Breaking the Data Chain: The Ripple Effect of Data Sharing Restrictions on Financial Markets

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Motivation

- Context:
  - Increasing reliance on alternative data, driven by AI and ML, to improve forecasting in both corporations and financial markets
  - In parallel, growing privacy concerns driving regulations and corporate policies that restrict data collection and sharing
  - Limits to data sharing in particular can affect the flow of insights generated from alternative data
  - The interconnectedness of the data economy means these disruptions can ripple through capital markets
  - Limited research on how privacy-led data sharing restrictions may affect market efficiency and how capital markets may amplify their impact

- Research Questions:
  - How do privacy-motivated data sharing restrictions affect the information environment in capital markets?
  - Do they impact forecast accuracy and price efficiency?
  - What channels drive these effects?

This Paper

- Use Apple's App Transparent Tracking (ATT) policy (April 2021), as a natural experiment providing a causal shock to mobile data sharing
- Leverage ATT's sudden rollout to isolate its effect on mobile-generated data, used by market participants
- Build a dataset combining mobile app usage, ad data, and data policies to measure how ATT changes the information environment
- Analyze changes in earnings forecast errors and price informativeness around ATT, using a diff-in-diff approach for causal estimation
- Investigate the link between reduced ad targeting precision and the decline in accuracy of mobile-derived signals as a potential mechanism

Results Preview

- Stronger link between SUE and CAR around earnings announcements Post-ATT (i.e., lower ST price informativeness):
  - For data-sharing firms, the CAR response to a one st.dev increase in SUE rises from 74 to 99.2 bps (a 34% increase)
  - For firms followed by analysts specialized in alternative data, the CAR response rises from 58.1 to 128.5 bps (more than doubling)
- Increased forecast errors of analysts specialized in alternative data:
  - Absolute errors increase by 5.89%
  - Relative errors move analysts from the median to the 55th percentile
- Loss of mobile app traffic predictive power:
  - Mobile app traffic loses predictive power over app engagement and firm performance
  - Pre-ATT, a 1 st.dev download increase raises SUE by 1.16 points and sales growth by 17.15%. Post-ATT, these drop to 0.56 points and 12%.
- Implications for trading strategies:
  - Pre-ATT, buying high-download stocks and short-selling low-download stocks yields 35%-120% CAR (2017-2023). Post-ATT, no further gains

Literature Contribution

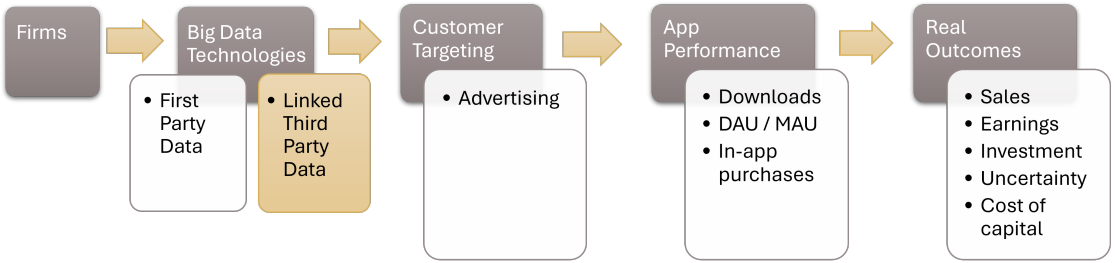
- Privacy in Economics & Finance
  - E.g., GDPR (Goldberg et al. 2019; Janssen et al. 2022; Jia et al. 2021; Aridor et al. 2020; Bessen et al. 2020; Demirer et al. 2024; Peukert et al. 2022), CCPA (Doerr et al. 2023; Bae et al. 2023), and ATT (Kesler 2022; Bian et al. 2023; Kraft et al. 2023)
  - We provide novel evidence on how privacy regulations like ATT affect capital markets via data economy disruptions
- Privacy Regulations and Targeted Marketing
  - E.g., Goldfarb and Tucker 2011, Kraft et al. 2023, Johnson et al. 2020
  - We connect privacy regulations to a loss in predictive power from mobile data, linking these effects to capital markets
- Alternative Data in Capital Markets
  - E.g., satellite images (Zhu 2019; Katona et al. 2024; Ke 2023), customer and employer reviews (Huang 2018; Green et al. 2019), real-time and granular sales information (Froot et al. 2017; Blankespoor et al. 2022; Dichev and Qian 2022; Jin et al. 2022; Du and Qian 2024), (EDGAR) web traffic and Google searches (Huaizhi Chen et al. 2020; Da et al. 2011), social media (Antweiler and Frank 2004; Hailiang Chen et al. 2014; Dessaint et al. 2024), weather (Hirshleifer and Shumway 2003; Goetzmann et al. 2015)
  - We show how ATT reduces the usefulness of mobile-generated alternative data for capital markets
- Analyst Forecasts and Alternative Data
  - E.g., Chi et al. 2023
  - We demonstrate how ATT decreases analyst forecast accuracy, particularly for those using alternative data

