Market Mapping for Product Optimization

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Introduction

If you were going to take a trip across unfamiliar territory, you might consult maps in advance to gain your bearings. Up until recently, such maps were almost uniformly two-dimensional diagrams that pointed out roads and cities and lakes and whatever else seemed important to their cartographers. In modern times you can use digital maps, devices that constantly update your position, point you in the right direction, and offer suggestions about finding your way if you get lost. Digital mapping offers a number of improvements compared to traditional mapping. Once introduced to the new technology, it is hard to go without it.

Just as cartographers plot physical position for geographic maps, some people have plotted markets, using a variety of two-dimensional methods. Many such maps indicate economic goings-on by geographic location, often by adding a color scale to indicate the activity level [Illinois Atlas, University of San Francisco]. Others place the economic sectors on a two-dimensional plane and represent submarket portions as a part of the whole [Smartmoney]. Still others represent the entire market as a series of connected links, with proportionally sized spheres to represent the sub-segments [ACCSYS]. While such mapping offers knowledge about the economy at large and individual markets in particular, it does not allow analysts to easily examine and track the potential openings within those markets.

This paper presents a method for depicting the Gross World Product (GWP) with a focus on the market for new aircraft. This requires an N-Dimensional map of the world's economy. This method allows extraction of market positions, limits and opportunities over time.

Methodology

This paper uses several open data sources and some that require subscriptions. The open sources include the CIA World Fact book [CIA-1] and several suppliers' websites. The subscription services include The Teal Group [Teal] and Forecast International [Forecast International]. Tecolote Research's COSTAT [Tecolote] tool provided the framework in which to perform multiple stepwise regression analysis. Tecplot 10 [Tecplot] displays the multidimensional graphs.

Geographic Maps

We have all seen geographic maps such as that for Cleveland, Ohio shown in Figure 1 [Color-Art, Inc.]. Such depictions have all of the features we have come to expect in a map. We use such maps to provide us a way to get from one point to another. The map shows the roads and the streets. They help us move about. But such maps do more for us. They provide the east-west and north-south coordinates of a place, and some may give the altitude or height of it

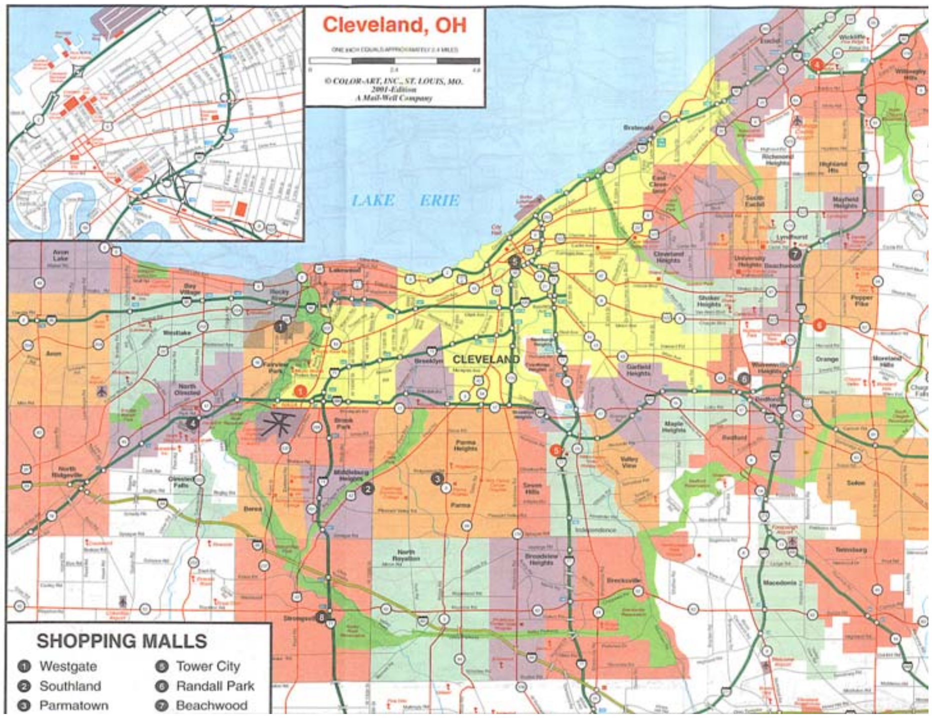


Figure 1: Map of Cleveland, Ohio

as well, thus moving from two dimensions to three.

They also indicate some physical limits. For example, Figure 1 reveals that we cannot navigate a boat from Lake Erie to the middle of the Cleveland Hopkins International Airport. The Lake Erie shoreline forms a boundary. Boats only come inland only on rivers and streams. Cars cannot drive into Lake Erie.

However, cars can drive into what used to Lake Erie. Specifically, the rectangular piece of real estate just to the right of the last “e” in Lake Erie (in purple) is the Burke Lakefront Airport, which reclaimed waterfront with landfill in 1957 to offer more real estate to the airport [CWRU]. The boundary between Lake Erie and Cleveland moved. What was once under water is now dry.

Markets have important boundaries are important as well. They can move over time too.

This map of Cleveland lists the major shopping malls in the region, as indicated by numbered black dots, the key for which is in the lower left hand corner of the map. Notice that, in general, each mall has positioned itself at a distance from all others. While malls thrive on the shared traffic that they generate, apparently sharing it with like stores is bad business. If exactly the same sets of stores were in two adjacent malls, such positioning would split their markets.

It seems likely that for durable, non-commodity goods such as aircraft, it is probably true that if a pair of aircraft models offer exactly the same set of attributes, in lieu of any distinguishing characteristics, they would split their markets as well. We shall consider this a bit later.

Gross World Product (GWP) Maps

All of us have our budget constraints. By extension, so, too, does the world. There are only so many industrial products, services and agricultural products going about the planet in any given year. Several institutions track the world economy. One of the best-known sources for this data comes from the United States' Central Intelligence Agency, or CIA. In their CIA World Factbook [CIA-1], they annually estimate the world's total production, and the split between industry, agriculture and services. The CIA put the World Domestic Product (WDP) at $49 trillion in 2003 [CIA-2] and $78.4 trillion in 2008 [CIA-3], with 4% of it coming from agriculture, 32% of it coming from industry and 64% of it coming from services in both years. There are varieties of ways to show this graphically, but a log-scale "pie-cylinder" type is best suited for our purposes, as shown in Figure 2 [Batagelj and Mrvar].

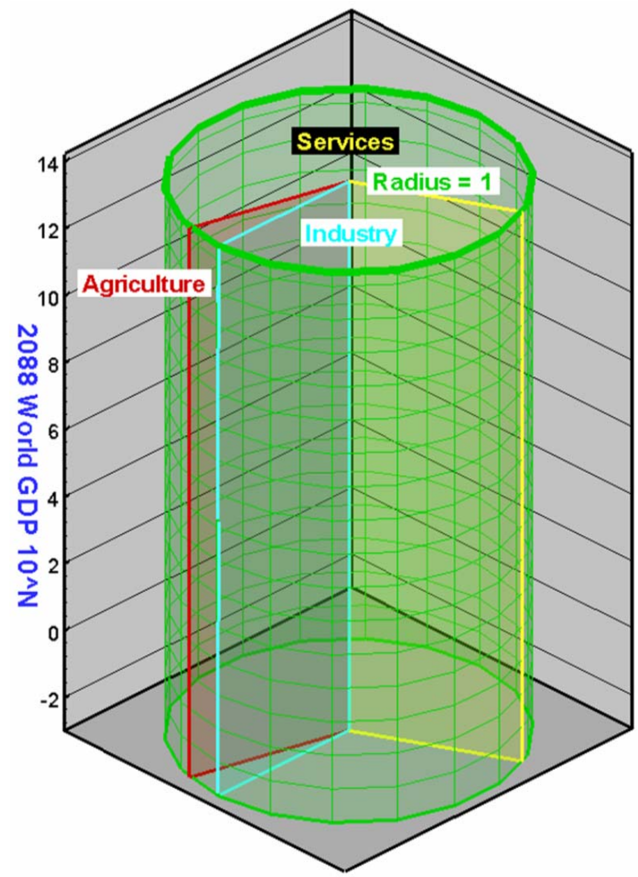


Figure 2: 2008 GWP Pie-Cylinder Chart

Charts of this type capture volume in the same way a drinking glass contains fluid. A glass has a certain diameter to it, along with its height. The capacity of our green-colored log-scale cylinder of Gross World Product is:

$$\text{Volume} = \Pi r^2 h \qquad (1)$$

Where:

Volume = Capacity (dollars of GWP)
r = radius of the cylinder (in dollars)
h = height (in dollars)

In Figure 2, we have let the radius of the green cylinder = $1. Now, if we used normal scaling, given that the area of the circular cross-section of the cylinder = Π, the vertical scale would have to reach to nearly $25 trillion. This calls for logarithmic scaling. In Figure 2, the vertical and polar axes are logarithmic, with the vertical component of GWP = 13.894 (log of

$78.4 trillion/Π). Notice that the polar components of the chart extend beyond the radius 1 boundary. Later on, we will make use of the currently unused territory.[1]

The CIA estimates industry to comprise 32% of the $49 trillion 2003 GWP. That amounts to about $15.7 trillion. Meanwhile, Forecast International estimated the market for new commercial aircraft in 2003 to be about $86 billion [Forecast International -1], about 0.18% of the total GWP, or 0.55% of the industrial component. Perhaps if the data reveals some relationships in the market for commercial aircraft, those relationships would apply to the economy at large. It is to the commercial aircraft market that we turn our attention.

Mapping the Commercial Aircraft Market

In 2003, Forecast International estimated the market for new commercial aircraft for the then upcoming decade running from January 1, 2004 to December 31, 2013. They looked at 233 models, which they separated into five groups: airliners, regional aircraft, business aircraft, helicopters and general aviation. That prediction forms 233 quantity-price prediction points, as shown in Figure 3. The simple act of placing these points on a chart offers some important information. We notice that the market map for commercial aircraft has boundaries, in the same manner as maps of physical locations. Specifically, upper boundaries form for markets, beyond which there are no sales.[2] In Figure 3, the upper boundary is the line parallel to the x-axis at $300 million (in 2004$). Products priced higher than their markets' upper limit demonstrate low quantities purchased, making them untenable for producers. The upper boundaries of markets connect to their outer boundaries that push quantity axes. For Figure 3 the outer boundary is the diagonal line roughly running from the ordered pair (750, $300 million) to the ordered pair

