

Conversion Effects of Online Advertising Vehicles: Nonparametric Bounds and Parametric Estimates

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Different Types of Online Ads

- Sponsored Search
- Display Banner
- Email Ads

The screenshot shows a Google search for "laptop". The search bar at the top has "laptop" entered and a magnifying glass icon. Below the search bar, it says "About 902,000,000 results (0.29 seconds)".

On the left side, there are filters for "Everything", "Images", "Maps", "Videos", "News", "Shopping", and "More". Below these are filters for "Davis, CA" (Change location), "Any time" (Past hour, Past 24 hours, Past week, Past month, Past year, Custom range...), and "More search tools".

The main search results area displays several sponsored advertisements:

- New MacBook Air Laptop** - Thin and light. Yet rock solid. www.apple.com/macbookair. The ultimate everyday notebook.
- Sony VAIO Laptops** - Portable, High-Performance Laptops. store.sony.com/VAIO. Smart performance w/Intel® Core™ i5.
- Laptop at Sears®** | sears.com. Find the **Laptop** That's Right For Your Computing Needs. Shop Now!
- HP® Laptops**. www.shopping.hp.com. shopping.hp.com is rated ★★★★★. Buy Direct from HP for Our Best Deals on Laptops Powered by Intel®!
- High-Performance Laptops**. www.dell.com/laptops. Check Out Powerful XPS & Inspiron Laptops w/ Intel® Core™ at Dell! [Show products from Dell](#)
- Cheap Laptops**. www.tigerdirect.com. tigerdirect.com is rated ★★★★★. Lowest Prices and Huge Selection Same Day Shipping. Save Now! [Show products from TigerDirect.com](#)
- Outlet Laptops & Netbooks | Dell**. www.dell.com/us/dhlp/laptops. Dell Outlet Home & Home Office; Outlet **Laptops** ... XPS 17 Dell Outlet **Laptops** ... The XPS™ 15 **laptop** brings movies, games, music and Web chat to life with ...

At the bottom right, there are icons for "Ads", "Images", "Maps", "Videos", "News", "Shopping", and "More".

Size of the Industry

- The IAB-PWC 2008 Report
 - The total revenue is 23.4 billion in 2008.
 - 45% was paid for sponsored search ads.
 - 21% was paid for banner ads.

The screenshot shows the front page of The New York Times website. At the top, there are navigation links: HOME PAGE, TODAY'S PAPER, VIDEO, MOST POPULAR, and TIMES TOPICS. On the right, there are subscription links: Subscribe: Digital / Home Delivery, Log In, and Register Now.

The main header features the New York Times logo, the date Tuesday, October 18, 2011, and the last update time: 3:09 PM ET. Below the header, there are several advertisements: Lufthansa FlyNet, CloudStream, and a Lufthansa banner for FlyNet and CloudStream. The banner includes the text "Enjoy Internet at 600 mph." and "Create a digital carry-on." with an image of a Lufthansa airplane.

The main content area features a large article titled "Hamas Frees Israeli Soldier as Prisoner Swap Begins" by Ethan Bronner and Stephen Farrell, dated 1:53 PM ET. The article discusses the release of Gilad Shalit, an Israeli soldier held for more than five years by Hamas, in exchange for hundreds of Palestinian prisoners in Israeli jails. The article includes a sub-headline "Updates on the Prisoner Swap" and a link to "Names: Released Prisoners".

To the right of the main article is a section titled "CRITIC'S NOTEBOOK" featuring a photo of a notebook with handwritten notes and a pen. Below the photo is the text "Long Gonzo on the New York Times".

On the far right, there is a section titled "OPINION" with a sub-headline "Rejection of Reason" and a list of contributors: Brooks, Bruner, Nicosia, Editorial, and Redford. Below this is a section titled "WHAT'S POPULAR NOW" with a list of popular articles: "The Evangelical Rejection of Reason", "We Can All Become Job Creators", and "The Evangelical Rejection of Reason".

At the bottom of the page, there is a section titled "Log In With Facebook" with a link to "Log in to see what your friends are sharing on nytimes.com." and links to "Privacy Policy" and "What's This?".

