

# A DIFFERENCES WAY OF ANALYZING SIMULATION RESULTS

Richard Teach  
Georgia Institute of Technology  
richard.teach@scheller.gatech.edu

Elizabeth Tipton  
Eastern Washing University  
etipton@ewu.edu

## ABSTRACT

*This paper presents the advantages of using a simulation's results or output statements as the primary source of information for making input decisions for the ensuing periods. This methodology uses difference equations, using the changes in variables from period to period. Economists tell us to do marginal analysis to better understand the relationship between input decisions such as price, promotion, etc. and the results of these decision. Then they use differential equations to equalize the rates of change between decision inputs and the resulting outputs. However, the seen to never explain how to determine the needed functions from which to determine the derivatives! As a result the needed differential equations are impossible. Thus, difference equations are an approached of attempting to equalizing the marginal rates of return for many decision variables in business simulations.*

## BACKGROUND

For some unknown reason, one of the authors suddenly recalled a lecture from a course in econometrics taken in his Ph.D. program about 50 years ago. That lecture was a discussion on analyzing economic data that was released every week, or month or quarter. In most economic situations, multivariate output functions could be maximized by taking the first derivative of the input and output functions and, using differential equations, to derive the point where the each of the function's marginal changes were equal to all the others. However, economic data had no know set of equations; so, how could macro-economic data be used to change economic policy? The answer was, on hind-sight, simple. Use the first differences of the streams of data. As the derivative represents the rated of change, first differences represent the amount of change of the variable. A system of "difference equations" could be used to estimate the rate of change occurring in each variable, thus, a good estimate of the condition of equal rates of change could be derived. If that were true of macro-economic data, why couldn't this system of difference equations be used to made decisions that would maximize the profit (or other desired performance measure) of simulated firms in a competitive business simulation. A quick search of the ABSEL on-line catch of proceedings papers using the search term "difference equations" came up with no papers that used this term. Maybe a few ABSElers had taken this approach

however, they had not labeled their methods as "difference equations." There were some papers that discussed system dynamics, but a systems dynamics approach requires a change in the way simulations are programed. A search of ABSEL archives using the term "marginal analysis" generate eleven documents.

Ronald Frazer (1985) wrote, *Among the concepts that are covered as one of the main parts of a game are statistical inference, replacement theory, time value of money, price elasticity, **marginal analysis**, and linear programming.* (The bolding was included to emphases the inclusion of the term marginal analysis by the authors of this paper.( Quote from page 179) This seems to be the first ABSEL author to suggest that a study of the changes in variables could or should be used by students using a business simulations.

In that same year, Peter Markulis and Dan Strang (1985) wrote. *Because of the nature of the simulation and the decisions that must be made, students must apply a variety of quantitative techniques in order to make meaningful decisions. For example, making decisions under conditions of risk and uncertainty, multiple regression applications, cost/benefit and **marginal analysis**... (The boulding was once again used by the authors of this paper to emphases the term.) Nonetheless, student teams would frequently be forced to use hand calculators, guess work, or worse; or would riot use quantitative techniques at all--either because it was too difficult to use such techniques without a computer or because not enough time was given between sessions to use such techniques. The real problem, however, was that even with computers, students had to spend considerable time setting up computer programs and many of them just 'did not bother to do so. Hence one of the key objectives of the game, i.e., applying and understanding how various quantitative techniques were integrated, was not accomplished.* (Quote from page 32) This comment points to the difficulties of using marginal analysis, but if the first differences would be provided as standard simulation outputs by the game vendors, it would be decidedly easier and quicker to use,

While a difference equation method of analysis is more difficult than guessing or using intuition it is an important skill that is easily transferred to the practitioner world as all firms collect periodic data very similar to that produced by business simulations. This similarity is a major reason that business simulations are used as a teaching tool. Most of the difficulty is due to the processing the currently supplied data to produce first difference. The concept of equalizing the marginal rates of

change is well understood by most business students.

In 1990, ABSEL published *A guide to business gaming and experiential learning*. In Chapter 14, Hugh Cannon and Theodore Alex (1990) explained how a simulation was being used in an advertising course. The wrote

“...the last assignment is built around the basic economic model of marginal return on advertising expenditure. In class, the assumptions behind different budgeting models are discussed. The assignment then gives them test market data and requires them to develop the following analyses:

1. An optimal budget based on marginal analysis.
2. A percent-of-sales budget.
3. A task and objective budget based on a share-of-voice model.
4. A payout analysis based on a budget that includes investment spending. (Quote from page 230)

Note their reliance on marginal analysis as an important budgeting tool.

Anderson and Lawton (2002) in an appendix to their paper questioning the methods used to development of simulation teams marketing strategy included the term, margin analysis in a list of 24 possible analytical methods. While marginal analysis was only 1 out of 24 methods mentioned, they recognized marginal analyzed as a decision making tool. They did not include the percentage (or the number) of students that had used this method of analysis

Cannon et.al. (2007) wrote, *Given the availability of response estimates provided by the [response) curve, the company can construct a series of profit projections representing each of several possible customer-acquisition budgets, as we have done in Table 2. The table, in turn, enables the company to optimize its customer acquisition expenditures through marginal analysis, selecting a budget where the additional revenue created by customer acquisition activities is offset by the additional cost.* (Quote from Page 56)

In describing their new two decision variable game entitle the WEE GAME, Teach and Murff (2007) wrote, “*Even though many of these students have had a course in microeconomics, they often have only had a theoretic explanation of marginal analysis and do not clearly see the connection between their classroom knowledge and the real world that complex business simulations are attempting to model.* That two decision variable game was designed to encourage participants to do marginal analysis and use difference equations to assist them in their needed decisions on price and promotional budgeting.