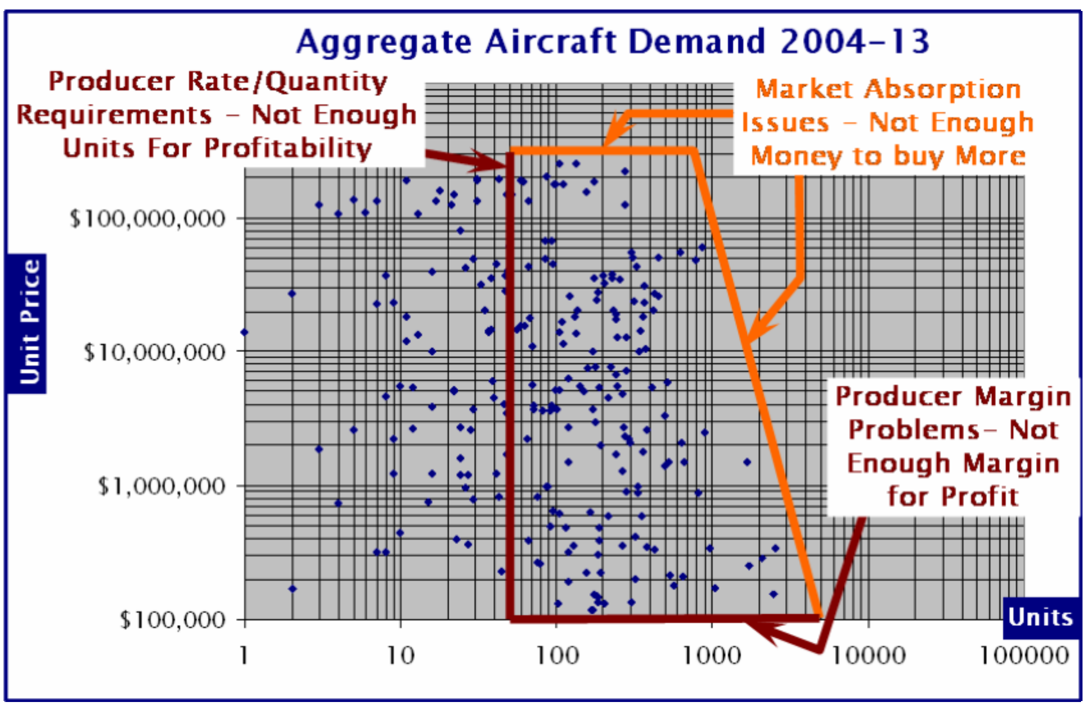


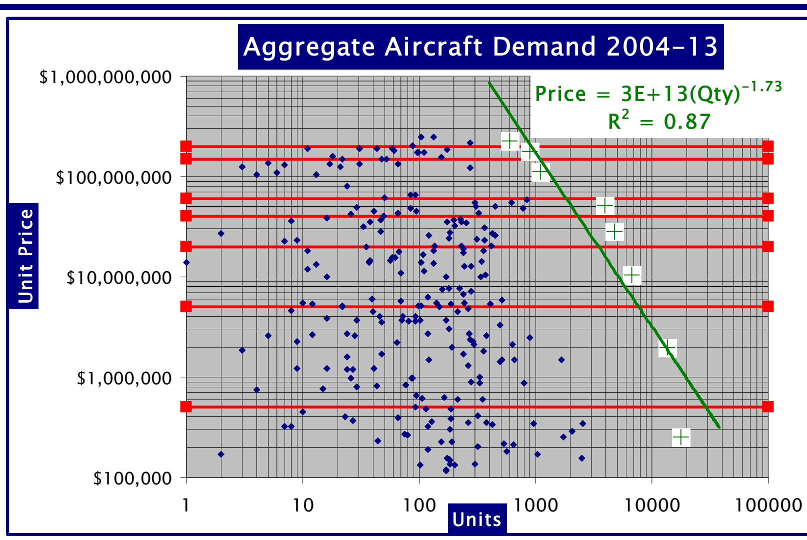
Figure 3: 2004-13 Map of Aircraft Quantity/Price Prediction

(5000, \$100,000). These outer boundaries indicate the limit of the number of products markets can absorb.

Lower boundaries form for producers when there are not sufficient margins between their costs and the prices that they receive for the products that they produce. We have a lower limit in the market for new commercial aircraft shown as the line running along the x-axis from (50, \$100,000) to (5000, \$100,000) in Figure 3. While consumers might be willing to buy new commercial aircraft for less than \$100,000, producers have not been able to find a way to drop their cost sufficiently below this threshold to make a profit, so they do not build such vehicles.

Still another threshold exists for producers, one that addresses their output per given periods. If producers cannot generate sufficient sales over time, they must either find a way to sell more or withdraw from the market, as they will not generate sufficient revenue to make a profit. For new commercial aircraft, as shown in Figure 3, such a limit exists as a vertical line for 50 units over a decade (the line running from the ordered pair (50, \$100,000) to (50, \$300 million). This lower limit varies by producer and by market. For aircraft, it may well be higher than 50 vehicles over the course of a decade, or more than five aircraft a year. Vehicles to the left of this line in Figure 3 may be just entering or leaving the market, or variations of a base model that has higher sales figures, in which case the model-related sales for a decade do not fully reflect their production line outputs for an entire aircraft family. In the long run, though, producers need to have a certain amount of sales to stay afloat. In aircraft, this is probably closer to at least 10 vehicles per year, or 100 per decade, in order to keep staff working at an orderly pace. For automobile makers, this minimum figure is higher; for makers of cruise ships, it is lower.

Once we have quantity and price figures for markets, we can plot their demand curves. Figure 4 shows a demand curve for new commercial for 2004-2013 [Howarth-1, 2]. In this case, we have separated the data into bins based on prices. In the lowest bin, we have all of the vehicles selling for less than or equal to \$500,000. This amounts to 17,716 units, for an average price of \$260K. This ordered pair, (17,716, \$260,000) is the cross on the white background in the lower right hand corner of Figure 4. The next bin up reaches to \$5 million and includes 13,571 vehicles; it produces the ordered pair (13,571, \$5,000,000). If we continue using



Vehicle Price >	Units	<= Vehicle Price	Segment Revenue	Average Price
	17,716	500,000	\$4,527,438,000	\$260,000
\$500,000	13,571	5,000,000	\$26,864,961,000	\$1,980,000
\$5,000,000	6,707	20,000,000	\$70,377,257,000	\$10,490,000
\$20,000,000	4,770	40,000,000	\$133,549,675,000	\$28,000,000
\$40,000,000	3,971	60,000,000	\$205,461,500,000	\$51,740,000
\$60,000,000	1,091	150,000,000	\$123,185,500,000	\$112,910,000
\$150,000,000	888	200,000,000	\$156,237,500,000	\$175,940,000
\$200,000,000	599		\$136,806,000,000	\$228,390,000
Totals	49,313		\$857,009,831,000	

Figure 4: Total Aircraft Demand

this method, we obtain the series of points designated by the crosses on the white backgrounds. Running a curve fit through the data reveals a statistically significant aggregate demand curve:

$$\text{Price} = 3E+13(\text{Qty})^{-1.73} \quad (2)$$

Interestingly, notice that there is no single upward sloping line than can describe some form of equilibrium in the market for new commercial aircraft. This is in disagreement with long-accepted views on the subject. According to Paul Samuelson, the Nobel-Prize winning economist from MIT, "the equilibrium price, i.e., the only price that can last, is that at which the amount *willingly* supplied and the amount *willingly* demanded are equal. Competitive equilibrium must be at the intersection points of supply and demand curves [Samuelson]." In the case of the beef market in the United States, for example, one might extract consumption data for a seven-year span [USDA] and get the observed downward-sloping demand curve for beef as shown in Figure 5. In theory, then, there ought to exist an upward-sloping supply curve that would intersect this demand curve in any given year. In 1986, by this definition, a singular hypothetical equilibrium exists where the demand and supply intersect in Figure 5. There, in theory, suppliers have exactly met consumers' needs. More beef delivered that needed causes surpluses; less than required induces shortages.

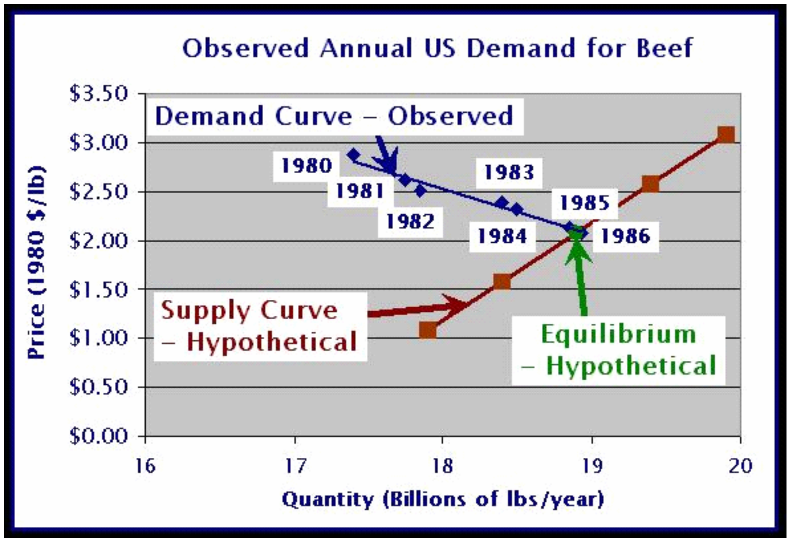


Figure 5: Hypothetical Equilibrium where Supply and Demand Intersect

In the standard model of supply and demand, which is usually if not always applied to commodities, the single determining feature of the value of a product is the amount consumers have of it. There was a single average quantity and price for the commodity, beef, in the United States in 1986. More beef in the market would have driven prices down. Less would have forced prices up. The supply and demand model, therefore, may work for commodities such as beef and apples and hog bellies.

It does not work for business jets, airliners and helicopters. The new aircraft market supports prices up to $250 million, and as low as $100,000. No single solution satisfies all of the sales quantities and price points. There are instead 233 ordered pairs of quantities and sales points, one for each vehicle, not one for the entire market. There has to be another explanation for the supported prices of these vehicles.

