Introduction
00000000

Data and variables
0000

Identifying Algo Sellers
000

Algo Pricing Patterns
000

Econometric Analysis
00000

Discussion
0

Algorithms in the Marketplace - An Empirical Analysis of Automated Pricing in E-Commerce

Geza Sapi and Marcel Wieting

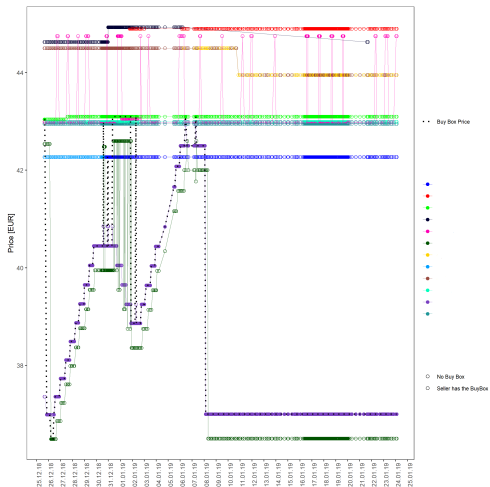December 10, 2021

Overview

Introduction

Figure: Example Product
- Toy Truck

Introduction

- What is the effect of Algorithmic Pricing in E-Commerce?
    - ...on prices?
    - ...on sales?
- We find:
    - ...an inverted-U shaped relationship between the number of competitors and prices where algorithms are present;
    - ...algorithms are able to increase sales.

Literature

- Theory remains ambiguous on how algorithms affect market outcomes:
- Increased transparency Albæk et al. (1997), Albano et al.(2006)
- More frequent interaction Bigoni et al. (2019), Kühn and Tadelis (2017), Brown and MacKay (2020)
- Common agency issues Bernheim and Whinston (1985), Decarolis and Rovigatti (2019)
- Algorithms may learn how to collude autonomously Calvano et al. (2020), Klein (2019), Johnson et al. (2020)
- Better prediction and monitoring makes deviations more profitable Miklos-Thal and Tucker (2019), O'Connor and Wilson (2020)
- Empirical Evidence from Gasoline markets Assad et al. (2020), Clark and Houde (2013, 2014), Byrne and De Roos (2014)
- Empirical Evidence from E-Commerce Chen et al (2016), Zhu and Liu (2018), Jiang et al (2011)

Bol.com as a marketplace

- bol.com is the largest online store in the Netherlands. (1.6 b EUR = five times Amazon in NL)
- bol.com admits third-party sellers and acts itself as both platform operator and seller.
- Buy Box - default seller chosen by operator and prominently displayed (80-90% of the transactions).
- Win the Buy Box = $f(Price, Rating, DeliveryTime...?)$

Introduction
○○○○○●○○○

Data and variables
○○○○

Identifying Algo Sellers
○○○

Algo Pricing Patterns
○○○

Econometric Analysis
○○○○○

Discussion
○

Bol.com as a marketplace

Re-Pricer Software on bol.com and elsewhere

- *"Don't Be a Prisoner in Amazon Price Wars"* (SellerSnap)
- *"Your goal should be to get the Buy Box share you are entitled to while keeping the price high instead of racing to the bottom"* (SellerSnap)
- *"When your competitor increases the price, your price will go up along with that of your competitor"* (EffectConnect)
- Channable offers an entire menu block for *"Do not compete with"* to avoid price competition with selected rivals.

