Advertising as a reminder: evidence from the Dutch State Lottery

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Motivation

- Firms spend large amounts on advertising while relying largely on "industry practice" and "experience" for deciding on how to exactly spend the money.
- This paper:
  - relate online sales/site visits to TV and radio advertisements
  - do this using high frequency data (at the minute/hourly level)
  - in a context that is much cleaner than usual: online sales of lottery tickets
  - use the data to estimate a model of ticket sales that predicts total sales per month as a function of the advertising schedule and can thus be used to improve the timing of TV advertisements.

Related results

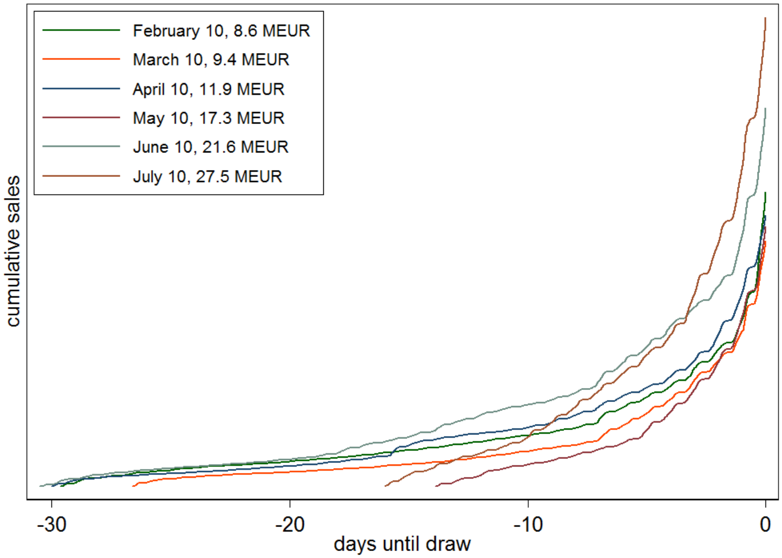
- Effectiveness of TV advertising:
  - Lodisch *et al.* (1995): TV advertising works, but not always; Hu *et al.* (2007): effects for packaged goods significant and stronger after 1995
  - Ackerberg (2001, 2003): distinguishes between informative and image advertising, finds mainly support of former.
- TV advertising and online sales:
  - Joo *et al.* (2013): TV advertising and online search
  - Lewis and Reiley (2013): effect of Super Bowl advertising on online search behavior
  - Stephens-Davidowitz *et al.* (2015): effects of Super Bowl advertising on movie ticket sales.
- From a modeling perspective:
  - Dubé *et al.* (2005): model of sales response to advertising in a discrete choice framework.
  - adoption models: Melnikov (2013) for durable products, De Groote and Verboven (2016) for solar panels.

The market for lottery tickets in the Netherlands

- Staatsloterij: biggest lottery in NL, turnover of 890 MEUR in 2009. Run by the government, goes back to 1726, merger of smaller lotteries.
- Numbers are drawn and the size of the prize depends on how many numbers match with the ticket number. There is a jackpot whose size varies over time.
- $1/5$ Staatslot costs 3 EUR.
- Regular draws on the 10th of the month. Additional draws on King's day, on 1 July, 1 October, and on 31 December (biggest jackpot). Draws take place at 6pm.
- Only other big lottery, Postcodeloterij, works differently and its purpose is to donate money to charity.

Data

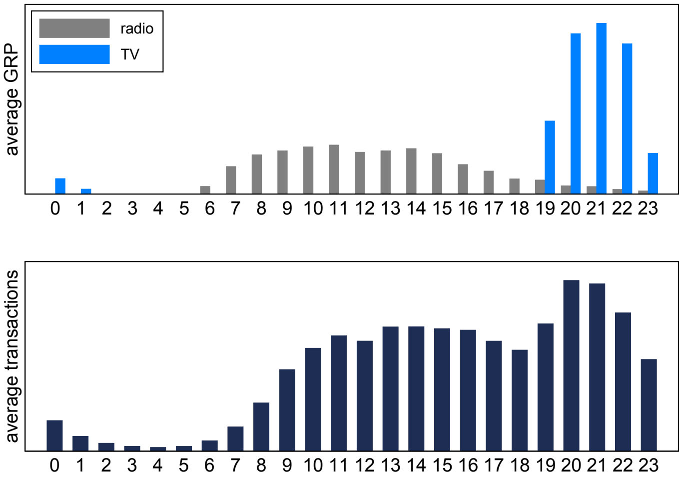
- Online sales and gross rating points (GRP) for TV and radio advertising at the minute level.
- 1 complete year of data, 16 draws.