Product Attribute Maps: Business Aircraft and General Aviation

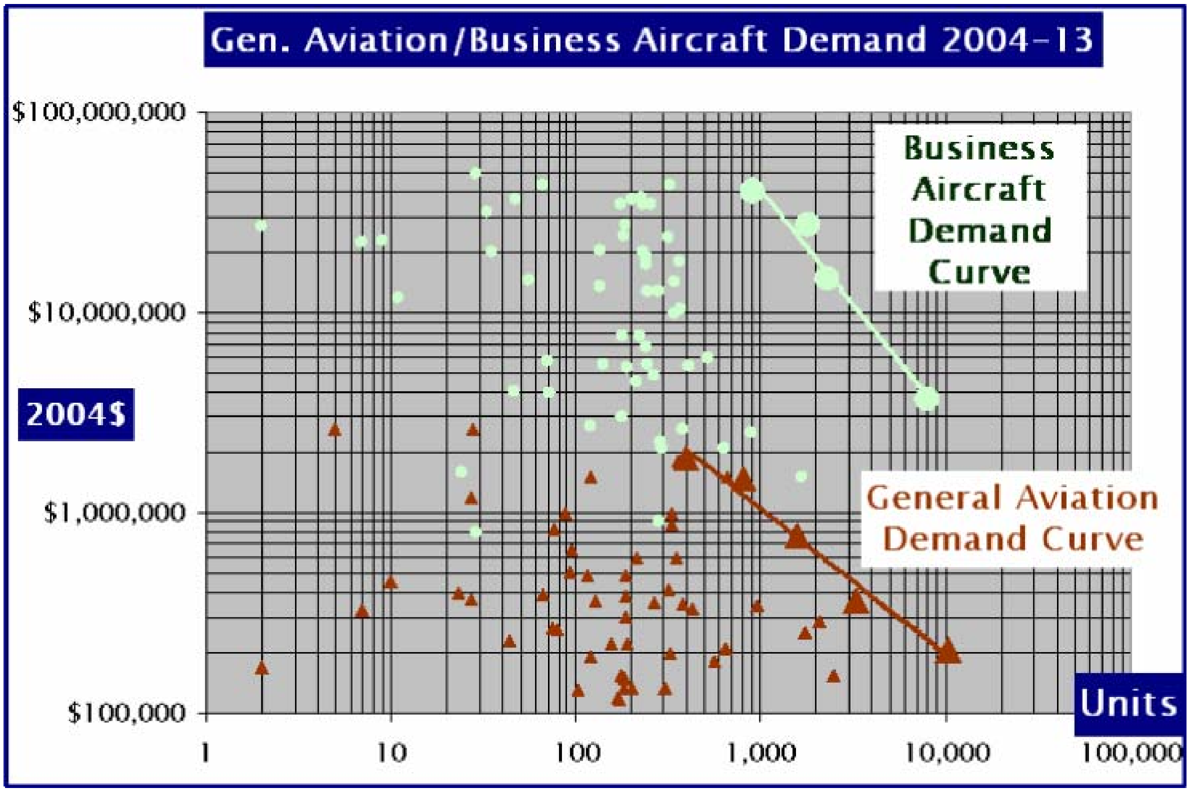


Figure 6: General Aviation and Business Aircraft Demand

In Figure 4, we derived the demand for all new commercial aircraft for a decade. Suppose we were going to enter this market and we decided we could not afford the funds to develop airliners or regional aircraft, and that our expertise lies with fixed-wing aircraft, not helicopters. We then might target the remaining market, which leave us with business and general aviation aircraft. Since we managed to derive a demand curve for the entire market, we might wonder if we could replicate curves for the submarkets in which we are interested. To that end, then, we can derive Figure 6, in which we figure separate demand curves for business and general aviation aircraft, respectively, using the same techniques we employed for the entire commercial aircraft market. In Figure 6, light circles represent business aircraft quantity-price points, while dark triangles stand in for the general aviation quantity-price points. Notice that the markets overlap one another. Observe as well that the data suggests that there are apparent gaps in the aircraft prices, with no vehicle identified that sells for more than $8 million but less than $10 million, and that no planes sells for more than $27 million but less than $31 million. Perhaps, then, there might be a market for a new aircraft that could sustain a price in either range. What will it take to make a plane that can command that price? In order to know that, we need to see what market offers.

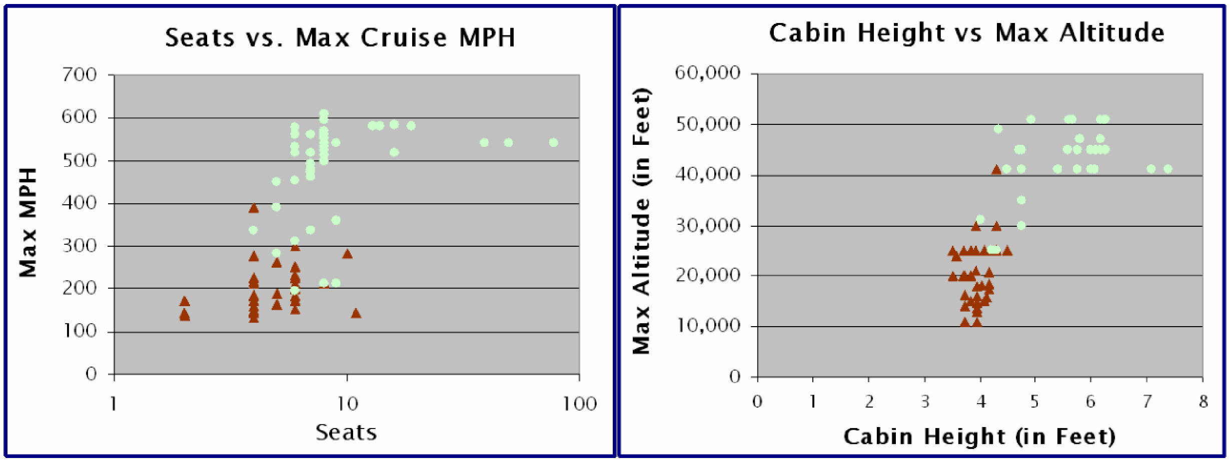


Figure 7: General Aviation and Business Aircraft Valued Attributes

While one pound of beef may be just like any other, not all aircraft are created equal. We have only to look to Figure 7 to verify this. There, using the same conventions as Figure 6, where the light round dots indicate the values of business aircraft and dark triangles represent the speeds and seating capacities of the general aviation aircraft, we find a wide range of attributes offered to the market by the manufacturers (for a list of these features, see Appendix A). In the chart on the left, we plot the number of seats, a measure of capacity, against the maximum cruise speed. On the right, we indicate the cabin heights and the maximum altitudes at which the vehicles in question fly, both measures of comfort (the taller the cabin, the easier it is for occupants to stretch and walk about upright; the higher the aircraft ceilings, the greater the vehicles' ability to move out of bad weather). Far from being indistinguishable from one another, the vehicles demonstrate a wide range of attributes. The tallest cabin is roughly twice as high as the shortest; maximum speeds and altitudes vary by over a factor of four, and the seating capacity demonstrates a wider range still. A glance of the dataset for these planes (see Appendix A) reveals that the planes commanding the highest prices have more of these features.

We hazard a guess, then, that the sustainable prices general aviation and business aircraft command relate to their attributes [Cook and Wissmann].[3] Specifically, we posit that

$$V_m = A_1 * A_2 * \ldots A_n * e_i \qquad (3)$$

Where:

V_m = value in a market (of a good or service, as represented by a sustainable price)
A_i = contribution of i^{th} attribute to product value
e_i = error term of the equation

Performing multiple stepwise regression upon the data in Appendix A yields these results:

	Pearson's^2	F-Stat	MAD	
$V_m = 24800 * Seats^{2.45}$	57.4%	117.0	30.8%	(4)
$V_m = 0.0764 * Seats^{0.940} * MPH^{2.71}$	77.8%	856.7	35.0%	(5)
$V_m = 0.0946 * Seats^{0.618} * MPH^{2.07} * CabH^{2.64}$	83.0%	810.4	26.4%	(6)
$V_m = 8.56E\text{-}05 * Seats^{0.573} * MPH^{0.936} * CabH^{3.01} * Alt^{1.26}$	88.6%	809.2	23.7%	(7)

Where:
Seats = number of seats in typical configuration[4]
MPH = typical cruising speed (in miles per hour)
Cabin H = Cabin height (in feet)
Alt = Maximum Cruising Height (in feet)
Pearson's^2 = Pearson product-moment correlation coefficient^2 [(5)]
F-Stat = F-Statistic[6]
MAD = Mean Absolute Deviation

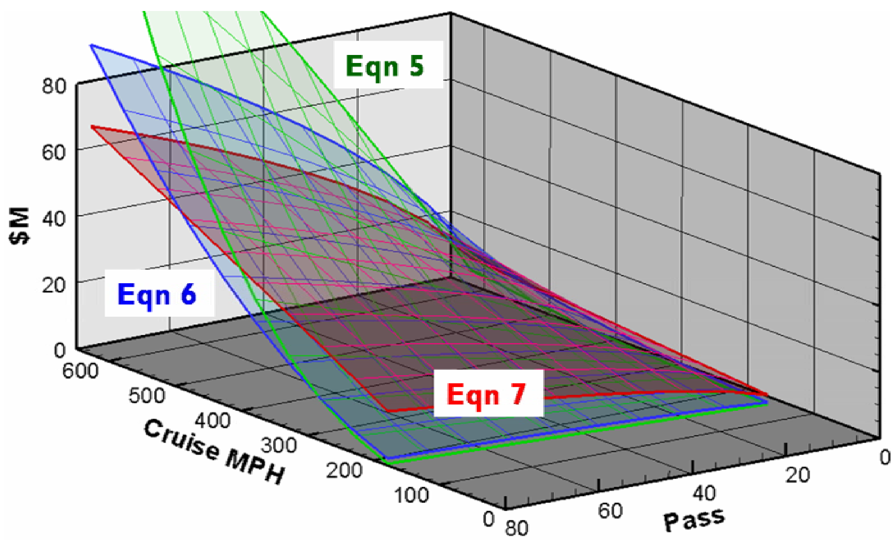


Figure 8: General Aviation & Business Aircraft Value Plots

The "P-Values" for all terms in equations 4-7 are all <0.0001, excepting only the MPH expression in Equation 7, which is 0.0003.[7] Note that using only a single independent variable, seats, in Equation 4, yields a poor adjusted R^2 but that adding important effectors of value as independent variables improves correlation and lowers the Mean Absolute Deviation, a measure of the "absolute values of average misses" of the equation, or a measure of average error.[8]

The plots of Equations 5 through 7 are in Figure 8. The surfaces differ quite a bit from one another, and that the surface representing Equation 7 looks little like the one for Equation 5. Observe that we have selected the independent variables "Seats," a measure of capacity, and Cruise Mile per Hour, a measure of speed, serve as the "x" and "y" axes. Adding additional parameters such as cabin height and the aircraft ceiling forces us to set these variables as constants for Figure 8. Here, we fix cabin height to 73" and set the operational ceiling to 45,000 feet. We observe that as we get more of the attributes we want in a plane, the value of it goes up, as measured in currency (here, we have used United States Dollars, but it could just as easily be any other currency). Stated another way, the vertical axis for value is identical to that for demand. Value and demand lie on opposite sides of the same pillar. This calls for an examination of a series of special economic frameworks that have analogous physical structures.

4D Economic Structures and the Central Pillar

If we consider a rectangular, two-room house as shown in Figure 9, we observe some useful information about its geometry. We notice that there is exactly one common wall between the rooms. Along the far wall, there is a common intersection of these two rooms. There are four distinct lines originating from the point where that common intersection meets the floor at the local origin, (0,0,0,0). In Room 1, there is a line or axis where the far wall meets the floor that moves in a positive direction from the origin to the front wall. In Room 2, moving in the opposite direction, there is an axis where the far wall meets the floor that moves in a positive direction from the origin to the back wall. Both rooms share an axis that moves in a positive direction from the origin along the intersection of the common wall and the floor to the door between the rooms. In similar fashion, both rooms share the vertical axis, which begins at the origin and moves straight up. Such structures form systems of four positive dimensions. If we rename the axes and properly account for the properties of the adjoining geometric regions, these frameworks are useful for economic analysis.