Roadmap

1. Conceptual Framework
2. Data, and Measures
3. Hp 1: Price Efficiency
4. Hp 2: Forecast Errors
5. Mechanism: Targeting Ability & Signal Precision
6. Next Steps
7. Conclusion

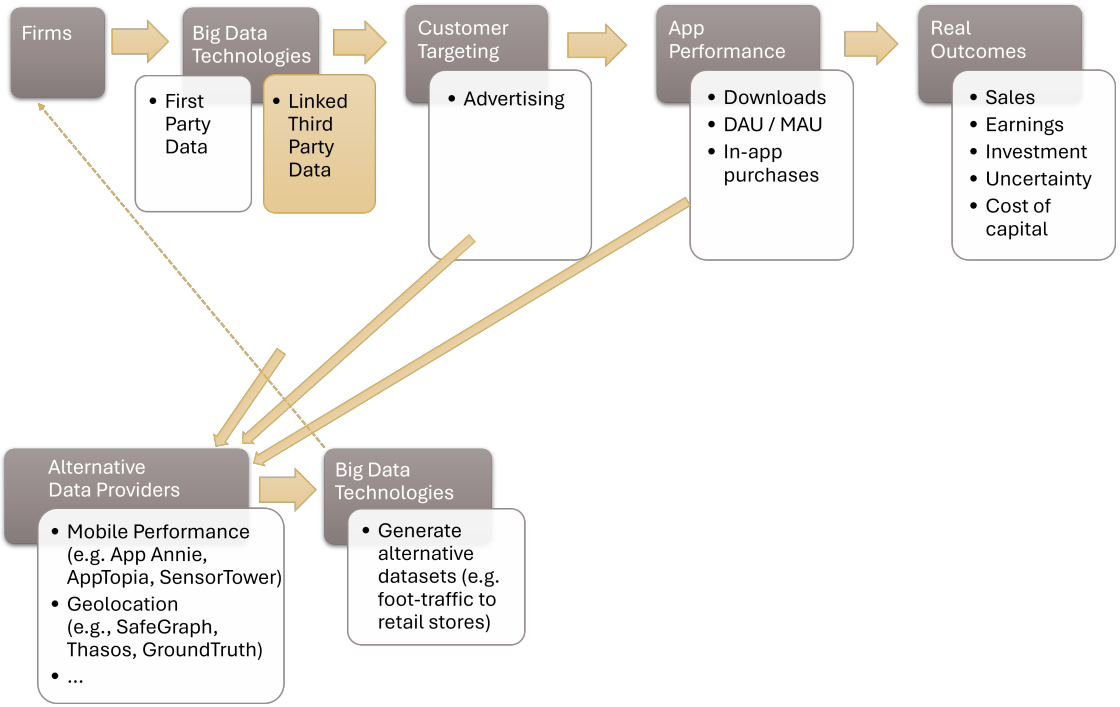
Roadmap

Firms & the Mobile Apps Market



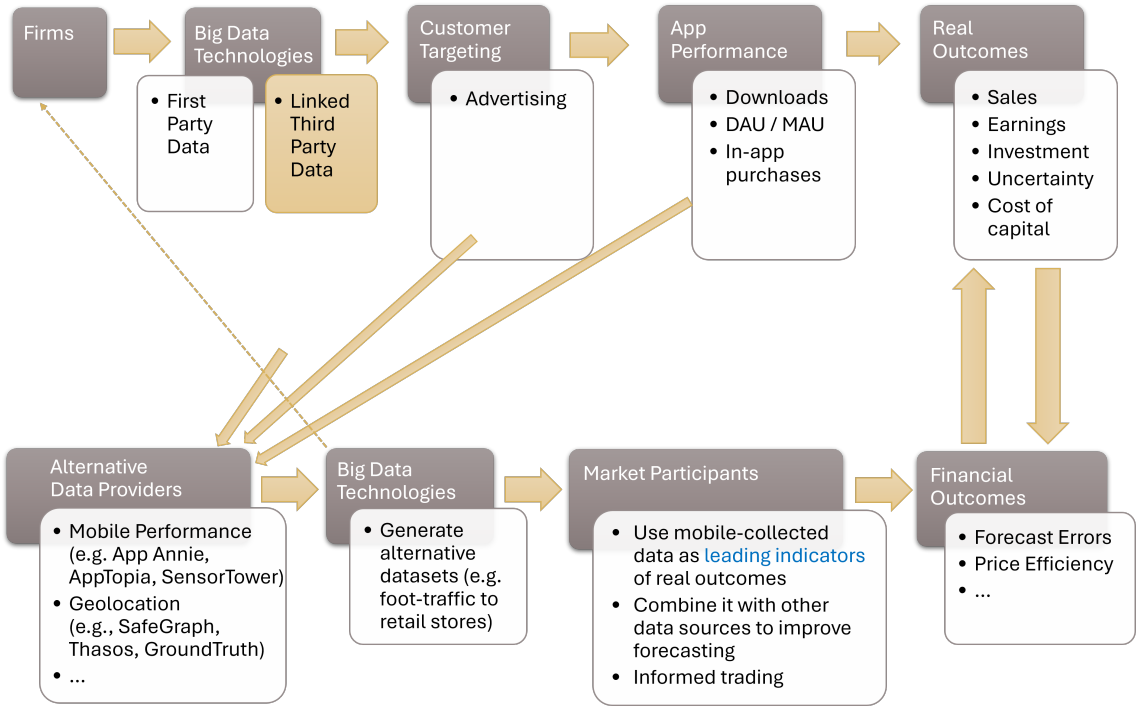
- Mobile Apps Market: A rapidly growing sector for businesses
  - Fast growth in internet penetration, smartphone usage, available apps (Statista 2024c; Statista 2024b)
  - Innovations in services provided through apps, driven by AI, ML, and AR (Forbes 2024)
  - Mobile revenues expected to grow from $153bn in 2023 to $230.44bn by 2027 (sales and ads only) (Statista 2024a)