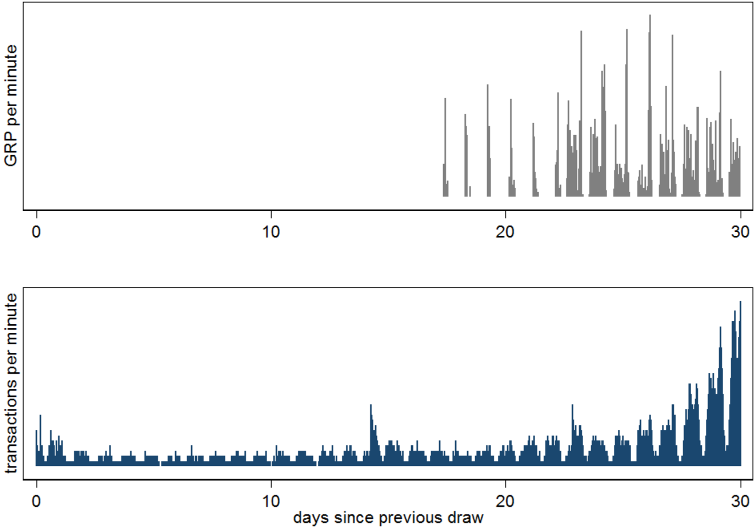

February 10, 8.6 MEUR
March 10, 9.4 MEUR
April 10, 11.9 MEUR
May 10, 17.3 MEUR
June 10, 21.6 MEUR
July 10, 27.5 MEUR
cumulative sales
-30
-20
-10
0
days until draw

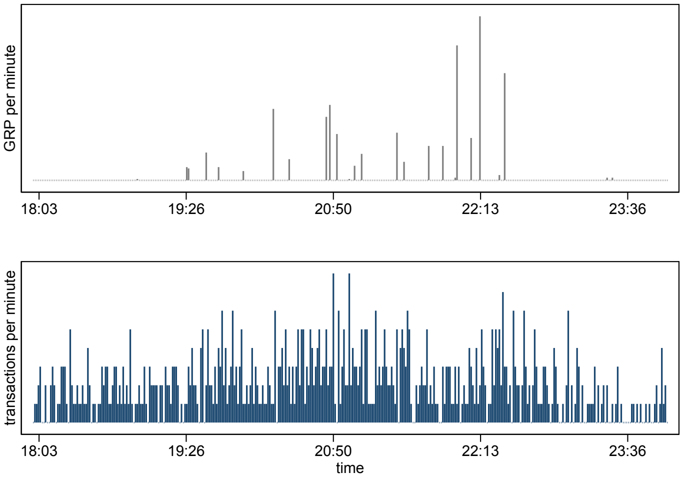
	(1) all draws	(2) regular draws	(3) special draws	(4) all draws
log jackpot size	0.366*	0.366***		0.509*
	(0.178)	(0.106)		(0.251)
special draw	1.509***			2.107**
	(0.492)			(0.633)
log number of days	0.182	0.153	0.805	0.408
	(0.174)	(0.106)	(1.657)	(0.558)
log jackpot size previous draw				-0.245
				(0.297)
special draw in previous draw				-0.107
				(0.969)
log number GRP previous draw				0.954
				(0.583)
Observations	16	12	4	15
R^2	0.562	0.605	0.106	0.727

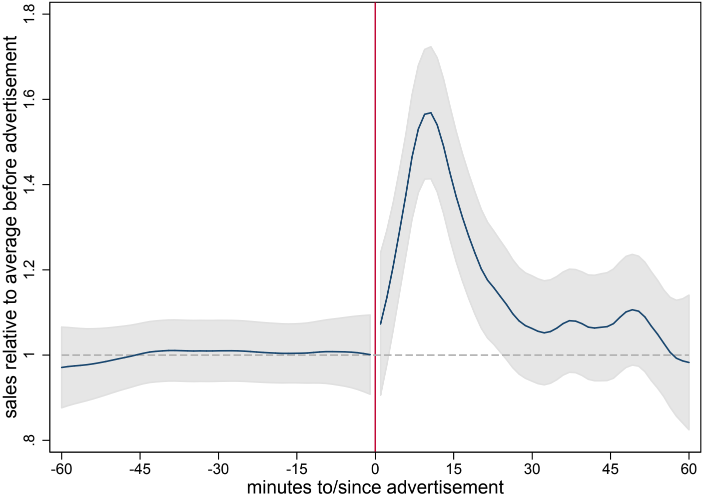
Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$


radio
TV
average GRP
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
average transactions
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23