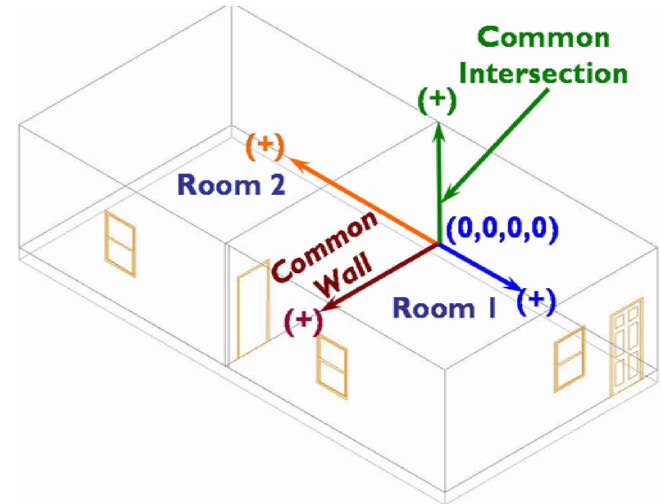


Figure 9: A Common Intersection for a 2-Room House yields 4 Positive Dimensions

We find such a framework in Figure 10. Here we have named the line running from the origin to the front of the structure the Quantity Axis, and the vertical line we previously called the common intersection we now designate the Currency Axis. Quantity and currency (the latter expressed as a price) are the axes that form the demand plane, as shown in Figures 4-6. As we discovered in Figure 8, we can portray value as a function of two (or more) independent variables. In the general form in Figure 10, we call the axis running in the opposite direction from the quantity axis Value Axis 1, and one running at right angles to it Value Axis 2. Value Axis 1, Value Axis 2 and the

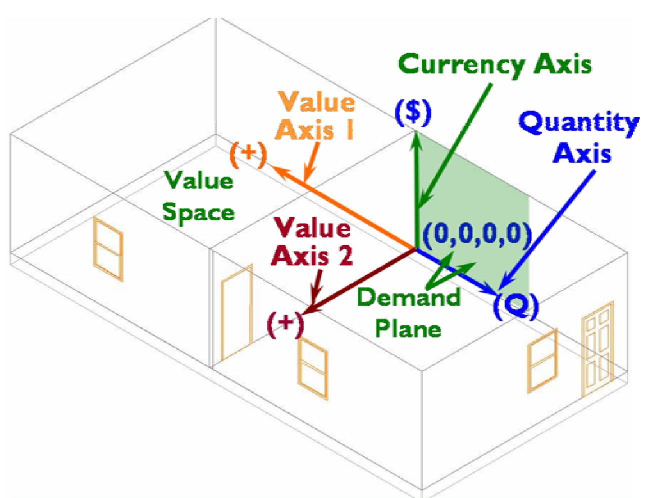


Figure 10: The Value Space is Adjacent to the Demand Plane

Currency Axis bound a region known as the Value Space. Because Value Space and the Demand Plane share the currency axis, they are adjacent to one another.

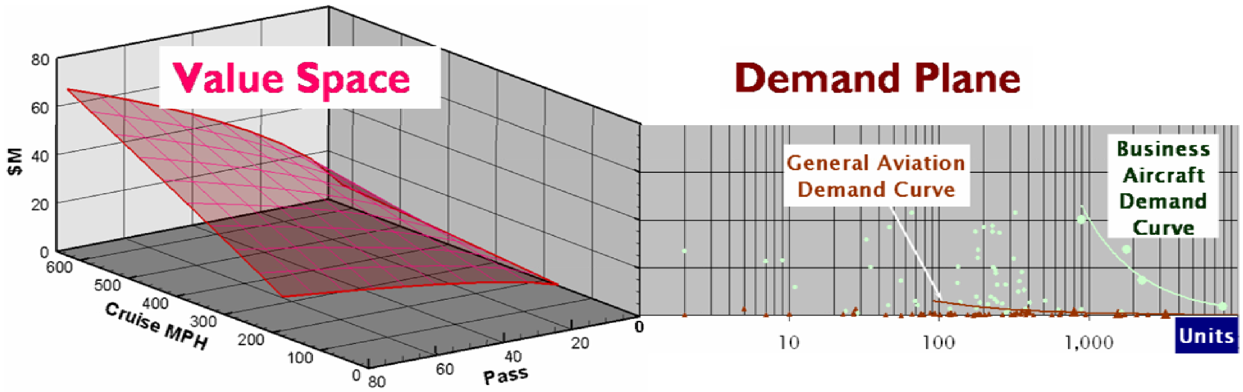


Figure 11: General Aviation, Business Aircraft Value Space Abuts Demand Plane

In Figure 11, we move from the hypothetical condition shown in Figure 10 and apply the principles we learned there to relationships we discovered in Figures 6 and 8. In Figure 6, we determined separate demand curves for general aviation and business aircraft, both of which combine to help form the aggregate demand curve for all new commercial aircraft. We observed that while in both cases that quantity of units sold formed their horizontal axes. At the same time, we noted that currency (often denoted as price) formed their vertical axes. The currency axis and the quantity axis form the demand plane, as originally represented in Figure 6, which we can depict as the plane to the right side of Figure 11.[9]

If we rename Value Axis 1 as Speed and Value Axis 2 as capacity, we can move the figure we originally created in Figure 8 and place it adjacent to the Demand Plane in Figure 11 (using the output of Equation 7 only). Now we can see how adding valued attributes, specifically speed and capacity affect the aggregate demand. Too much of either or both improves the value of the product, but at the risk of reduced sales. Too little of these features drops the value, and the cost along with it, but if the value does not fall as quickly as cost there may be some room for profit.

The analysis just presented looks at the combined market for business and general aviation aircraft. However, the market for new commercial aircraft is larger than just those two sub-markets. Other work [Howarth 1-2] indicates that similar results derive from an analysis of the markets for regional aircraft and helicopters. In fact, in some cases the data (see Appendix C) statistically supports derivation of demand curves for a single product, as shown Figure 12. There we derive a demand for a vehicle having characteristics to the Sikorksy S-92 helicopter. Notice that in this case that while the axes pertinent to demand are same as we used above (units sold and price in millions, though the year changed), one of the value axes changed. While we still employ the number of passengers, we have now swapped the cruise speed axis to one that captures balanced field length in feet. In addition, while the market for 87 models of business and general aviation aircraft is substantial, the market for a single helicopter model is smaller.

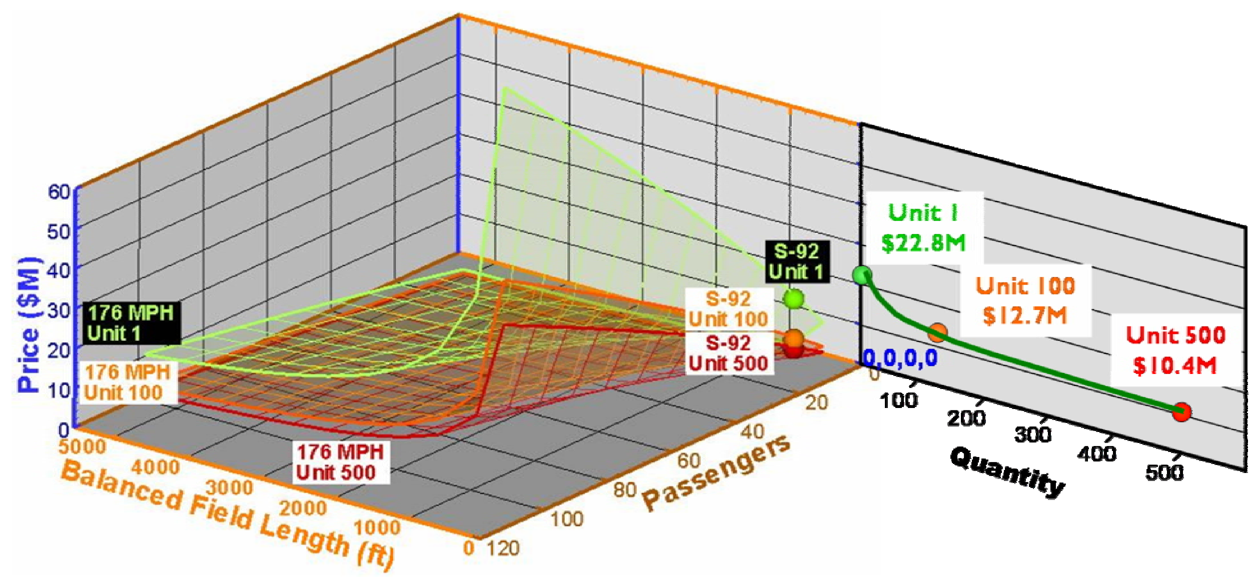


Figure 12: Hypothetical Demand Curve for a Helicopter like the Sikorsky S-92

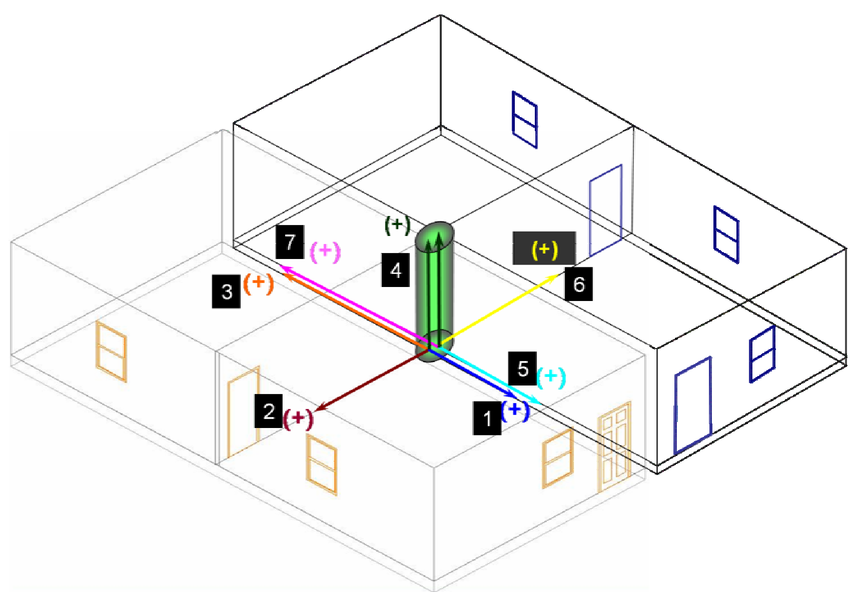


Figure 13: 4-Room, 7-Dimensional Space

Given that this technique works for different markets and that their common elements exist for all markets, one wonders if this four-dimensional structure extends beyond a single market at a time. In other words, is there a way to build a more encompassing framework to handle all of the world's markets at the same time?

If we return to the analogy of our house, we find that the answer is yes. We discover that multiple four-dimensional economic structures abut one another. Suppose that the common vertical axis, the one for currency, is not simply a line with a width of a single point but is instead a column. In theory, then, other structures could tie into this column. Instead of having, say, a simple two-room house with a common intersection tying the two rooms along their back wall along a common intersection, we now have a pair of two room houses that tie to a common column, as shown in Figure 13. The four dimensions we had in our single two-room remain, and are numbered 1-4. The adjacent structure shares the vertical column, so dimension 4 is common to both structures. However, the second structure has three additional dimensions, so that the total number of dimensions entertained is now 7.

If we continue expanding this approach, our next step would another pair of rooms to our structure and arrive at the condition shown in Figure 14. There, the two rooms originally added in Figure 13 have been reduced in size by half and lie in the right hand corner of Figure 14, now separated by a diagonal wall. Meanwhile, another two rooms added to the mix at the top of the structure. Note that their vertical column is the same as it is for all others, and that the addition of the two rooms nets another 3 dimensions, labeled 8, 9 and 10. We see a pattern emerging from these investigations.