Introduction
○○○○○○○●○

Data and variables
○○○○

Identifying Algo Sellers
○○○

Algo Pricing Patterns
○○○

Econometric Analysis
○○○○○

Discussion
○

Re-Pricer Software on bol.com
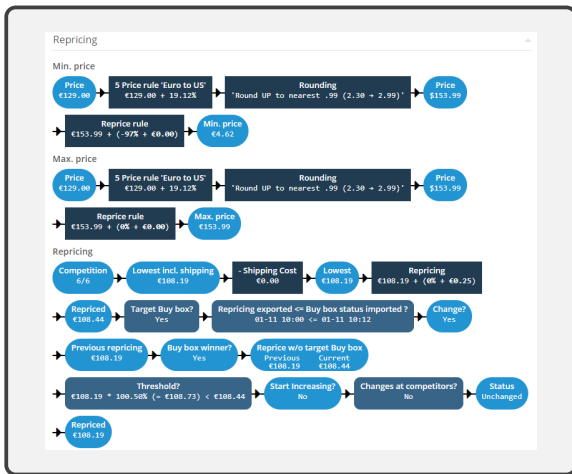

Figure: Example Price Rule from a third party Re-Pricer (ChannelEngine)

Bol.com as a marketplace

- Bol is open to experimenting with new features.

Home › Allowable Retail Price

Allowable Retail Price

DISCLAIMER: Providing this information might lead to price increases, possibly interfering with Dutch and Belgian competition law. If the experiment proves that prices increase significantly, the endpoint will not be continued in V4.

The technical documentation for developers can be found on https://api.bol.com/retailer/public/redoc/v4#operation/get-retail-price

Data and variables

- The data was obtained by scraping bol.com in *three* rounds.
    1. Baseline: Generate sample of best-selling products (around 2500 products).
    2. First crawl: 3.0 Mio. observations (approx. every 2h)
    3. Second crawl: 30 Mio. observations (approx. every 30 min.)

- Key Variables: Time, Seller and Product IDs, Prices and Shipping fees, Buy-Box Owner and prices, Seller Ratings and Delivery Times

Summary Statistics

|	Crawl 1 Mean (sd)	Crawl 2 Mean (sd)
BuyBox Price in EUR	45.04	39.34
	(87.29)	(88.55)
Price in EUR	50.03	43.04
	(87.40)	(89.59)
Seller Rating (1-10)	8.78	8.75
	(.44)	(.58)
Delivery Time in Days	2.99	3.77
	(2.92)	(2.47)
Nr. of Sellers per Product	6.05	5.51
	(2.74)	(2.65)
Shipping Fees in EUR	.03	.03
	(.27)	(.31)
Crawl Frequency in Min.	122.85	32.89
	(453.82)	(439.67)
N	2437557	17066561
Products	2846	1949
Sellers	1871	2190
Period	Dec 18 - Jan 19	Feb - Mar 20

Table: Summary Statistics
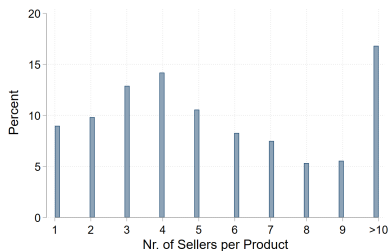
Summary Statistics
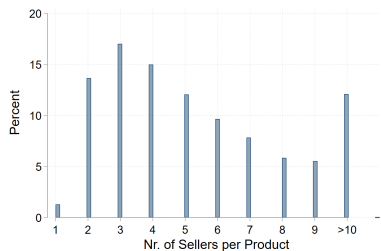
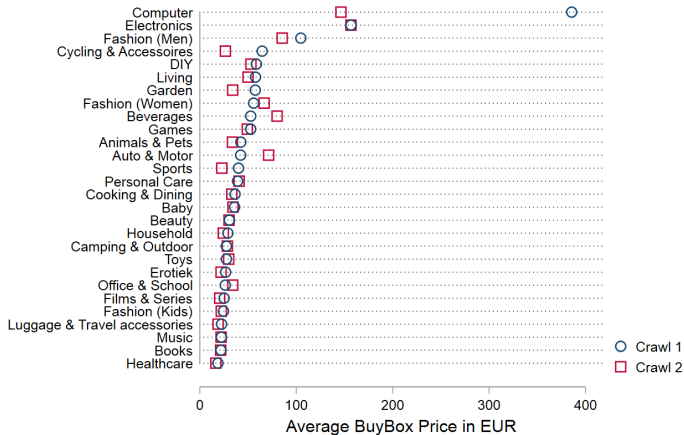Figure: Number of Sellers per Product (Crawls 1 and 2)
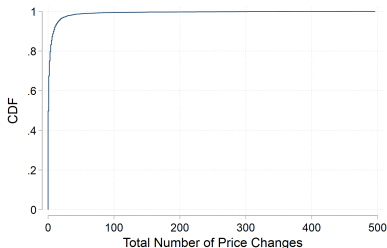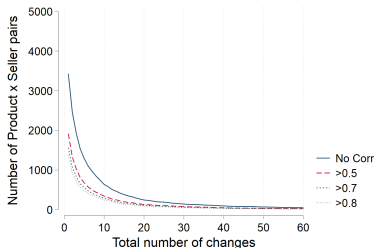
Summary Statistics