GRP per minute
0
10
20
30
transactions per minute
0
10
20
30
days since previous draw


GRP per minute
18:03
19:26
20:50
22:13
23:36
transactions per minute
18:03
19:26
20:50
22:13
23:36
time



Notes: We select advertisements with at least 9 GRP and then only keep the ones for which we do not see another advertisement in the hour before and after.

	(1) baseline	(2) before last week	(3) last week	(4) no controls
GRP between 0 and 4 minutes ago	0.0152***	0.00888***	0.00319**	0.0485***
	(0.000982)	(0.00147)	(0.00100)	(0.00200)
5 and 9 minutes	0.0350***	0.0343***	0.0193***	0.0677***
	(0.00101)	(0.00176)	(0.00103)	(0.00195)
10 and 14 minutes	0.0369***	0.0378***	0.0205***	0.0685***
	(0.000881)	(0.00151)	(0.000955)	(0.00184)
15 and 19 minutes	0.0272***	0.0250***	0.0124***	0.0578***
	(0.000911)	(0.00144)	(0.000982)	(0.00187)
20 and 24 minutes	0.0224***	0.0176***	0.00926***	0.0517***
	(0.000908)	(0.00140)	(0.000924)	(0.00185)
25 and 29 minutes	0.0194***	0.0124***	0.00748***	0.0468***
	(0.000978)	(0.00148)	(0.00103)	(0.00187)
0.5 and 1 hour	0.0152***	0.00992***	0.00217***	0.0375***
	(0.000394)	(0.000579)	(0.000441)	(0.000719)
1 and 1.5 hours	0.0106***	0.00737***	0.00102*	0.0242***
	(0.000389)	(0.000573)	(0.000433)	(0.000720)
1.5 and 2 hours	0.00830***	0.00469***	0.00117**	0.0192***
	(0.000397)	(0.000568)	(0.000446)	(0.000698)

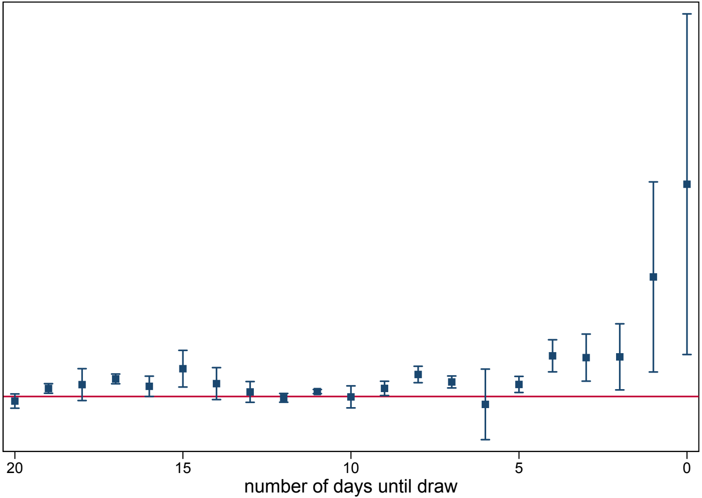
More evidence on the effect of advertising

- Collapse data to the hourly level.
- Regress log of 1 plus online sales on GRP's and lags thereof. Throughout, control for draw, hour and days left until draw dummies.