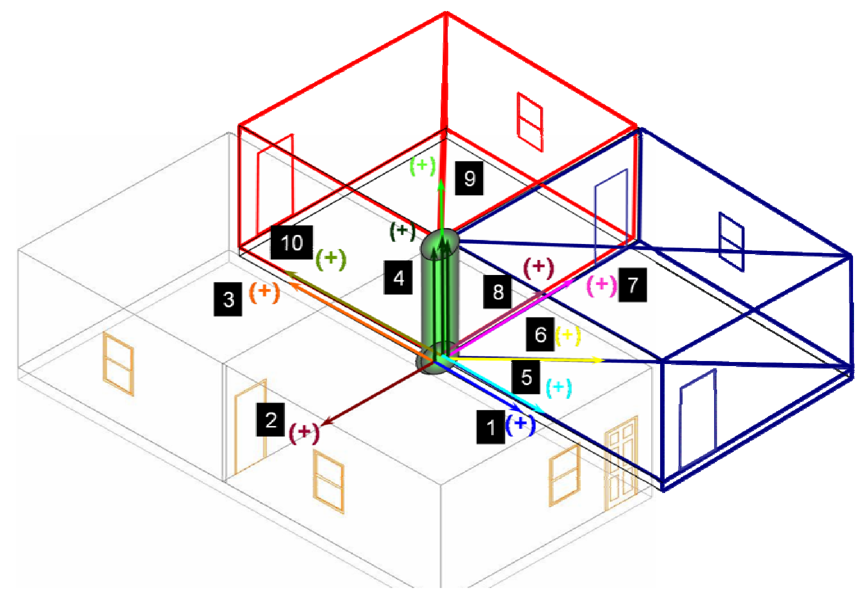


Figure 14: 6-Room, 10-Dimensional Space

In moving from Figure 10 to Figure 11, we found out how we could go from an analogy about physical structures to market structures. We discovered that a two-room structure describes one market. Once we changed the physical dimensions for economic ones we found that a single market has two primary value dimensions, one quantity dimension and one currency dimension. If we move to two-market condition, much like Figure 13, we keep our single currency dimension, but add a pair of dimensions for value and another one for

Number of Markets	Primary Value Dimensions	Quantity Dimensions	Currency Dimension	Total Dimensions
1	2	1	1	4
2	4	2	1	7
3	6	3	1	10
4	8	4	1	13
5	10	5	1	16
n	2n	n	1	3n + 1

Figure 15: Expansion of Market Dimensions

quantity. In Figure 14, we did the same thing, as we added another three dimensions. Figure 15 reveals this pattern, from which we project the total number of physically equivalent dimensions considered by such models. Specifically, we find that

$$\text{Total Dimensions}_{ms} = 3n + 1$$

Where:

$\text{Total Dimensions}_{ms}$ = Physically-Equivalent Market Dimensions in a Market Study (8)
n = Number of Markets Considered

Economic dimensions, then, have physically analogous representations. The ever-expanding house with its central column, as shown in Figures 10, 13 and 14, provides the analytic geometry needed to depict the central pillar approach of market analysis. Once we get beyond a few markets, however, we will need to have a way to be able to keep track of economic positions as we add sectors for analysis. Commonly, we use a Cartesian coordinate system to track position.

On the left, Figure 16 has several points on a standard Cartesian plot. Added to the plot are circles of designated radii as well. By definition, Cartesian axes are at right angles to one another. The x-axis is horizontal, while the y-axis is vertical. However, we can convert the same series of points to Polar Coordinates by simply changing the angle between the x and y axes from 90° to any other angle. In the chart on the right side of Figure 16, we have changed that angle to 45°.[10]

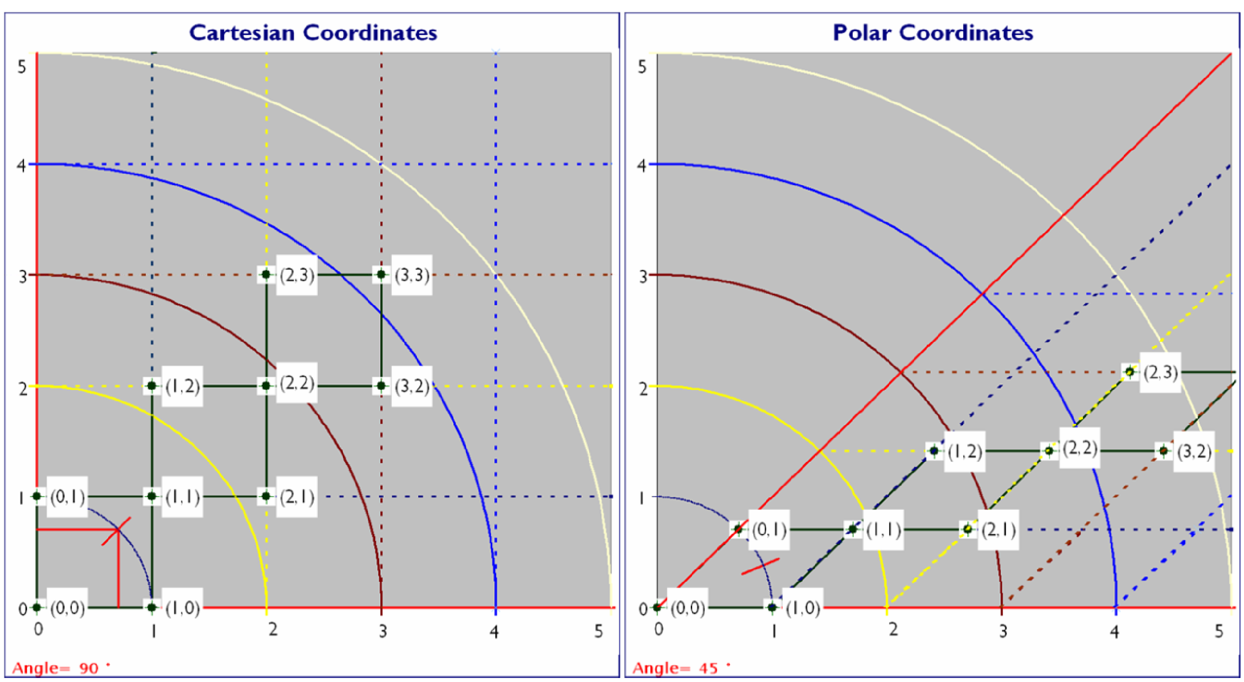


Figure 16: Cartesian (left) and Polar Coordinate (right) Plotting

We can do the same for the value attributes we have examined to date, the number of seats and cruise speeds for our general aviation and business aircraft models. Given that we will need to be able to compress this data, we can take the base 10 logarithm of these values and plot them in a Cartesian system, as shown in the left hand diagram in Figure 17.

