Daniel Research Group
Understanding the Future

An Equilibrium Approach to Forecasting Technology Products and Markets

Context

A few years ago, a client asked me to develop a market size and forecast of the United States PC and Tablet Market. As I often do, I conducted a review of the forecasts and analysis published by my competitors, the leading technology market research firms. The lack of clarity as to the causes of the continuing decline in PC purchases was a surprise, and a disappointment. At first, the analyst community seemed to point the causal finger at the surge in Tablet purchases. Subsequently, causality shifted to the failure of Microsoft's Windows 8 to gain any traction at all in the market.

Sprinkled throughout the press releases and blogs entries were references to the lengthening of the average life of the PCs in use, or its corollary, the slowdown in the replacement rate. Surprisingly, the analysts viewed these metrics as a result, when in fact they are a cause. No one was offering any rigorous analysis that linked cause to effect. Furthermore, most of the forecasts were simple trending of vendor reported sales. This is akin to driving a car by looking at the rear view mirror.

In order for a market model to be credible, it must have superior descriptive, normative, and predictive properties. Descriptive properties relate to how well the model fits actual historic data. Normative refers to the way in which the taxonomies, metrics, and logic of the model explain all of the significant influencing trends, factors, and events. Predictive simply means how accurate has the model been in forecasting the market. **A model must have superior descriptive and normative properties in order to have superior predictive properties**.

Theory

Daniel Research Group (**DRG**) believes that a rigorous market model for many technology end-user products must incorporate variables and logic that describe market activity from three different perspectives.

1. **Installed Base** of Units in Use
2. **Units Purchased** by End-Users
3. **Units Retired** from the Installed Base

The relationship linking these three variables is.

$$Ending\ Installed\ Base - Starting\ Installed\ Base = Units\ Purchased - Units\ Retired$$

Each of these terms may also be derived from independent models or functions incorporating causal trends and events.

$$Installed\ Base\ at\ the\ End\ of\ Time\ t = Penetration\ Model$$
$$Units\ Purchased\ during\ Time\ t = Sales\ Trend\ Model$$
$$Units\ Retired\ during\ Time\ t = Retention\ Rate\ Distribution$$

Installed Base

Almost all technology products, as well as many services, penetrate the total available market following some form of the logistics S-Shaped curve. This model encapsulates the long-term advocacy and observational influences driving adoption, as well as the resistive forces inhibiting growth. Other influences such as economy shocks and cycles, as well as the success or failure of new market entries will add localized variance. However, the long-term trend has proven to be very accurate for thousands of technologies and innovation over the past millennium.

In most cases, the penetration process may be represented by a simple logistics function with two parameters and a variable. The α parameter governs when half of the market will be penetrated, the parameter β governs the shape of the curve – flat and wide, or steep and narrow, while t represents the time-period variable, usually the year. The α and β parameters are commonly derived from a regression analysis of historic data, but may be estimated from survey data, or even quantitative expression of analysts' qualitative assessments. Once the parameters are set, the installed base forecast can be produced.

Units Purchased

In contrast to the relative stability of the adoption process, end-user purchases often exhibit significant variance over time. There are many challenges analyst may face in selecting and applying the appropriate methodology. However, in all case the most important is determining if the influences that were important in the past are the same as those that will be important in the future. The task is to identify these influences, and the nature of their relationship to purchaser behavior. There are hundreds of method and approaches that may be applied including time-series analysis, multi-variate causal models, and many trending algorithms acting on the unit shipment data itself, or a derivative such Periodic Growth Rates. Regardless of which methods are applied, the output will be a forecast of end-user unit purchases.

Units Purchased are a result, not a cause. While measuring and understanding the trend is necessary to provide context for a Units Purchases forecast, in and of itself, it possesses limited predictive properties.

