REPORT

TO: WHOM IT MAY CONCERN

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SUBJECT: BUDGET UNCERTAINTY IN A COORDINATED VACCINE MARKET

DATE: 2018-10-21

PURPOSE

The purpose of this report is to introduce to you a research project that I've been working on. The problems associated with the vaccine market will be demonstrated to highlight the need for a coordinated effort to improve access to vaccines globally. A model for such coordination (Antigen Bundling Problem, *ABP for short*) is presented to show access to pediatric vaccines is improved by balancing profitability and affordability in the procurement of vaccines. A study on budget uncertainty is conducted using the ABP in a monte carlo simulation under a repeated general factorial design to understand the adverse effects of budget reductions on the accessibility, profitability, and affordability of vaccines. Results will illustrate how the ABP balances profitability and affordability, and provides access to vaccines. Finally, a conclusion on the observations and take-aways from this study is outlined.

DESCRIBING THE PROBLEM

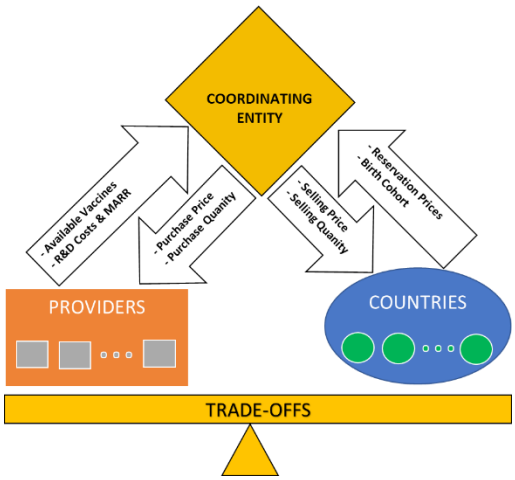
The vaccine market is complex, and the issues that create the gap between the current and desired state include inadequate government financing, difficult access to vaccine supply, decrease in the number of vaccine manufacturers for certain vaccines, increase in the number of recommended vaccines, complex production processes for current and new vaccines, and changes in the perception of vaccines as a necessary biological aid.

The relationship between manufacturers and consumers is limited to high income countries that can afford to negotiate directly, and organizations representing the interests of the low income countries who would otherwise be unable to receive aid. This leaves out most consumers who are middle income countries that don't qualify for organizations and cannot afford current international prices. These countries are forced to rely on local unregulated manufacturing to provide pediatric vaccination. A key mechanism in the current system is pooled procurement, which is what allows lower income countries to secure lower prices that are affordable to them and allows manufacturers to sell vaccines in large economic quantities to organizations. This mechanism if applied to the entire system may lead to balancing the profitability and affordability of vaccine procurement.

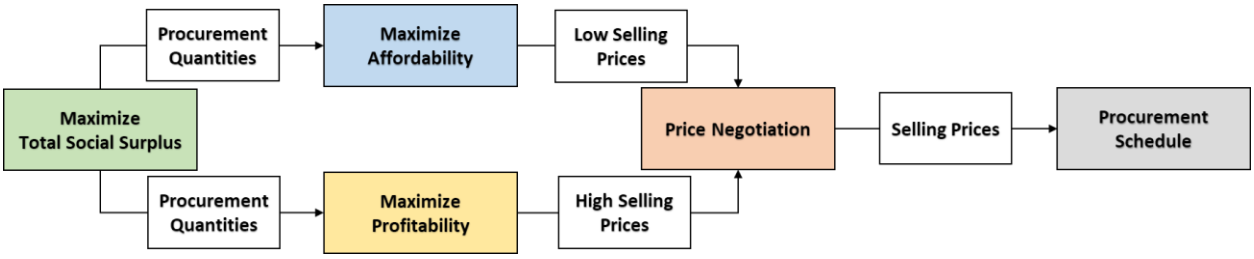
MODELING THE PROBLEM

Pooled procurement for the entire vaccine market is represented below as a hypothetically coordinated market design. The coordinating entity in this design is a third-party single decision maker balancing the trade-offs of securing profitable and affordable vaccine procurement. An advantage for this proposed

system, is that countries can be grouped to create any number of market segmentations. By increasing the number of market segmentations, the coordinating entity can reduce the within group variance of income level to offer more appropriate vaccine prices for each market. By decreasing the number of market segmentations, the coordinating entity can have markets buy vaccines at larger economic quantities. Another advantage of this system is that the coordinating entity can offer any vaccine to any country, allowing more vaccines to be made available to each country for the first time. This increased vaccine access allows the manufacturers return on investment for their latest vaccines to be secured sooner.



