Detecting Collusion by Profitable Deviation: An Application to London Bus Depots

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Bus Operators are often Private in the UK

(a) GoAhead (b) Arriva (c) StageCoach

Figure: Some Examples From London

UK Competition Commission 2011: Competition Outside London is limited, because...

- *"[...] operator conduct by which operators avoid competing with other operators in* **'Core Territories'** *(certain parts of an operator's network which it regards as its 'own' territory) leading to geographic market segregation."*

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- *"We found, in relation to two operators (Arriva and Go-Ahead) in parts of the North-East of England, conduct by which they avoided competition in Core Territories, leading to geographic market segregation."*
- *"We have seen retaliatory conduct in several areas, and consideration of retaliation elsewhere [...]"*
- *"[...] concerned that geographic market segregation might be a more widespread feature than we have identified"*

This Paper

1. Build Custom Dataset of London Bus Garage ownership.
2. Document spatial segregation of London Operators.
3. Propose an equilibrium model of Garage Choice.
4. Use the model to predict moves into garages which did not happen.
5. Make inference about collusive behavior.

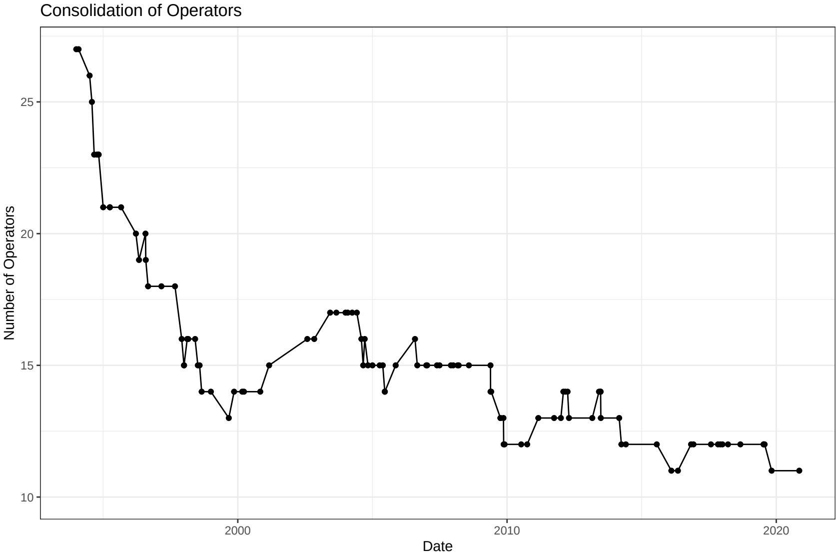
London Bus Market

- **London Buses** (London Bus Services Ltd) is part of **Transport for London (TfL)**, a local government body (Chairman: Mayor of London)
- London Buses transports over 6 million passengers per day on 675 routes.
- TfL purchases bus operation services for an average 261 million £ per year from private operators.

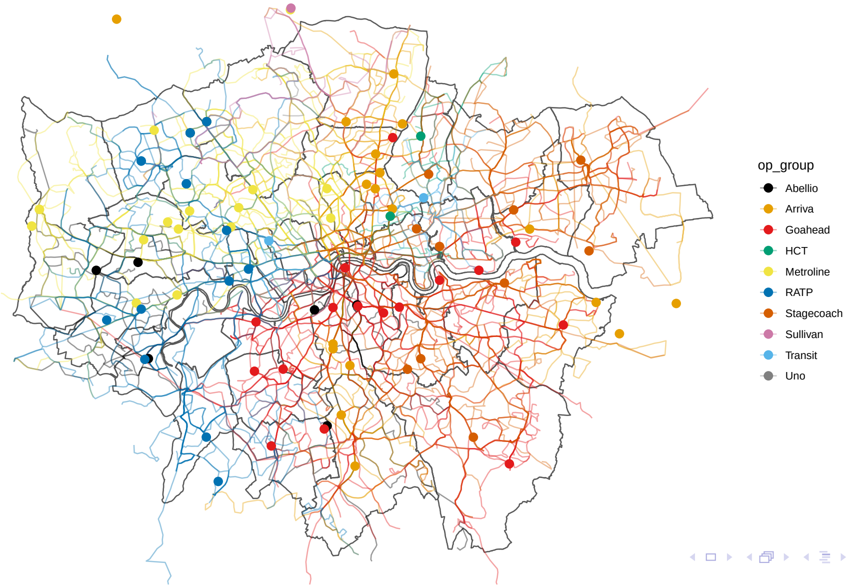
History of London's Bus System

- Initially, several private entities provided public transport in UK.
- 1969: Full Nationalization: *The National Bus Company*.
- 1995: London Bus Operations divested into 12 companies.
- We still find some reference to this initial geography today.
- today: Market dominated by 6 large international firms.

