

What DAIV (Demand as an Independent Variable) says About Your Market

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ABSTRACT

This paper shows how the quantity demanded, viewed as an independent variable, interacts with customer values, producer costs and constraints. Failure to analyze Demand as Independent Variable (pronounced “Dave”) increases the chances that new programs will not launch, or once started, will fail.

All producers in all markets face demand curves that describe their customers' reaction to price changes. Aggregate market demand curves show how buyers react to price changes within broad product sets, while product demand curves show buyer responses to a specific item.

Demand curves relate quantities sold relative to their prices. In several military, transit and fleet cases, minimum quantity requirements form upper price boundaries along demand curves. Allowing prices to go so high that buying authorities cannot acquire the required numbers of units likely means that there may not be sufficient resources to form systems that can accomplish the buyers' goals. Simultaneously, pressure on producers to reduce costs and prices without relaxing requirements may force them into historically unattainable cost estimates. Understanding demand history provides guidance in determining reasonable prices paid and quantities sold.

Knowing how demand works in conjunction with value, cost and constraints allows analysts to provide insight into the best tradeoffs possible given limited funds. Product requirements reflect customer values; more of desired attributes or less of undesired attributes increases costs and values at the same time. Some attributes are more important than are others. Demand as Independent Variable, or DAIV permits analysts to construct frameworks for more financially valid trade studies.

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INTRODUCTION

Companies are in business to make money. In civil markets, where profits are not restricted, it makes sense to seek moneymaking opportunities using Profit as An Independent Variable (PAIV), as a previous study revealed [1].

In cases in which contractors deal with profits limited by government decree, it makes sense to approach product requirements using Demand as an Independent Variable, or DAIV. This method helps contractors and government contracting agencies alike.

WHAT IS DEMAND?

Market demand is the relationship of prices and quantities sold. It relates how quantities sold change as prices vary.

How do we Estimate Demand?

Consider [Table 1](#), in which we list nineteen of the longest flying fighter/bomber/attack vehicle models purchased by the United States in the last 60 years, but excluding the F-35, an emerging model. What does this data tell us about the demand for this vehicle class?

A simple regression of the data provides a statistically significant result, as shown as a Demand Curve in [Figure 1](#).

Table 1. United States Fighter/Bomber/Attack Aircraft

Aircraft	Quantity	2013 Unit Flyaway \$M
B-52H	740	\$76.6
B-1B	100	\$405.3
AV-8B	323	\$40.5
F/A-18A/B/C/D	1480	\$48.5
F/A-18E/F	565	\$61.9
F-15E	1415	\$49.2
F-117A	64	\$81.4
F-16A/D	4450	\$26.9
F-22	195	\$196.7
B-2	21	\$1,091.2
A-6	693	\$61.7
A-10	716	\$18.7
F-14	712	\$54.5
F-111	563	\$101.2
F-4	5195	\$17.8
A-7	1569	\$12.6
F-8	1219	\$11.4
A-4	2960	\$6.8
F-5	2246	\$9.3

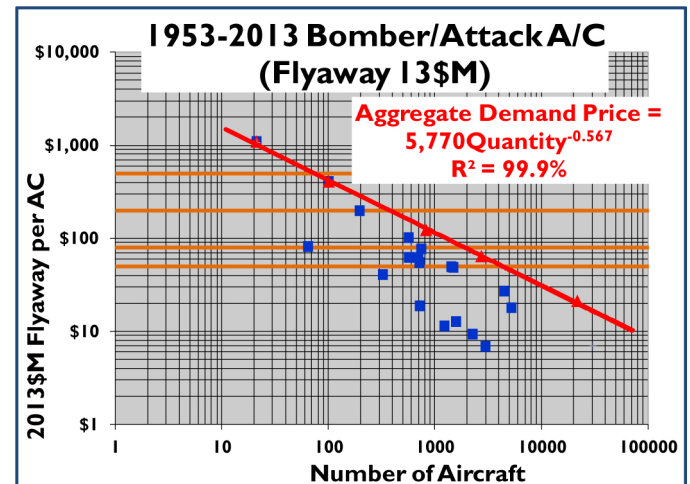
**Figure 2. Aggregated Demand Curve (with 5 bins)**

