Modeling the Effect of Competitors' Strategies Using Curve45

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ABSTRACT

Beyond the immediate company of interest, competitors of that company are an integral part of many business simulation games (and nearly universally an integral part of real marketplaces). At the heart of business simulation games are algorithms that transform company decisions into outcomes, perhaps the most common outcome being sales though many other types of outcomes may also result. For competitive games the algorithm must model the impact of competitors' strategies on the effectiveness of a given company's strategy. The present research describes a function, Curve45, specifically designed for this purpose.

INTRODUCTION

Generically, business games transform participant strategy decisions into outcomes. Strategy decisions can be of a wide variety, often marketing, but also including production, finance, and so on. The most elemental outcomes are company sales and profits, though here again outcomes, too, can be of a wide variety. So-called "scorecards" (Dickinson, 2003), for example, prescribe a mix of outcome criteria. Executing this transformation of strategy decisions into outcomes in computerized games is an algorithm of some description. Gold and Pray (1990) provide a review of this facet of games, while Gold (2005) as well as Goosen (2010, 1986) and numerous others (e.g., Dickinson, 2014b; Carvalho, 1992; Thavikulwat, 1988) have put forth specific algorithms.

Continuing, business games may be dichotomized into competitive or noncompetitive. "The primary basis for this distinction has been whether the decisions of players influence the results of one another (competitive) or not (noncompetitive)." (Biggs, 1990, p. 25) Typifying the former, "The decisions that [players] make during each period of competition will be deemed 'good, bad, or indifferent' only after being compared to those made by your competitors. This is, in fact, the point at which COMPETE most closely approximates reality." (Faria, 2006, p. 3) Support from numerous and disparate sources evidences that the effect of a company's marketing strategy decisions cannot be isolated from competitors' decisions (Dickinson, 2003b).

(Noncompetitive games do exist, of course. "In simulations that are independent across firms, the demand available to a firm is not dependent on the decisions of other firms." [Thavikulwat, 1988, p. 183].)

The present research describes a function that is particularly suited to incorporating the effects of competitors' strategies on the effectiveness of a given company's strategy decisions.

CONCEPTUAL EFFECT OF COMPETITORS' STRATEGY DECISIONS

It is useful to adopt the framework of main effects and interaction effects. A main effect is the relationship between two variables Y and X where, say, Y might be unit sales and X might be price. An interaction effect is where the *relationship* between two variables is affected by a third variable. The effect of competitors' strategies may be characterized as an interaction effect, competitors' decisions being the "third variable."

(It might be noted that interactions among the elements of a single company's marketing mix are commonly recognized [Teach, 2000]. Gold with numerous co-authors [e.g., 2011] promote a completely interactive model.)

Simply enough, for sales-stimulating marketing decisions such as advertising, unit sales realized from a company's advertising of, say, $1000 will be greater where competitors' advertising is less than $1000 and will be lesser where competitors' advertising is greater than $1000. Correspondingly, unit sales realized from a company's price of, say, $600 will be greater where competitors' prices are greater than $600 and will be lesser where competitors' prices are less than $600.

For quantitative decisions, the collective of competitors' decision values may be operationally defined as the mean of those decisions. (Alternatively, their respective decision values might be weighted by, say, market share.)

A basic operationalization of competitors' effects is the ratio of a company's decision value to the mean value of its competitors' decision values. For example, where a company's advertising expenditure is $1000 and its competitors' mean expenditure is $800 the relative-to-competitors influence on demand might be 1.25 (=1000/800). Whatever its merits, this is a linear transformation that does not reflect varying marginal response. The function presented here incorporates disproportional effects, i.e., both increasing and decreasing marginal response.

COMPANY DECISION VALUES EQUAL TO (THE MEAN OF) COMPETITORS' VALUES

With the above conceptualization, it follows that a company's decision value exactly equal to the mean value of its competitors' decision values should not be affected by those competitors' decisions. This requirement is a defining property of Curve45 (Dickinson 2014a).

Curve45 is an S-shaped function that transforms an X variable into a Y variable. In the present application, the X variable is the given company's decision value and the Y variable is that decision value transformed to reflect competitors' decisions. It is the transformed value that would be input to the simulation game's demand-determining algorithm.