Operator Consolidation



Route Network and Garage Locations (2019)



Market Arrangements: Tendering of Routes

- TfL renews roughly 15% of route contracts each year via *bundled auction*.
- Each contract lasts for 5 years and specifies *all* details of operations: route, frequence, vehicle type, minimum performance standards etc. Garages are **privately owned**.
- Cantillon and Pesendorfer (2006) study same market. Combinatorial Auction. Lowest cost bid obtains the contract.
- Bid = Revenue of operator, e.g. GoAhead in 2003–2019 obtained 399 routes for a total of 1,030 million £.
- What do we know about bidding behaviour?

Bid statistics

13 operator groups, 6 large ones* but minimal competition by route:

	mean	sd	min	median	max
Bid (millions)	2.57	2.06	0.00	2.24	18.17
Cost per Mile	7.86	8.34	1.94	5.17	83.53
Number Bidders	2.83	1.10	1.00	3.00	9.00
Length of Route	7.91	2.61	2.00	8.00	24.00
PVR route	11.66	7.08	0.00	11.00	53.00

* Arriva (German), StageCoach (Scottish), Go-Ahead (British), RATP (French), ComfortDelGiro (Italian), Abellio (Dutch)

From TfL procurement data 2003-2018

Conceptual Framework

- Two-stage setup: Operators first get garage(s), then bid for routes. (We document this.)

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- Given fixed contract details, the location of garages is one of a few remaining **margins for competition**.

Conceptual Framework

- Two-stage setup: Operators first get garage(s), then bid for routes. (We document this.)
- Operator Profit is determined at bidding stage.
- Given fixed contract details, the location of garages is one of a few remaining **margins for competition**.
- We focus on the first stage only here: Who owns which set of garages? We assume a competitive market, hence a unique equilibrium price p_j^* for garage j. (We document the importance of garage location for bids.)

Literature

1. Firm Entry: Bresnahan and Reiss (1990, 1991); Berry (1992)
2. Spatial Entry rather than product space diversification: Mazzeo (2002); Seim (2006)
3. Importance of Density of existing establishments: Jia (2008); Holmes (2011)
4. Collusion Detection: Porter and Zona (1993, 1999)
5. Local profits: Krugman (1991); Combes and Gobillon (2015)
6. London Bus Market Auction: Cantillon and Pesendorfer (2006, 2007)

Literature

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Here: Two opposing forces.

Want to be far away from competitors to capture local monopoly rents; But also agglomeration benefits of garages close to each other. Like Olivares et al. (2012)!

Outline

Introduction

Data

- Garage Location $\mapsto$ Bidding Behaviour
- Garage Ownership (Changes)

Garage Choice Model

Predicting Non-Realized Moves

Data

Tender-, Route- and Garage-level Data

- Tender data: TfL publishes all tender data since 2003.
- Which route operated from which garage: London Omnibus Traction Society, and `londonbusroutes.net`, `londonbuses.co.uk`, `countrybus.org`, `bus-routes-in-london.fandom.com`, `wikipedia.com`
- Garage Locations and Ownership: London Bus Routes website.
- We build a custom data set defined on *change dates*, i.e. dates when at least one garage changes ownership, spanning 1995–2019.

