Simulating Equilibrium in Multi-Product Postal Markets Following De-regulation and Liberalization

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The views presented in the paper are solely those of the authors and do not necessarily represent the opinions of the Postal Regulatory Commission.

Summary of the Presentation

- What is a liberalized postal market? How do they reach equilibrium? We present the concept of a single-product liberalized market as a non-zero-sum non-cooperative two-person game.
- How does our simulator apply the basic concept? The simulator finds Nash equilibriums iteratively using the method of fictitious play. The simulator mimics the operation over time of a set of inter-related postal markets.
- How does our simulator generalize the basic concept? The simulator may be applied to postal markets under a variety of regulatory constraints and market conditions.
- Example: The U.S. Postal Service (USPS) and its potential competitors. We examine the Nash equilibrium for a 6-product model of U.S. domestic mail under an assumed partial de-regulation and liberalization.
- Experimentation: The model is an apparatus for conducting controlled experiments. We display the results of several such experiments.
- Our Principal Finding: Equilibrium in postal markets is very likely to be characterized by:
  - Limit Pricing by the incumbent Postal Operator (PO).
  - Stochastic Entry and Exit by potential Entrant/Competitors (ECs)

What is a Liberalized Market?

Assumed Properties of a Liberalized Single-Product Market with a profit-maximizing incumbent Postal Operator (PO) and a single potential Entrant/Competitor (EC):

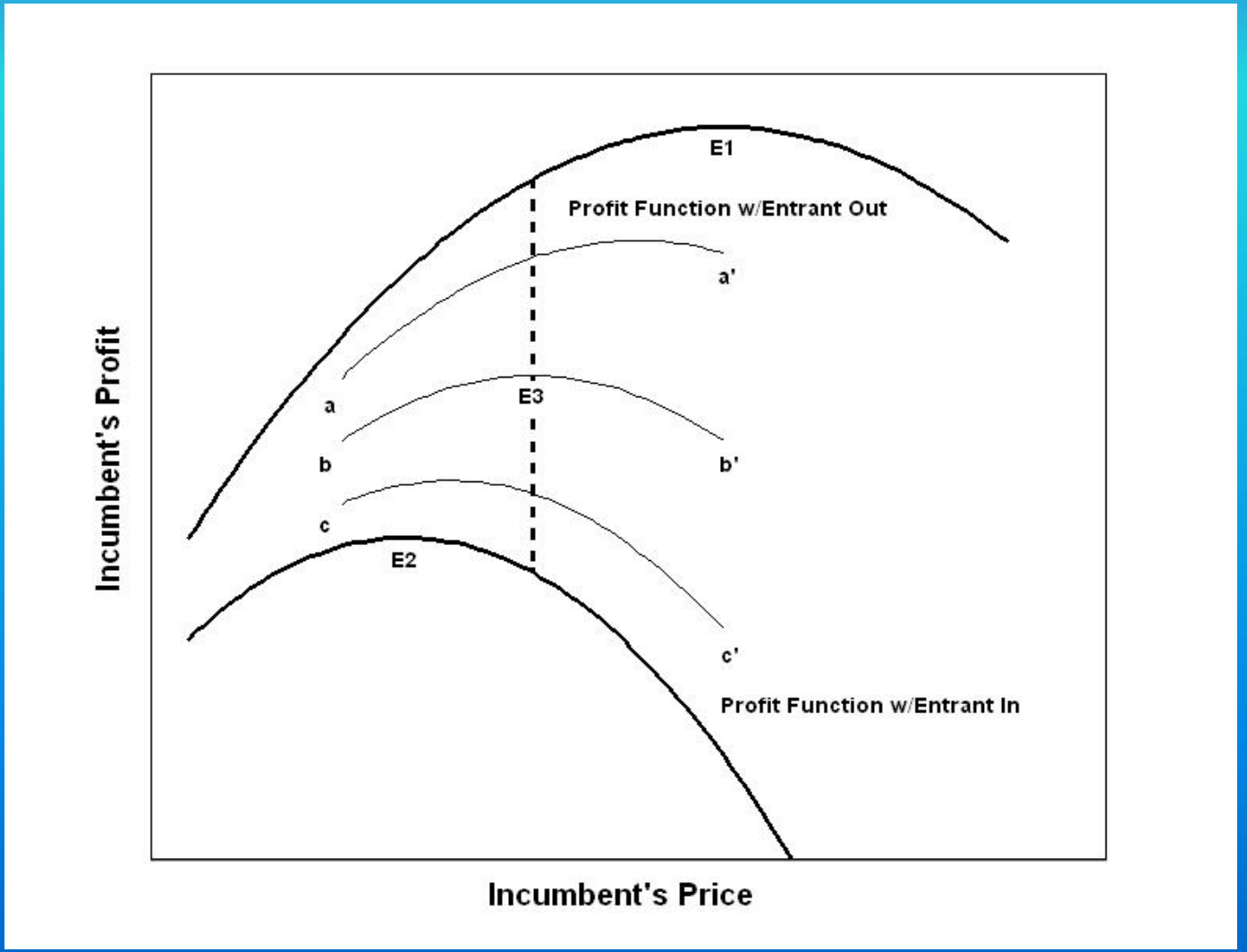
- PO (USPS in our examples)
  - always present in the market and acts as the price leader.
  - does not know if the EC will be *in* or *out* of the market when it sets its price.
  - maximizes expected profit given an estimate of the probability that the EC will be *in* the market.
- EC (UPS, FedEx and/or others in our examples)
  - decides to be *in* or *out* based on the PO price that it currently observes.
  - enters the market if it believes it can make a profit but remains out if it cannot.
  - It is indifferent if it is equally profitable to be *in* or *out.*
  - if it enters, it sets its price to maximize its profit based on the PO's price.