  - Apps within a unique device provide an opportunity to connect user behaviors to enable better targeting/customization
  - User data be shared or sold to third parties

Firms & the Alternative Data Market



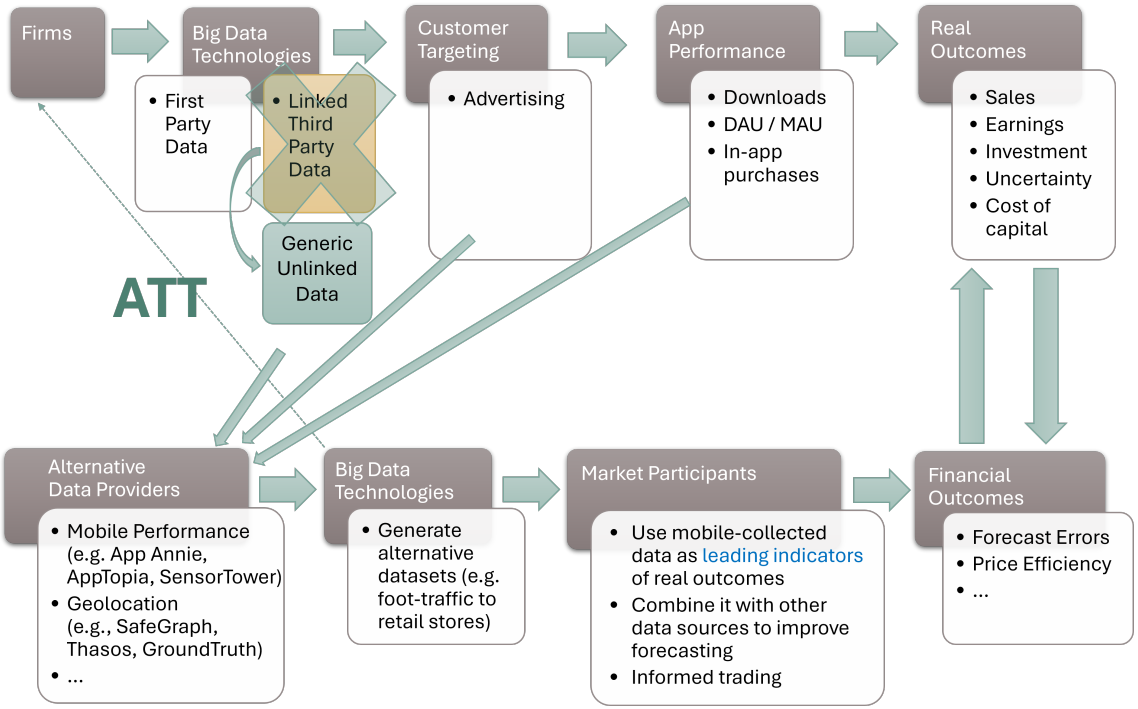
- Alternative Data Market: Rapid growth in providers and data types
  - Valued at $7.2bn in 2023, projected to grow at 50.6% CAGR from 2024 to 2030, driven by AI and new data sources (GrandViewResearch 2023)
  - Firms sell/share user data with third parties, much is mobile-collected
  - Alternative data providers aggregate, model that data to then sell it to firms or market participants

