprise so long that people have trouble discerning the impact of even the most terrible business decisions. When revenues finally do begin to decline, people cannot connect this effect with its cause. This article links product innovation activities to revenue growth with a useful conceptual model that clarifies cause and effect relationships that often extend beyond the learning horizon of business leaders.

This discussion begins with a description of the business enterprise as a system with product innovation acting as the engine that drives revenue growth. Next, three drivers of revenue growth are described. As it turns out, these growth drivers are linked by a set of useful mathematical relationships that can be presented as a growth table that is unique to a particular enterprise. In deference to the non-mathematical reader, the derivation of these relationships has been swept into an appendix. Revenue growth versus research and development (R&D) investment is analyzed for three types of enterprises - 1) businesses with short market windows such as personal computers, 2) businesses with long market windows such as agricultural products, and 3) a middle case. Finally, some implications of this business model on the management of new-product-related investments and business processes are outlined.

The Innovation Engine in the Revenue Loop

Figure one depicts graphically the closed-loop flow of value between a company and its customers. A company's operational activities convert labor, parts and materials into products and services that are delivered to customers. In return for the value they receive, customers send the company checks in the mail and thereby create the revenue stream. Part of that cash is used to pay for the cost of goods sold (COGS), and the rest is used to fund other parts of the business and to provide profit. In this diagram, the cost of operations includes not only the expense of delivering products and service, but also all general, administrative and selling expenses – everything except investments in the

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creation of new products and services. As long as the company has products and services that customers want and maintains an effective system for distribution and sales, this revenue stream continues, fluctuating up and down a bit as market conditions vary. If left alone, though, over time this revenue stream will decline to nothing as the competition has its way and an ever-aging product line becomes less and less attractive to the customer community.

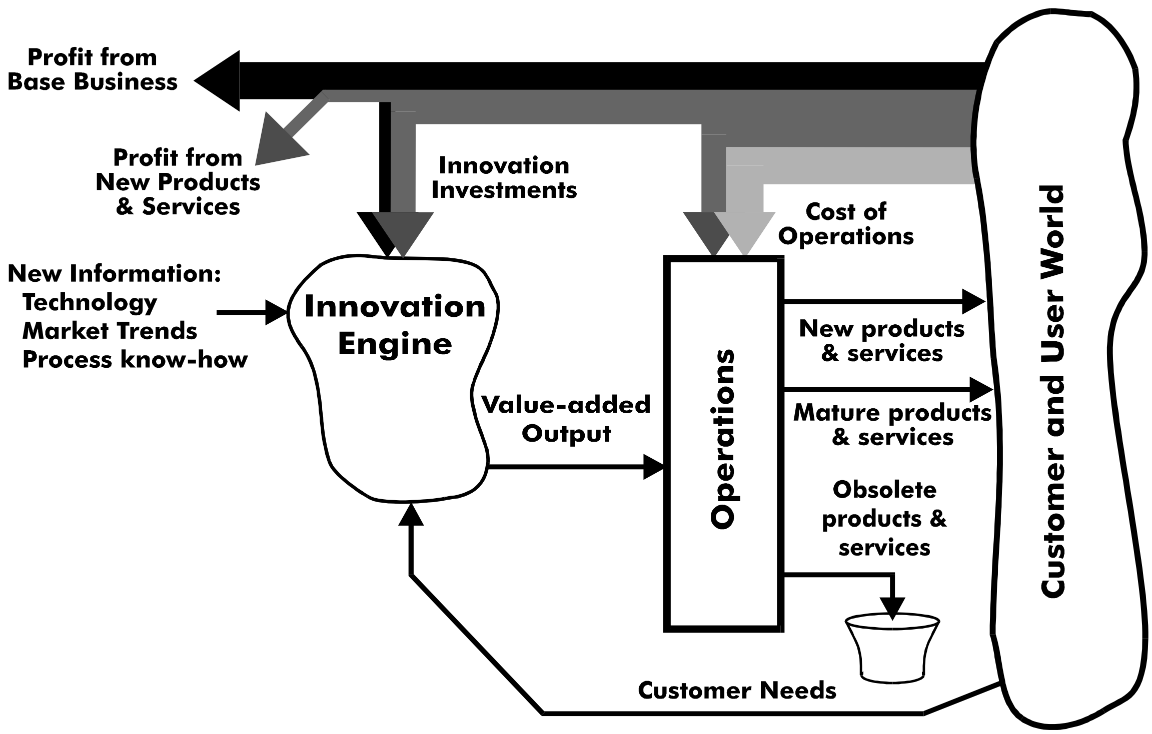

Figure One. The Innovation Engine Drives Growth

To counteract this decline, some of the money from the revenue stream that is left over after the cost of operations has been paid must be invested in a critical business process – labeled here *the innovation engine* – that is responsible for generating new products and services. As shown here, the innovation engine symbolizes all of the enterprise-wide resources – the people, the business processes and tools, the plants and equipment – that are devoted to bringing new value to the customer. From a broad perspective, the work of the innovation engine is to gather information that might have business value – market information, customer needs, new technologies – and to systematically add value to this information until it describes how to manufacture, use, sell and support exciting new products or services.[2]

When the investment in the innovation engine is large enough and effectively applied, the resulting stream of new products and services more than replaces the revenue lost as old products and services become obsolete. This contest between new value creation and obsolescence goes on all the time in most businesses. When the balance tips in favor of new value creation, revenue grows exponentially. But how much investment in new products and services is enough? How does this amount vary from company to company? How can a company get more out of its R&D investment? The discussion that follows provides answers to these important questions.

The HP Vintage Chart **–** How new products contribute to exponential revenue growth is best illustrated by the product vintage chart published by the Hewlett-Packard Company (HP) in its annual report each year.[3] A version of this graph, compiled from several annual reports, is shown in figure two. Total revenues for each fiscal year are shown as the sum of revenues contributed by products introduced in that year and in each preceding year. In this graph, product revenues are pattern-coded by vintage year, that is by the year in which the products were introduced. This allows the impact of each vintage year on future revenues to be easily visualized. Like fine wines, new products in HP apparently have great vintage years and other years that are not so great. The revenues contributed by vintage years 1989 and 1991 are relatively weak, for instance. 1990 and 1992, in comparison, are somewhat stronger.