Figure: Buy Box Price by Product Category

Identifying Algorithmic Sellers

- Algorithmic sellers change prices *often*
- Algorithmic sellers' prices *correlate* highly with other benchmarks

Figure: Price changes: Long-tail are algorithmic sellers

Figure: Algorithmic seller IDs captured by different measures

Introduction
oooooooo

Data and variables
oooo

Identifying Algo Sellers
ooo

Algo Pricing Patterns
ooo

Econometric Analysis
ooooo

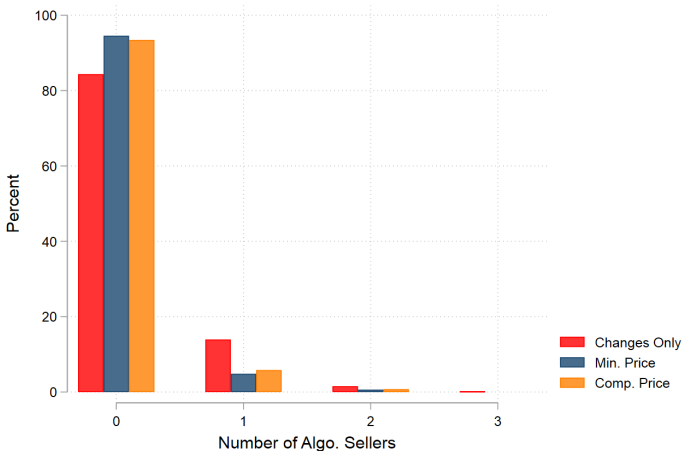Discussion
o

Identifying Algorithmic Sellers

Figure: Distribution of Algorithmic Sellers
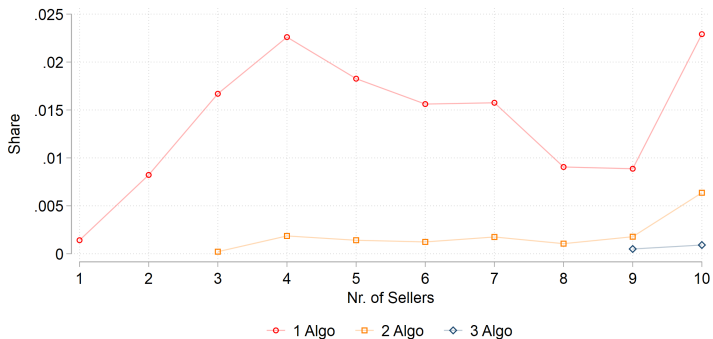
Identifying Algorithmic Sellers

Figure: Distribution of Algorithmic Sellers over Number of Sellers

Algo Pricing Patterns

- We find several distinct Patterns in Algorithmic Pricing
- The most prominent patters are up-and-down jitters.
- Edgeworth cycles or "rockets and feathers" in about 11% of the first crawl.