Capital Markets & Alternative Data



- Market Participants: Increasing reliance on alternative data
  - By 2018/2019 28% of financial analysts use it (Chi et al. 2023)
  - By 2021, 50% of asset managers used it, with 25% planning to start within 12 months (Tingley 2021)
  - Adoption raises regulatory and data risks (Deloitte 2017)–App Annie
  - Concerns that Big Tech (Meta, Apple, Google) policy changes *"can have ripple effects on data quality, security, and governance"* (Ryan 2023)

Apple's App Tracking Transparency (ATT) policy



- ATT: A major shock to data tracking and sharing
  - Apple's iOS has above 50% market share in the US (comScore 2024)
  - ATT launched globally on April 26, 2021, with iOS 14.5
  - Shift tracking from opt-out to opt-in, significantly reduces data shared
  - In the US, only 4% opted-in during the first month; 18% after one year (Balasubramanian 2022)

ATT on Youtube

Roadmap

Data

- Timeline: 2017-2023 (ATT: April 2021)

- Sources:
  - *AppTopia:* App usage and mobile advertising data
    - ⋆ We only consider apps with on average at least 1000 active users
    - ⋆ App usage is available to investors through the Bloomberg terminal
    - ⋆ Ads: creatives (images, videos, . . .) and metadata (size, channels, . . .)
  - *Apple App Store:* Data collection and sharing policies
  - *I/B/E/S:* Analyst forecasts
    - ⋆ Made within 90 days of earnings announcements
  - *LSEG (Refinitiv):* Full text of analyst reports (in progress . . .)
  - *Compustat:* Quarterly accounting data for publicly listed firms
    - ⋆ Price per share $>$ \$1, market/book equity $>$ \$5 million
  - *CRSP:* Financial market data
  - *Ken French Data Library:* Market factors