How Online Advertising Works

- The Impression Effect
 - Information
 - Public image
- The Click-through Effect: unique to online advertising

The screenshot shows an email interface on the left with a sidebar containing 'Compose mail', 'Inbox', 'Buzz', 'Starred', 'Important', 'Sent Mail', 'Drafts', and 'chat'. The main area displays an email from 'Costco News' with the subject 'Get \$70 OFF The Blendtec Total Blender at Costco.com, Plus Shop Our Online-Only Coupon Offers!'. The email content features the Costco logo, a large image of a Blendtec Total Blender with a red bow, and text stating 'Blendtec® Total Blender Includes WildSide Jar and FourSide Jar' and '\$369⁹⁹ Delivered After \$70 OFF'. It also mentions 'ONLINE-ONLY COUPON OFFERS Valid Through 11/27/11' and 'Click Here for All Offers >'. On the right, there is a small advertisement for a 'Fresh-Cut Premium-Grade Fraser Fir Christmas Tree' with 'Up To \$50 OFF' and 'Valid 11/10/11 - 12/18/11'.

Question of the Paper

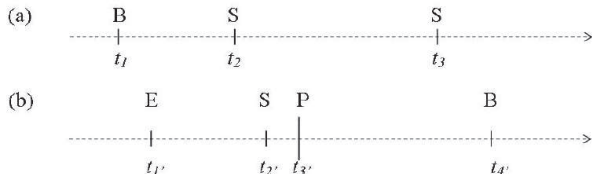
- Question: what is the tangible outcome by which ad clicks are converted to purchases?
 - The conversion rate
 - The conversion dollar

Previous Empirical Literature

- User Browsing Behavior and Future Website Visit Prediction
 - Park and Fader 2004; Montgomery et al. 2004; Johnson et al. 2004
- Conversion Effect of Website Visits
 - Moe and Fader 2004
- Conversion Effect of Banner Ad Exposure
 - Manchanda et al. 2006
- Browsing behaviors are assumed exogeneous even for studies on conversion effects.

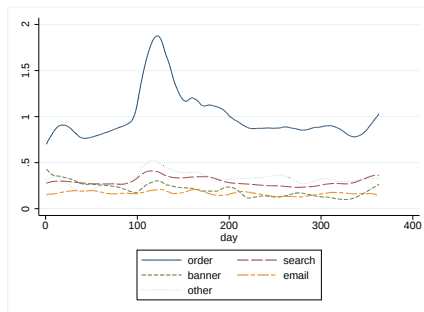
The Full Dataset

- Time Period: August 4th 2007 to July 31th 2008
- Source: a major seller of electronics that sells most of its products online within the time period.
- Consumer Identifier: Cookies
- Consumer enters the dataset through one type of ad-click
- All subsequent ad click and purchase behaviors of the consumer are documented until July 31th, 2008
- Detailed purchase transaction information (product(s) sold, revenue, margin) if purchases are made.



Daily Aggregate Analysis

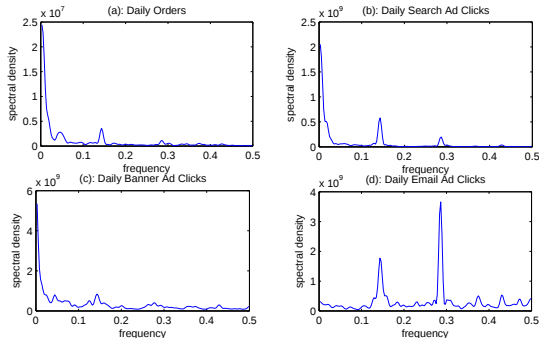
Figure: Purchase and Ad Click Fluctuations During the Year



- Kernel smoothed normalized daily purchases/ad clicks.
- Huge “holiday effect” for daily purchase.
- Small “holiday effect” for daily search and banner ad clicks.

Spectrum Analysis

Figure: Cycles Daily Purchase/Ad Click Numbers

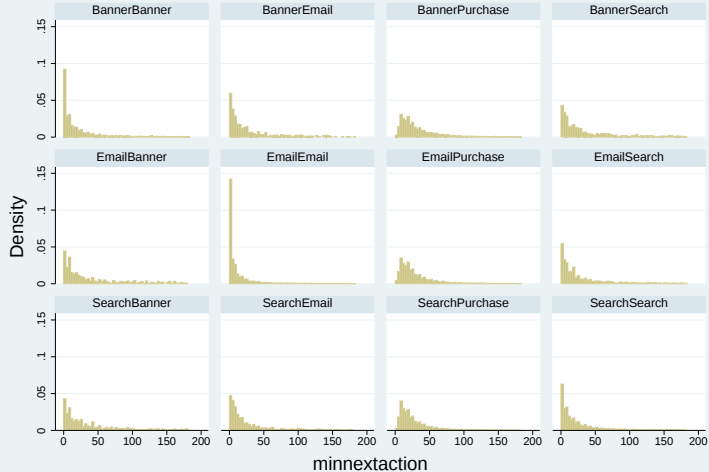


- Big half-weekly cycle of banner ad clicks.
- Weekly cycle of search ad clicks.