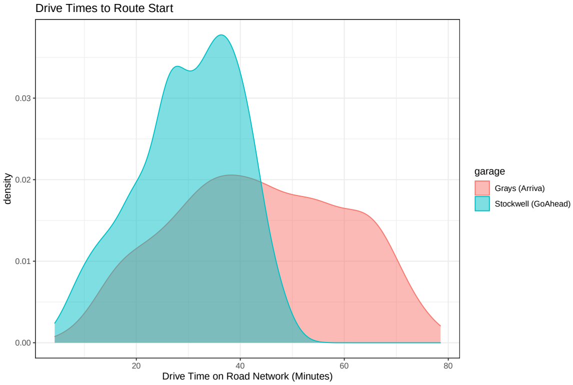
Data

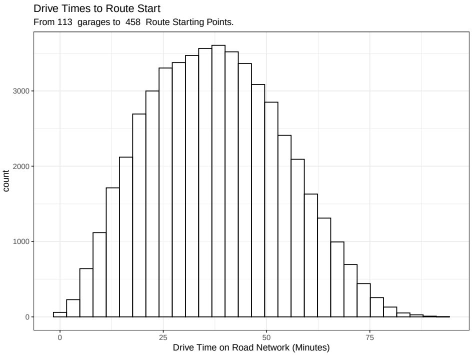
Drivetimes on London Street Network

- We compute the number of minutes it takes on London's street network from garage i to point of interest j.
- Points of interest: all (56K) bus stops, all other garages.
- We use the Open Source Routing Machine for this task.
- Drive times are **highly nonlinear**.

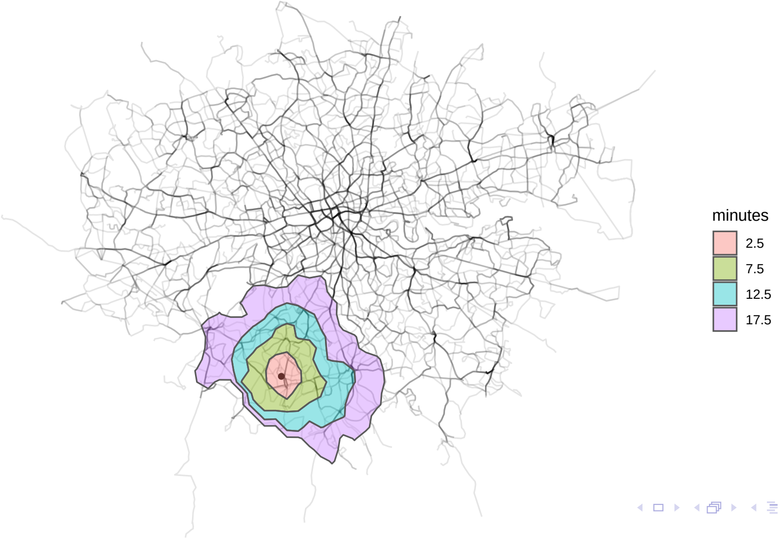
Data

Drivetimes on London Street Network





Isochrones for garage A



Isochrones for garage AC

Isochrones for garage BE

Garage Location $\mapsto$ Bidding Behaviour

- Cantillon and Pesendorfer (2007) find for operating costs of operators:

$$
\begin{aligned}
c_{irt} = {} & Constant_t + DeadMiles_{irt} + DeadMiles_{irt}^2 + Fringe_i \\
& - NrGarages_{it} - DensityGarages_{it} + \nu_{irt}
\end{aligned}
$$

- **Dead Miles** are industry measure of distance garage - start (stop) of route.
- We use drive times to measure dead miles and re-run this regression to verify our data.