This single third party decision maker is a monopsonistic coordinating entity solving for affordable and profitable vaccine procurement in the Antigen Bundling Problem (ABP). The objective of ABP is three-fold, solving for a procurement quantity (1) that allows for low (2) and high (3) price points to be solved for, such that price negotiation can finalize the procurement schedule. An illustration of the optimization process that the coordinating entity follows is given below. The conditions that must be satisfied to ensure a procurement schedule is realistic for buyers and sellers, are defined below as well.



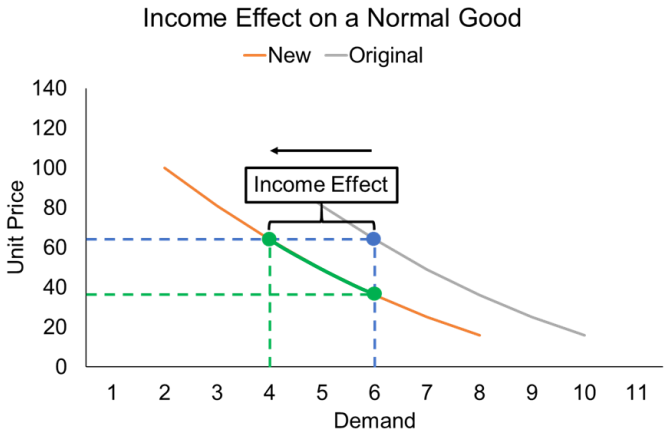
Demand	Antigen demand must be satisfied at each market segment
Affordable Pricing	Vaccines must be priced below their reservation price in each market segment
Tiered Based Pricing	Vaccines are priced higher for market segments with higher GNI per capita
Demand Elasticity	Vaccine demand resistantly decreases as its price reaches its reservation price
Combination Vaccine Value	The savings from a combination vaccine must be higher than the savings from any group of vaccines that could satisfy the same demand
Profitable Pricing	Revenue from vaccine sales must ensure a given ROI to vaccine providers
Supply	Providers cannot supply vaccines exceeding their manufacturing capacities

STUDYING BUDGET UNCERTAINTY

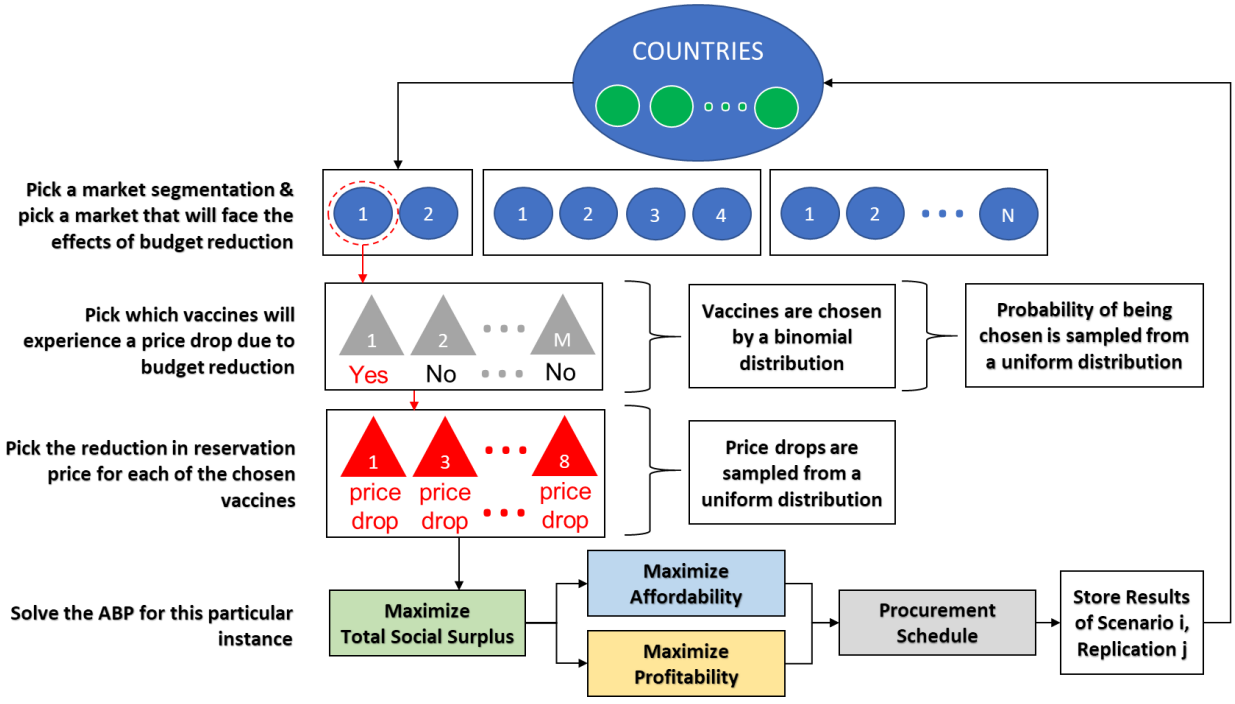
The research questions of interest to drive the study of budget uncertainty in a coordinated vaccine market are the following:

1. How can government budget uncertainty about vaccine spending be modeled?
2. When any given buyer unsuspectingly reduces their vaccine spending, how is the profitability, affordability, and demand coverage of global vaccine procurement affected?