Units Retired

Units Retired, Average Life, and Replacement Rate are all metrics that measure the effect of end-user decisions to continue to use, or to replace a unit in service. The result of these decisions can be expressed by a Retirement Rate Distribution - a schedule that shows the percent of installed base units that will be retired in each year, **as a function of how long they have been in use.**

There are three different reasons that will cause a unit to be removed or replaced from the installed base, each with its own descriptive probability distribution.

1. **Loss or damage beyond repair** – This is best represented by a uniform function since the probability of this event for any unit is constant over time.

2. **Failure** – This can be modeled by a U shaped distribution reflecting initial manufactures defects and damage during distribution, followed by a long period of low failure, and finally an increase near end of physical life due to material fatigue, and normal wear and tear.

3. **Elected or Incented Obsolescence** – This is normally best described by a bell shaped function, similar to a normal distribution. The probability of the unit exiting the installed bases starts low, increases to a peak, and then falls again.

In almost all cases, Elected or Incented Obsolescence will dominate the aggregate distribution.

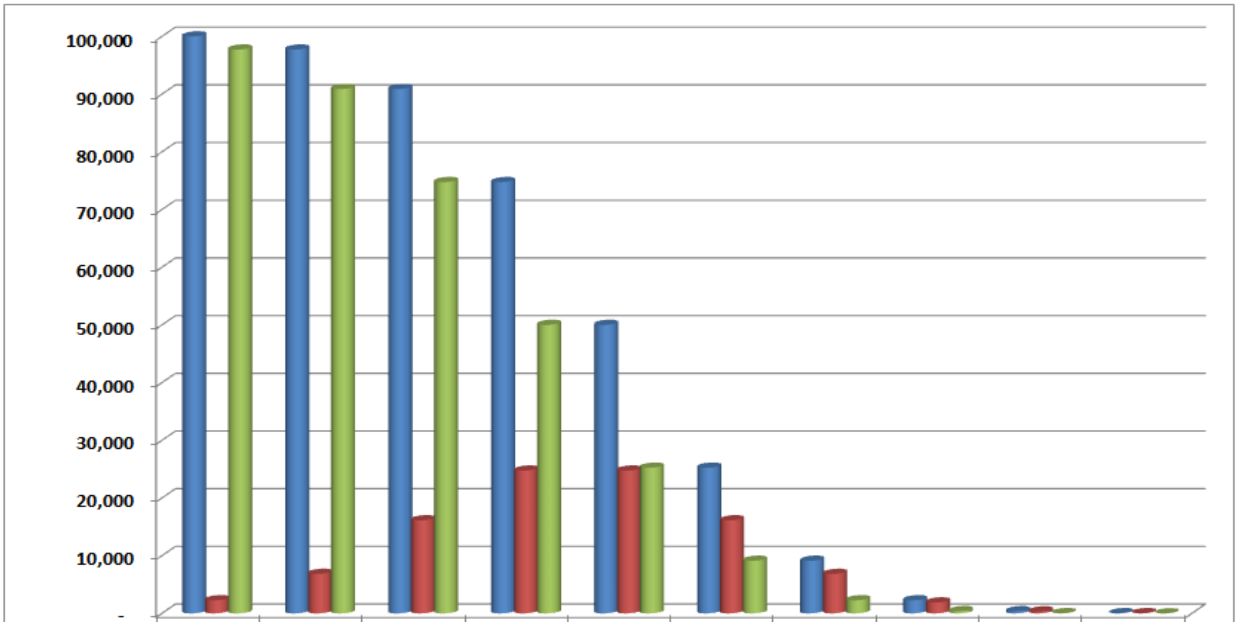
The **Retention Rate Distribution** represents the probability that a unit will be retained in the installed base, given the length of time the unit has been in service. For practical purposes, it may be represented by a left and right truncated normal distribution. It is truncated on the left by the first year and on the right by an estimate of the practical maximum number of years that a unit can be considered in use. The mean **μ** and standard deviation **σ** parameters will then govern the mid-point and shape of the distribution.

The **Retirement Rate Distribution** represents the percent of an installed base cohort (all units entering the installed base in a specific year) that will be retired in the current year as a function of the age of that cohort. The Retirement Rate Distribution is computed from the Retention Rate Distribution.