Measures

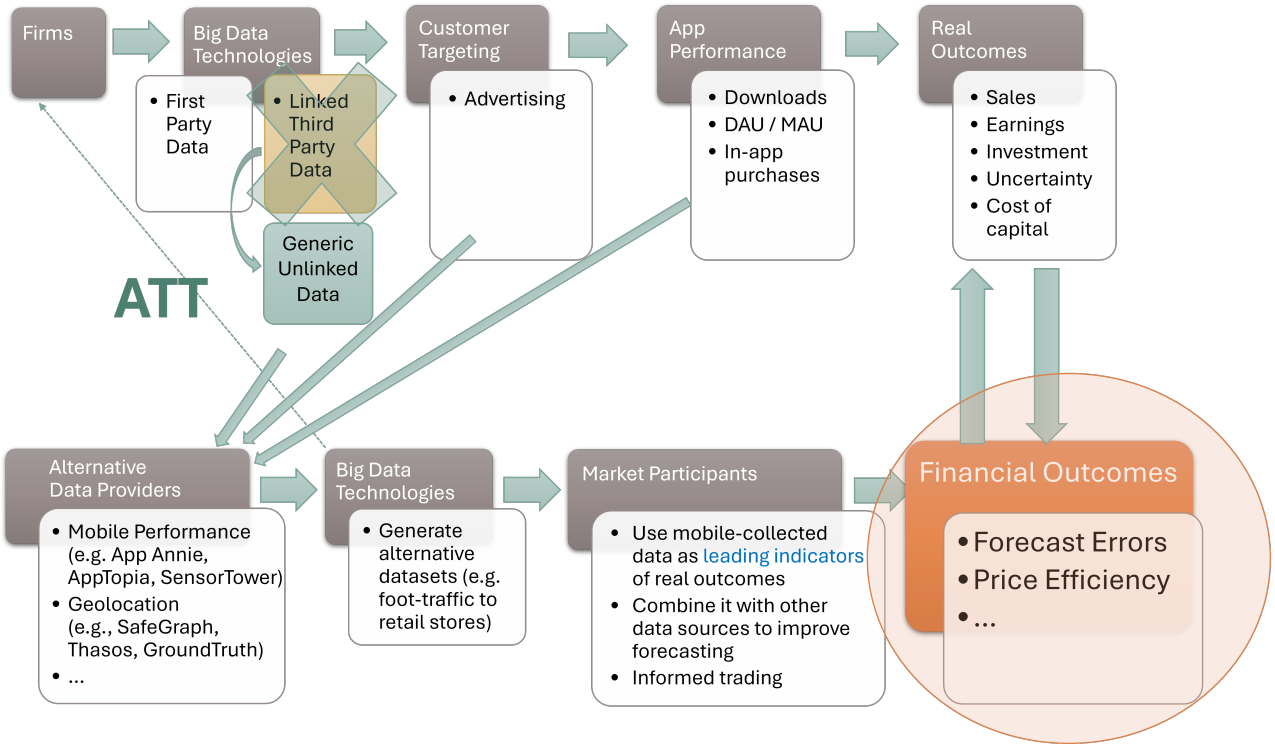
- Mobile Ads: Number of active ads, share of video ads, share of large static ads, and ad publisher concentration
- Mobile Apps: Total downloads, daily and monthly active users
- Data Sharing: Indicator variable for whether firms track/share user data
- Cumulative Abnormal Returns (CAR):
  - Computed over trading days [0, +10] after earnings announcements
  - Relative to the CAPM or Fama-French-Carhart 6-factor model
- Surprise Earnings (SUE):

$$SUE_{it} = \frac{EPS_{i,t} - EPS_{i,t-4}}{P_{it}}$$

- Analyst Specialization in Big Data:
  - *Specialized*: Analysts covering an above-average number of big data firms or firms followed by these analysts
  - *Specialized_R*: Analysts mentioning alternative data in their reports or firms followed by these analysts

Roadmap

Hypothesis 1 – Information Environment & Price Efficiency



- ATT reduces the quantity/quality of data collected through mobile apps
- If mobile data is useful for forecasting future payoffs, the information environment of affected firms should worsen
- This should reduce price efficiency, particularly for firms:
  - where mobile data is more relevant to future payoffs
  - that are followed by analysts/investors that rely on mobile-collected data

ST Price Informativeness & Analyst Specialization

$$CAR_{it} = \alpha + \beta_1 SUE_{it} + \beta_2 Specialized_{it} \times SUE_{it} + \beta_3 Post^{ATT} \times SUE_{it} +$$

$$\beta_4 Post^{ATT} \times Specialized_{it} \times SUE_{it} +$$

$$\beta_5 Specialized_{it} + \beta_6 Post^{ATT} \times Specialized_{it} + \Gamma X_{it-4} + \theta_i + \iota_t + \epsilon_{it}$$

	CAR - CAPM			CAR - FF6		
SUE	0.098***	0.119***	0.101***	0.098***	0.122***	0.099***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Specialized × SUE		-0.162***	-0.179***		-0.188***	-0.188***
		(0.06)	(0.06)		(0.05)	(0.06)
ATT × SUE	0.022	-0.020	-0.013	0.020	-0.024	-0.001
	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
ATT × Specialized × SUE		0.285***	0.304***		0.307***	0.308***
		(0.09)	(0.09)		(0.09)	(0.09)
Controls	N	N	Y	N	N	Y
Firm & Year × Quarter FEs	Y	Y	Y	Y	Y	Y
Observations	16,344	16,344	15,543	16,344	16,344	15,543
R-sq	0.062	0.063	0.065	0.060	0.061	0.062