The pattern of revenue growth followed by obsolescence for a given vintage year is quite apparent in figure two. Revenue contributed by new products is modest in their year of introduction and then peaks dramatically in the following year. By the third year revenues have begun to decline, and they are quite small in the fourth year. Revenue continues to decline exponentially beyond the fourth year. This time dynamic is characteristic of the kinds of products that HP develops and of HP's tendency to obsolete its own products with new versions. Other companies in other industries will, in general, exhibit different patterns of revenue versus time for a given vintage year.

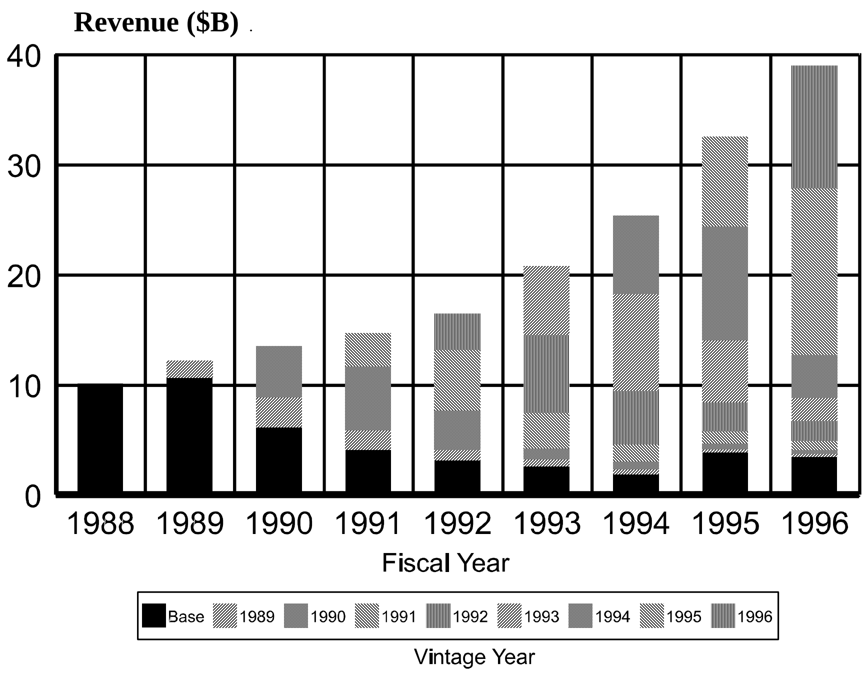

Figure Two. HP Vintage Chart

Revenue Growth Drivers

Three factors determine the growth of revenues in response to investments in product innovation; 1) the fraction of revenues invested in product innovation, 2) an attribute of the new product program labeled *new product revenue gain*, and; 3) the dynamics of product revenue versus time typical to a particular business. The first factor is under management control and is established each fiscal year by executive decisions on where to spend available funds. The second factor is determined by a combination of influences that all relate to 1) the excellence of the new product program, and 2) the ability of the enterprise to distribute and sell its products. The behavior of revenue over time is established by market dynamics and by the nature of the technology and products introduced. As we shall see next, for a large company such as HP, the dynamic performance of revenue for each vintage year tends to stabilize into fairly regular patterns.

***Vintage-year-revenue dynamic* –** The dynamic relationship between new product revenue and time for HP is easily seen in figure two. An average vintage-year revenue dynamic, typical of HP's operations, was derived by analyzing the revenue data used to plot figure two. Table one provides statistical data for these vintage years. These data were gathered by measuring graphs printed in HP annual reports so they are very approximate. Percentage changes in revenue from one year to the next were analyzed for each vintage year data set. These changes were then averaged to create a typical year-to-year revenue dynamic. For instance, the revenue increase from the year of introduction to the second year for vintage year 1989 is 83%. The average value of this initial increase is 68.9% over vintage years 1989 through 1995. The typical revenue dynamic was thus adjusted to exhibit a 68.9% revenue increase between the year of introduction and the second year.

Table One. HP Vintage-year Revenue Data ($B)

Vintage Year	Intro	Year 2	Year 3	Year 4	Year 5	Year
1989	1.51	2.76	1.79	0.95	0.66	0.46
1990	4.61	5.81	3.55	1.01	0.72	
1991	3.02	5.54	3.23	1.57		
1992	3.24	7.06	4.83	2.66		
1993	6.25	8.81	5.62	2.12		
1994	7.12	10.34	3.89			
1995	8.13	15.1				
1996	11.14					

Figure three shows the prototypical revenue dynamic derived from the HP vintage chart. The data have been normalized so that the sum of all annual revenue contributions is 1.0. The meaning of the data presented in figure three is that, for a typical HP vintage year, about 20% of its total revenue will, on average, occur in the initial year of introduction. A little over 34% of the total revenue will be received in the second year and about 20% in the third. The fourth year will yield 9% and annual contributions will taper off after that to a final installment of a little over 2% in the eighth year. The revenue is assumed to drop to zero after the eighth year.

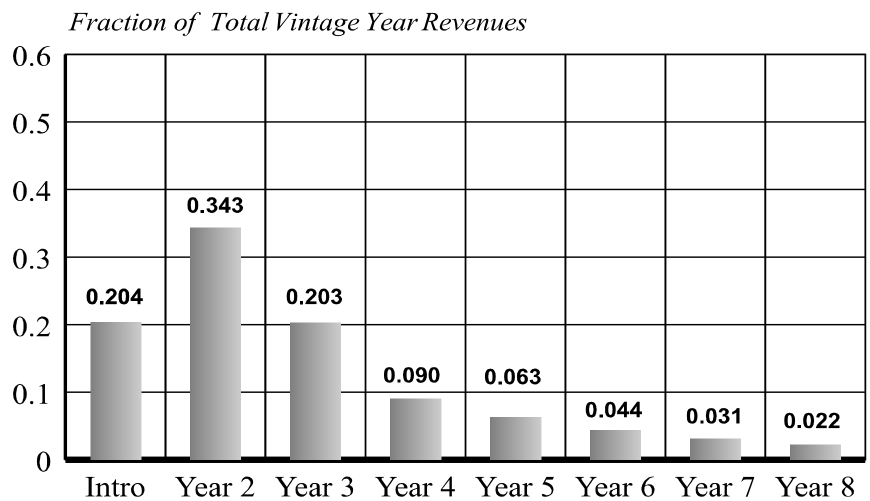

Figure Three. Vintage-year revenue dynamic

The revenue dynamic typical to HP's new product operations has changed over the years. Vintage chart data from 1979 through 1996 was analyzed by plotting the wave of revenues created by each vintage year. Market window trends were then estimated by measuring the width of each wave at 50% of its peak amplitude. These data are plotted in figure four. Figure four indicates that market windows for HP's products declined dramatically in the years after 1979 and then stabilized in about 1988. During these years, the HP product line was in transition, going from mostly test and measurement products in 1979 to a heavy emphasis on personal computers and desktop printers in 1996. As figure four shows, the data used to create figure three comes from a period in which the shape of the revenue dynamic was relatively stable.