The proposed answer to the first research question comes from the income effect from economics. The income effect shows that when a consumer has a reduction in income they will either buy less units of a normal good at the original price, or they will buy the same units of a normal good at a new lower price. A normal good is defined quantitatively as a good with a positive income elasticity of demand. Government vaccine expenditure has been shown to have a positive income elasticity of demand.



The proposed answer to the second research question is a repeated general factorial design to conduct a monte carlo simulation of budget uncertainty. The factors and levels of the design include the following: *Market Segments (2, 4, 8, 12), Vaccines Affected (1%-20%, 21%-40%, 41%-60%, 100%), Price Drops (1%-12%, 13%-26%, 27%-40%), MARR (5%, 10%, 15%, 20%),* and *Replications (50).* The structure of the monte carlo simulation is given below. This simulation starts with grouping countries into *Market Segments* and choosing which market of the segment to study budget uncertainty with. The next step is to determine the *Vaccines Affected* by budget uncertainty. Then determining the *Price Drops* for the affected vaccines. These price drops refer to the reduction in how much a country is willing to pay for a unit of a vaccine. Finally, a *MARR* is chosen to determine how manufacturers will get a minimal return. This information is then passed to the ABP and the results are collected for later analysis.



RESULTS OF THE STUDY

The balance between profitability and affordability in the procurement schedules is visualized below by *Provider Market Value* which is computed as [*Total Profit / (Total Savings + Total Profit)]*. This measure represents the manufacturer's share of the total welfare in the market. When the global market is segmented into 8 markets grouped by income level, the balance in profitability and affordability is closest to a 50-50 share.

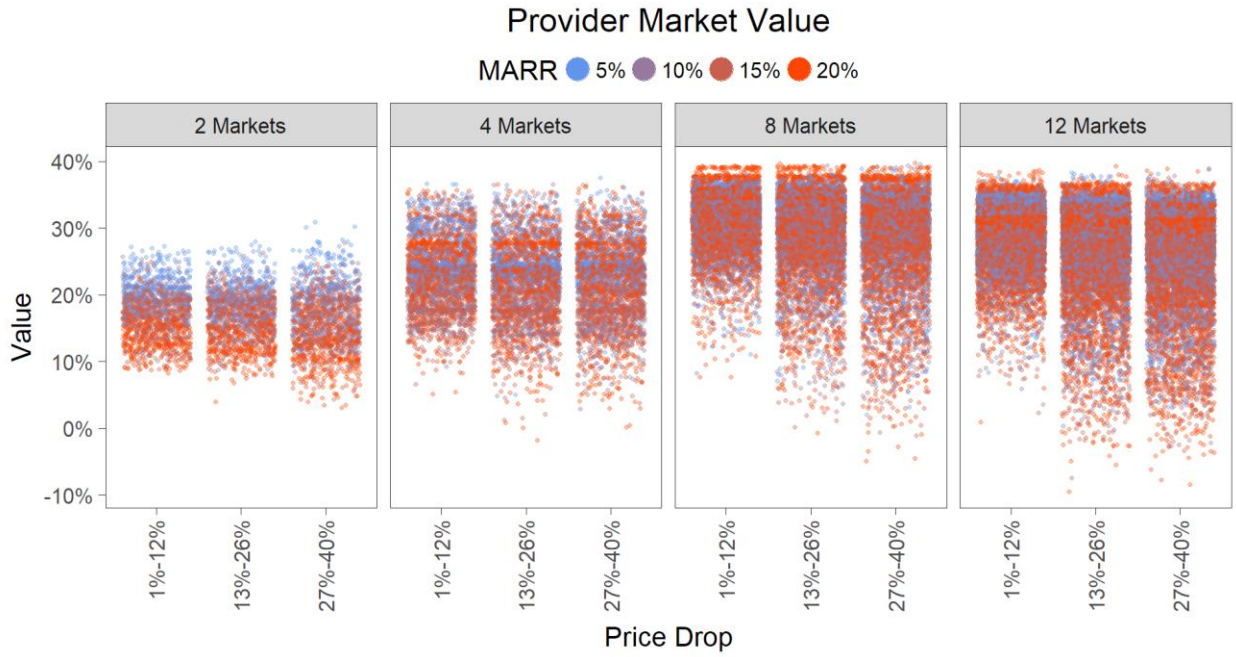


Figure 1: Provider Market Value under Budget Uncertainty
Each data point represents a global procurement schedule from the ABP.