Controls: size, and cash, tangibles and debt over assets, at (t-4)
CAR: cumulative abnormal returns relative to FF6 model over days [0,+10] post earnings announcements
SUE: change in EPS (excluding special items) in consecutive years, scaled by price (seasonal random walk)
Specialized: analysts following an above average number of big data firms

An increase in SUE of 1 st.dev. **Pre & Post-ATT (non-Specialized)** → increases CAR of 58bps
Pre-ATT (Specialized) → not significant **Post-ATT (Specialized)** → increases CAR of 128.5bps (more than double)

ST Price Informativeness & Data Sharing Policies

$$CAR_{it} = \alpha + \beta_1 SUE_{it} + \beta_2 DataSharing_{it} \times SUE_{it} + \beta_3 Post^{ATT} \times SUE_{it} +$$

$$\beta_4 Post^{ATT} \times DataSharing_{it} \times SUE_{it} +$$

$$\beta_5 DataSharing_{it} + \beta_6 Post^{ATT} \times DataSharing_{it} + \Gamma X_{it-4} + \theta_i + \iota_t + \epsilon_{it}$$

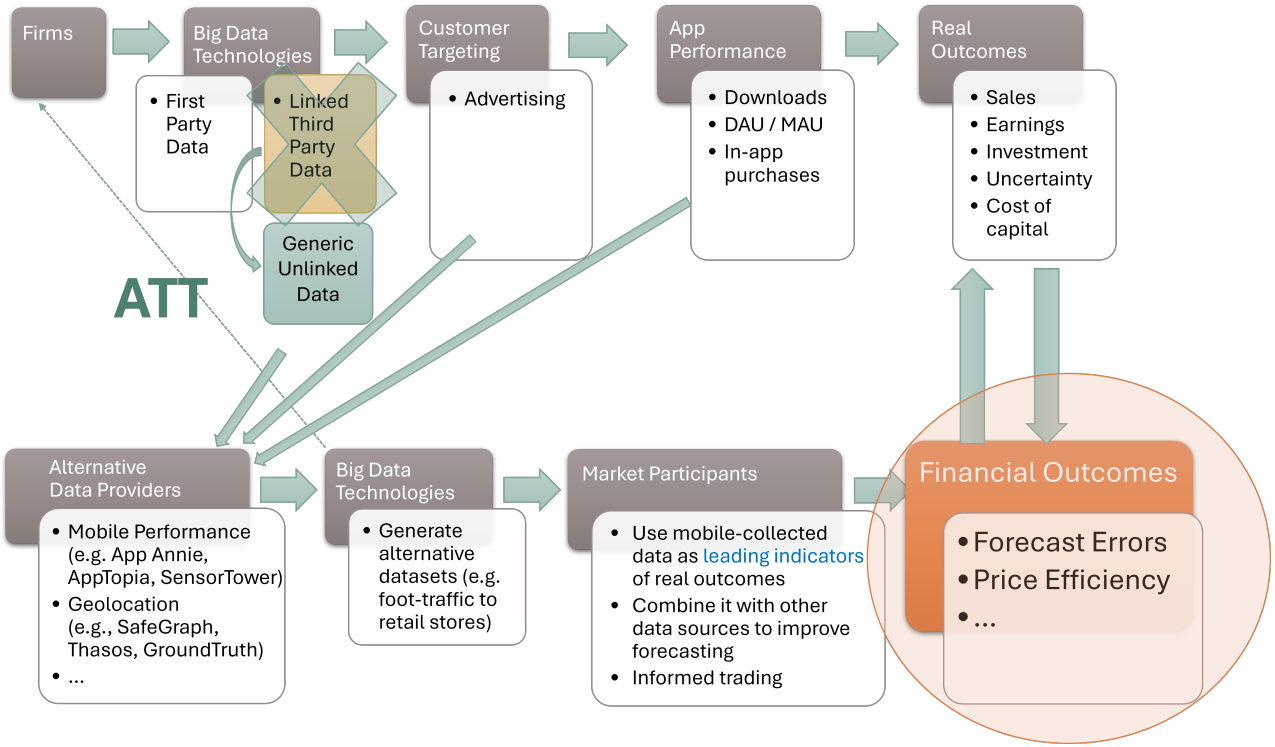
	CAR - CAPM			CAR - FF6		
SUE	0.098***	0.155***	0.130***	0.098***	0.152***	0.126***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Data sharing × SUE		-0.211***	-0.195***		-0.200***	-0.187***
		(0.04)	(0.04)		(0.04)	(0.04)
ATT × SUE	0.022	-0.087**	-0.062	0.020	-0.059	-0.025
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)
ATT × Data sharing × SUE		0.327***	0.286***		0.257***	0.230***
		(0.07)	(0.07)		(0.06)	(0.07)
Controls	N	N	Y	N	N	Y
Firm & Year × Quarter FEs	Y	Y	Y	Y	Y	Y
Observations	16,344	16,344	15,543	16,344	16,344	15,543
R-sq	0.062	0.064	0.066	0.060	0.062	0.063