Garage Location $\mapsto$ Bidding Behaviour

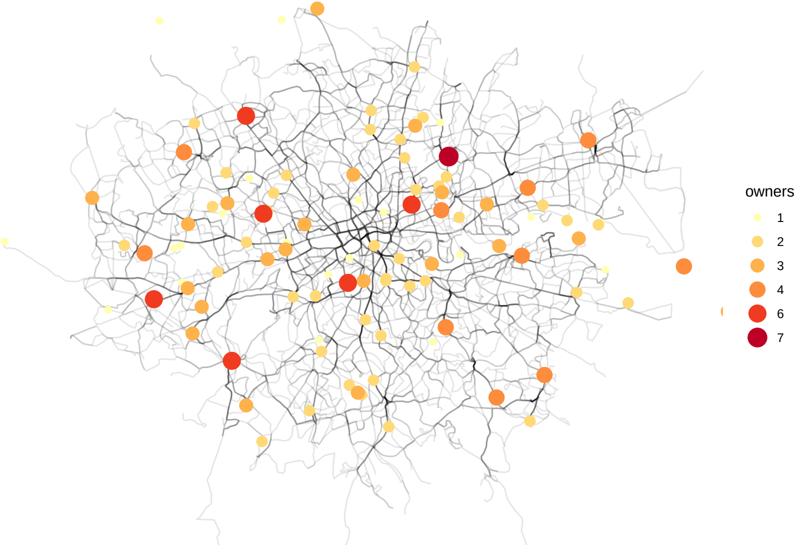
	Accepted Bid (in Million Pounds Sterling)				
	(1)	(2)	(3)	(4)	(5)
Dead Miles Start-Stop (Minutes)	0.073***	0.074***	0.081***	0.082***	0.020**
	(0.012)	(0.012)	(0.012)	(0.012)	(0.006)
Route Length	0.082***	0.085***	0.071**	0.082***	-0.026*
	(0.023)	(0.022)	(0.022)	(0.022)	(0.012)
Number of Bidders				-0.335***	-0.139***
				(0.055)	(0.030)
Peak Vehicle Requirement (PVR)					0.233***
					(0.005)
Constant	1.371***	0.791**	0.539	1.489***	-0.577**
	(0.218)	(0.285)	(0.362)	(0.389)	(0.217)
Year FE	-	✓	✓	✓	✓
Winner FE	-	-	✓	✓	✓
Num.Obs.	1126	1126	1126	1126	1126
R2	0.052	0.139	0.185	0.211	0.762
RMSE	1.98	1.90	1.86	1.83	1.01

$+$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

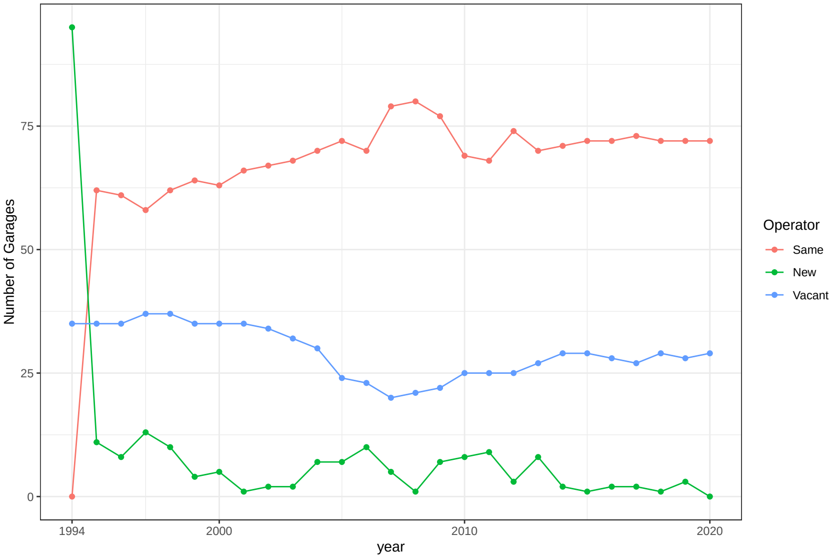
Garage Ownership (Changes)

- We have 96 *change dates* with at least one garage ownership change 1995–2019.
- So, ownership changes are infrequent.
- We observe extremely few *new* garages (building restrictions) and assume those away – set of garages is fixed over time!
- We call a garage which does not exist anymore (or not yet): *vacant*.
- Some garages change owners very often – others never.

Garage Ownership 1994−2020



Ownership Changes over Time



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Garage Choice Model

Setup

- In reality, operators transact garages. At time t we observe a **matching** $M_t(\mathcal{N}, \mathcal{J})$ of $\mathcal{N}$ operators to $\mathcal{J}$ garages. (We don't observe the transaction price for most cases.)

Garage Choice Model

Setup

- In reality, operators transact garages. At time t we observe a **matching** $M_t(\mathcal{N}, \mathcal{J})$ of $\mathcal{N}$ operators to $\mathcal{J}$ garages. (We don't observe the transaction price for most cases.)
- For now, we simplify and say: $\boxed{\text{garages choose operators.}}$ Also: Static model (huge simplication).
- We observe garage i changing from operator A to B at date t: The utility of the garage was highest from that choice.
- We observe *another* garage j *not* change ownership in t: highest utility from same owner: hence, chooses current occupier.
- We think of *garage utility* as a reduced form of **match surplus**.