The Sample

- Time Period: May and June 2008
- Rules: no activity documented in April 2008 (no left censoring); cannot enter the sample through purchase; no observed other ad click activities; dropped out of the sample once purchase is made.
- Sample Size: around 2 million

Dynamics of Consumer Clickthrough Behaviors



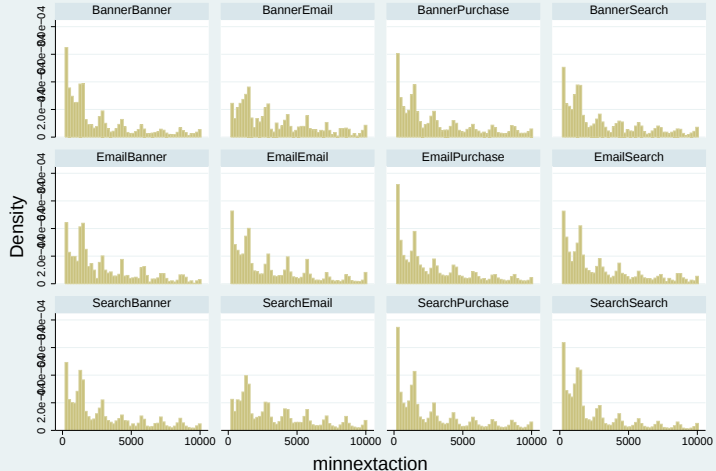
Graphs by typettnext

Dynamics of Consumer Clickthrough Behaviors



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Dynamics of Consumer Clickthrough Behaviors



Graphs by typetnext

The Treatment Effect Framework

- Treatment: T_{is}, T_{ib}, T_{ie}
- Outcomes: $Y_i(t_s, t_b, t_e)$
 - Observed: $Y_i(t_s, t_b, t_e)$ if $T_{is} = t_s, T_{ib} = t_b, T_{ie} = t_e$
 - Counterfactuals: $Y_i(t_s, t_b, t_e)$ if $T_{is} \neq t_s$ or $T_{ib} \neq t_b$ or $T_{ie} \neq t_e$
- ATE: $E[Y_i(t_s, t_b, t_e) - Y_i(t'_s, t'_b, t'_e)], \forall (t_s, t_b, t_e) > (t'_s, t'_b, t'_e)$

Simplified Single Treatment Model

- Drop out individuals who interact with multiple types of ads and group the rest of the individuals into three groups.
- Treatment: T_i
- Outcomes: $Y_i(t)$
 - Observed: $Y_i(t)$ if $T_i = t$
 - Counterfactuals: $Y_i(t)$ if $T_i \neq t$
- ATE: $E[Y_i(t) - Y_i(t')], \forall t > t'$

Data Evidence

Table: The Structure of Ad Click Data

#	S Only	B Only	E Only	S-B	S-E	B-E
1	0.56	0.24	0.20	0	0	0
2	0.53	0.14	0.25	0.06	0.02	0.01
3	0.46	0.10	0.29	0.07	0.05	0.02

- Do we really care about the ATEs for the full sample?

Data Evidence

- Different unobserved purchase incentive might be attached with different ad click behaviors including different types of ad clicks and different numbers of ad clicks.

Table: Evidence of Unobserved Purchase Incentive for Those Purchased

#	Group	Revenue ¹	Cost ¹	M/C If Pos.	If Neg. M ²
1	Search	0.80 (0.98)	0.78 (0.92)	1.59 (1.37)	0.11 (0.32)
	Banner	0.94 (0.98)	0.95 (0.93)	1.36 (0.92)	0.20 (0.40)
	Email	1.04 (1.00)	1.06 (0.94)	1.27 (0.82)	0.21 (0.41)
2	Search	1.06 (0.99)	0.94 (0.97)	1.49 (1.18)	0.13 (0.34)
	Banner	1.27 (1.06)	1.08 (0.93)	1.30 (0.80)	0.23 (0.42)
	Email	1.18 (0.97)	1.21 (0.92)	1.19 (0.58)	0.25 (0.43)
3	Search	1.09 (1.07)	1.08 (0.99)	1.39 (0.99)	0.15 (0.36)
	Banner	1.15 (1.02)	1.18 (0.93)	1.26 (0.72)	0.24 (0.43)
	Email	1.24 (0.94)	1.29 (0.88)	1.16 (0.48)	0.26 (0.44)

¹Dollar values are divided by average revenue/cost.

²Dummy variable indicating negative margin of the purchase.