Figure 2 is the Aggregate Demand Curve, in which we have gathered the data in five bins, separated by four orange lines. In the lowermost of these lines, up to \$50 million, we gather all of the vehicles with average sales prices less than or equal to this amount. This amounts to 10 of our 19 models, with 21,573 units and \$455 billion in revenue. If we take this revenue and divide it by the number of units, we find that the average value in this group is \$21.1 million. If we take the units in this group and match it with the average price, we get the ordered pair, 21,573, \$21.1 million, which is lowest red triangle in Figure 2. In similar fashion, we can add up the total number of vehicles in the next highest bin, and their average price and came up with another ordered pair (2710, \$63.9 million) which is the next highest red triangle in Figure 2. We keep using this paradigm through the next three bins, and come up with the three remaining red triangles. When we run a regression line through this data, we obtain this equation:

$$\text{Aggregate Demand Price} = 5570 * \text{Quantity}^{-0.567}$$

(2)

While we have reduced the significance of the F-statistic (it falls to 5.77E-05), Equation 2 is much better correlated (at 99.9% it is closer to 100%, which is perfect correlation, than is Equation 1, at 68.1%). Its P-Value (the probability that the independent variable, quantity, affected the dependent variable, price due to chance) is 1.60E-05 (where any number below 0.05 negates the null hypothesis). Thus, Equation 2 is statistically significant.

The slope of the Equation 2 curve, at -0.567, is relatively flat (flat meaning that the curve has an exponent > -1.0) which means that there is more revenue at the bottom of the market than there is at the top of it, as revealed in Table 2.

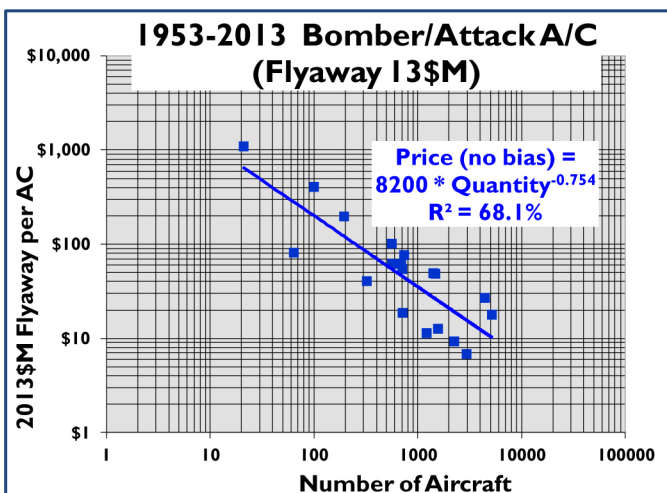
**Figure 1. Disaggregated Demand Curve**

Figure 1 is a Disaggregated Demand Curve, denoting the fact that there is no aggregation of the data into bins. The equation describing this result is [2]:

$$\text{Price} = 8200 * \text{Quantity}^{-0.754}$$

(1)

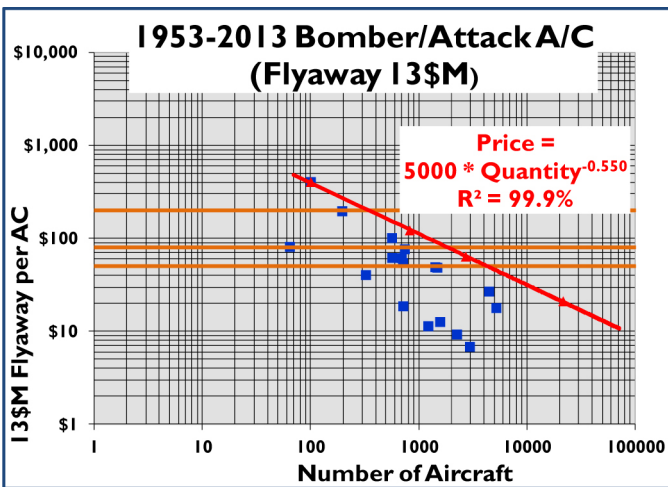
While Equation 1 is statistically significant (the significance of the F-Test, which reveals the probability that the independent variable in question affected the dependent variable due to chance, is 8.31E-06, where anything less than 0.05 is acceptable), we wonder if it is the best that we can do.