Garage Choice Model

Setup

- Model utility of garage i - operator j match as

$$\pi_{ijt}\left(X_i, \Gamma^O_{i,j}, \Gamma^C_{i,j}\right)$$

where

- X_i: garage characteristics.
- $\Gamma^O_{i,j}$: distance of i to j *own's* network
- $\Gamma^O_{i,j}$: distance of i to j *'s competitors'* network.
- We parameterize π as a linear function and add a logit shock.
- Each period, each garage chooses most prefered operator (stayers choose incumbent.)

Garage Choice Model

Results: Estimated for Actual Entry Decisions Only

$$\Pr(i \text{ chooses } j) = \frac{exp(\pi_{ijt})}{1 + \sum_k exp(\pi_{ikt})}$$

	(1)	(2)	(3)
Avg. drivetime to own garages	-0.076***	-0.086***	-0.076***
	(0.009)	(0.010)	(0.010)
# of own garages		0.070**	0.046+
		(0.023)	(0.025)
# of comp garages within 10min			-0.410**
			(0.152)
Num.Obs.	109	109	109

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Is That a *Good* Garage Choice Model?

- No widely accepted R^2 measure for MLE problems.
- From Statistical Learning: how good at predicting are we?
- In a binary setting: confusion matrix, tabulate data vs model.
- Importance of **cutoff**: Must classify probability $p \in [0, 1]$ as `TRUE/FALSE`.
- ROC curves, and *Area Under Curve* measures.

Is That a *Good* Garage Choice Model?

Here we look at the predictions for alternative *Arriva*:

	Model	
	FALSE	TRUE
FALSE	0.7981651	0.0733945
TRUE	0.0733945	0.0550459

(a) Cutoff 0.2

	Model	
	FALSE	TRUE
FALSE	0.4403670	0.4311927
TRUE	0.0366972	0.0917431

(b) Cutoff 0.1

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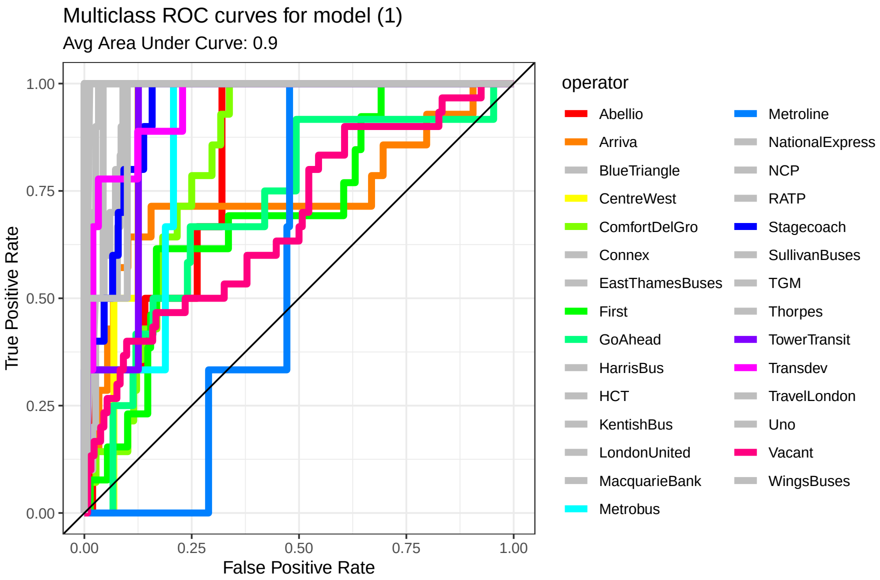
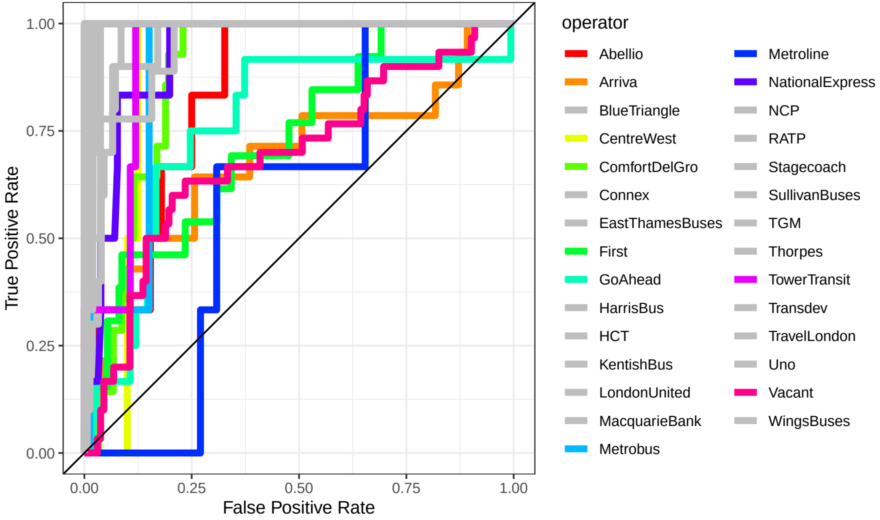
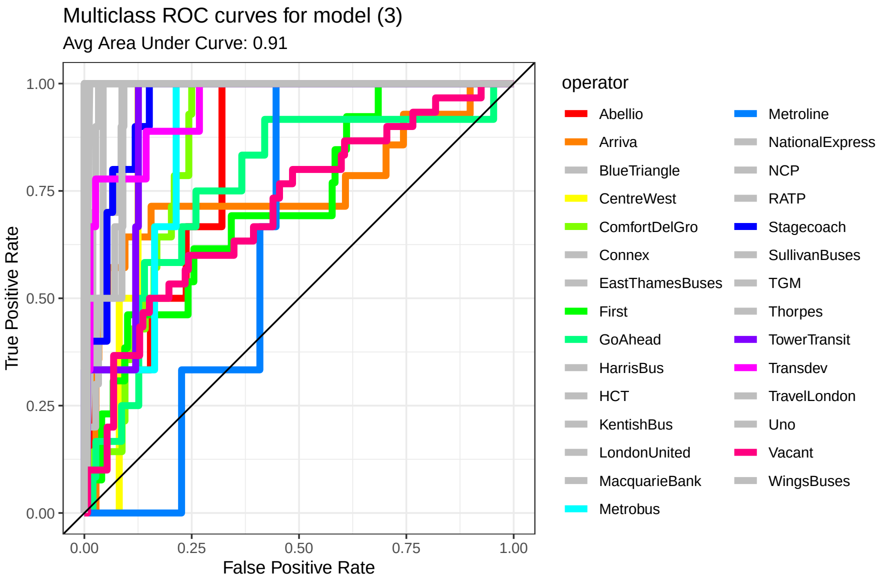
We need a way to quantify each class against the others: *One vs Rest* strategy.