The Manski Bounds: MTR+MTS

- Assumptions:

- MTR: $t_2 \geq t_1 \Rightarrow Y_j(t_2) \geq Y_j(t_1), \forall j = 1, \dots, N$
- MTS: $t_2 \geq t_1 \Rightarrow E[Y(t)|T = t_2] \geq E[Y(t)|T = t_1], \forall t$

- A necessary condition:

$$t_2 \geq t_1 \Rightarrow E[Y|T = t_2] \geq E[Y|T = t_1]$$

- ATE Bounds:

$$\begin{aligned} E[Y(t)] &= E[Y(t)|T = t]P[T = t] + \sum_{s < t} E[Y(t)|T = s]P[T = s] + \sum_{s > t} E[Y(t)|T = s]P[T = s] \\ &\leq E[Y(t)|T = t]P[T = t] + \sum_{s < t} E[Y(t)|T = t]P[T = s] + \sum_{s > t} E[Y(s)|T = s]P[T = s] \\ &\leq E[Y(t)|T = t] \sum_{s \leq t} P[T = s] + \sum_{s > t} E[Y(s)|T = s]P[T = s] \end{aligned}$$

The Manski Bounds: MTR+MTS

- ATE Bounds:

$$\begin{aligned}
 LB(t) &= E[Y(t)|T=t] \sum_{s \geq t} P[T=s] + \sum_{s < t} E[Y(s)|T=s] P[T=s] \\
 &\leq E[Y(t)] \\
 &\leq E[Y(t)|T=t] \sum_{s \leq t} P[T=s] + \sum_{s > t} E[Y(s)|T=s] P[T=s] = UB(t) \\
 \Rightarrow LB(t_2) - UB(t_1) &\leq E[Y(t_2) - Y(t_1)] \leq UB(t_2) - LB(t_1) \quad \forall t_2 \leq t_1
 \end{aligned}$$

- Lower Bound of ATE is always NOT sharp.
- ATE Bounds: $[0, UB(t_2) - LB(t_1)]$, $\forall t_2 \leq t_1$

Naive Estimates

- $E[Y(t_2)|T = t_2] - E[Y(t_1)|T = t_1]$

Table: Naive Estimates (%)

$t_1 < t_2$	Point Estimates			95% CI		95% CI		95% CI	
	S	B	E	Search		Banner		Email	
1-2	1.52	0.63	2.51	[1.49	1.64]	[0.59	0.74]	[2.46	2.69]
1-3	2.71	1.71	4.65	[2.62	2.96]	[1.57	2.10]	[4.52	5.03]
1-4	4.59	2.05	7.83	[4.44	4.99]	[1.86	2.58]	[7.63	8.33]
2-3	1.19	1.08	2.13	[1.08	1.45]	[0.94	1.48]	[1.99	2.57]
2-4	3.07	1.42	5.32	[2.91	3.50]	[1.23	1.98]	[5.12	5.86]
3-4	1.88	0.34	3.19	[1.71	2.38]	[0.12	1.00]	[2.95	3.83]

The Manski Bound Estimates: MTR+MTS

Table: Manski Bound Estimates (%)

	Interval Estimates			95% CI		
	Search	Banner	Email	Search	Banner	Email
1-2	[0 1.59]	[0 0.65]	[0 2.74]	[0 1.67]	[0 0.75]	[0 2.88]
1-3	[0 2.74]	[0 1.71]	[0 4.74]	[0 2.94]	[0 2.05]	[0 5.07]
1-4	[0 4.59]	[0 2.05]	[0 7.83]	[0 4.94]	[0 2.56]	[0 8.27]
2-3	[0 2.53]	[0 1.66]	[0 4.26]	[0 2.73]	[0 2.00]	[0 4.61]
2-4	[0 4.38]	[0 2.00]	[0 7.36]	[0 4.73]	[0 2.51]	[0 7.80]
3-4	[0 4.34]	[0 4.68]	[0 7.22]	[0 4.68]	[0 2.48]	[0 7.65]

- The naive estimates always fall in the MTS+MTR bounds derived since the naive estimation imposes ITS which is stronger than MTS.