	(1) baseline	(2) TV and radio	(3) before last week	(4) last week	(5) no controls
GRP current hour	0.0120***		0.0110***	0.00406*	0.0779***
	(0.00145)		(0.00238)	(0.00163)	(0.00536)
GRP 1 hour lagged	0.0120***		0.0121***	0.00529***	0.0431***
	(0.00133)		(0.00245)	(0.00156)	(0.00533)
GRP 2 hours lagged	0.00428**		0.00457	0.000309	0.0277***
	(0.00134)		(0.00235)	(0.00147)	(0.00677)
GRP 3 hours lagged	0.00412*		0.00369	-0.000451	0.0545***
	(0.00168)		(0.00306)	(0.00200)	(0.00654)
GRP TV current hour		0.0128***			
		(0.00185)			
GRP TV 1 hour lagged		0.0133***			
		(0.00168)			
GRP TV 2 hours lagged		0.00329*			
		(0.00163)			
GRP TV 3 hours lagged		0.00154			
		(0.00246)			

Purchase acceleration vs. market expansion

- Purchase acceleration: advertisements make people buy earlier, but not more.
- Market expansion: they also buy more.
- Usually hard to characterize empirically.
- Nice context here: there can be no purchase acceleration towards the end of the time in which people can buy a ticket, which means that if we see advertising effects shortly before that time, then there must at least be some market expansion.



Notes: We aggregate data to the hourly level and then regress the first difference in sales on the first difference in GRP's. We set GRP's to 0 if they are less than 3. We drop all observations where we see more than 3 GRP's of advertising in any of the four hours prior to the advertisement. One separate regression for each time until the draw.

Motivation for estimating a structural model

- The goal of an advertising strategy can be split up in two sub-goals
  - maximize the number of sold tickets for a given number of total GRP in a month
  - in light of this allocate more or less GRP.
- We focus on the first sub-goal.
- Data are informative about the immediate impact of advertisements, model helps us to also understand the cannibalization effect:
  - if, due to a lot of advertising, many individuals buy early, they are out of the market and will not buy late. Moreover, it may be more costly to reach them early, since they plan to buy later (which they may never do)
  - at the same time, only advertising later could be a suboptimal strategy because then one does not get multiple shots at reaching some people.

Model: Overview

- Adoption model in discrete, finite time $t = 1, 2, \ldots, T$.
- At any point in time, consumer decides whether or not to buy a lottery ticket. Can buy at most one ticket.
- Buying a ticket yields flow utility $u_{it} = -p + \delta^{T-t}\Psi + \Gamma(g^a_{it}) + \sigma\varepsilon_{i1t}$, where p is the price of the ticket, δ is the hourly discount factor, Ψ is the value to holding a ticket at the time of the draw, g^a_{it} is an advertising goodwill stock (see below), and ε_{it} is a type 1 extreme value distributed taste shock.
- Not buying a ticket is associated with continuation value $\delta\mathbb{E}[V(g^a_{it+1})|g^a_{it}] + \varepsilon_{i0t}$, where again ε_{i0t} is a type 1 extreme value distributed taste shock.
- Users take into account that the probability to see an advertisement, which serves as a reminder, changes over time. Form expectations consistent with the actual data.

Model: The effect of advertising

- Flow utility of buying a ticket depends on advertising goodwill stock g_{it}^a.
- Following Dubé *et al.* (2005), we specify

$$\Gamma(g_{it}^a) = \gamma log(1 + g_{it}^a)$$

$$g_{it}^a = \begin{cases} g_{it} & \text{if } i \text{ did not see advertisement} \\ g_{it} + log(2) & \text{if } i \text{ saw advertisement} \end{cases}$$

$$g_{it+1} = (1 - \lambda) \cdot g_{it}^a.$$

- (Aside: we use log(2) because in Dubé *et al.* (2005) the specification is $\log(1 + A_t)$, where A_t is the number of advertisements; they do not allow for the fact that some individuals are reached multiple times and others are not reached; we instead model this but then assume that advertisements have a maximal impact when a consumer is reached at least once in a given hour; reaching consumers multiple hours in a row increases the advertising goodwill stock.)

Solving the model

- One time unit is equal to one hour. Compromise between computational burden and how realistic the model is.
- Numerically solve dynamic decision problem on a grid.
- State variables: time, whether or not a consumer has bought, g^a_{it}.
- Decision depends on the expectation of the decision maker on whether he will see an advertisement in the future. Use GRP data to estimate this probability using specification