New Product Revenue Gain **–** Until now this discussion has emphasized product innovation as an enterprise-wide activity, not just the function of engineering operations. Ideally, corporations should keep track of all expenses associated with product innovation whether they occur in engineering operations, manufacturing, marketing or elsewhere. Typically, however, the only relevant number that is reported in external financial reports is total annual expenditures for R&D. The discussion from this point forward will thus focus on that number as a measure of total investment in product innovation.

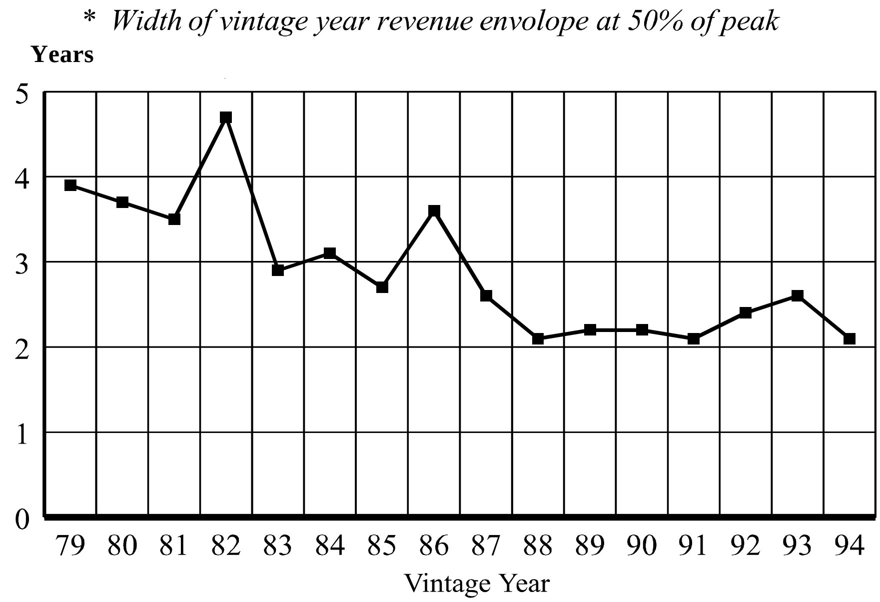

Figure Four. HP market window trend*

New product revenue gain is the total non-discounted revenue generated by products introduced in a given vintage year divided by the total investment in product innovation in that vintage year. Referring to figure two, revenue gain is calculated by adding up the revenue segments associated with a given vintage year and then dividing that number by the R&D investment made in that year. Table two provides estimated revenue gain information derived from HP financial data. Since there are eight annual installments to the revenue created by products introduced in a given HP vintage year, the full revenues returned by vintage years 1990 through 1996 had not occurred by 1996. In view of this, the totals for these years were estimated by weighting the revenue returned through 1996 with the appropriate segments from figure three. The average value of new product revenue gain calculated for vintage years 1990 to 1993 is 13.07. This means that, on average, HP has created or will create over time about $13.07 in revenue for each dollar invested in R&D during those years.

Revenue Growth Relationships

Mathematical relationships for revenue growth as a function of R&D investment and new product revenue gain are derived in the Appendix. For simplicity, this derivation assumes that, over the analysis period, both revenue growth rate and a factor used in the derivation, labeled K, are constant. K is equal to the product of R&D investment rate times new product revenue gain. The relationship between K and revenue growth rate is unique for a given shape of the vintage-year-revenue dynamic. There are many combinations of R&D investment rate and new product revenue gain, however, that will yield a given value of K. To make these relationships more tangible for the reader, revenue growth values are given here as a tabular function of both R&D investment rate and revenue gain.

Table Two. Estimated HP Revenue Gain Performance

Vintage Year	Total Vintage Revenue ($B)	R&D ($B)	R&D as a % of Revenue	Revenue Gain
1989	8.69	1.27	10.7	6.85
1990	16.94*	1.37	10.3	12.39
1991	16.10*	1.46	10.1	11.00
1992	21.79*	1.62	9.9	13.45
1993	27.18*	1.76	8.7	15.43

*** Estimated from incomplete vintage-year returns**

Growth relationships for the typical HP case described above were derived with these assumptions in mind and are summarized below as table three. The investment rate shown in the left-hand column of this table is the fraction of current revenues expended on current R&D operations. To use the table, pick the row in the table that corresponds to the R&D investment rate and then read the revenue growth at the intersection of that row with the column corresponding to the estimated value of new product revenue gain. For example, an R&D investment rate of 10.0 % (0.1) combined with a new product revenue gain of 12.5 yields a revenue growth of 1.144. Under these conditions, revenues for a given year will always be 1.144 times the revenues of the previous year for an annual growth rate (AGR) of 14.4%.