Multiclass ROC curves for model (1)
Avg Area Under Curve: 0.9
True Positive Rate
False Positive Rate
0.00
0.25
0.50
0.75
1.00
0.00
0.25
0.50
0.75
1.00
operator
Abellio
Arriva
BlueTriangle
CentreWest
ComfortDelGro
Connex
EastThamesBuses
First
GoAhead
HarrisBus
HCT
KentishBus
LondonUnited
MacquarieBank
Metrobus
Metroline
NationalExpress
NCP
RATP
Stagecoach
SullivanBuses
TGM
Thorpes
TowerTransit
Transdev
TravelLondon
Uno
Vacant
WingsBuses

Multiclass ROC curves for model (2)

Avg Area Under Curve: 0.91





Multiclass ROC curves for model (3)
Avg Area Under Curve: 0.91
True Positive Rate
False Positive Rate
0.00
0.25
0.50
0.75
1.00
0.00
0.25
0.50
0.75
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Predicting Moves Which Should Have Happened

WORK IN PROGRESS

- **If** we believe our model of entrants, we can apply it to incumbents.
- If our model predicts a different garage-operator combination than to the observed one, this is not compatible with a competitive outcome.
- We can quantify the required **punishment** necessary to sustain collusion – the bribe paid not to make the predicted move.
- Punishment is related to the difference in predicted utilities.

Predicting Moves Which Should Have Happened

WORK IN PROGRESS

choice ID	alternative	Incumbent	Entrant	π
A2004-09-18	Metrobus	FALSE	FALSE	0.50
A2004-09-18	NationalExpress	FALSE	FALSE	0.49
A2004-09-18	GoAhead	TRUE	FALSE	-0.10
A2004-09-18	Transdev	FALSE	FALSE	-0.33
A2004-09-18	TravelLondon	FALSE	FALSE	-0.75

Next step: Relate difference in π to size of implicit punishment necessary to sustain GoAhead's position.

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