The Manski Bounds: MTS+MTR+IV

- Assumptions:

- MTS+MTR

- IV: $E[Y(t_2) - Y(t_1)] = E[Y(t_2) - Y(t_1)|X = x], \forall t_1 < t_2, x$

- ATE Bounds:

$$0 \leq E[Y(t_2) - Y(t_1)] \leq \min_x \{UB(t_2|x) - LB(t_1|x)\}$$

The Manski Bounds: MTS+MTR+IV

- Assumptions:
 - MTS+MTR
 - IV: $E[Y(t_2) - Y(t_1)] = E[Y(t_2) - Y(t_1)|X = x], \forall t_1 < t_2, x$
- ATE Bounds:
$$0 \leq E[Y(t_2) - Y(t_1)] \leq \min_x \{UB(t_2|x) - LB(t_1|x)\}$$
- X : the weekday (MTWTFSS) when a consumer first enters the dataset
- Informal check of the IV assumption: regress Y on T , X and the interaction between T and X .

The Manski Bound Estimates: MTS+MTR+IV

Table: Manski Bound Estimates (%)

	Interval Estimates			95% CI		
	Search	Banner	Email	Search	Banner	Email
1-2	[0 1.36]	[0 0.48]	[0 1.77]	[0 1.45]	[0 0.54]	[0 1.97]
1-3	[0 1.74]	[0 0.95]	[0 3.13]	[0 2.18]	[0 1.21]	[0 3.55]
1-4	[0 3.96]	[0 1.41]	[0 6.04]	[0 4.26]	[0 1.58]	[0 6.67]
2-3	[0 1.56]	[0 0.89]	[0 2.80]	[0 1.98]	[0 1.16]	[0 3.18]
2-4	[0 3.78]	[0 1.37]	[0 5.70]	[0 4.05]	[0 1.51]	[0 6.30]
3-4	[0 3.72]	[0 1.34]	[0 5.61]	[0 4.01]	[0 1.50]	[0 6.18]

- The naive ATE estimates assuming exogenous treatment are biased upwards.
- The naive ATE estimates for banner ad conversion effect are most severely overestimated.

Parametric Panel Estimation Strategies

- Construct a weekly panel from 5% of the click stream subsample.
- Pros
 - Focus on the effect of most recent ad clicks.
 - Study the interaction between different types of ads.
- Approaches:
 - LPM: Arrelano-Bond
 - DCM: Rivers-Voung

The Linear Probability Model

- Model Setup

- $Y_{it} = X_{it}\beta + z_{it}\gamma + c_i + u_{it}$
- X_{it} : Log Ad Click Numbers;
- z_{it} : Approximation of the "Deal" individual i see at time t
- $E[u_{it}|X_{is}] = 0, \forall s \leq t$

The Binary Model

- Model Setup

- $Y_{it}^* = X_{it}\beta + z_{it}\gamma + u_{it}$
- $Y_{it} = 1(Y_{it}^* > 0)$
- $X_{it} = X_{is}\Pi + z_{it}\lambda + V_{it}$
- $(u_{it}, V_{it}) \perp (X_{is}, z_{it}), \forall s < t$

- Empirical Recipe

- First Step: Run $X_{it} = X_{is}\Pi + z_{it}B + V_{it}$, obtain $\hat{V}_{it}$.
- Second Step: Run $Y_{it} = 1(X_{it}\beta + z_{it}\gamma + \hat{V}_{it}\eta + u_{it} > 0)$

Results

Table: LPM and DCM Estimates of APEs

	Pooled	LPM			DCM		¹
		FD	FD-IV	Probit	Tobit	Probit-IV	
S	0.028***	0.028***	0.017***	0.007***	0.006***	0.006***	
B	0.010***	0.012***	0.008	0.004***	0.003***	0.000	
E	0.032***	0.031***	0.018***	0.007***	0.006***	0.011***	
R/C	-0.002***	0.003	0.0071*	-0.002***	-0.000	0.003	
J			12.16%			6.54%	

¹APEs are reported, evaluated at the mean values of RHS variables.

Results

Table: The Interaction Between Different Types of Ad Clicks

	Probit	Tobit	Probit-IV
Search	0.0076***	0.0066***	0.0057***
Banner	0.0042***	0.0037***	-0.000
Email	0.0067***	0.0058***	0.011***
SearchBanner	-0.0019***	-0.0029***	0.0033 ***
SeachEmail	-0.0026***	-0.0020***	-0.0049***
BannerEmail	-0.0017***	-0.0030***	-0.0022***
R/C	-0.0036***	-0.0029***	0.0022

¹APEs are evaluated at the mean values of RHS variables

Conclusion

- Obtain nonparametric bound and parametric point estimates of the conversion effect of different types of online advertising vehicles.
- Endogeneity of consumers browsing behaviors plays a big role in conversion effect estimation, especially for banner ad click through contributed purchases.
- Email ad click-throughs are found to have higher conversion effect than search ad click-throughs than banner ad click-throughs.
- The interaction between sponsored search and display banner ad clickths on average has positive effect on purchase.