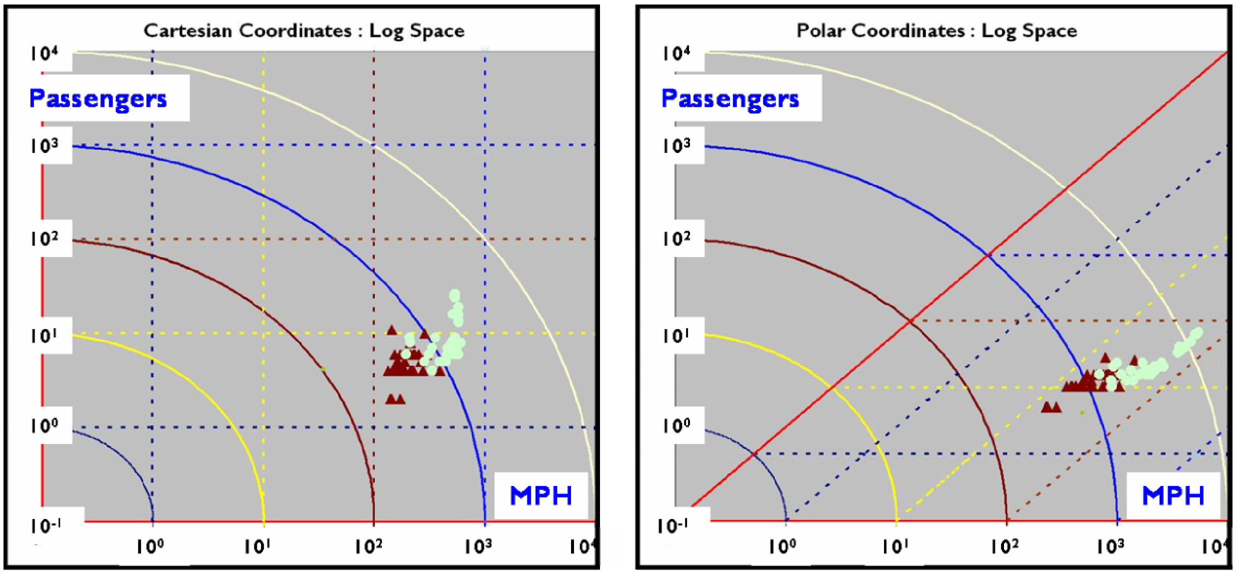


Figure 17: Log Cartesian and Polar Coordinate Plots of Primary Value Attributes

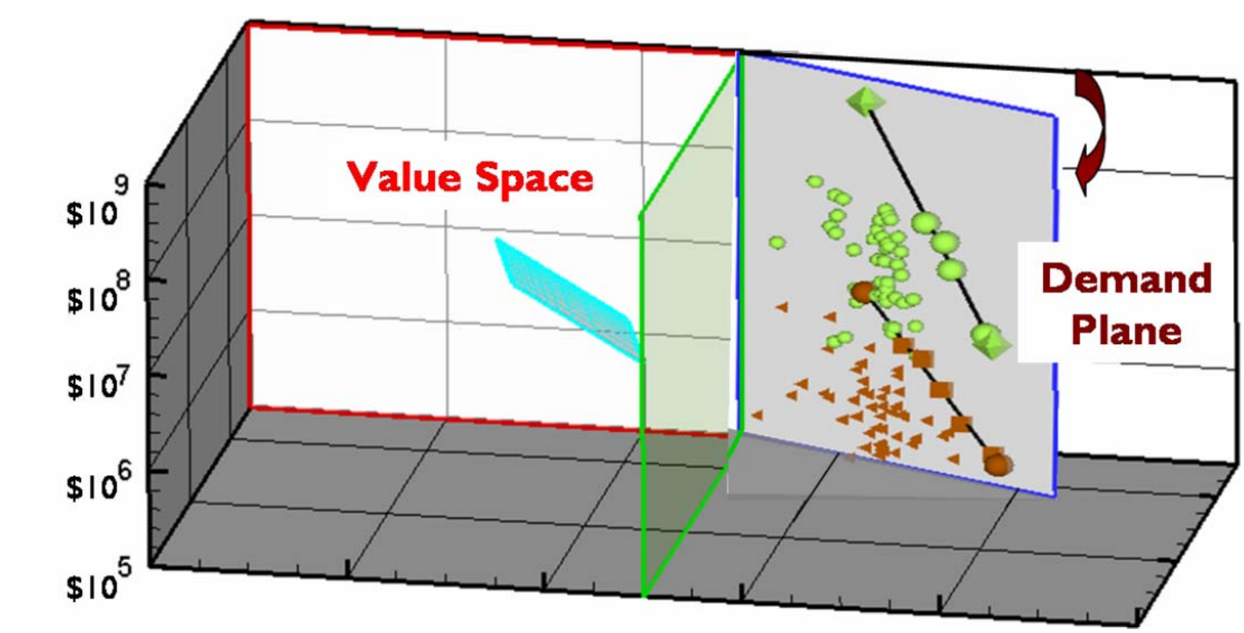


Figure 18: Collapsing the Demand Plane onto Value Space

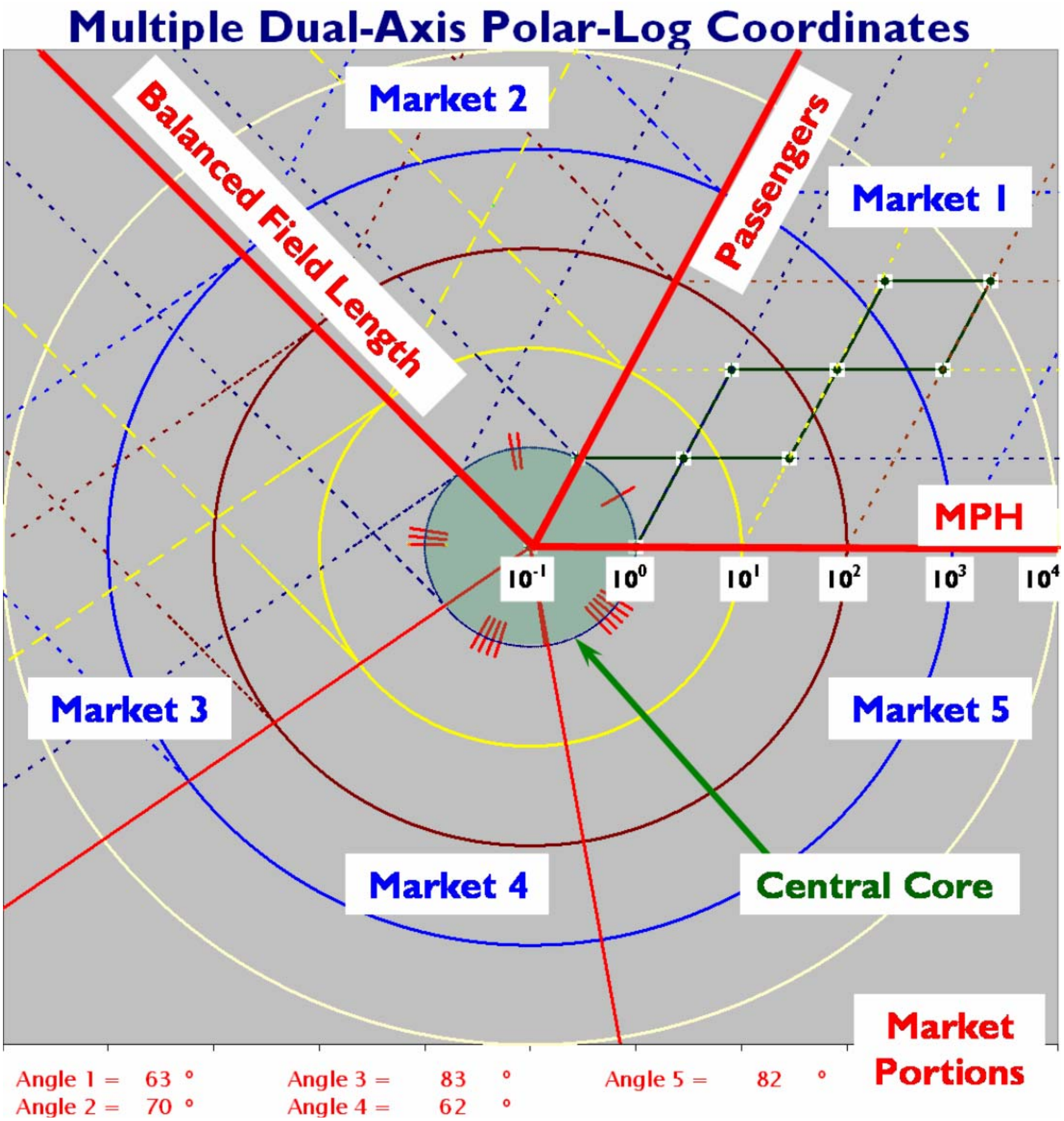


Figure 19: N-Dimensional Polar-Log Coordinates describe all Markets

Once we do this, we can convert them into a polar coordinate system, as shown on the right hand side of Figure 17. Moreover, since this process works for the value space axes, it also works for the demand plane. That is, we can collapse the demand plane onto the similarly compressed value space, using another polar coordinate conversion, as shown in Figure 18. In fact, the demand plane can lie adjacent to value space for any given market. This permits the requisite compressibility of all markets.

In Figure 19, we compress five sample markets using a dual axis system. The "Central Core," the center green circle, is a plan view of, say, a series of markets open to a producer, or perhaps, the entire GWP. It is the top view of a diagram like that in Figure 2. The angles represent the relative portion of each market's share of the entire system. In theory, there is nothing preventing depicting every market in the world in this framework.

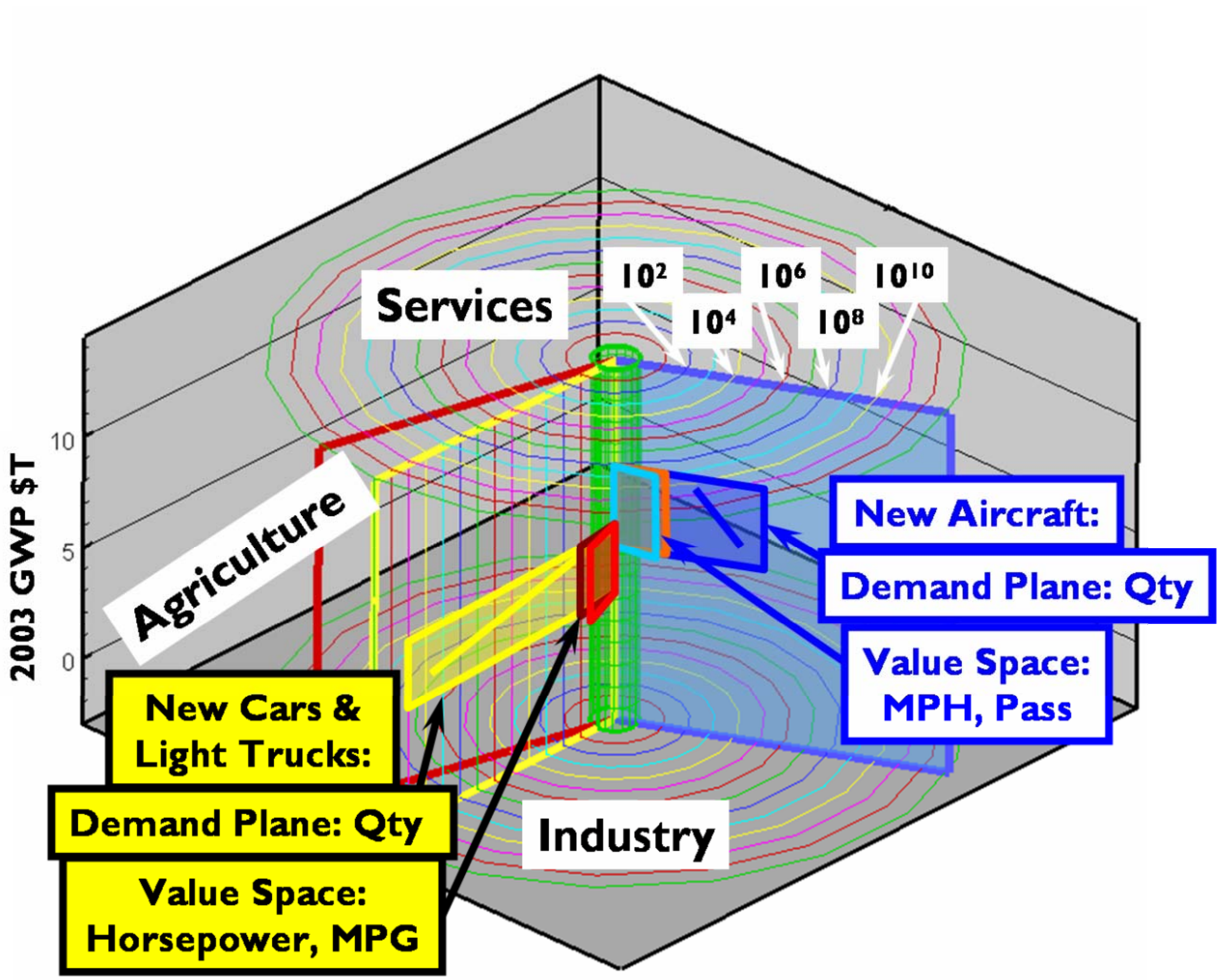


Figure 20: Market Wedges with Adjacent Demand Planes

General aviation aircraft and business aircraft might make up Market 1, and describe their value space using passenger capacity and cruise MPH as value axes, which extend beyond the Central Core as far as necessary. Market 2, perhaps consisting of regional aircraft and helicopters is adjacent to Market 1 and share the value axis for passengers, but have a different second axis, that for balanced field length. In every case, we may assume that the market demand planes collapse against their appropriate value spaces. All axes are expandable from their polar coordinates to equivalent Cartesian positions as in Figures 11 and 12.

Continuing this method, we arrive at Figure 20, which provides a partial worldview of the GWP across the planet in 2003. The market for new aircraft, which we concluded was about $1/500^{th}$ of the world economy, lies within the bounds of the industry sector. It shows a minimum price of about $100,000, a maximum price of $250 million and an out demand limit of just below 18,000 units for the lowest price group of aircraft within it. The automobile and light truck industry is also within this sector, with far more vehicles sold, though at a lower price.

A fully populated version of Figure 20, with all of the world's markets and their entire list of product attributes, amounts to the first page in a World Economic Atlas.

Mapping Analysis: Product Attributes versus Market Response

For any new proposed product, it is possible, given statistically significant demand and value responses for its market, to plot its position against all other competitors. Such a plot of a new hypothetical product, specifically a business jet, is in Figure 21. There, we model a new plane that can carry 12 people, cruise at 580 miles per hour, has a cabin that has a height of 6.25 feet and has a ceiling of 51,000 feet. We find that our cabin height is in keeping with several vehicles in this class, as is our proposed ceiling. We are, then, competitive, but not distinctive, in these attribute regions. The same holds true for our operating speed of 580 miles per hour, in that the market offers nearly continuous coverage in cruise speed from 450 to 610 miles per hour. However, with respect to capacity we are unique: There are no competitors offering vehicles that typically carry 12 people. This is in part to Federal Aviation Administration regulations that are more stringent for aircraft carrying more than nine passengers than they are for vehicles with less capacity. It might be worth it to consider a plane with these or similar capacities if the cost of complying with the regulations is not prohibitive, for the estimated value of this hypothetical plane is roughly $29 million according to Equations 6 and 7, within an observed price gap in the market of between $27 million and $31 million (see above). In all cases, we would want to examine the projected benefit of additional features relative to their added costs. There are no instances in which we would willing add cost at a rate faster than we add value.

Additionally, for this particular exercise we have proposed to sell 500 aircraft over the course of a decade. This sounds ambitious, and it is, for our observation about demand is that at that figure, given the price the vehicle will command, we are outside of the demand boundary by which the entire market abides, as shown in the upper right hand corner of Figure 21. We may to consider reducing this sales target, as the market has, of yet, shown no ability to make purchases at these price levels in these amounts.