Mean	4.00
Standard Deviation	1.50
Maximum Life	10.00

Year	Cumulative	Retention Rate Distribution	Difference	Retirement Rate Distribution
1	2.3%	97.7%	2.3%	2.3%
2	9.1%	90.9%	6.8%	7.0%
3	25.2%	74.8%	16.1%	17.7%
4	50.0%	50.0%	24.8%	33.1%
5	74.8%	25.2%	24.8%	49.5%
6	90.9%	9.1%	16.1%	63.9%
7	97.7%	2.3%	6.8%	75.1%
8	99.6%	0.4%	1.9%	83.2%
9	100.0%	0.0%	0.3%	88.8%
10	100.0%		0.0%	100.0%

The number of units retired is computed by applying the Retirement Rate Distribution to the declining Installed Base Units.



	1	2	3	4	5	6	7	8	9	10
Starting IB	100,000	97,725	90,879	74,751	50,000	25,249	9,121	2,275	383	43
Retired	2,275	6,846	16,128	24,751	24,751	16,128	6,846	1,892	340	43
Ending IB	97,725	90,879	74,751	50,000	25,249	9,121	2,275	383	43	-

Retention Rate Distribution, and therefore the Retirement Rate Distribution are not static; **they changes over time** reflecting trends, as well as events that influence user behavior. End-users delay replacing products when economic conditions are declining, and accelerate replacing products when economic conditions improve. End-Users accelerate replacing products when given compelling incentives to do so, and delay when there are no compelling reasons.

It is the mean of the Retention Rate Distribution, and to a lesser extent, the standard deviation and maximum life that encapsulates the causal influences.

The other metrics - Units Retired, Average Life, and Replacement Rate – are all computed from the result of applying the Retirement Rates to the Installed Base.

Finding the Equilibrium

Each of the three input time-series may be derived two different ways, as a function of the other two inputs, and as a function of independent causal influences