(DYNAMIC) INFLECTION POINT

With the Curve45 function, Y takes on the same range as X. Dickinson's (2014b) demand-determining procedure utilizes decision values normalized to 0-1. With that, both X and Y range between 0 and 1, inclusive. Such normalization is not necessary, though, for Curve45 to operate.

One property of Curve45 is that its inflection point is bound to the 45-degree diagonal. An X value greater than the inflection point yields a Y value greater than the X value. An X value less than the inflection point yields a Y value less than the X value.

Suppose, then, that the inflection point is set equal to the mean of the competitors' decision values, say $1000 for advertising. Note that this setting of the inflection point may be done dynamically. It is readily incorporated into the software code of the game algorithm and varies in conjunction with game participants' decisions.

In light of the 45-degree diagonal property of Curve45 and this setting of the inflection point, the effect of a company's $1000 advertising (X) would not be affected by its competitors' advertising, i.e., Y=X.

OTHER PROPERTIES OF CURVE45

As just described, the inflection point of Curve45 being bound to the 45-degree diagonal was specifically designed to incorporate, on the fly, the mean of competitors' values for a given decision. Too, the resultant Y takes on the same range as X. Additional properties of Curve45 are presented here.

(UPWARD- OR DOWNWARD-SLOPING) S-SHAPE

Considering Curve45's S-shape, the effect of a company's advertising greater than $1000 would have a *disproportionately* greater effect after accounting for its competitors' advertising, Y>X, and that greater effect is subject to diminishing marginal response. Corresponding opposite effects occur for a company's advertising less than $1000.

The basic Curve45 is upward-sloping, appropriate for sales-stimulating marketing decisions, e.g., advertising, sales force size, product quality, etc. However, Curve45 is readily adapted to be downward-sloping for transforming price.

MULTIPLIER

The S-shape of Curve45, as with S-shaped curves generally, at first features increasing marginal response inflecting into decreasing marginal response. The respective degrees of the marginal changes may be altered by specification of a multiplier. The multiplier is explained below but, in short, it serves to make Curve45's S-shape of more or less curvature.

WHAT IS CURVE45

Curve45 is an algorithm, as opposed to being an equation. That is, Curve45 comprises computer programming code.

Curve45 is made up of the arcs of two circles. The left-hand concave-up arc intersects the origin (X=0, Y=0) and the 45° diagonal at the specified inflection point. The right-hand concave-down arc intersects that inflection point and (X=specified maximum value, Y=specified maximum value). (As noted above, Curve45 is readily modified to be downward-sloping and, making Curve45 more widely applicable, likewise the respective concavities of the two arcs may be readily reversed.) Comprised of these two arcs Curve45 is particularly "regular" in that each of the arcs has a constant second derivative. The left-hand portion, i.e., that of increasing marginal response, is of constant second derivative, as is the right-hand portion, i.e., that of decreasing marginal response.

Curve45 is defined by three parameters. The first is the specified maximum value for X (this being also the maximum value for Y). The second parameter is the inflection point which, for application to competitive games, is the mean of competitors' decision values. This would be calculated automatically by the game software. The third parameter is a multiplier that determines the degree of curvature of the left-hand concave-up arc and the right-hand concave-down arc of Curve45. In light of Curve45's S-shape, increasing this multiplier from its default value of 1 has the effect of making the marginal transformation of X into Y less pronounced. That is, the two arcs become less curved. (As the multiplier increases to around 5, Curve45 approaches the linear 45° diagonal.)

Technical specifics of how Curve45 actually works may be found in Dickinson (2014a).

AN ILLUSTRATION

Curve45 transforms an X variable into a Y variable. An example of the usefulness of this may be found in the software of marketing simulation games. A typical introductory level game (e.g., Dickinson, 2006b; Mason & Perreault, 2002) has managers make marketing strategy decisions, e.g., price, advertising, number of sales representatives, etc. These decisions are entered into the game software where the decisions are processed by algorithms to arrive at sales. Generically, respective functions (i.e., curves), S-shaped or otherwise, are applied to the strategy decisions to determine market response, i.e., sales.

