Financial Aid Leveraging Using Linear Programming in Microsoft Excel

Bryce Mason, Ph.D.
Director of Institutional Research

Ryan Johnson, Ph.D.
Research Associate

LMU|LA
Loyola Marymount University

Objectives

- Become aware of the linear/non-linear programming technique
- See it applied in a home-grown leveraging model
- Learn common “gotchas” surrounding the technique

- Objective to maximize or minimize by a set of decision variables
- But there is a set of constraints (e.g., $X_2<12$, $X_1<X_2$, $X_1X_2>0$)
- Mathematically assisted brute force method
  - Smartly searching through the feasible space of DVs
  - Find optimum solution (X_1^*, X_2^*, ..., X_N^*)

As Applied to Financial Aid Leveraging

- Building the "best" incoming freshman class
  - Certain objective is to be optimized: SAT average (HSGPA)
  - Incentivize admits to enroll using institutional aid
- Constrained choices
  - Aid budget (fixed $ or some target % tuition discount)
  - Minimum and maximum class size (university & college/major levels)
  - Minimum levels of diversity (gender, ethnicity, income, first-generation)
  - Minimum and maximum award size (no insults and the cost of attendance)
  - As many others as fits the situation

The Fundamental Leveraging Gotcha

- N admits implies an N-dimensional decision variable space
- Limits on computing power
  - Brute force search time increases with N (polynomially at best)
  - Premium Solver & Large GRG Engine
    - $5,000
    - Still limited to 12,000 admits

Workaround: Clever Reduction in the Decision Variable Space

- Many admits are the "same"
  - Objective factors (SAT bands, e.g., 1000-1049, 1550-1600)
  - Constraint factors (College 3, Hispanic, male, first-generation)
- Treat key characteristics as the DVs vs. the individual admits
  - Give everyone equivalent starting aid (S)
  - Base aid (multipliers or addends) on membership to various groups
    - SAT 1300-1349 → $DV_i * S$
    - African-American → $DV_j * S$
    - College 3 → $DV_k * S$

$$S * \prod_i DV_i$$

  - Similar admits will wind up with similar awards

Prerequisites

- Basic probability concepts (e.g., expected value)
- Excel 2007+ w/ Solver add-in (free)
- Excel skills (SUMPRODUCT, INDEX, MATCH, INDEX+MATCH)
- A yield model (admit to enroll probabilistic model)
  - Individual level
  - Logistic/probit regression
  - Model coefficients to calculate individual-level probabilities of enroll
  - Institutional aid (your underlying DV) must be in this model

Excel Setup (Data Worksheet)

- Each row an admit
  - Header row with yield model coefficients
  - Probability model in left set of columns
  - More variables for other constraints in right set of columns
- Color scheme
  - White: raw data (note Col J, $9.3K starting aid)
  - Yellow: calculated value via some formula
- Columns M&N for table lookups (INDEX/MATCH)

Excel Setup (Leverage Model Worksheet)

- Objective function panel
- Constraints panel (calculated and compared to requirement)
- Leveraging variables (allow LP to choose aid via these)
- LP-optimized aiding in left columns (the final product!)
  - Person-level synopsis, with cap and floor built in
  - Comparison of original vs. leveraged probability of enrollment
- Color scheme
  - Blue: Computer-chosen DVs

- Objective function
- Decision variables
- Constraints
- Solving method
  - Linear
    - Objective function linear
    - Constraints linear (convex DV space)
  - Non-linear GRG
    - Objective function non-linear
    - Smoothly shaped DV space
  - Evolutionary (disjointed DV space)

Solving in Expectation and Predicting the Future

- Optimized outcomes are expected values (means)
  - Actual enrollment is still a stochastic process
  - You just nudged the likelihoods of people a little bit
- Simulate the future to analyze variance
  - 1000 enrollment simulations given the optimum aiding
  - Obtain standard deviations for objective and constraint variables
- Calculate probabilistic statements
  - 95% confidence intervals
  - There is an X% chance of 40% or fewer males
  - There is a Y% chance of overenrolling in the science college

Other Leveraging Gotchas

- Timing of leveraging process
  - Admitted students may not all be known
  - Yield model can only use factors known at the time of leveraging
- Getting a solution
  - Start with a feasible solution
  - Getting "stuck" in a local maximum
- Speed issues
  - Limit the number of DVs
  - Setup for non-negative, integral DVs

LMU|LA