The equations used here are imperfect, meaning that there is an error term with which to contend in using these predictions. As analysts add valued attributes to such analyses,

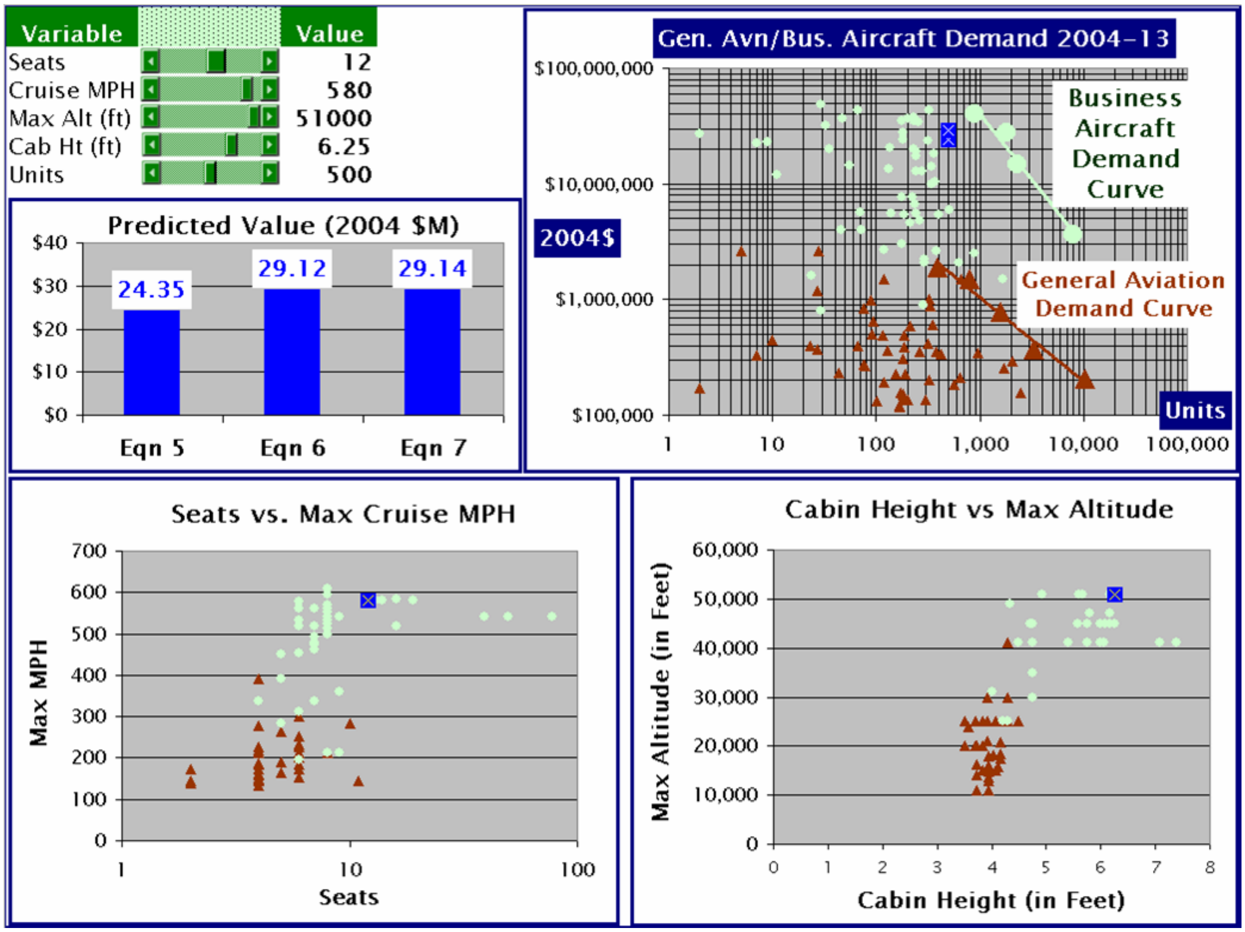


Figure 21: Market and Attribute Positions of a Hypothetical New Business Jet

sometimes the correlations improve and the error term becomes smaller, adding to the confidence associated with their related equations. However, the chances of perfect correlations are low. Because of this, it is prudent to use several predictive equations at the same time to gain insight into the ultimate value in the marketplace. It may also be prudent to further segment markets, if possible. Splitting the market for business aircraft and general aviation aircraft into two pieces has merit. The market for business aircraft alone demonstrates higher correlations [Howarth-3] than the combined analysis here presented, and is worthwhile to narrow the analysis by to business jets only and observe the market responses. In all cases, it is prudent to use more than a single predictive equation for value, so that multiple views of the projected market responses are considered. Ultimately, changes in value must be measures against changes in cost and discounted cash flows to determine the best course of action.

Conclusions

Economic mapping is analogous to geographic mapping. Just as lakes and rivers form physical boundaries, markets have economic boundaries related to their consumers' ability to absorb products within them, while the suppliers to such markets have limits on the quantities that they can effectively produce, and minimum margins between cost and price that they must meet. Geographic maps depict physical locations of shopping centers that compete for buyers. Economic maps show the location of competitors relative to the attributes of the products that they offer. Maps for single markets have at least four distinct dimensions: quantity demanded, a pair of value axes, and a currency axis. Other important effectors of value modulate the consumers' ultimate response to value, as indicted by sustainable product price. All markets combine to form GWP. A pie-cylinder chart captures the world's total product, which, in combination with polar coordinates, forms an N-Dimensional Log Polar Coordinate system. This system, condensable to a single view, represents all markets. Expansion of its constituent markets allows insight into each of them.

Footnotes

[1] Any chart of this type must necessarily remove a "core" of decreasing diameter that forms about its vertical axis in the polar directions, as the lower end of the logarithmic scale approaches, but never reaches, zero. For convenience here, the "0" point used for the vertical origin is really 10^{-1}. The same applies to the "bottom" of the chart, which also approaches but does not reach zero. There, the "floor" of the chart is 10^{-3}. Thus, this method excludes $\Pi(10^{-1})^2 * (10^{13.864} - 10^{-3})$ about its vertical core and $\Pi(10^{-3})^2$ from zero. This amounts to about $2.3 trillion. If analysts require more precision, the "origin" must shift toward zero to reduce the excluded amount.

[2] Occasionally, some buyers will buy a top of the line airliner and convert it to business purposes, with their total expenditures exceeding this upper limit. The US Air Force 1 and 2 modified Boeing 747s are examples of this type of conversion, as is Saudi prince Alwaleed bin Talal's modified Airbus A380, which was purchased for roughly $333 million and which will have about $150 million in modifications. Such modifications always mandate a baseline aircraft model, which the Forecast International data considers.

[3] Many writers have worked on a related topic called "revealed preferences." The idea behind this concept, again pioneered by Paul Samuelson, rests on the "diminishing marginal rate of substitution." One measures "Revealed preferences" in a formless unit call the util, a cornerstone of Utility Theory. Value Theory, by contrast, always uses some form of currency, and never uses utils.

[4] This database has a few vehicles that are converted jetliners. Their typical maximum seat count in their business aircraft mode places them into roughly the same context as the general aviation aircraft. Cabin height, which was available for all models studied, stood in as comfort variable (along with maximum sustained altitude – higher aircraft ceilings allow them to avoid more bad weather). Cabin height is not the preferred value variable for passenger comfort. Cabin volume per passenger is a more comprehensive variable as is captures how much room the aircraft affords each passenger. However, cabin volume was not available for all general aviation aircraft models. This forced the move to height as an independent value variable. In all cases, cabin height is highly correlated to value in aircraft.

[5] The Pearson product-moment correlation coefficient is a common measure of correlation of two variables, as X and Y. The output for Pearson's is from -1 to 1, thus the Pearson's^2 ranges from 0 to 1. The closer Pearson's^2 is to 1, the better the correlation.

[6] The F-Statistic is the ratio of the variation from the mean explained by the regression equation over the variation from the mean not explained by the regression equation. The higher the F-Statistic, the better it is.

[7] The smaller the P-Value, the less likely that chance caused the experimental results.

[8] It is likely that no amount of added variables will make the error terms go to zero. There are several reasons for this. Buyers consider many attributes when purchasing an aircraft, far more than considered here. Additionally there can be errors in reporting (of sales prices, number of units sold, aircraft features, etc.) as well in those in recording (some information posted may be incorrect as reflected here – this could be the fault of the data service or the author or both). In addition, data services typically lump purchases into categories represented by average prices. There are likely several individual transactions with distinct prices within such sets. If isolated, they would provide more insight into their relevant markets.

[9] Using a log-scale for the quantity axis for convenience means that the left end of the scale never goes to zero. Here we will assume that the demand curve begins at unit 1.

[10] To convert from the Cartesian coordinate system to the Polar Coordinate System:

For X: $X_{PC} = X_C + Y_C * \cos\theta$
For Y: $Y_{PC} = Y_C * \sin\theta$

Where:
X_{PC} = X value in Polar Coordinate System
X_C = X value in Cartesian Coordinate System
Y_{PC} = Y value in Polar Coordinate System
Y_C = Y value in Cartesian Coordinate System
θ = Angle (theta) between the x and y axes

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APPENDIX A: General Aviation and Business Aircraft Database and Market Forecast 2004-2013

Below you will find the combined database of general aviation and business aircraft used for this analysis. It has 89 models, with the names removed to protect the Forecast International databases that offered sales and some pricing information (some prices posted by Forecast International changed based on information from the suppliers of the vehicles that they analyzed.) Price adjustments used suppliers posted prices in 2008, deescalated to 2003 dollars using a Bureau of Labor Statistics inflation table (found in Appendix B). Not included in the database are 12 agricultural aircraft (crop-dusters), which have their own special sub-market.