How Does a Liberalized Market Work?

The PO and the EC are engaged in a non-zero-sum non-cooperative two-person game with a Nash equilibrium consisting of strategies for the PO and EC that are optimal against each other.

- PO's strategy (pure)
  - A price maintained whether the EC is *in* or *out* of the market.
  - The equilibrium price maximizes the PO's expected profit given the EC's probability of entering the market.
  - Mixed strategies for the PO are never used because they are all dominated by pure strategies.
- EC's strategy (mixed)
  - To be *in* or *out* of the market. These are the EC's pure strategies.
  - The EC chooses the most profitable of the two pure strategies if the two yield different profits.
  - If it is equally profitable to be *in* or *out*, the EC enters and exits according to a probability of entry in the range [0,1].
  - EC's profit functions *in* or *out* are strictly concave functions of the EC's price so the EC's strategies have corresponding prices that maximize the EC's profit.

Equilibrium in a Liberalized Single-Product Market



Notes to the Graph

Dashed Vertical Line : The boundary between Incumbent prices that attract entry (to the right) and Incumbent prices that discourage entry (to the left).

$\mu =$ the probability of entry by a potential Entrant.

Forms of Equilibrium

E1: Monopoly, Entrant stays *out,* $\mu = 0$, Incumbent sets its price at the maximum of the Profit function w/Entrant *out,* Entrant cannot make a profit if it enters. Dashed line is to the right of E1.

E2: Duopoly (a la Bertrand), Entrant is always *in*, $\mu = 1$, Incumbent sets its price at the maximum of the Profit function w/Entrant *in,* Entrant makes a profit by entering and setting a price knowing the Incumbent's price. Dashed line is to the left of E2.

E3: Stochastic Entry with Limit Pricing, Entrant is *in* with $0 < \mu < 1$, Incumbent sets its price to leave the Entrant with zero profit if it enters, Entrant enters with probability μ which leaves the Incumbent unable to increase its profit by changing its price. Dashed line is between E1 and E2 as drawn.