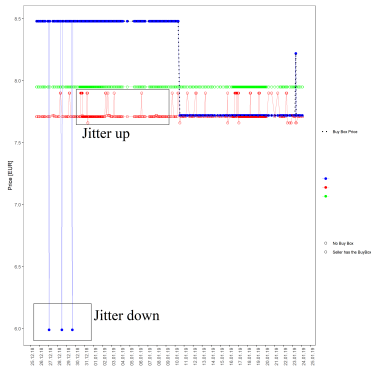| **Algo Pattern**	**Frequency** (in %)
Jitter	52
Alternate	20
Feathers and Rockets	11
Random Jumps	11
Balloons and Rocks	6

Algo Pricing Patterns
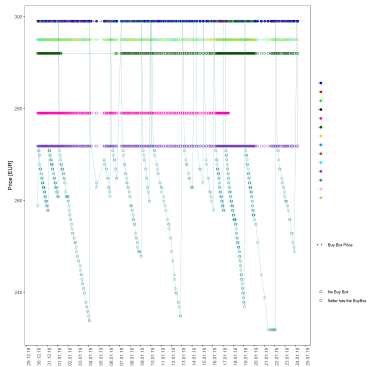

Figure: *Price jitter up* and *down*.

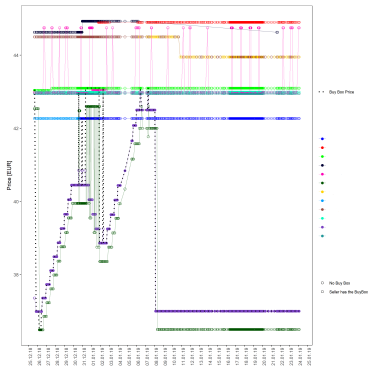Figure: *Rockets and feathers*.
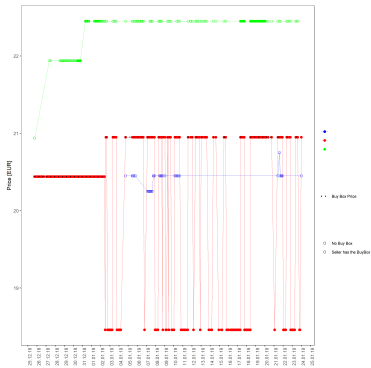
Algo Pricing Patterns

Figure: *Balloons and rocks.*

Figure: *Alternating price.*

Econometric Analysis

1. What is the effect of algorithmic pricing on the Buy Box Price?

$$Log(BboxPrice_{it}) = \beta_0 + \beta_1 Bol_{it} + \beta_2 N.Algo_{it} + \mathbf{X} + \mu_{id} + \epsilon_{it} \tag{1}$$

2. What is the effect of algorithmic pricing on Winning the Buy Box?

$$Bbox_{ijt} = \beta_0 + \beta_1 Log(Price_{ijt}) + \beta_2 Bol_{it} + \beta_3 Algo_{ij} + \mathbf{X} + \mu_j + \lambda_d + \epsilon_{ijt} \tag{2}$$