The demand coverage for 6 antigens in an 8 market segmentation is visualized below. Antigens are the proteins in vaccines that induce an immune response. Markets 1 to 8 are staggered by decreasing income level. The pairs of *Market 1 & 2, Market 3 & 4, Market 5 & 6,* and *Market 7 & 8* represent high income countries, high middle income countries, low middle income countries, and low income countries respectively. The black diamonds for each market segment represent the expected value for coverage across all scenarios studied. Markets 1 to 5 are expected to have full access and full coverage for all 6 antigens studied. Markets 6 to 8 are not expected to have full access nor full coverage for all 6 antigens covered. The lack of coverage affects antigens 2 and 5; and the lack of access affects antigens 2, 3, and 5 in this 8 market system.

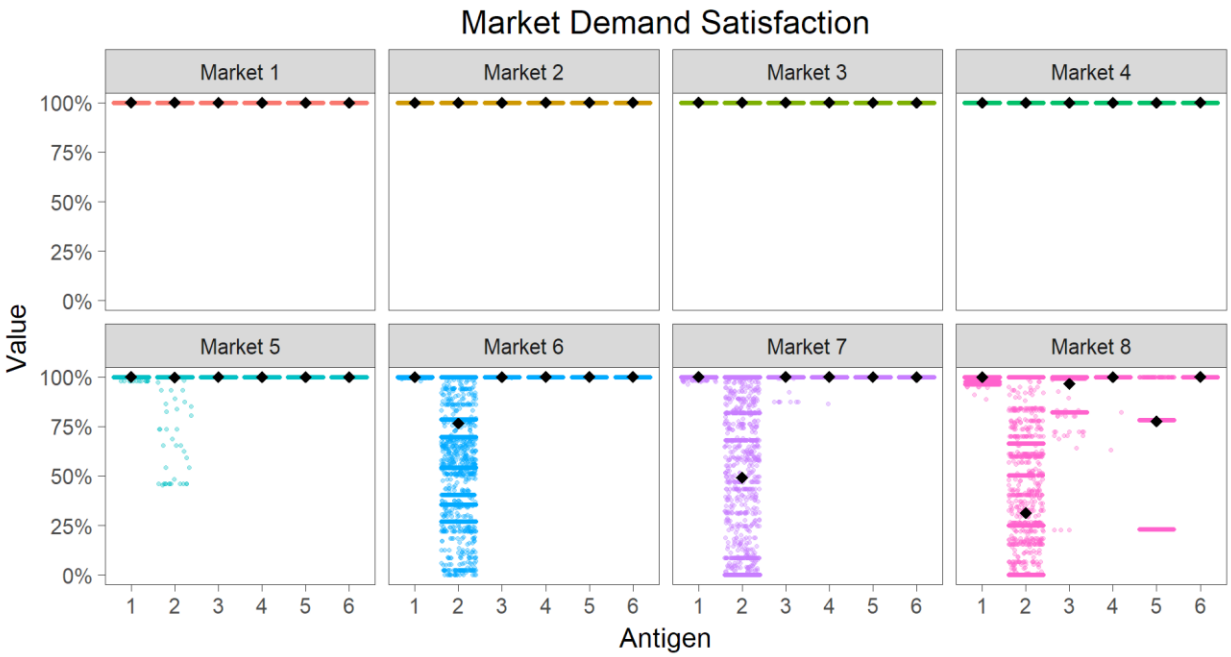


Figure 2: Demand Satisfaction under Budget Uncertainty
Each data point represents a market procurement schedule from the ABP.

CONCLUSIONS ON THE STUDY

The analysis of the monte carlo simulation lead to the following observations:

- When countries face a reduction in budget, increasing the market segmentations improves the expected value and variability of total welfare (affordability & profitability).
- When countries face a reduction in budget, increasing market segmentations improves the expected value and variability of consumer surplus (affordability).
- When countries face a reduction in budget, 8 market segmentations improve the expected value but increases the variability of provider profit. The other market segmentations reduce the expected value of profitability.

The take-aways from this study on budget uncertainty are the following:

- Increasing market segmentations continues to show better results for the ABP.
- We have developed a framework to implicitly explore the effects of budget uncertainty in a coordinated vaccine market without explicating stating the budget value.
- As the price paid for vaccines continues to become more transparent across countries, developing an explicit estimate of vaccine budget on a country level becomes possible.
- Risk of budget uncertainty may not be best represented by drop in price or demand, and there is growing availability of public data on countries that could be used for developing a risk index for governments reducing their budget for vaccines.