$$grp_t = x_t\beta + \varepsilon_t,$$

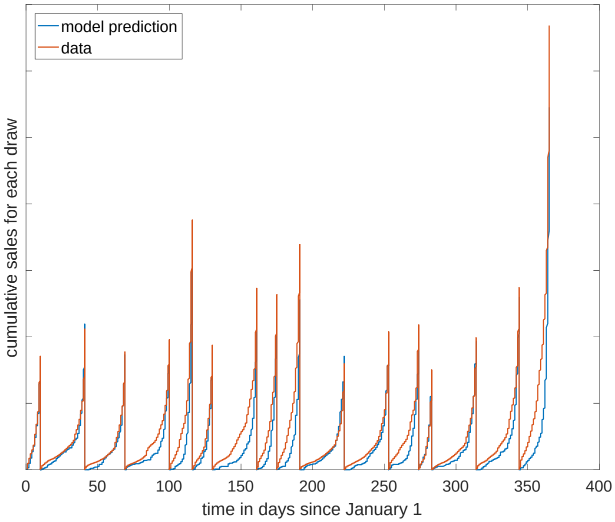
  where x_t has constant term, full set of hour, day, and month dummies.
- Collapse time during the night (count time between Midnight and 8am as 1 hour).

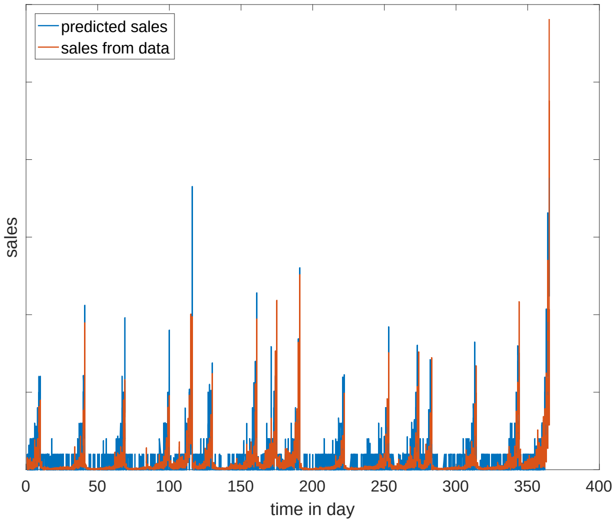
Estimation

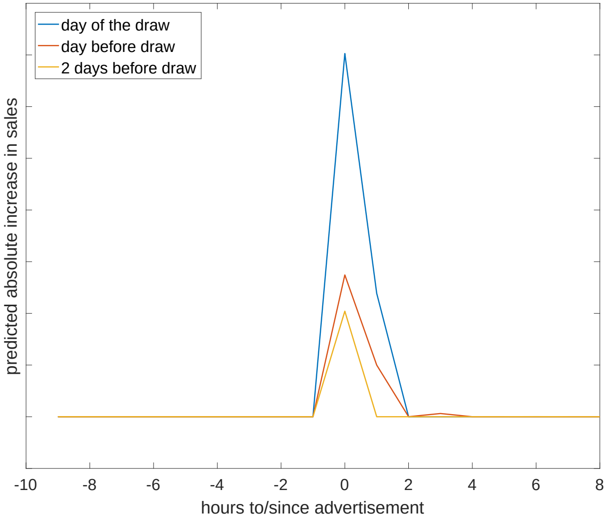
- Assume market size of 250,000 (results robust to alternative assumption).
- 1000 simulated consumers, with smoothing so that the function is smooth in the parameters.
- Simulated method of moments estimation.
- Moments: cumulative sales and sales at a given point in time, with equal weight.
- Our estimation procedure allows for heterogeneity across consumers: some consumers are reached multiple times by advertisements, possibly even in spite of having already bought, while others are not reached repeatedly. Achieved through simulation with smoothing.
- Allowing for this makes the estimation problem more complex. Still, one function evaluation takes less than 1 minute.

Parameter estimates

parameter	estimate	std.err.
depreciation rate goodwill stock (λ)	0.407	0.047
effect of goodwill stock on flow utility (γ)	0.597	0.082
hourly discount factor (δ)	0.992	0.000
multiplying factor taste shock (σ)	0.299	0.002
value to having a ticket on the day of the draw		
10 January, 2014	1.316	0.054
10 February, 2014	1.474	0.040
10 March, 2014	1.268	0.068
10 April, 2014	1.386	0.061
26 April, 2014 (King's Day)	1.763	0.058
10 May, 2014	1.324	0.037
10 June, 2014	1.495	0.042
24 June, 2014 (Orange draw)	1.567	0.030
10 July, 2014	1.488	0.046
10 August, 2014	1.297	0.043
10 September, 2014	1.415	0.050
1 October, 2014 (special 1 October draw)	1.497	0.058
10 October, 2014	1.360	0.044
10 November, 2014	1.378	0.041
10 December, 2014	1.622	0.040
31 December, 2014 (New year's eve draw)	2.051	0.063


model prediction
data
cumulative sales for each draw
0
50
100
150
200
250
300
350
400
time in days since January 1


predicted sales
sales from data
sales
0
50
100
150
200
250
300
350
400
time in day



day of the draw
day before draw
2 days before draw
predicted absolute increase in sales
-10
-8
-6
-4
-2
0
2
4
6
8
hours to/since advertisement