Model	Unit Sales 2004–13	Unit Sales to 2004	Total Sales	Forecast Intl Price	Adjusted Price	Seats	Max Cruise MPH	Max Altitude (ft)	Cabin Height (ft)
1	302	500	802	135000	176000	2	140	20000	3.73
2	119	540	659	192000	249000	2	173	21000	3.92
3	2481	41760	44241	155000	246000	4	145	14000	4.00
4	956	8319	9275	345000	469000	6	174	15700	4.13
5	120	41	161	1500000	1635000	8	214	25000	4.50
6	655	1163	1818	1500000	1675000	8	212	25000	4.50
7	1734	21329	23063	255000	345000	4	173	18100	4.04
8	640	343	983	210000	318000	4	173	17500	4.17
9	2080	1115	3195	290000	471000	4	213	17500	4.17
10	187	1417	1604	388000	377000	4	184	25000	4.08
11	202	765	967	134000	218000	4	146	13000	3.94
12	322	594	916	201000	327000	4	187	16000	3.94
13	183	101	284	148000	241000	4	150	16000	3.94
14	155	235	390	225000	365000	4	219	16000	3.94
15	102	475	577	132000	214000	4	132	11000	3.94
16	27	876	903	370000	693200	6	227	25000	3.83
17	66	138	204	393000	645000	6	152	23800	3.58
18	10	8	18	450000	707000	5	190	20000	3.83
19	180	54	234	152000	185000	5	164	20000	3.83
20	183	498	681	135000	178000	5	160	20000	3.83
21	170	380	550	118000	151000	4	145	15000	3.83
22	23	89	112	400000	537500	4	278	25000	3.71
23	380	333	713	350000	438000	4	227	20000	3.71
24	184	8981	9165	305000	415600	4	219	20000	3.71
25	27	525	552	1200000	1200000	11	144	25000	4.21
26	565	10323	10888	182000	198900	4	147	14100	3.73
27	44	32778	32822	232000	280700	4	158	16200	3.73
28	359	194	553	1810000	1645000	6	299	30000	3.92
29	331	366	697	880000	988800	6	253	25000	3.92
30	318	328	646	415000	497600	6	213	20000	3.50

Model	Unit Sales 2004-13	Unit Sales to 2004	Total Sales	Forecast Intl Price	Adjusted Price	Seats	Max Cruise MPH	Max Altitude (ft)	Cabin Height (ft)
31	128	177	305	362000	496900	4	186	15000	4.08
32	92	4630	4722	505000	693200	6	227	25000	3.50
33	174	3000	3174	155000	212800	4	132	11000	3.73
34	329	2072	2401	1000000	887000	6	232	20688	4.17
35	352	4033	4385	600000	491000	6	202	18500	4.17
36	33	78	111	2600000	1834000	10	283	30000	4.30
37	186	300	486	485000	485000	6	184	18000	3.94
38	56	55	111	95000	95000	4	161	13681	3.94
39	169	101	270	120000	120000	2	144	14764	3.94
40	355		355	1150000	1114000	5	265	25000	4.30
41	295		295	2100000	2034000	4	391	41000	4.30
42	44	13	124	49455000	47896000	39	542	41000	7.38
43	33	75	132	52200000	50554000	50	542	41000	7.08
44	16	7	162	65390000	63328000	78	542	41000	7.08
45	360	567	927	18402000	17822000	8	541	45000	6.08
46	184	4	188	24000000	23243000	9	540	41000	6.07
47	229	0	229	41104000	39808000	13	581	51000	6.23
48	208	105	313	46865000	45387000	19	582	51000	6.27
49	177	238	415	8035000	7782000	6	534	51000	4.92
50	367	196	563	10508000	10177000	8	533	51000	4.92
51	199	242	441	13467000	13042000	8	534	51000	5.68
52	70	187	257	6078000	5886000	7	462	45000	4.70
53	222	1434	1656	8138000	7881000	7	493	45000	4.70
54	368	218	586	10405000	10077000	8	498	45000	5.58
55	65	0	65	15246000	14765000	8	526	47000	5.80
56	236	168	404	19882000	19255000	8	608	51000	5.60
57	268		268	2472000	2394000	5	391	41000	4.50
58	73	425	498	4430000	4290000	5	451	41000	4.75
59	298	0	298	5872000	5687000	7	474	45000	4.75
60	565	0	565	6181000	5986000	7	480	45000	4.75
61	34	340	374	21012000	20350000	8	560	49000	5.92
62	36	203	239	32239000	31223000	8	554	51000	6.17
63	172	148	320	35793000	34664000	8	554	51000	6.17
64	28	216	244	23896000	23143000	8	568	47000	6.17
65	323	49	372	25719000	24908000	8	568	47000	6.17
66	250	0	250	38073000	36873000	8	595	51000	6.17
67	135	109	244	22000000	21306000	16	518	41000	6.00
68	4	95	99	12440000	12048000	6	578	45000	5.58
69	158		158	13521000	13095000	7	562	45000	5.75
70	223	33	256	21090000	20425000	8	562	45000	6.25
71	154		154	27583000	26713000	14	582	45000	6.17
72	0	472	472	34885000	33785000	14	582	45000	6.17
73	300	159	459	48406000	46880000	16	585	51000	6.17
74	319	559	878	13240000	12823000	8	514	41000	5.75
75	214	2	216	18749000	18158000	8	541	45000	6.00
76	215	621	836	6945000	6726000	7	518	45000	4.75
77	400	31	431	5409000	5238000	6	519	41000	5.42
78	217	3	220	5817000	5634000	6	560	49000	4.33
79	32	1221	1253	1500000	1453000	6	196	25000	4.20
80	647	1305	1952	1608000	1557000	8	214	25000	4.30

Model	Unit Sales 2004–13	Unit Sales to 2004	Total Sales	Forecast Intl Price	Adjusted Price	Seats	Max Cruise MPH	Max Altitude (ft)	Cabin Height (ft)
81	47	100	147	1762000	1706000	9	212	25000	4.30
82	148	47	195	5661000	5483000	6	454	41000	5.75
83	617	401	1018	3254000	3151000	6	311	30000	4.75
84	251	4046	4297	2833000	2744000	5	283	30000	4.75
85	216	649	865	5120000	4959000	7	336	35000	4.75
86	179	376	555	5977000	5789000	9	359	35000	4.75
87	280	183	463	2813000	2724000	4	339	31000	4.00

APPENDIX B: Bureau of Labor Statistics Inflation Table
(from: ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual Average
1976	55.6	55.8	55.9	56.1	56.5	56.8	57.1	57.4	57.6	57.9	58.0	58.2	56.9
1977	58.5	59.1	59.5	60.0	60.3	60.7	61.0	61.2	61.4	61.6	61.9	62.1	60.6
1978	62.5	62.9	63.4	63.9	64.5	65.2	65.7	66.0	66.5	67.1	67.4	67.7	65.2
1979	68.3	69.1	69.8	70.6	71.5	72.3	73.1	73.8	74.6	75.2	75.9	76.7	72.6
1980	77.8	78.9	80.1	81.0	81.8	82.7	82.7	83.3	84.0	84.8	85.5	86.3	82.4
1981	87.0	87.9	88.5	89.1	89.8	90.6	91.6	92.3	93.2	93.4	93.7	94.0	90.9
1982	94.3	94.6	94.5	94.9	95.8	97.0	97.5	97.7	97.9	98.2	98.0	97.6	96.5
1983	97.8	97.9	97.9	98.6	99.2	99.5	99.9	100.2	100.7	101.0	101.2	101.3	99.6
1984	101.9	102.4	102.6	103.1	103.4	103.7	104.1	104.5	105.0	105.3	105.3	105.3	103.9
1985	105.5	106.0	106.4	106.9	107.3	107.6	107.8	108.0	108.3	108.7	109.0	109.3	107.6
1986	109.6	109.3	108.8	108.6	108.9	109.5	109.5	109.7	110.2	110.3	110.4	110.5	109.6
1987	111.2	111.6	112.1	112.7	113.1	113.5	113.8	114.4	115.0	115.3	115.4	115.4	113.6
1988	115.7	116.0	116.5	117.1	117.5	118.0	118.5	119.0	119.8	120.2	120.3	120.5	118.3
1989	121.1	121.6	122.3	123.1	123.8	124.1	124.4	124.6	125.0	125.6	125.9	126.1	124.0
1990	127.4	128.0	128.7	128.9	129.2	129.9	130.4	131.6	132.7	133.5	133.8	133.8	130.7
1991	134.6	134.8	135.0	135.2	135.6	136.0	136.2	136.6	137.2	137.4	137.8	137.9	136.2
1992	138.1	138.6	139.3	139.5	139.7	140.2	140.5	140.9	141.3	141.8	142.0	141.9	140.3
1993	142.6	143.1	143.6	144.0	144.2	144.4	144.4	144.8	145.1	145.7	145.8	145.8	144.5
1994	146.2	146.7	147.2	147.4	147.5	148.0	148.4	149.0	149.4	149.5	149.7	149.7	148.2
1995	150.3	150.9	151.4	151.9	152.2	152.5	152.5	152.9	153.2	153.7	153.6	153.5	152.4
1996	154.4	154.9	155.7	156.3	156.6	156.7	157.0	157.3	157.8	158.3	158.6	158.6	156.9
1997	159.1	159.6	160.0	160.2	160.1	160.3	160.5	160.8	161.2	161.6	161.5	161.3	160.5
1998	161.6	161.9	162.2	162.5	162.8	163.0	163.2	163.4	163.6	164.0	164.0	163.9	163.0
1999	164.3	164.5	165.0	166.2	166.2	166.2	166.7	167.1	167.9	168.2	168.3	168.3	166.6
2000	168.8	169.8	171.2	171.3	171.5	172.4	172.8	172.8	173.7	174.0	174.1	174.0	172.2
2001	175.1	175.8	176.2	176.9	177.7	178.0	177.5	177.5	178.3	177.7	177.4	176.7	177.1
2002	177.1	177.8	178.8	179.8	179.8	179.9	180.1	180.7	181.0	181.3	181.3	180.9	179.9
2003	181.7	183.1	184.2	183.8	183.5	183.7	183.9	184.6	185.2	185.0	184.5	184.3	184.0
2004	185.2	186.2	187.4	188.0	189.1	189.7	189.4	189.5	189.9	190.9	191.0	190.3	188.9
2005	190.7	191.8	193.3	194.6	194.4	194.5	195.4	196.4	198.8	199.2	197.6	196.8	195.3
2006	198.3	198.7	199.8	201.5	202.5	202.9	203.5	203.9	202.9	201.8	201.5	201.8	201.6
2007	202.4	203.5	205.4	206.7	207.9	208.4	208.3	207.9	208.5	208.9	210.2	210.0	207.3
2008	211.1	211.7	213.5	214.8	216.6	218.8	220.0	219.1	218.8	216.6	212.4	210.2	215.3

APPENDIX C: Regional Aircraft and Helicopter Database 2006-2015

Below you will find the combined database of regional aircraft and helicopters used for this analysis. It has 27 models, with the names removed to protect the Forecast International (FI) databases that offered sales and some pricing information (some prices posted by Forecast International changed based on information from the suppliers of the vehicles that they analyzed). Note that this list includes only a few of the helicopters for which FI offers information.

Model	Price $2005M	Quantity Sold by 2005	Forecast International Sales 2006-15	Grand Total	Max Cruise MPH	Typical Passenger Capacity	Balanced Field Length (ft)	1 Fixed Wing 2 Helicopter
1	14.00	358	37	395	345	42	3825	1
2	16.50	407	109	516	318	72	4015	1
3	1.97	1018	68	1086	196	9	1250	1
4	14.00	284	1	285	311	37	3250	1
5	14.00	79	2	81	334	37	3280	1
6	15.00	179	41	220	330	50	3460	1
7	20.00	125	137	262	414	74	4265	1
8	5.50	153	11	164	224	24	1925	1
9	2.71	500	900	1400	311	8	2300	1
10	45.00	27	191	218	542	117	5479	1
11	12.00	102	118	220	460	34	4535	1
12	36.50	150	40	190	542	106	5500	1
13	23.00	689	459	1148	562	50	5010	1
14	27.00	181	406	587	562	64	5790	1
15	31.00	257	164	421	562	86	5790	1
16	15.40	106	109	215	518	37	5577	1
17	17.80	56	92	148	518	44	5643	1
18	20.10	477	442	919	518	50	6465	1
19	25.00	91	472	563	542	74	5545	1
20	28.00	55	311	366	542	104	6510	1
21	3.10	844	240	1084	209	19	1200	1
22	1.80	1500	600	2100	212	14	2420	1
23	1.30	84	116	200	144	7	1443	1
24	0.59	7783	1810	9593	189	6	1740	1
25	18.0	1	9	10	173	30	150	2
26	14.4	900	56	956	172	24	128	2
27	14.0	34	105	139	176	19	137	2