Stability of Equilibrium

aa' probability of entry is too low, Incumbent will raise its price, Entrant then enters or remains *in* raising μ thereby shifting aa' down.

cc' probability of entry is too high, Incumbent will lower its price, Entrant then exits or remains *out* lowering μ thereby shifting cc' up.

bb' probability of entry is a Nash equilibrium, Incumbent's expected profit is maximized at the price that leaves the Entrant with zero profit, bb' is stable because the Incumbent does not have an incentive at the margin to change its price (Drawn with probability $\mu \cong 0.5$).

How the Simulator Generalizes the Model

- Multiple Products – The PO and EC each may offer up to six directly competing products. The EC's pure strategies consist of different feasible combinations of the six products. There are 64 possible combinations including not entering any market.
- Multiple Incumbent Objectives – The PO is not necessarily a profit maximizing enterprise. It may maximize welfare, profit, cost, revenue and arbitrary combinations of these objectives.
- Profit constraint – welfare, cost and revenue may (or may not) be maximized subject to a floor on profits.
- Adjusted Cost – When the PO maximizes "cost" the marginal costs of the products may be adjusted by the user to define unconventional objectives.
- Reserved Area – The EC may be prevented from offering products that directly compete with some of those offered by the PO.
- Always Entered – The EC may be assumed to always be present in some of the markets. These markets may constitute core businesses for the EC.

How the Simulator Generalizes the Model, cont'd

- Price Floors – By default the PO's individual prices are subject to a set of price floors (which may be zeroed out).
- Price Caps – The floors may be replaced individually by price caps.
- Global Price Cap – The PO's prices may be constrained by a global price cap. The product weights for the price index used for the cap are preset by the user.
- Demand Models – The model accepts different matrices of demand elasticities and different price/quantity points for linearizing the demand functions.
- Substitutability – The model accepts different assumptions regarding the market shares of the PO and EC and the marginal diversion rates between them.
- Cost Models – The model accepts different linear cost models for the PO and EC.
- Number of ECs – There may be multiple potential ECs.

An Application to US Domestic Postal Markets

- Six Aggregate USPS Domestic Mail Categories:
  - 1Cls - First-Class Mail
  - PrOth - Priority Mail and Expedited Packages
  - 2Per - Periodicals
  - 3Std - Standard Mail
  - 4Pkg - Market-Dominant Packages
  - PclSR - Parcel Select and Return Services
- The application is made by extrapolating from existing econometric demand models and USPS cost models to describe postal markets after entry for each possible EC product combination.
- The application is calibrated to USPS accounts for FY 2015.
- Demand Model: USPS elasticities etc. derived from a branching AIDS model
- Revenue and Cost Model: USPS Cost and Revenue Analysis for FY 2015.
- Centering Prices: The larger of USPS revenues per piece or unit vol. var. costs

An Application to US Domestic Postal Markets, cont'd

- Centering Market Shares:
  - PrOth 0.494,
  - PclSR 0.299,
  - all other categories 1.000.
- Aggregate Volume Variabilitiies: (Volume variability is the elasticity of cost with respect to a cost "driver" based on volume)
  - USPS variability in FY 2015 was 0.585.
  - EC assumed variability 0.700.
- Basis Case Market Shares: The basis case assumes that all markets are entered and that the PO and EC charge the same prices. The simulation used a combination of observed and assumed values as follows:

- 1Cls 0.900	- 2Per 0.800	- 3Std 0.700
- PrOth 0.494	- 4Pkg 0.700	-PclSR 0.299

- Marginal Diversion Rate: The rate at which the EC and PO divert mail from each other in response to an unmatched price change. Assumed to be 0.900 for all categories.