Table Three. Revenue Growth Relationships
(Growth = 1 + AGR)

IR	New Product Revenue Gain												
	9.0	**9.5**	**10.0**	**10.5**	**11.0**	**11.5**	**12.0**	**12.5**	**13.0**	**13.5**	**14.0**	**14.5**	**15.0**
0.070	0.811	0.828	0.845	0.862	0.880	0.898	0.915	0.934	0.952	0.971	0.989	1.008	1.028
0.075	0.833	0.851	0.870	0.889	0.908	0.927	0.947	0.967	0.987	1.007	1.028	1.049	1.070
0.080	0.855	0.875	0.895	0.915	0.937	0.958	0.979	1.000	1.022	1.044	1.067	1.091	1.114
0.085	0.877	0.899	0.921	0.943	0.965	0.988	1.011	1.035	1.059	1.083	1.108	1.134	1.160
0.090	0.900	0.923	0.947	0.971	0.995	1.019	1.044	1.070	1.097	1.123	1.151	1.179	1.207
0.095	0.923	0.948	0.973	0.999	1.025	1.051	1.079	1.107	1.135	1.165	1.195	1.225	1.257
0.100	0.947	0.973	1.000	1.028	1.056	1.085	1.114	1.144	1.176	1.207	1.241	1.274	1.309
0.105	0.971	0.999	1.028	1.057	1.088	1.119	1.151	1.183	1.217	1.252	1.288	1.325	1.363
0.110	0.995	1.025	1.056	1.088	1.120	1.154	1.188	1.224	1.261	1.298	1.338	1.378	1.420
0.115	1.019	1.051	1.085	1.119	1.154	1.190	1.227	1.266	1.305	1.347	1.389	1.433	1.479

The simulated vintage chart in figure five illustrates graphically the relationships between R&D investment, new product revenue gain and revenue growth. In this example, the revenue for fiscal year 1978 was picked as $200M and the annual revenue contributions generated by products from each vintage year were calculated by multiplying the fractional revenue elements in figure three by the total R&D investment (10% of annual revenue) in each vintage year times the assumed revenue gain of 12.5. Figure five is the graphical result of those calculations. It does indeed reflect an annual revenue growth rate very close to 14.4%. Furthermore, the internal structure of this graph reflects its origins and is quite similar to that of figure two.

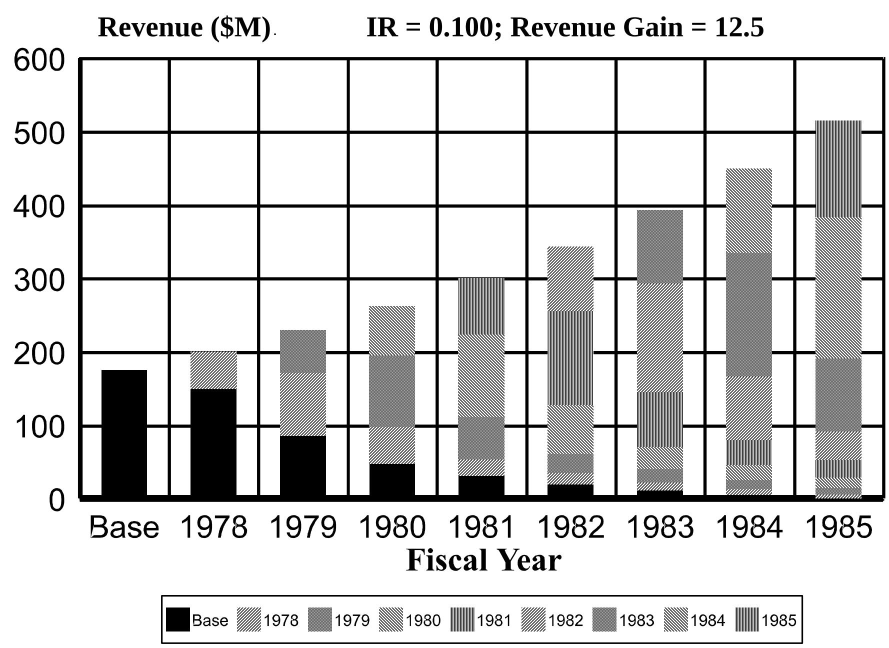

Figure Five. A simulated vintage chart

Growth Models for Other Businesses

The derivation of growth relationships in the Appendix is applied here to two other types of enterprises, both quite different from the case described above. The intent is to bracket the revenue behavior of a company like HP so that the reader can see how these relationships may vary over a range of revenue dynamics. This also provides a total of three different cases that the reader can compare to their own operation as an aid in understanding the fundamentals of their own revenue growth.

The products of the first hypothetical company have a long market life, typical of the paper industry, perhaps, or maybe an agricultural products operation. The revenue for a vintage product set from this company delivers only 5% of total revenues during the first year, contributes 10% of total revenues in each of the next nine years and then declines to zero with the remaining 5% of total revenues occurring in the eleventh year.

Products from the second enterprise have a very short market window, typical of the personal computer industry or perhaps a toy manufacturer. The revenue profile assumed for this business has 60% of the revenue for new products arriving in the year of introduction. In the second year, 35% of total vintage revenues are received and then revenues rapidly fall to zero with only the remaining 5% occurring the final year of the market window.

Table Four. Growth Relationships for Products With Long Life

(Growth = 1 + AGR)

IR	New Product Revenue Gain													
	10.0	**10.5**	**11.0**	**11.5**	**12.0**	**12.5**	**13.0**	**13.5**	**14.0**	**14.5**	**15.0**	**15.5**	**16.0**	**16.5**
0.070	0.935	0.943	0.951	0.959	0.967	0.974	0.982	0.989	0.996	1.003	1.010	1.017	1.023	1.030
0.075	0.947	0.955	0.964	0.972	0.980	0.987	0.995	1.003	1.010	1.017	1.024	1.032	1.038	1.045
0.080	0.958	0.967	0.975	0.984	0.992	1.000	1.008	1.016	1.023	1.031	1.038	1.046	1.053	1.060
0.085	0.969	0.978	0.987	0.996	1.004	1.012	1.021	1.029	1.037	1.044	1.052	1.060	1.067	1.075
0.090	0.980	0.989	0.998	1.007	1.016	1.024	1.033	1.041	1.049	1.058	1.066	1.073	1.081	1.089
0.095	0.990	1.000	1.009	1.018	1.027	1.036	1.045	1.053	1.062	1.070	1.079	1.087	1.095	1.103
0.100	1.000	1.010	1.020	1.029	1.038	1.048	1.057	1.066	1.074	1.083	1.092	1.100	1.108	1.117
0.105	1.010	1.020	1.030	1.040	1.049	1.059	1.068	1.077	1.086	1.095	1.104	1.113	1.122	1.130
0.110	1.020	1.030	1.040	1.050	1.060	1.070	1.079	1.089	1.098	1.108	1.117	1.126	1.135	1.144
0.115	1.029	1.040	1.050	1.061	1.071	1.081	1.091	1.100	1.110	1.120	1.129	1.139	1.148	1.157
0.120	1.038	1.049	1.060	1.071	1.081	1.092	1.102	1.112	1.122	1.132	1.141	1.151	1.161	1.170
0.125	1.048	1.059	1.070	1.081	1.092	1.102	1.113	1.123	1.133	1.143	1.153	1.163	1.173	1.183
0.130	1.057	1.068	1.079	1.091	1.102	1.113	1.123	1.134	1.145	1.155	1.165	1.176	1.186	1.196
0.135	1.066	1.077	1.089	1.100	1.112	1.123	1.134	1.145	1.156	1.167	1.177	1.188	1.199	1.209
0.140	1.074	1.086	1.098	1.110	1.122	1.133	1.145	1.156	1.167	1.178	1.189	1.200	1.211	1.222