Let

$$I_{end} = Installed\ Base\ at\ the\ End\ of\ Time\ t$$

$$I_{Start} = Installed\ Base\ at\ the\ Start\ of\ Time\ t$$

$$R = Units\ Retired\ during\ Time\ t$$

$$P = Units\ Purchased\ during\ Time\ t$$

Then

Installed Base

$$I_{end} = I_{Start} + P - R$$

$$I_{end} = F(\alpha, \beta, t)$$

Units Purchased

$$P = I_{end} - I_{Start} + R$$

$$P = Trend(P)$$

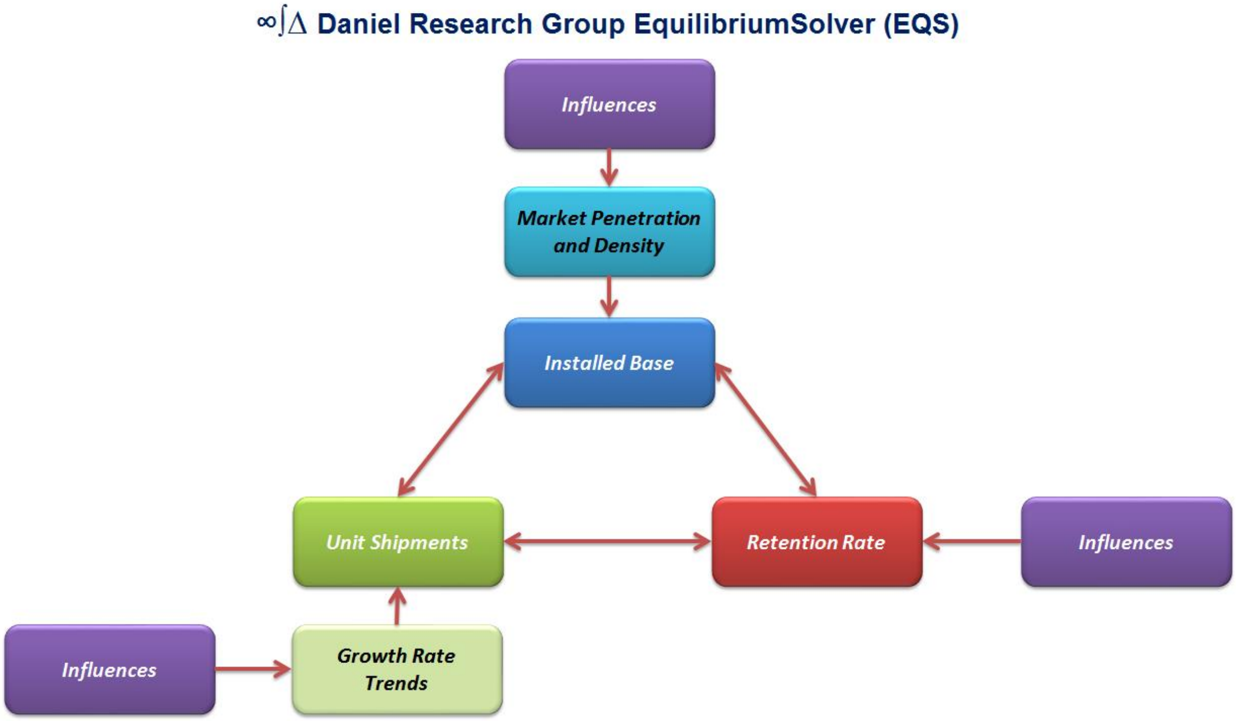
Units Retired

$$R = I_{Start} - I_{end} + P$$

$$R = RRD(\mu, \sigma, Max)$$

DRG has designed and developed a modeling tool, the **EquilibriumSolver (EQS)** that incorporates the Installed Base time-series, the Unit Shipment (Purchased) time-series, and the Retention Rate Parameters Time-Series such that each one may be derived given the other two, as well as being independently derived from causal variables. The tool is designed to find an equilibrium solution that is consistent with the current understanding of all the market influences acting on long-term adoption trends, short-term sales activity, and end-user replacement behavior.