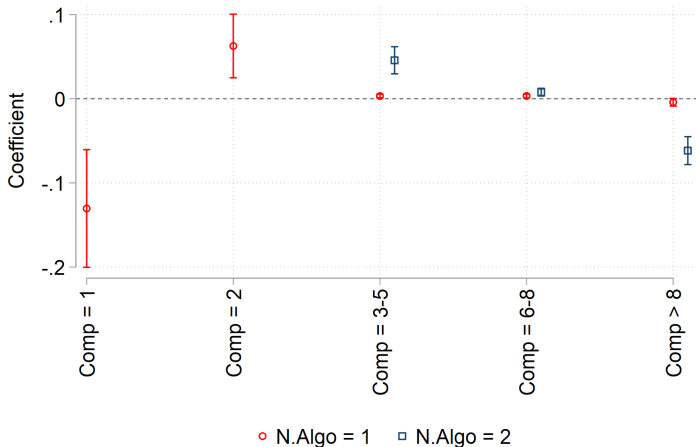# Algo sellers and the Buy Box price

Figure: Results - Algo: Changes
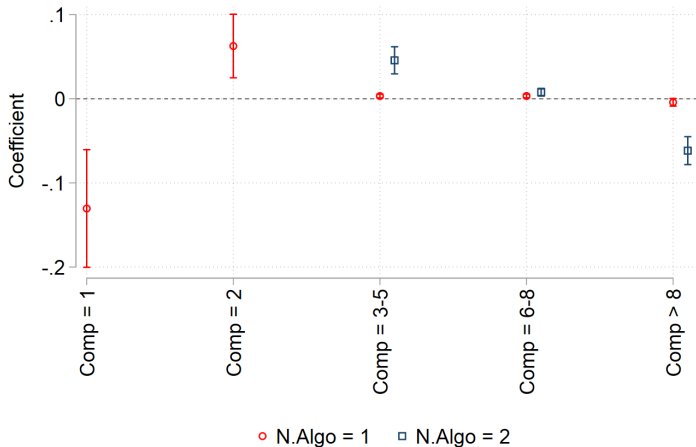
Algo sellers and the Buy Box price

Figure: Results - Algo: Changes & Correlation

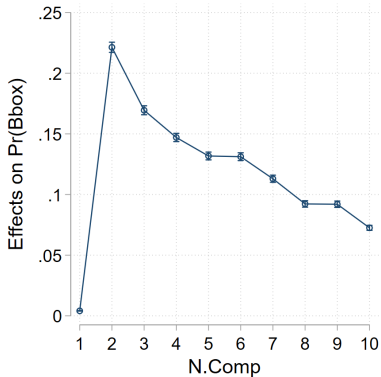## Algo sellers and winning the Buy Box
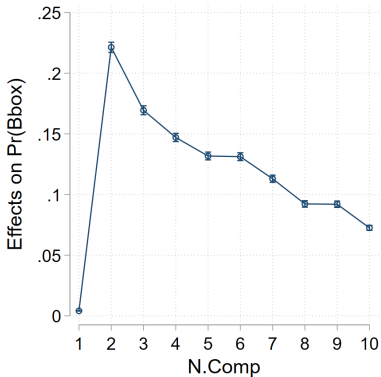

Figure: Algo: Changes

Figure: Algo: Changes & Corr.

▸ Table - Probit   ▸ Table - LPM

Results - Summary

- Inverted-U shaped relationship between Buy Box price and competition when algorithmic sellers are present.
    - Monopoly markets: algorithms reduce prices.
    - Medium competition: algorithmic sellers increase the Buy Box price. Even more so if other algorithms compete.
    - Strong competition: algorithmic sellers reduce the Buy Box price and compete particularly fiercely.
- Algorithmic pricing pays off: sellers using algorithmic pricing generate more sales as they win the Buy Box more often.

Discussion

- Under certain circumstances - The presence of algorithmic sellers goes together with higher prices.
- *"Failing to learn to compete"* (Hansen et al. (2020)) vs. *"Learning to coordinate"* (Calvano et al. (2020))
- We identify price patterns for *screening*. Proof of collusion would most likely require other type of evidence.
- Our screen relies on price *changes*. Stable collusive prices are not *caught*.
- Policy needs to be careful: We observe efficiencies as well as price increases.
- What comes out? vs. What goes in?

Supplementary Material

- Results: Margin ▸ Table ▸ Figure
- Different Algo. Definition ▸ Table

Algo sellers and the Buy Box price

	(1)	(2)	(3)	(4)	(5)
	Comp = 1	Comp = 2	Comp = 3-5	Comp = 6-8	Comp > 8
(1) Algorithmic Pricing: Price Changes only					
Bol comp.=1	-0.0581***	-0.228***	-0.142***	-0.0796***	-0.145***
	(-3.31)	(-12.42)	(-33.46)	(-18.65)	(-26.94)
N.Algo=1	-0.130***	0.0626**	0.00322**	0.00327**	-0.00420
	(-3.66)	(3.25)	(2.85)	(2.89)	(-1.81)
N.Algo=2			0.0457***	0.00780***	-0.0616***
			(5.56)	(3.34)	(-7.28)
Rating	-0.0213	0.00112	-0.0122***	0.00738*	-0.0268***
	(-0.50)	(0.55)	(-5.88)	(2.11)	(-4.63)
Deliverytime	0.00275***	-0.000164	-0.00105***	0.00217***	-0.00462***
	(3.84)	(-1.12)	(-3.31)	(3.67)	(-5.03)
Constant	3.773***	3.513***	3.527***	3.367***	3.513***
	(10.02)	(170.83)	(189.14)	(107.90)	(68.66)
N	104981	156384	317755	99307	73527