Table four gives growth relationships for the long market-life case. Again, revenue growth rate and the product of R&D investment and new product revenue gain are assumed to be constant throughout the analysis period. A vintage chart typical of this business type is presented as figure six. As in the previous section, R&D investment rate and revenue gain are set at values that produce a revenue annual growth rate near 14% and the level of revenue for 1978 is set to $200M. R&D investment rate is chosen as 0.12 and a revenue gain of 15.0 is assumed. The long product life and stable level of mature revenue levels for each vintage year are quite evident in this graph. While the internal structure of revenues is quite different from that of figure five, total revenues for corresponding years is much the same and the revenue growth from year-to-year is nearly identical.

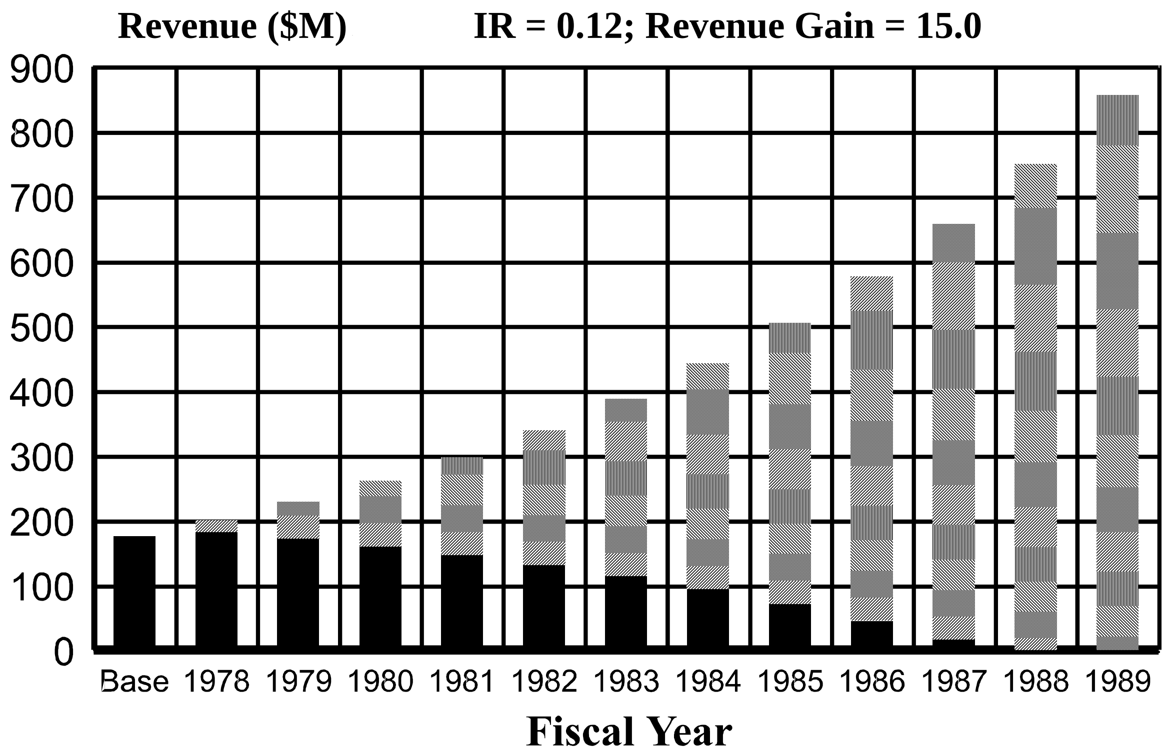

Figure Six. Vintage Chart - Long Product Life

Growth relationships for the short product life case are presented in table five and the corresponding vintage chart is presented as figure seven. Again, values of R&D investment rate and revenue gain are picked for a revenue growth rate near 14% and the level of revenues in 1978 is assumed to be $200M. R&D investment rate is set at 0.085 and a revenue gain of 12.45 is assumed. Note that the change in growth rate for each incremental change in revenue gain is much greater in this case. Interpolating between columns is thus required to get a growth rate near 14%. While the internal revenue structure in figure seven is quite different than those found in figures five and six, this case exhibits nearly identical total revenue growth performance.

Discussion of Assumptions

The derivation of the growth tables presented here presumes that a number of business parameters remain constant that, in many businesses, are rarely stable for long. The derivation of these tables assumes a stable vintage-year revenue dynamic, a constant annual revenue growth rate and a stable value for K, the product of R&D investment rate and revenue gain. The HP performance data presented in figures two and three and in table two show that HP's performance in these areas is not constant, but in fact, varies considerably. Nonetheless, the understanding of fundamentals has to start somewhere. The temporary assumption of stability is necessary to the derivation of the underlying relationships illustrated by the tables.

Table Five. Growth Relationship for Products With Short Life

(Growth = 1 + AGR)

IR	New Product Revenue Gain									
	9.0	**9.5**	**10.0**	**10.5**	**11.0**	**11.5**	**12.0**	**12.5**	**13.0**	**13.5**
0.070	0.465	0.500	0.536	0.575	0.617	0.663	0.712	0.767	0.825	0.888
0.075	0.510	0.550	0.593	0.640	0.690	0.748	0.808	0.874	0.947	1.029
0.080	0.558	0.605	0.656	0.712	0.775	0.842	0.917	1.000	1.095	1.203
0.085	0.611	0.666	0.727	0.795	0.869	0.952	1.046	1.153	1.277	1.419
0.090	0.669	0.734	0.808	0.888	0.978	1.082	1.203	1.341	1.505	1.702
0.095	0.734	0.812	0.897	0.995	1.107	1.240	1.393	1.577	1.802	
0.100	0.808	0.897	1.000	1.120	1.262	1.429	1.631	1.883		
0.105	0.888	0.995	1.120	1.270	1.447	1.667	1.941			
0.110	0.978	1.107	1.262	1.447	1.679	1.970				
0.115	1.082	1.240	1.429	1.667	1.970					

If these assumptions are valid, then the tables will accurately predict revenue growth rate. Variations from year-to-year in R&D investment rate, revenue gain, or revenue dynamic may, however, cause actual revenue growth performance to differ from what the tables predict. The usefulness of the numbers published in the tables depends upon the validity of the underlying assumptions for a given business. The quantitative information published here should thus be applied with considerable suspicion.