Control Settings for an Application to US Domestic Postal Markets

- Incumbent Objective: Welfare defined as the sum of the consumers' surplus on just the PO's mail services and the PO's (USPS) profit.
- Incumbent Profit Floor: Imposed at -5.5 million ($000)
  - Amount of a congressionally mandated annual USPS contribution to a Treasury account for retiree health coverage.
- Reserved Area: 1Cls is reserved for the PO
- Entered Area: PrOth and PclSR are always entered by the EC.
- Price Caps and Floors:
  - The PO is subject to floors on all products set at unit volume-variable cost.
  - No individual price caps.
  - No global price cap. The price index is calculated with FT 2015 volumes as weights.
- Frequency Model: The PO estimates frequencies using an exponentially weighted average of previously selected product combinations. The estimates truncate the start of the sample and censor frequencies below 0.010.
- Iterations: The iteration limit is 200 and the sample size for averaging results is 100. [The maximum number of iterations for the simulator is 681.]

Simulated Nash Equilibrium for US Domestic Postal Markets

Set ID:	Global Price Cap Experiments	3/14/2016 13:51	Simulated ($000)
Demand	Branching AIDS Model	Consumers' Surplus	86,508,542
Objective	Welfare Max., -5.5M Profit Floor	Producers' Surplus	-8,381,559
Reserved	First-Class	Social Welfare	78,126,984
Price Controls	Floors Only	Welfare Benchmark	90,279,649

	Simulated Prices ($)		Expected Volumes (000)	
Product	Incumbent	Entrant	Incumbent	Entrant
1Cls	0.4123		64,203,839	0
PrOth	4.8048	4.8774	2,143,068	1,766,360
2Per	0.5311	0.5399	4,892,083	724,786
3Std	0.1833	0.1731	70,856,084	22,708,440
4Pkg	2.5050	2.4897	381,828	160,340
PclSR	1.5910	1.6631	3,562,907	4,154,949

Product	Price Constraint Multiplier	Simulated Entry Frequency	Market Condition	Price Control
1Cls	0	0.0000	Reserved	Floor
PrOth	0	1.0000	Always Entered	Floor
2Per	0	0.7030	Open to Entry	Floor
3Std	0	0.5347	Open to Entry	Floor
4Pkg	0	1.0000	Open to Entry	Floor
PclSR	0	1.0000	Always Entered	Floor

Incumbent Objective	Incumbent Value ($000)	Objective Weight	Global Price Cap	None
Welfare	42,810,306	0.7826	Price Cap Index	0.4544
Profit	-5,500,000	0.2174	Last Cap Multiplier	0
Adj'd Cost	64,535,685	0.0000	Inc. Profit Floor	-5,500,000
Revenue	59,035,685	0.0000	Single Ent. Profit	-2,864,513
			No. of Entrants	1.0000

	Product	Simulated	Profit from Combination ($000)	
Index	Combination	Frequency	Incumbent	Entrant
50	010011	0.1386	-4,625,314	-2,868,006
54	011011	0.3267	-4,790,265	-2,867,907
58	010111	0.1584	-6,076,610	-2,872,569
62	011111	0.3762	-6,238,530	-2,873,329

Observable Properties of the Nash Equilibrium for US Domestic Postal Markets

- Product Combinations – The EC uses four combinations of products that differ with respect to 2Per (Periodicals) and 3Std (Standard Mail).
- Limit Pricing – The PO's prices leave the EC with about the same profit (-2,864,513) on each product combination.
- Stochastic Entry – The EC's product combinations are used with different frequencies resulting in entry frequencies less than one for 2Per and 3Std.
- Number of Entrants – The market is not profitable for more than one entering EC.
- PO Objective – The PO maximizes welfare on its own products subject to a profit floor. This results in an objective that positively weights both Welfare and Profit.
- PO Welfare, Profit etc. - The PO's objective values are weighted averages over the outcomes for the EC's four product combinations.

Observable Properties of the Nash Equilibrium for US Domestic Postal Markets, cont'd.