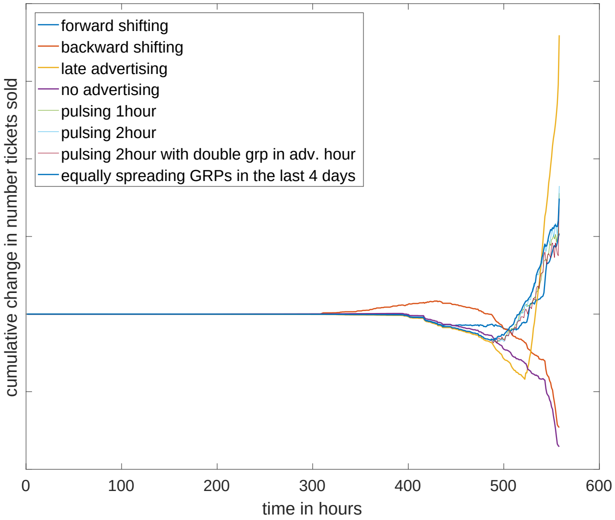
Counterfactuals

- Use the model to evaluate different advertising strategies for February 2014.
- Do this for two cases (to see whether expectations matter):
    - expectations on the probability to see an advertisement in the future consistent with the actual data
    - expectations adapt to the counterfactual strategy.
- Hold total number of GRP fixed and focus on the total number of tickets sold.

Counterfactuals

	expectations	
strategy	unchanged	rational
data (reference point)	100%	100%
no advertising at all	84%	85%
all advertising in the last 2 days before the draw	138%	132%
spreading advertisements equally in the last 4 days before the draw	116%	113%
pulsing strategy in the last 4 days before draw (1 hour blocks)	116%	114%
pulsing strategy in the last 4 days before draw (2 hour blocks)	117%	115%
pulsing strategy in the last 4 days before draw (1 hour double, 3 hour none)	115%	113%
shift advertising from third week before draw to fourth week	111%	109%
shift advertising from fourth week before draw to third week	86%	87%

Notes: In the column labeled "data" consumer expectations are consistent with the actual advertising data. In the last column, we adjust expectations to reflect the change in the policy.

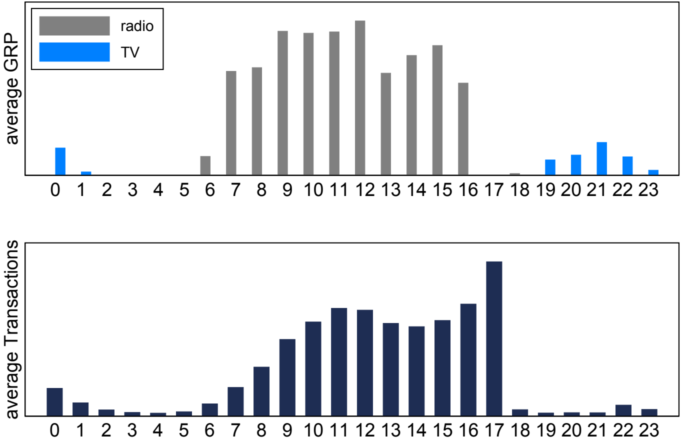


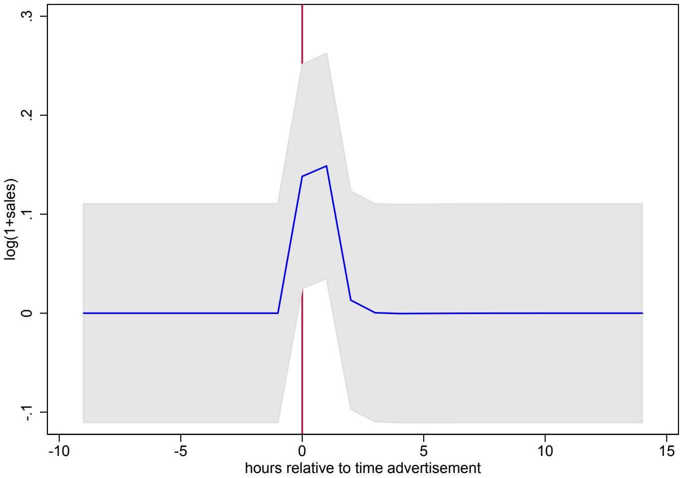
Notes: Number of individuals relative to the baseline case in the data. Consumer expectations are consistent with the GRP schedule.