Aspy Palia (2008) wrote, *In order to prosper, firms need to move beyond cost-based pricing, markup pricing, and rate-of-return pricing, which add a desired rate of return on the investment needed to produce the product. Marginal analysis can be used to identify the point at which profits will be maximized – the point at which marginal costs equal marginal revenues. Indeed, marginal analysis based on more realistic downward sloping demand curves and non-linear cost functions, reveals two breakeven points enclosing a region of profitability.* (Quote from page 198) Thus, the simulations participants are able to see the range of prices, promotion budgets, product quality and other decision variables, that produce profits and can select the best decisions that the data

provide and for that point in time.

In describing his new simulation for the consumer marketplace Gold (2009) wrote, *In addition to measuring game performance, there is also a set of optional multiple choice questions associated with game exercises that evaluate the student's understanding of basic economic concepts derived from the game such as: law of demand, price elasticity, production and cost relationship, economies of scale, marginal analysis, revenue and profit maximization.* (Quote from page 102) Here again is the recognition that marginal analysis is a key learned ability for decision making.

- Difference equations are, in general, a form of marginal analysis.
- Difference equations are, in general, a form of marginal analysis.

The key to teaching of marginal analysis, in a simulation situation setting, is the use of difference equations and knowledge of marginal analysis using difference equation can easily be transferred to almost any practitioner world situation. It is not just an academic exercise. There is a large body of knowledge available on difference equations. Simply search Google using the term “difference equations and over a million and a half citations appear. While the initial set of citations include differential equations, there are still a very large number of difference equation references. So there is an abundance of easily obtained information on difference equations

## HOW DO WE DEMONSTRATE THE USEFULNESS OF THIS APPROACH TO DECISION?

While the necessary data can be derived from most simulations, the current output statements makes this option possible but a little laborious. Each team would need to collect the simulation outputs in spreadsheet form. Then, simply create a column that calculates the changes (differences) from the prior periods output statements and the current period's output. In addition to output variables, the participants need to include the set of decision variables as well as the outputs. With first order differences available, most players could then use their data to make better decisions. By better decision, we mean they can approach the decision making problem in a way that orients the team's decisions to equalizing marginal difference. This does not reduce the need for judgments and creativity, in fact, it enhances the need for these decision making abilities. This knowledge of marginal changes should, with a few instruction and tutorials on using first order difference equations, reduce the guessing and the reliance on “gut feelings” to make decisions. It results in pushing the players into making decisions based upon data reported by the simulation. It is always helpful for the learning process to use available data in the decision making process.

ABSEL, by pooling it knowledge, could prove that this approach to decision making is viable. If a number ABSEL members would develop a spreadsheet analysis package for obtaining the first differences and provide it to each other and then this package is used in their simulation using classes, a

meta-study of users and non-user could demonstrate the efficacy of this methodology. It would be great if computer-run business simulation vendors would provide sets of tables showing all the variable difference, as this would greatly reduce the amount of time and effort creating spreadsheet calculations the “players” need in using a difference equations approach to decision making..

## REFERENCES

- Anderson, Philip H and Leigh Lawton (2002), “Is simulation performance related to application? An exploratory study,” *Developments in Business Simulation and Experiential Learning*, Vol. 29, pp 108-113
- Aspy, Palia (2008), “Target profit pricing with web-based breakeven analysis package,” *Developments in Business Simulation and Experiential Learning*, Vol.35, pp 197 - 204
- Cannon, Hugh M., Hugh Cannon, James Cannon, and Manfred Schwaiger (2007), “Simulating customer lifetime value implications for game design and student performance,” *Developments in Business Simulation and Experiential Learning*, Vol.34 pp 54 -64
- Cannon, Hugh M, John D, Leckenby and Avery M Abernethy (1996), “Modeling advertising media effectiveness,” *Developments In Business Simulation & Experiential Exercises*, Vol. 23, pp 1 - 7
- Cannon, Hugh M, and Theodore C Alex, (1990) Chapter 14, “Structuring a live case: A method and example from an introductory advertising class” *A guide to business gaming and experiential learning*. pp 216 230
- Faria, Anthony A, J. R. Dickenson and Rein Peterson (1996), “Administering business simulations in transitioning economies: The introduction of simulation gaming to Estonia,” *Developments In Business Simulation & Experiential Exercises*, Volume 23, pp 15-21
- Frazer, J. Ronald, (1985) “Advantages of a multigame simulation course,” *Developments in Business Simulation & Experiential Exercises*, Vol. 12, pp 177 - 179
- Gold, Steven (2009). “BEAT THE MARKET game,” *Developments in Business Simulation and Experiential Learning*, Vol. 36, pp 102-108
- Markulis, Peter M, and Daniel R Strang (1985), “The Use of Decision Support Systems (DSS) and Operations Research/Management Science (OR/MS) Techniques to Enhance the Learning Experience of Students Participating in Computerized Simulations,” *Developments in Business Simulation & Experiential Exercises*, Vol.12, pp 30 - 34
- Teach. Richard D and Elizabeth J. T. Murff, (2007), The WEE FAME, a pre-game, *Developments in Business Simulation and Experiential Learning*, Vol.34, pp 201 - 204.