- Prices – The PO's prices are Ramsey/Boiteux prices given the EC's probabilities of entry and Reaction functions. The EC's prices maximize the EC's profit when it is entered given the PO's prices.
- Price Constraints – Price floors were set at unit volume-variable cost. None of the floors are binding.
- Global Price Cap – There is no global cap. The price cap index computed using USPS FY 2015 volumes is 0.4544.
- Expected Volumes – These volumes are the weighted averages of the volumes for the different product combinations. Opening the markets for 2Per, 3Std and 4Pkg will result in substantial losses of market share by USPS in these markets. USPS gains market share in PrOth and PclSR.
- Social Welfare – Calculated as the sum of the weighted averages of Consumers' and Producers' surpluses for all products offered by both the PO and the EC. The benchmark uses PO prices at marginal cost and the product combination that maximizes social welfare. The equilibrium does well against the benchmark.

Examples of Experiments with the Simulator

	Case 1		Case 2		Case 3		Case 4		Case 5	
Set ID:	Global Price Cap Experiments		Global Price Cap Experiments		Global Price Cap Experiments		Global Price Cap Experiments		Global Price Cap Experiments	
Demand	Branching AIDS Model		Branching AIDS Model		Branching AIDS Model		Branching AIDS Model		Branching AIDS Model	
Objective	Welfare Max., -5.5M Profit Floc		Profit Max.		Profit Max.		Cost Max., -5.5M Profit Floor		Revenue Max., -5.5M Profit Flo	
Reserved	First-Class		First-Class		First-Class		First-Class		First-Class	
Price Controls	Floors Only		Global Cap w/ Ramsey Wgts		Global Cap w/ Calibration Wgts		Global Cap w/ Calibration Wgts		Global Cap w/ Calibration Wgts	
	Simulated Prices ($)		Simulated Prices ($)		Simulated Prices ($)		Simulated Prices ($)		Simulated Prices ($)	
Product	Incumbent	Entrant	Incumbent	Entrant	Incumbent	Entrant	Incumbent	Entrant	Incumbent	Entrant
1Cls	0.4123		0.4119		0.4393		0.4747		0.4448	
PrOth	4.8048	4.8774	4.8038	4.8776	4.5625	4.7714	4.5323	4.7607	4.5323	4.7583
2Per	0.5311	0.5399	0.5347	0.5402	0.5359	0.5402	0.5155	0.5398	0.5295	0.5409
3Std	0.1833	0.1731	0.1835	0.1732	0.1833	0.1731	0.1573		0.1808	0.1732
4Pkg	2.5050	2.4897	2.5041	2.4903	1.9192	2.2323	1.8840	2.2210	1.9074	2.2220
PclSR	1.5910	1.6631	1.5909	1.6632	1.5063	1.6261	1.5063	1.6261	1.5063	1.6262
	Expected Volumes (000)		Expected Volumes (000)		Expected Volumes (000)		Expected Volumes (000)		Expected Volumes (000)	
Product	Incumbent	Entrant	Incumbent	Entrant	Incumbent	Entrant	Incumbent	Entrant	Incumbent	Entrant
1Cls	64,203,839	0	64,224,175	0	62,096,022	0	59,132,778	0	61,689,486	0
PrOth	2,143,068	1,766,360	2,143,778	1,765,609	2,589,348	1,441,426	2,671,809	1,408,199	2,648,075	1,402,710
2Per	4,892,083	724,786	4,898,233	714,369	5,280,016	270,825	5,094,763	119,171	5,324,968	206,742
3Std	70,856,084	22,708,440	70,911,680	22,626,453	72,635,739	21,454,163	99,757,952	0	88,680,383	4,792,344
4Pkg	381,828	160,340	381,944	160,306	438,523	123,450	457,570	107,187	452,964	110,687
PclSR	3,562,907	4,154,949	3,563,969	4,154,779	4,413,535	3,503,869	4,410,634	3,505,138	4,414,503	3,504,693
	Price Limit	Entry	Price Limit	Entry	Price Limit	Entry	Price Limit	Entry	Price Limit	Entry
Product	Multiplier	Frequency	Multiplier	Frequency	Multiplier	Frequency	Multiplier	Frequency	Multiplier	Frequency
1Cls	0	0.0000	0	0.0000	0	0.0000	0	0.0000	0	0.0000
PrOth	0	1.0000	0	1.0000	0	1.0000	-5,626,235	1.0000	-7,364,918	1.0000
2Per	0	0.7030	0	0.6931	0	0.2574	0	0.1188	0	0.2079
3Std	0	0.5347	0	0.5248	0	0.4950	0	0.0000	0	0.1188
4Pkg	0	1.0000	0	1.0000	0	1.0000	0	0.8812	0	0.8911
PclSR	0	1.0000	0	1.0000	-317,532	1.0000	-10,126,772	1.0000	-13,597,319	1.0000
Welfare (000)	78,126,984		78,141,807		80,120,429		84,718,218		83,621,682	
Benchmark	90,279,649		90,279,649		90,279,649		90,279,649		90,279,649	
Entrant Profit	-2,864,513		-2,861,094		-3,561,868		-3,601,033		-3,604,424	
Last Cap Multiplier	0		114,243,826		116,421,775		0		82,748,486	
Inc. Profit/Floor	-5,500,000	-5,500,000	-5,488,199	None	-5,094,611	None	-5,500,087	-5,500,000	-4,553,851	-5,500,000
Price Index/Cap ($)	0.4544	None	0.4039	0.4039	0.4544	0.4544	0.4538	0.4544	0.4544	0.4544