The qualitative information provided by the model developed here is, however, more robust. More investment in R&D, for example, will always increase revenue growth rate for a given level of revenue gain. Increasing revenue gain will always create more revenue growth for a given level of R&D investment. Short product market windows will always make revenue growth rate more sensitive to changes in revenue gain. The value of the model developed here is more in the understanding of these fundamental interdependencies than in the quantitative data that it provides.

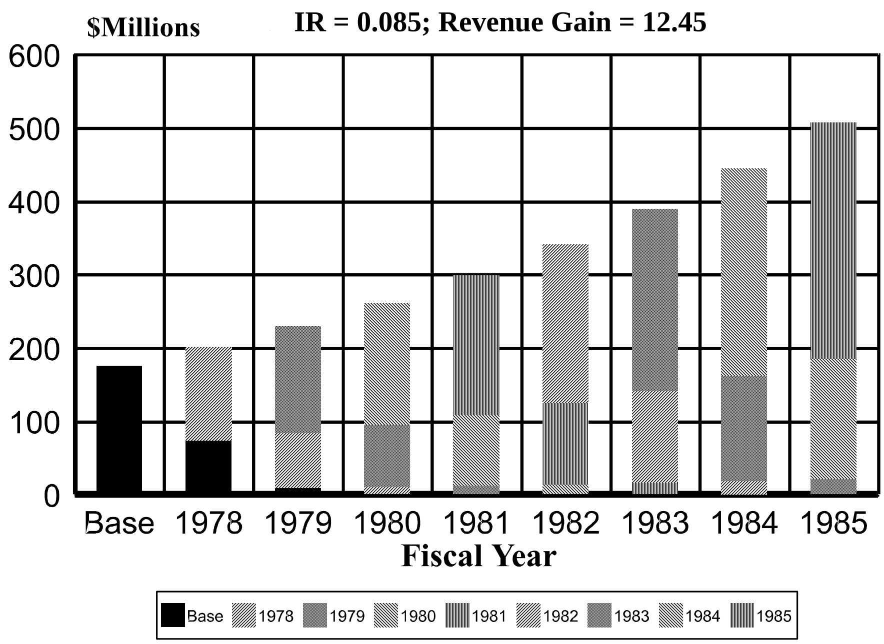

Figure Seven. Vintage Chart - Short Market Life

Finally, there is an implicit assumption here that the R&D investment made in a given vintage year *causes* a corresponding wave of revenue to occur. Revenue gain for a vintage year is calculated using only the R&D investment made in that year. In reality, the wave of revenue launched in a given vintage year is caused by R&D activity in not only that year, but perhaps in the preceding one, two or more years as well. Nonetheless, for simplicity, the vintage-year R&D investment is used here as a surrogate for value creation activities that may have occurred much earlier and that are, at least partially, responsible the wave of new revenue.

Yield on the R&D Investment

The financial yield on the R&D investment is the incremental profit that it creates. The analysis presented in the preceding sections has only addressed the essential drivers of revenue growth. Whether or not profits grow in step with revenues depends on many attributes of the particular business situation including competitive pressures, product pricing, distribution channel discounts, unit manufacturing cost, and internal expense structures. Growth rates for profits will match revenue growth rates only if the new products introduced have gross margins and expense structures that are similar to those of the base product line. In fact, profit growth rates can be either less than or greater than the revenue growth rate depending on 1) the nature of the markets addressed by the resulting stream of new products, and 2) the level of contribution that new products make to the customer.

R&D investments have a strategic payoff as well. They set the strategic direction for an enterprise and move it towards its future. Judicious placement of R&D investments can move a firm out of one business arena that has stopped providing growth and into another that holds greater promise. HP's history illustrates how this can happen.

In the late 1970's HP was concerned that the electronic test and measurement business had matured to a point that limited future growth potential. The firm's strategic sights were thus aimed at the computer industry and, under John Young's leadership, the company began to emphasize R&D investments in computer technologies & products. The 1980's were a time of transition as HP learned how to compete in this dynamic new business arena. Revenue and profit growth were problematic at times and the stock price dropped to half of its peak value at one point. John occasionally endured severe criticism for leading the company into such difficult waters. Discount structures and sales costs for computer products proved to be quite different and operating profit margins were driven to much lower levels than the company had experienced in the electronic instrument business. John persevered, though, and by the early 1990's HP had become the second largest computer company in the world. Today HP's growth in revenues and profits is among the healthiest in the industry. The company still produces test and measurement equipment, but these products create a fairly small fraction of the company's annual revenues. While HP's profit growth has not kept pace with revenue growth rates, annual profits are vastly greater now than they were when this transition began. This increase in earnings is, in part, a long-term yield on R&D investments that were made almost two decades ago.

Implications for Business Leaders

The model developed here has important implications for the business leader who is responsible for keeping shareholders happy. Some of these implications are obvious, some are more subtle. The purpose of this final section is to summarize key insights that can be drawn from this work.

***Product innovation drives growth* –** The growth tables show that the fraction of revenues that are invested in R&D directly impacts revenue growth rate. For a given level of performance in revenue gain and vintage-year-revenue dynamic, more R&D investment will yield a greater revenue growth rate, regardless of short or long term product life. This is true, however, only so long as incremental increases in R&D spending can be effectively utilized. A point will inevitably be reached where the revenue gain declines because the new product organization has reached its limits and can no longer create additional development projects that have the same level of "bang per buck". Most enterprises, however, traditionally operate far short of this point.

The right level of R&D investment depends, though, on the profit picture as well. Increasing the R&D investment decreases current profit from operations by an equal amount. The right level of R&D investment for an enterprise will thus be one that strikes a suitable balance between revenue growth rate and current profit levels.