▸ Figure

Algo sellers and the Buy Box price

	(1)	(2)	(3)	(4)	(5)
	Comp = 1	Comp = 2	Comp = 3-5	Comp = 6-8	Comp > 8
(2) Algorithmic Pricing: Price Changes and Price Corr. with Comp.					
Bol comp.=1	-0.0586***	-0.232***	-0.142***	-0.0796***	-0.147***
	(-3.38)	(-12.06)	(-33.45)	(-18.65)	(-27.01)
N.Algo=1	-0.184***	0.0300	-0.00364*	-0.00293**	-0.0161***
	(-6.70)	(1.47)	(-2.32)	(-2.64)	(-3.34)
N.Algo=2			0.0396***	-0.00291*	-0.0237**
			(7.59)	(-2.48)	(-2.96)
Rating	-0.0214	0.00175	-0.0122***	0.00725*	-0.0270***
	(-0.50)	(0.80)	(-5.86)	(2.07)	(-4.66)
Deliverytime	0.00275***	-0.000159	-0.00110***	0.00209***	-0.00436***
	(3.83)	(-1.08)	(-3.47)	(3.53)	(-4.74)
Constant	3.774***	3.513***	3.528***	3.370***	3.513***
	(10.02)	(169.97)	(189.22)	(108.01)	(68.61)
N	104981	156384	317755	99307	73527

▸ Figure

Algo sellers and winning the Buy Box

		Probit	
	(1)	(2)	(3)
Bol comp.=1	-1.363***	-1.354***	-1.360***
	(-448.54)	(-447.85)	(-449.91)
Rating	0.220***	0.216***	0.222***
	(58.76)	(57.84)	(59.45)
Price (Log)	0.00509***	0.0111***	0.00875***
	(3.69)	(8.08)	(6.35)
Deliverytime	-0.0931***	-0.0945***	-0.0950***
	(-170.33)	(-172.98)	(-173.87)
Algo=1	0.649***	0.751***	0.824***
	(126.73)	(107.73)	(105.87)
N.Comp=2	-4.414***	-4.435***	-4.441***
	(-177.02)	(-176.54)	(-176.51)
N.Comp=3	-4.876***	-4.884***	-4.884***
	(-194.99)	(-193.89)	(-193.62)
N.Comp=4	-5.098***	-5.093***	-5.095***
	(-203.33)	(-201.63)	(-201.40)
N.Comp=5	-5.219***	-5.217***	-5.226***
	(-207.40)	(-205.80)	(-205.90)
N.Comp=6	-5.270***	-5.268***	-5.282***
	(-208.64)	(-207.04)	(-207.30)
Constant	2.631***	2.668***	2.635***
	(61.18)	(62.00)	(61.13)
N	2553536	2553536	2553536
Algo	Changes	Comp.	Min.