Controls: size, and cash, tangibles and debt over assets, at (t-4)
CAR: cumulative abnormal returns relative to FF6 model over days [0,+10] post earnings announcements
SUE: change in EPS (excluding special items) in consecutive years, scaled by price (seasonal random walk)
Data Sharing: firms tracking users through mobile apps

An increase in SUE of 1 st.dev. **Pre & Post-ATT (non-Sharing)** → increases CAR of 74bps
Pre-ATT (Specialized) → not significant **Post-ATT (Specialized)** → increases CAR of 99bps (a 34% increase)

Roadmap

Hypothesis 2 – Forecast Errors



- Market participants use signals about future payoffs, some mobile generated, to update their priors
- If the precision of those signals decreases, posterior precision should also decrease, leading to greater forecast errors. Particularly so for analysts who utilize mobile-collected alternative data

Forecast Errors & Analyst Specialization

$$FE_{jit} = \alpha + \beta_1 Specialized_{jt} + \beta_2 Post^{ATT} \times Specialized_{jt} + \Gamma X_{jt} + \zeta_d + \theta_{it} + \iota_j + \kappa_b + \epsilon_{jit}$$

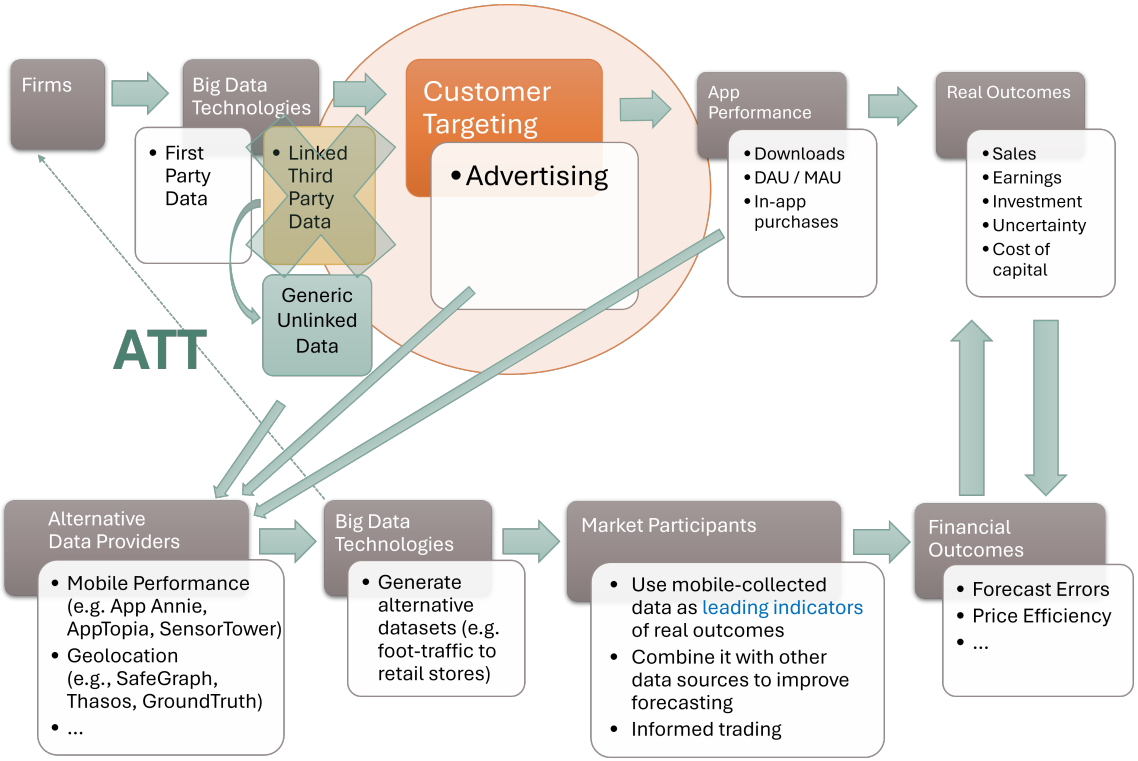
	Excess Forecast Error					
	AFE			PMAFE		
Specialized Analyst (0/1)	-0.004	-0.005	-0.004	-0.016	-0.021	-0.020
	(0.00)	(0.00)	(0.00)	(0.01)	(0.02)	(0.02)
ATT × Specialized Analyst (0/1)	0.010**	0.012***	0.012***	0.058***	0.046**	0.046**
	(0.00)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)
Controls	N	N	Y	N	N	Y
Firm × Quarter FE	Y	Y	Y	Y	Y	Y
Estimation date FE	Y	Y	Y	Y	Y	Y
Analyst FE	N	Y	Y	N	Y	Y
Brokerage FE	N	Y	Y	N	Y	Y
Observations	151,422	151,150	151,150	151,371	151,101	151,101
R-sq	0.853	0.860	0.860	0.041	0.093	0.093