As an example, advertising strategy decisions, say, might be made in units of dollars. Initially, though, the software may transform those dollar amounts into a proportion of some feasible or reasonable range. (Specifying that range prevents nonsensically extreme decisions from being processed as usual by the algorithms. Nonsensically extreme decisions are processed separately, e.g., restricting their effects to equal the effect at the relevant end of the feasible range.) Transforming a decision into a proportion of the corresponding reasonable range yields a 0-1 X variable. (Dickinson, 2014b)

(Some games do not accept strategy decisions outside some specified range. For example, *The Marketing Game!* [Mason & Perreault, 2002] restricts the number of sales representatives to

0-100. It is unlikely, though, that decisions of, say, 5 representatives and 95 representatives could both be plausible or reasonable strategies for companies competing for the same customers.)

It may also be desirable that whatever market response function/curve is applied that the result, i.e., Y, also be a value between 0 and 1. The reason for this lies in "weighting" the various decisions to reflect their relative importance in determining sales. For some market segments, say, advertising may be more influential than personal selling. Assigning weights is simplified where the strategy variables are measured in common units, i.e., between 0 and 1.

Table 1 presents values for Y over the X range from 0 to 1 for three example inflection points and two multipliers. The tabled values indicate increasing marginal response up to the inflection point, Y equaling X at the inflection point, and decreasing marginal response beyond the inflection point. Too, the flattening of Curve45 toward linearity with a higher multiplier is illustrated.

GENERAL APPLICABILITY

While Curve45 has been presented above in the context of modeling the effect of competitors' strategies (the application for which it was created), it may also serve to model the basic main effect of a strategy variable (marketing or otherwise) on some response (sales or otherwise).

It is a very adaptable function. Using combinations of its inflection point and multiplier parameters it is able to mimic models linear in parameters and variables, log-reciprocal, exponential, modified exponential, logistic, Gompertz, and ADBUDG functions (Lilien & Kotler, 1968, Chapter 4).

As mentioned earlier, Curve45 is readily converted to downward sloping and the concavities of its two arcs are readily reversed.

A REINVENTED PARADIGM

Curve45 is an algorithm, not an equation. It is an example of a tradition of late reinvented by Wolfram (2002) in which computation replaces derivation. Two recently developed measures of qualitative dispersion (*Intuit*, Dickinson, 2011, 2012 and *Angsta*, Dickinson, 2006a) are similarly algorithms.

TABLE 1
CURVE45 TRANSFORMED VALUES (Y)

	Inflection Point=0.5		**Inflection Point=0.6**		**Inflection Point=0.8**	
X	**Multiplier 1.0**	**Multiplier 2.0**	**Multiplier 1.0**	**Multiplier 2.0**	**Multiplier 1.0**	**Multiplier 2.0**
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.05	.0025	.0243	.0021	.0240	.0016	.0236
0.10	.0101	.0521	.0084	.0509	.0063	.0494
0.15	.0230	.0839	.0191	.0810	.0142	.0775
0.20	.0417	.1201	.0343	.1146	.0254	.1080
0.25	.0670	.1614	.0546	.1520	.0401	.1411
0.30	.1000	.2087	.0804	.1937	.0584	.1770
0.35	.1429	.2632	.1127	.2404	.0806	.2160
0.40	.2000	.3270	.1528	.2929	.1072	.2583
0.45	.2821	.4036	.2031	.3525	.1386	.3043
0.50	.5000	.5000	.2683	.4210	.1755	.3545
0.55	.7179	.5964	.3602	.5016	.2191	.4095
0.60	.8000	.6730	.6000	.6000	.2708	.4700
0.65	.8571	.7368	.7936	.6936	.3336	.5372
0.70	.9000	.7913	.8646	.7650	.4127	.6127
0.75	.9330	.8386	.9122	.8227	.5216	.6989
0.80	.9583	.8799	.9464	.8708	.8000	.8000
0.85	.9770	.9161	.9708	.9115	.9323	.8825
0.90	.9899	.9479	.9873	.9460	.9732	.9354
0.95	.9975	.9757	.9969	.9753	.9936	.9730
1.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Corr *	0.9583	0.9906	0.9540	0.9897	0.8925	0.9841

* Pearson (i.e., linear) correlation between transformed value (Y) and X.

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