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Dependent variable: Seller own the Buy Box (binary)

▸ Figure

Algo sellers and winning the Buy Box

		LPM	
	(4)	(5)	(6)
Bol comp.=1	-0.180***	-0.181***	-0.181***
	(-191.15)	(-191.21)	(-191.19)
Rating	0.00279**	0.00253**	0.00306***
	(3.00)	(2.73)	(3.30)
Price (Log)	-0.337***	-0.339***	-0.333***
	(-172.20)	(-172.58)	(-170.76)
Deliverytime	-0.0103***	-0.0106***	-0.0104***
	(-107.94)	(-110.62)	(-109.23)
Algo=1	0.145***	0.216***	0.261***
	(82.77)	(82.31)	(93.98)
N.Comp=2	-0.553***	-0.554***	-0.553***
	(-227.65)	(-227.27)	(-226.69)
N.Comp=3	-0.655***	-0.656***	-0.655***
	(-272.16)	(-271.54)	(-270.85)
N.Comp=4	-0.692***	-0.694***	-0.693***
	(-283.59)	(-282.97)	(-282.61)
N.Comp=5	-0.716***	-0.718***	-0.717***
	(-288.15)	(-287.49)	(-287.29)
N.Comp=6	-0.721***	-0.723***	-0.722***
	(-284.48)	(-283.83)	(-283.46)
Constant	2.073***	2.083***	2.060***
	(191.98)	(192.90)	(191.01)
N	2553519	2553519	2553519
FE	Y	Y	Y
Algo	Changes	Comp.	Min.

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Dependent variable: Seller own the Buy Box (binary)
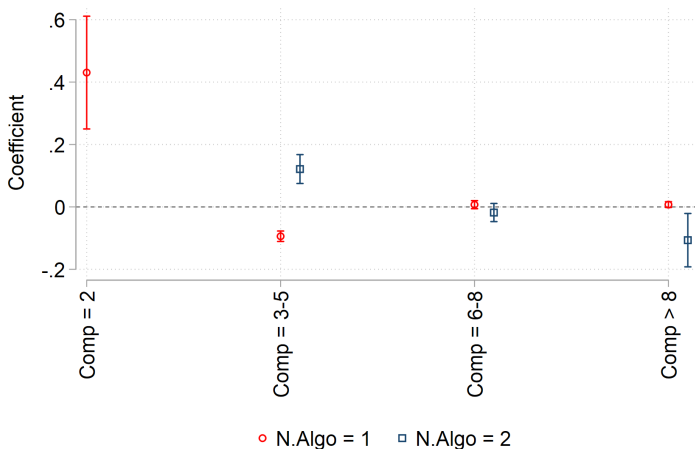
Algo sellers and Margin above the Min. Price

Figure: Results - Algo: Changes

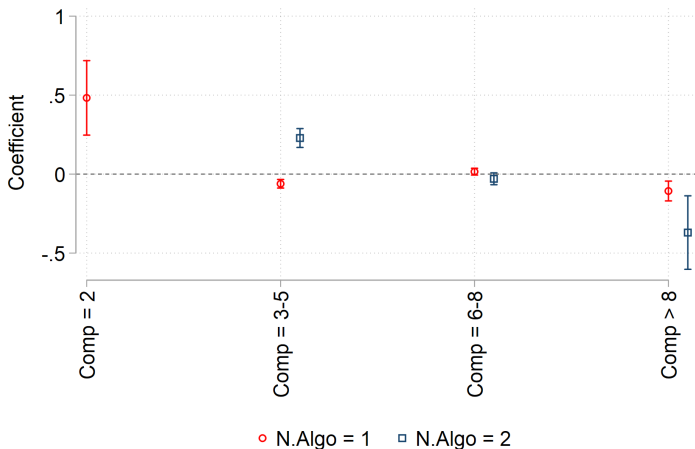# Algo sellers and Margin above the Min. Price

Figure: Results - Algo: Changes & Correlations

Algo sellers and Margin above the Min. Price

	(1) Comp = 1	(2) Comp = 2	(3) Comp = 3-5	(4) Comp = 6-8	(5) Comp > 8
(1) Algorithmic Pricing: Price Changes only					
Bol comp.=1		-0.0557	-0.0226**	0.00694	-0.0101
		(-1.03)	(-2.99)	(0.73)	(-1.86)
N.Algo=1		0.431***	-0.0940***	0.00723	0.00742
		(4.67)	(-10.96)	(1.10)	(1.57)
N.Algo=2			0.121***	-0.0180	-0.107*
			(5.14)	(-1.21)	(-2.44)
Rating	0.0651	0.00808	-0.0365***	0.0148	0.0149*
	(1.64)	(0.86)	(-10.06)	(1.80)	(2.08)
Deliverytime	-0.00178*	-0.0104***	0.0233***	0.00640***	0.0153***
	(-2.57)	(-8.46)	(46.35)	(11.60)	(27.97)
Constant	1.746***	2.696***	3.389***	3.183***	3.453***
	(4.99)	(30.83)	(104.67)	(43.81)	(54.94)
N	44748	177524	880283	564999	635145