Summary and concluding remarks

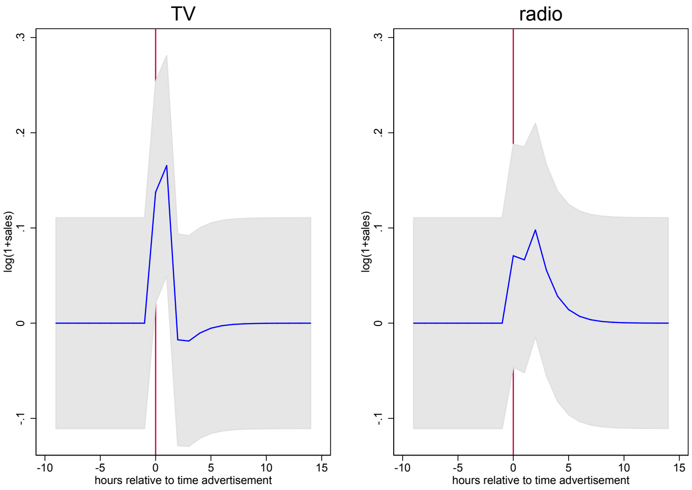
- Look at online sales of lottery tickets. Allows us to measure the short term effect of advertising.
- Find strong effects of advertising that last up to about 4 hours.
- Build a model of long term effects that allows us to simulate sales for counterfactual advertising strategies.
- Find that shifting advertisements to later times may increase overall sales.