Practice – Applying the EquilibriumSolver

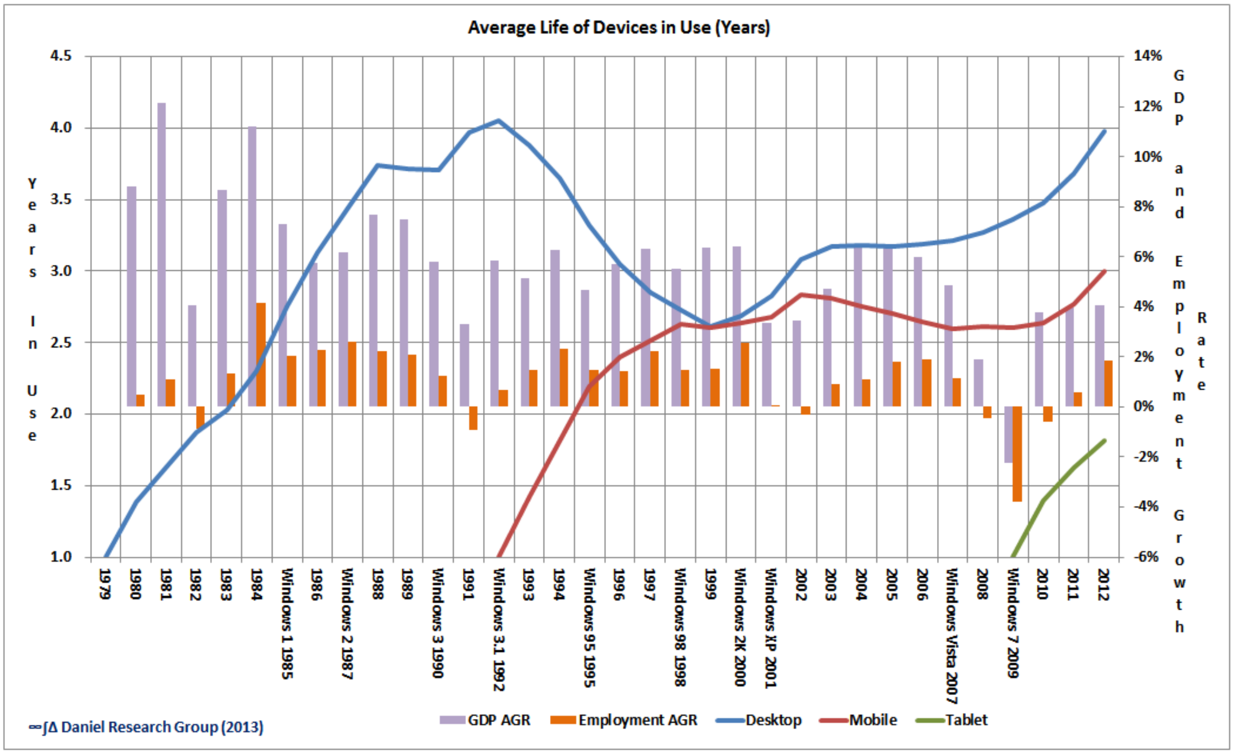


As a preliminary step to developing a model of the United States Personal Computer and Tablet market that incorporated Retention Rate Distributions, it was necessary to derive the historic time series for the mean and to determine if it did reflect major causal influences. Desktop and Laptop PC Unit Shipment data from 1978 to the present, originally published by IDC, was obtained from U.S. Government Sources and Press Releases. Desktop and Laptop PC installed base data from 1978 to the present was obtained from online sources including the WorldBank, Computer Almanac, and eTForcasters. Tablet installed base estimates were derived from survey data published by the Pew Research Center

The **DRG EquilibriumSolver** was used to derive the Retention Rate Mean time-series holding the Standard Deviation constant at 2 years, and the Maximum Life constant at 10 years. The **DRG EquilibriumSolver** was also used to estimate Tablet Shipments based on assumptions about the Retention Rate Distribution mean over the last four years.

Analysis

The resulting Average Life Time-Series for Desktop PCs, Mobile PCs, and Tablets are shown in the chart below, together with the percent change in GDP and employment, as well as major Microsoft OS introductions.



It is clear from the chart that the average life, and therefore the replacement rate for each of the devices, does vary considerably over time in response to both economic and market trends and events. Models that assume that the average life is constant over time, or apply a simple lag, are incorrect and will not produce accurate forecasts. Several major causal influences can be deduced from the chart.