Algo sellers and Margin above the Min. Price

	(1)	(2)	(3)	(4)	(5)
	Comp = 1	Comp = 2	Comp = 3-5	Comp = 6-8	Comp > 8
(2) Algorithmic Pricing: Price Changes and Price Corr. with Comp.					
Bol comp.=1		-0.0809	-0.0231**	0.00700	-0.0131*
		(-1.47)	(-3.07)	(0.73)	(-2.51)
N.Algo=1		0.483***	-0.0611***	0.0155	-0.107***
		(4.01)	(-4.41)	(1.41)	(-3.34)
N.Algo=2			0.229***	-0.0294	-0.370**
			(7.52)	(-1.54)	(-3.12)
Rating	0.0651	0.00854	-0.0365***	0.0148	0.0149*
	(1.64)	(0.90)	(-10.05)	(1.80)	(2.09)
Deliverytime	-0.00178*	-0.0104***	0.0233***	0.00640***	0.0153***
	(-2.57)	(-8.49)	(46.34)	(11.60)	(27.97)
Constant	1.746***	2.707***	3.378***	3.183***	3.465***
	(4.99)	(30.88)	(104.38)	(43.81)	(55.08)
N	44748	177524	880283	564999	635145

Seller-Level Algo. Definition

	(1)	(2)	(3)	(4)	(5)
	Comp = 1	Comp = 2	Comp = 3-5	Comp = 6-8	Comp > 8
(1) Algorithmic Pricing: Price Changes only					
N.Algo=1	0.00901	0.0224	0.00352	0.00226	-0.169***
	(0.59)	(1.82)	(1.32)	(0.50)	(-21.58)
N.Algo=2		0.0188	0.00549*	0.00323	-0.163***
		(1.48)	(2.15)	(0.68)	(-18.02)
N.Algo=3			0.00302	0.00751	-0.138***
			(0.95)	(1.64)	(-13.83)
N.Algo=4			-0.0374***	0.0141**	-0.135***
			(-6.52)	(3.01)	(-13.62)
N.Algo=5			-0.0389***	0.00820	-0.143***
			(-6.77)	(1.66)	(-14.38)
N.Algo=6				0.00792	-0.139***
				(1.57)	(-13.75)
N	104981	156384	317755	99307	73527

Table: Algo: Changes

Seller-Level Algo. Definition

	(1)	(2)	(3)	(4)	(5)
	Comp = 1	Comp = 2	Comp = 3-5	Comp = 6-8	Comp > 8
(2) Algorithmic Pricing: Price Changes and Price Corr. with Comp.					
N.Algo=1	0.0800***	0.0261*	0.000995	0.0152***	-0.0622***
	(5.99)	(2.48)	(0.40)	(3.45)	(-10.04)
N.Algo=2		0.0263*	0.00482*	0.0176***	-0.00542
		(2.47)	(2.09)	(3.85)	(-0.71)
N.Algo=3			-0.00962*	0.0250***	0.0000351
			(-2.27)	(5.63)	(0.00)
N.Algo=4			-0.0640***	0.0220***	-0.00129
			(-7.64)	(4.92)	(-0.17)
N.Algo=5				0.0194***	-0.00427
				(3.89)	(-0.53)
N.Algo=6				0.0238***	-0.0312***
				(3.30)	(-3.90)
N	104981	156384	317755	99307	73527

Table: Algo: Changes & Correlation