Vintage-year-revenue dynamics establish growth relationships – The answer to the question, “How much R&D is enough?”, depends upon the shape of the vintage-year-revenue dynamic that is typical to a given enterprise. Each collection of products introduced in a given vintage year will create a “bow wave” of revenue that begins at the time of introduction and extends into the future. The shape and extent of this wave is an important characteristic of each particular business and establishes the relationships between R&D investment and revenue growth rate. Yet, businesses often have no idea what their typical revenue wave looks like, with the notable exception of HP, of course. An important step for any enterprise in understanding how it creates growth in shareholder value through new products is to characterize both its typical vintage-year-revenue dynamic and its new product revenue gain performance. With these in hand, an enterprise can then develop its own revenue growth tables similar to those presented above. These growth tables will enable business leaders to set realistic targets for both revenue growth rate and R&D investment level that are based upon a solid understanding of underlying business principles.

New product revenue gain is key to business success – The business purpose of new product efforts is to convert the fraction of revenues that they consume into growth in revenue and profits for the enterprise. This is, of course, done best by creating new value for customers. As the tables above illustrate, increasing revenue gain has an immense impact on the level of revenue growth created by a given R&D investment rate. In a business with short product life, for example, the sensitivity of revenue growth to changes in revenue gain is a little scary. Table five indicates that, at an investment rate of 0.09, a change in revenue gain from 11.0 to 12.0 means the difference between a 2.2% annual decline in revenue and a 20.3% annual revenue growth rate.

The revenue gain that results from new product efforts is a function of the opportunities addressed and the productivity of the operation in creating new products and services. The four fundamental drivers of revenue gain performance are:

- Effectiveness of distribution and sales operations
- The quality of new-product-related business processes
- Effective executive leadership, and
- The impact of the working environment on employee creativity and productivity

Each of these drivers is essential and they work together to create an effective innovation engine. Management and improvement of performance in these areas is, however, beyond the scope of this article. These topics will be addressed in work that follows at a later date.

Manage R&D as the solution, not the problem – In times of financial stress, business leaders often cut R&D spending along with other expenses. When revenue growth softens and profits decline, the natural reflex is to control expenses in order to minimize the damage. Across-the-board cuts are typical - “All expense areas will hereby run at 85% of targeted levels until further notice.” Most often such policies include R&D and all other areas involved in getting new products out.

The impact on the bottom line is immediate. Every dollar saved is a dollar added to operating profits in the current accounting period. But the impact on revenue growth is more obscure. A cut in new product investment rate will move the operating position of the enterprise on its revenue growth table. Referring to table three, if the firm had been operating at a revenue gain of 12.5 and an investment rate of 0.10, a 15% cut in spending rate will change revenue growth in the future from 14.4% to 3.5%. If this change were permanent, revenue growth rates would eventually stabilize at the new value. Usually, though, these cuts are temporary so the result is simply a transitory weakening of revenue growth at some point in the future. The impact of this change is usually delayed to a point well beyond the learning horizon of business leaders, however, so it goes unnoticed.

In contrast, business leaders at HP have traditionally had an inherent understanding that new products drive financial growth and are the answer, not the problem, in times of financial stress. In hard times, the reflexes of Bill Hewlett and the late Dave Packard were quite different. They would cut expenses everywhere except R&D and then launch a close scrutiny of R&D efforts, company-wide. "Are we investing in the right new products? Are R&D efforts as effective as they should be? Are there obstacles to early new product introduction that we can remove?" Their natural reflex was to strengthen and focus R&D, not reduce it.

Inertia in the revenue loop can hide a multitude of sins **–** The revenue loop depicted in figure one has a built-in inertia that is related to the new-product-development cycle time and the vintage-year-revenue dynamic. The delay between a good decision on where to invest new product resources and its impact on business success includes the time-to-market typical of new product operations and the ramp-up time inherent in the vintage-year-revenue dynamic. The business impact of a good decision thus may not be felt for several years.

Likewise, damage to an effective new product program caused by bad decisions takes a long time to be reflected in business results. New products that have just been introduced will create their revenue wave, regardless of what happens to future new product efforts. Likewise, new products that are well along in the innovation cycle will be introduced more or less on time unless something truly drastic happens. The impact of bad decisions on revenue growth cannot occur until these products have run their course in the marketplace.

To visualize this revenue loop inertia in action, refer to the vintage chart in figure six. Suppose that, for some odd reason, this company decided in 1985 to scrap the new product program altogether so that no further products were introduced after this year. Future revenues for this company beyond 1985 are easy to visualize by simply ignoring the revenue contributions from vintage years beginning with 1986. The inertia built into this revenue loop is so strong that, even with no new products, revenues would actually grow from 1985 to 1986. In 1987 they would be only slightly lower than the 1985 level. Beyond 1987 revenues would begin a steady decline at roughly 9% per year. With the 12% annual investment in R&D eliminated entirely in 1986 and beyond, profits would immediately jump, probably to record levels. Common business indicators would show excellent performance in 1986. Revenue growth would be down a little but profit growth and earnings per share would be outstanding. The stock price would probably increase dramatically.

Many of the so-called turn-around experts that we read about in the business press use this revenue loop inertia to their advantage. Massive expense cuts and layoffs cause dramatic reductions in current cost structures. Of course, these cuts include reductions in new product efforts. As expenses are reduced, profits jump sharply and the stock price rebounds dramatically. Even though the firm's new product capability may have been severely damaged, revenue loop inertia keeps money flowing into the enterprise for a time. By the time revenues begin to drop, however, the turn-around expert will have cashed in his stock options and moved on to the next opportunity in another company. The wreckage created in new product operations will typically become apparent only after this person has left. In fact, thanks to learning horizon effects, the turn-around expert may never be connected with the future difficulties that befall his former employer.

Summary

This article has described a model of the business enterprise that positions the creation of new products and services as the engine that causes growth in revenue over time. The business enterprise was described as a value loop that delivers value to customers and then, in return, receives value from them in the form of revenue. Exponential revenue growth was seen to occur when the creation of new value for customers occurs faster than the rate at which old products and services become obsolete. Drivers of revenue growth include

- The fraction of revenues invested in creating new products and services
- The vintage-year-revenue dynamic, and
- New product revenue gain.