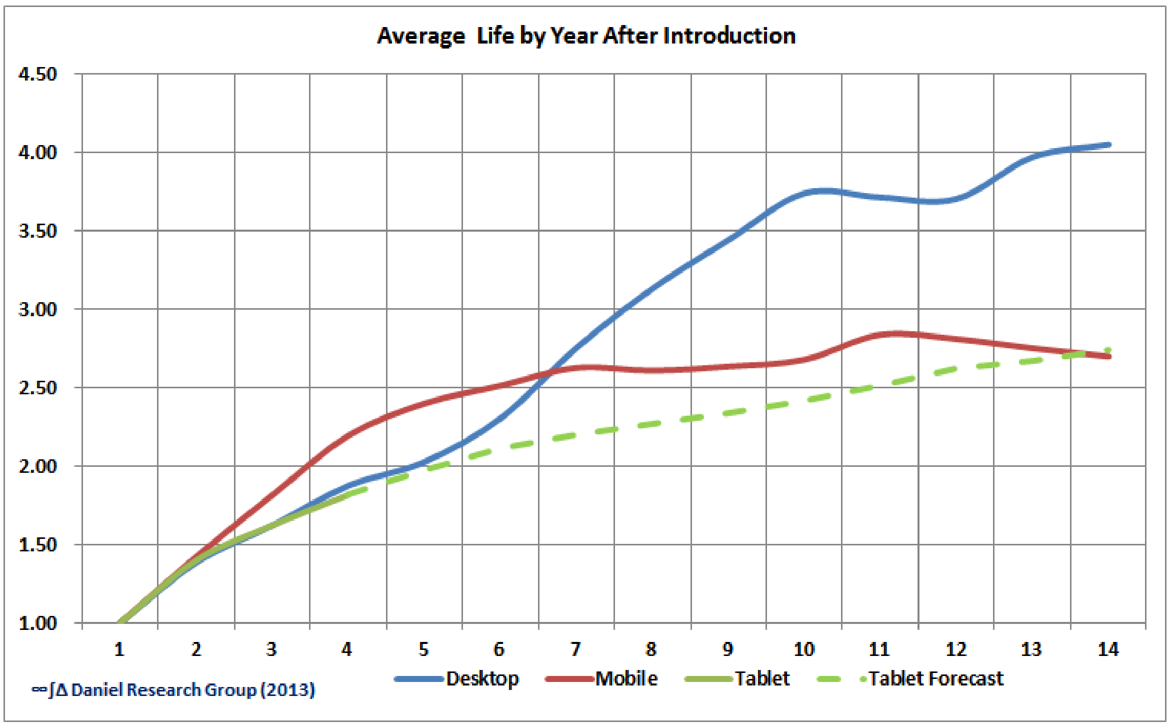
- Windows 3.1 and later Windows 95 were compelling enough to accelerate desktop PC replacement rates for almost a decade, even overcoming some cannibalization by the introduction of mobile PCs. This clearly shows that Mobile PCs were primarily a market expanding technology, not a substitution for desktops.

- Both the tech bubble burst, and the housing bubble burst significantly slowed replacement rates and increased average life.

- The lack of a compelling new OS during the mid-2000s had a negative impact on desktops replacement rates, less so on laptops.

- The introduction of tablets had had some negative impact on both desktop and laptop replacement rates. However, the lack of a compelling new OS from Microsoft may be more responsible for the slowdown.

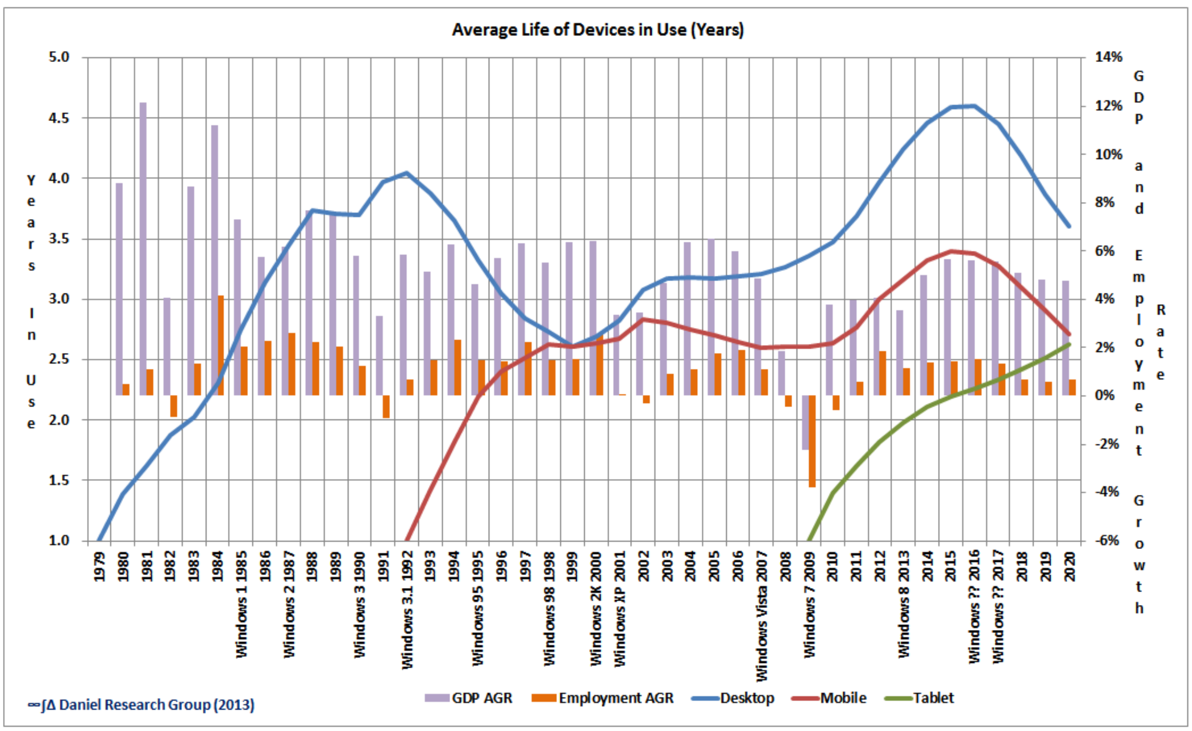
Additional understanding may be obtained by comparing the Average Life trends of the PCs and Tablets, independent of the years they were introduced. Both Desktops and Mobile took about a decade to reach their first peak. Desktops first peaked at 3.8 years, and Mobile at 2.8 years. An extrapolation of Tablets average life suggests that they will eventually reach the same length as Mobile. This is plausible if the technical progression for each is to evolve to the other. The analysis also suggests that this will be a long process.