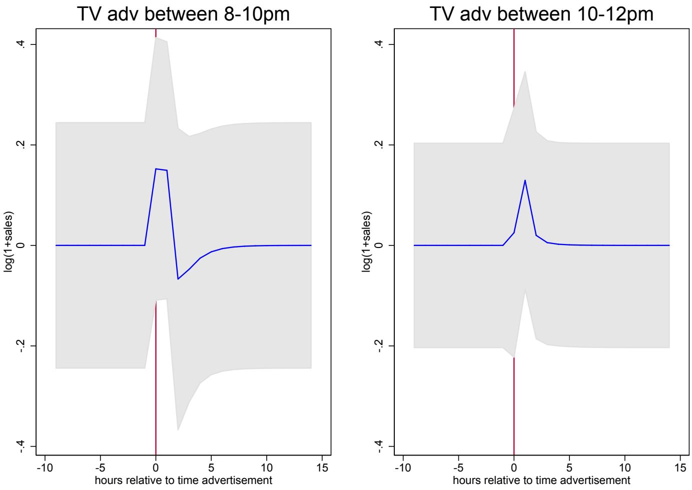
Day of the draw

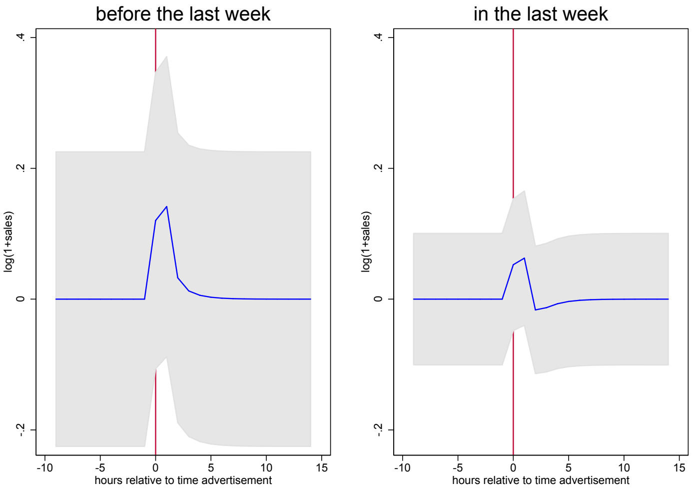


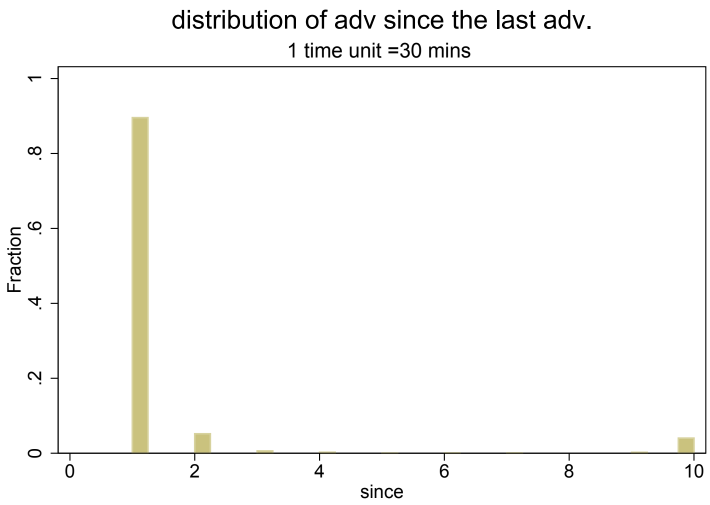


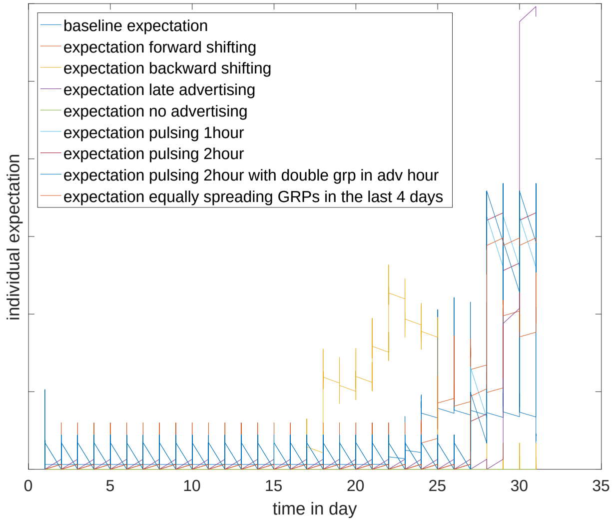
log(1+sales)
-.1
0
.1
.2
.3
-10
-5
0
5
10
15
hours relative to time advertisement


TV
radio
log(1+sales)
.3
.2
.1
0
-.1
-10
-5
0
5
10
15
hours relative to time advertisement

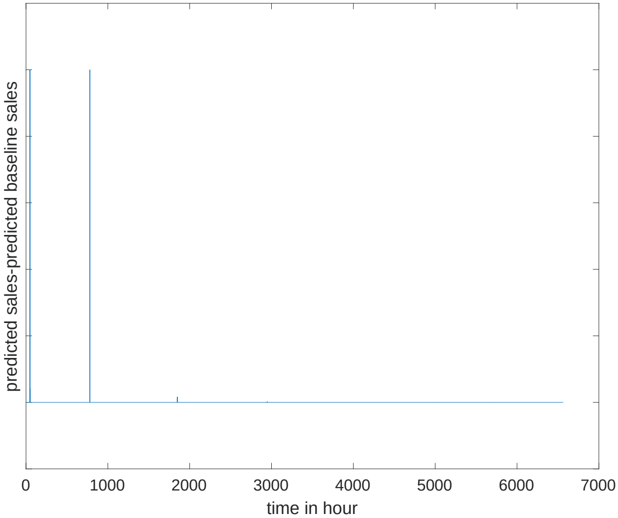

TV adv between 8-10pm
TV adv between 10-12pm
log(1+sales)
.4
.2
0
-.2
-.4
-10
-5
0
5
10
15
hours relative to time advertisement


before the last week
in the last week
log(1+sales)
.4
.2
0
-.2
-10
-5
0
5
10
15
hours relative to time advertisement


distribution of adv since the last adv.
1 time unit =30 mins
Fraction
0
.2
.4
.6
.8
1
0
2
4
6
8
10
since



Notes: Figure shows the expected probability to see an advertisement, from the individual perspective. Obtained from regression of GRP's on time, day, month and draw dummies.


predicted sales-predicted baseline sales
0
1000
2000
3000
4000
5000
6000
7000
time in hour