Interrelationships between these drivers were described and growth tables were derived that give quantitative relationships between revenue growth, investment rate and new product revenue gain for three different types of businesses. Key implications that this model has for business leaders were described. Finally, an appendix has been provided that outlines the mathematical derivation that underlies the growth tables presented.

Appendix

This appendix provides a derivation of the mathematics that relate revenue growth to the rate of investment in new product operations, the new-product revenue gain and the vintage-year dynamics of the revenue stream.

Figure six above is used here as a prototypical vintage year representation of annual revenues for a company. The total revenues for each year are a summation of contributions from products introduced in that year plus products introduced in some number of earlier years. How many years contribute to the revenues for a given year is a function of the vintage-year-revenue dynamic. A key assumption here is that the revenue dynamic is the same for all vintage years. In other words, the distribution of revenues into the future for products introduced in any vintage year can be represented by the same constant vector with fractional elements.

The row vector below, α, is an example for a business with an eleven-year revenue life for each vintage year. Figure six is derived using α as the revenue dynamic. Each element in the vector represents the fraction of total revenues for that vintage year that will occur for a given year after product introduction. The sum of all elements of α therefore must be 1.0. The elements of the vector are designated symbolically as a_0 through a_n.

$$\alpha = (.05\ \ 0.1\ \ 0.1\ \ 0.1\ \ 0.1\ \ 0.1\ \ 0.1\ \ 0.1\ \ 0.1\ \ 0.1\ \ .05) \tag{1}$$

The perspective assumed here is that new products *cause* revenue to happen. The total amount of revenue that a vintage year causes over the full life of its products is given by

$$\text{Revenue}_{\text{Total}}(k) = G_{RD} \times RD(k) \tag{2}$$

Where G_{RD} is a revenue gain factor ($ Revenue/$ R&D)
and RD(k) is the investment made in new products in year k.

The revenue gain factor, G_{RD}, depends on the nature of the opportunities selected for new product investment and on the productivity of the people, processes and tools involved in the new product effort. While G_{RD} may change over time as business conditions vary, for the purposes of this derivation it is assumed to be non-varying over the time span of interest.

The vector, α, describes how $\text{Revenue}_{\text{Total}}$ will be distributed forward in time. In year k, products from vintage year k will cause:

$$\text{Rev}_0(k) = a_0\, G_{RD}\, RD(k) \tag{3}$$

In year k + i, products from vintage year k will cause:

$$Rev_i(k + i) = a_i G_{RD} RD(k) \tag{4}$$

Revenue caused by vintage year k will continue in this manner through year k + n and then stop because the full value of $Revenue_{Total}$ will have been distributed..

Shifting the perspective to a single fiscal year, year k, the total revenues for that year can now be calculated by summing up the contributions from each of the relevant vintage years. In figure six, refer to 1988 as a suitable example. 1988 is the first year in the graph that is made up totally from contributions from vintage years that are all covered by the graph. Mathematically, total revenues for fiscal year k are given by:

$$Rev(k) = a_0 G_{RD} RD(k) + a_1 G_{RD} RD(k-1) + \ . \ . \ . \ . + a_n G_{RD} RD(k-n) \tag{5}$$

The investment in new products for a given year is given by:

$$RD(k) = RD\%(k) \ Rev(k) \tag{6}$$

For simplicity, the percentage of revenues invested in new products will be assumed to remain constant from year-to-year at a value represented symbolically as RD%. This is approximately true in most companies and is a reasonable approximation, in particular, for the Hewlett-Packard Company.

The revenues from year-to-year are related by the fractional growth term, g, such that:

$$Rev(k) = Rev(k-1) \ (1 + g) \tag{7}$$

Since revenue growth is caused by new products, g will be determined as a function of investments in new product activity and the revenue gain factor, G_{RD}. Again for simplicity, g will be assumed to be constant from year-to-year. Applying equations (6) and (7) to equation (5):

$$\begin{aligned} Rev(k) = a_0 G_{RD} RD\% \ Rev(k) + a_1 G_{RD} RD\% \ Rev(k) \ (1 + g)^{-1} + \ . \ . \ . \ . \\ + a_n G_{RD} RD\% \ Rev(k) \ (1 + g)^{-n} \end{aligned} \tag{8}$$

Let

$$K = G_{RD} RD\% \tag{9}$$

and

$$x = 1 + g \tag{10}$$

Applying these relationships to equation (8) and gathering terms on one side of resulting equation yields:

$$Rev(k)[1 - a_0 K - a_1 K x^{-1} - \ldots. - a_n K x^{-n}] = 0 \quad (11)$$

Finally, dividing both sides by Rev(k) and multiplying both sides by x^n gives:

$$(1 - a_0 K) x^n - K [a_1 x^{n-1} + a_2 x^{n-2} + \ldots. + a_n] = 0 \quad (12)$$

The relationships between RD%, GRD and the revenue growth term, g, are established by solving for the roots of equation (12). Specifying a value for RD% and estimating the value of G_{RD} allows calculation of a value for K. Evaluating the revenue time dynamic, either by averaging historical vintage year performance or by estimating future revenue performance, provides values for a_0 through a_n. Once these factors are all specified, equation (12) can be solved through either closed-form or approximation techniques to determine the root values for x which is, of course, equal to 1 + g. There will, in general be n different values for x that satisfy equation (12) so care must be taken to choose the one that is realistic for the business case. For typical values of RD%, G_{RD} and α, this will usually be the first real and positive value for x that satisfies equation (12).

Note that there are many different values of G_{RD} and RD% that can be combined to yield a given value for K. Equation (12) needs only to be solved for a particular value of K. That solution for x then works for any combination of G_{RD} and RD% that yields the value of K that was used in the solution.

The revenue growth tables above were derived using Mathcad 6.0 worksheets to systematically solve equation (12) for different values of RD% and G_{RD}. Each growth table utilizes a different vector, α, characteristic to the given business. For example, figure three gives the values of a_0 through a_7, characteristic to HP, that were used to derive table three.

[1] Senge, Peter M.; The Fifth Discipline: The Art & Practice of The Learning Organization; Doubleday/Currency, New York, 1990, pp. 23.

[2] Patterson, Marvin L.; Accelerating Innovation: *Improving the Process of Product Development*; Van Nostrand- Reinhold, 1993.

[3] HP began this practice in 1979 and has continued it through the 1996 annual report. The vintage chart has been omitted from the 1997 annual report.