Table 2. US Fighter/Bomber/Attack Revenue by Bin

Bin	Qty	Ave. Rev. 2013\$M	Total Rev 2013\$B
<=\$50M	21573	\$21	\$455
50M < \$ <=\$80M	2710	\$64	\$173
\$80M < \$ <=\$200M	822	\$122	\$101
\$200M < \$ <=\$500M	100	\$405	\$41
\$ > \$500M	21	\$1,091	\$23

Note that revenue steadily decreases in this market as vehicle prices go up. There is nearly 20 times the money in the lowest priced bin as there is in the highest. Inasmuch as the United States Government fixes fees as a percentage of revenue, it follows that not only is there less funding at the top of the market, there is less profit as well.

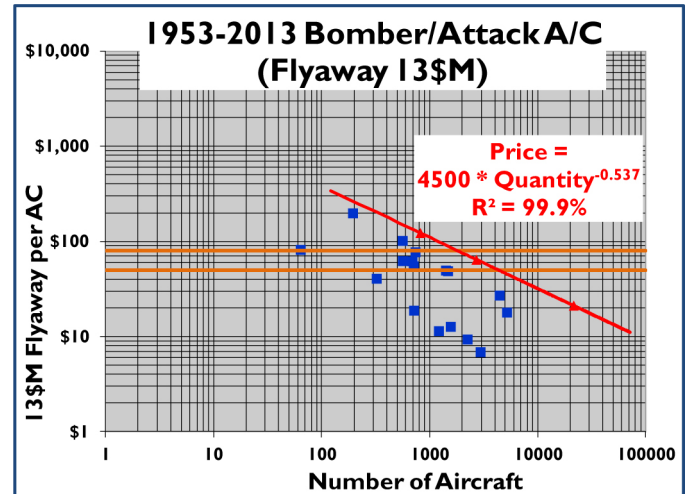
That the two uppermost bins distance themselves from the others and that each only has one model within it may cause unease in some. In order to address this potential issue, it may prove fruitful to see how the data behaves without one or both of these bins, and compare those results to that provide by Figure 2 and Equation 2. We first address this problem by removing the upper most bin in Figure 3.

**Figure 3. Aggregated Demand Curve (with 4 bins)**

With the uppermost bin gone, there are only four bins left to analyze. Importantly, though, their aggregate quantities and average prices in these remaining form a useful equation:

$$\text{Price} = 5000 * \text{Quantity}^{-0.550} \quad (3)$$

Equation 3 has an R^2 of 99.9%, and a P-value of 1.46E-04, indicating that it is statistically sound and that we can use it. If we remove yet another bin, leaving us with three, we get Figure 4:

**Figure 4. Aggregated Demand Curve (with 3 bins)**

In Figure 4, the slope and intercept changed from Figure 3, but not much. Our work in Figure 3 yields Equation 4:

$$\text{Price} = 4500 * \text{Quantity}^{-0.537} \quad (4)$$

Equation 4, as Equations 2 and 3 before it, has an R^2 of 99.9%, and while its P-value is not as good as that for Equations 2 and 3, at 0.00308, it is still well below the acceptable limit of 0.05.

What Figures 2, 3 and 4 and their associated aggregated demand curves make clear is that the demand for this product class is consistent across price ranges. As the market added more expensive vehicles, the demand curve changed, but only slightly. Given that the market demonstrates consistent behavior, how might we use this information to track past programs and predict future ones?

Demand and the B-2

We have just witnessed that the United States market for fighter, attack and bomber aircraft is remarkably stable across a wide range of prices and quantities. We can now compare how one of products in this analysis, the B-2 bomber, fared over time with respect to its requested quantities and estimated prices relative to the market trend, as revealed in Figure 5.

Initially, the United States Air Force (USAF) wanted to buy 133 B-2 bombers, and in 1981, thought that they might cost an average an average flyaway price of \$649 million (in 2013 dollars). Over the course of the next eight years, however, the price for these vehicles crept upward, eventually reaching an estimated \$981 million per vehicle in 1989 [3].