Findings Suggested by the Experiments

- Limit pricing by an Incumbent PO and stochastic entry by potential ECs are likely to be common characteristics of equilibrium in liberalized postal markets.
- Social welfare is inversely related to competitive entry. Postal service is an enterprise with increasing returns to scope/scale and decreasing average cost functions. When entry is less frequent welfare increases because the markets are more often supplied efficiently by one rather than two producers.
- A profit maximizing PO can be induced to price efficiently using a global price cap with index weights chosen as the demand volumes resulting from Ramsey/Boiteux prices.
- Good results may also be obtained using non-optimal index weights such as historical volumes.
- A non-profit maximizing PO can be regulated to price fairly efficiently by using a combination of a global price cap and a floor on profits. An effective floor on profits has the added advantage of encouraging efficient production.
- Price regulation should include individual floors on the PO's prices. When these floor are set at unit volume-variable cost they are sometimes effective, particularly if the PO is not a profit maximizer.
- Cost maximization and revenue maximization (both subject to the same profit floor and global price cap) yield surprisingly similar results.

Overview of the Issues Raised by the Paper

- Our simulator applies to liberalized markets with several distinct properties. Do such markets actually exist? Are they common? Do they require special treatment?
- Our simulator assumes that these markets behave as games with Nash equilibriums of a particular kind. Do liberalized markets actually work this way? Some other way?
- The simulator mimics the behavior of a liberalized market in order to determine its Nash equilibrium by the method of fictitious play. Is the simulator technically correct in all of its essential details? Does it work acceptably? Is it as original as the authors seem to believe?
- The simulator is an experimental apparatus intended for use in studies of liberalized markets under alternative market conditions and regulatory regimes. How far should a researcher trust empirical findings based upon simulated results? Is the simulator realistic?
- Our intention was to design and build a simulator that would be applicable to a wide range of liberalized markets and regulatory arrangements. Is the simulator a generally useful tool in its present form? With modifications?
- As it is designed, the simulator requires demand and cost data in specific forms. Are the information requirements mostly feasible?
- Does the example typify the application of the simulator to other markets and regulatory situations? Are limit pricing and stochastic entry as common as the simulated results from the example cases suggest?