Forecast

For obvious reasons most forecast user focus on unit shipments. If the historic data has a high degree of variance, or it seems to be trending in a new direction, relying solely on trend analysis of unit sales will fail to produce a forecast with a high degree of confidence. The **DRG EquilibriumSolver** addresses this problem by producing an independent shipment forecast as a function of the Installed Base Forecast and the Units Retired Forecast (derived from the Retention Rate Mean Forecast). In practice, the resulting Average Life time-series is used to validate this aspect of the model. The two shipment forecasts are compared, and if differences exist, adjustments are made to the input parameters for any, or all, of three independent sub-models.

The **DRG EquilibriumSolver** was used to produce a forecast of the U.S. PC and Tablet market from 2013 to 2020. The resulting Average Life forecast had been added to the chart.



The major assumptions for this forecast are:

- No significant shocks to the economy, however employments growth will be very slow, while GDP growth will improve for the next few years, and then slow again
- Compelling new hardware and software in 2016 and 2017
- Windows XP end of life will not have a significant impact.
- Tablet average life will slowly approach Laptop average life.

Applications

DRG EquilibriumSolver is a powerful modeling approach to forecasting many technology end-users products. In addition to forecasting unit sales to end-users and unit installed base, many other output metric are produced including

- Average Life of the Units in Use
- Length of Time Required to Replace all of the Installed Base Units
- Number of Units Retired in each Period
- Number of Unit Sales to New Users
- Number of Unit Sales that are Replacement Sales

These additional forecasts are important to firms providing after-market/reverse logistics services, as well as those in the asset recovery and re-cycling industries. The approach is easily expanded to include valuations metrics such as end-user spending, value of the installed base, and value of retired units, by adding pricing and depreciation logic.

Complete History and Forecast

The complete history and forecast of the U.S. PC and Tablet market from 1978 to 2020, with consumer and enterprise segmentation, may be obtained from Daniel Research Group by calling Steve Daniel at (617) 484-6225, or emailing Steve@DanielRG.com. The **DRG EquilibriumSolver** methodology may also be applied to many other technology products to produce forecasts with superior descriptive, normative, and predictive properties.

About Daniel Research Group

Daniel Research Group is a leading expert and consultant in the field of forecasting technology products, services, and markets. For 30 years, **Daniel Research Group** has worked with major technology market research firms, such as IDC, mid-sized and boutique firms, and individual consultants helping them improve the quality and accuracy of their forecasts, while significantly reducing client invested analyst and management time.