Controls: Forecast age, analyst-firm experience, analyst experience, number of firms covered, broker size
AFE: absolute(analyst forecast - actual earnings)
PMAFE: AFE scaled by mean absolute forecast error across all analysts making forecasts for the same firm-quarter

Post-ATT Specialized → AFE: 5.89% greater than the average analyst; PMAFE: a median analyst would move to the 55% percentile

Roadmap

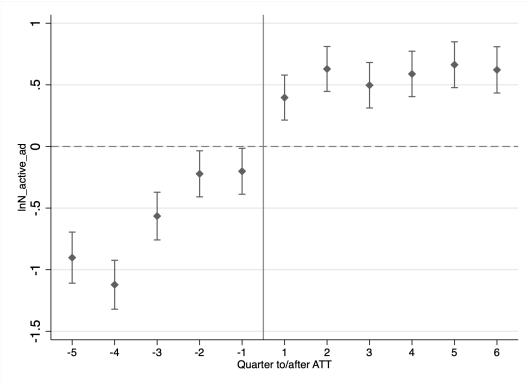
Mechanism – User Tracking & Ads Targeting



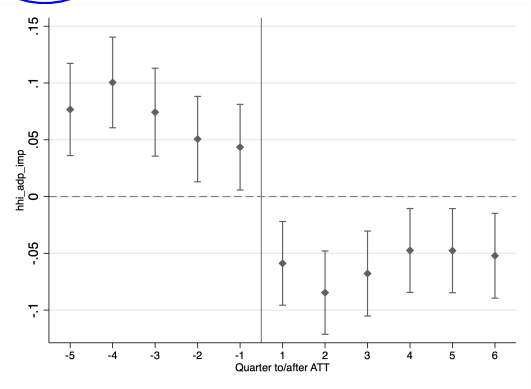
- ATT reduces firms' ability to track users, which lowers their ad targeting precision.
  - Less precise targeting should lead to more homogeneous, spread-out ads and reduced marketing efficiency (Iyer et al. 2005)
  - A higher proportion of dynamic ads, such as videos, which are better at engagement (Bruce et al. 2017)

User Tracking & Ads Targeting – Advertising Strategy

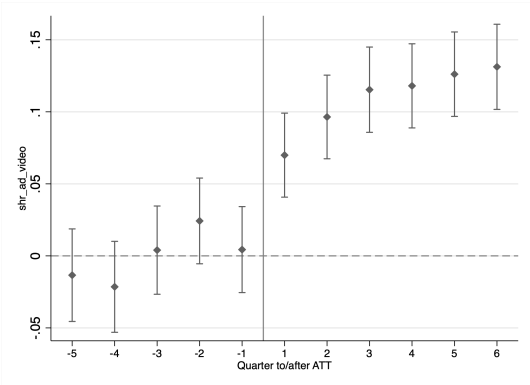
$$AdChar_{it} = \alpha + \Gamma\Theta + \iota_i + \epsilon_{it}$$



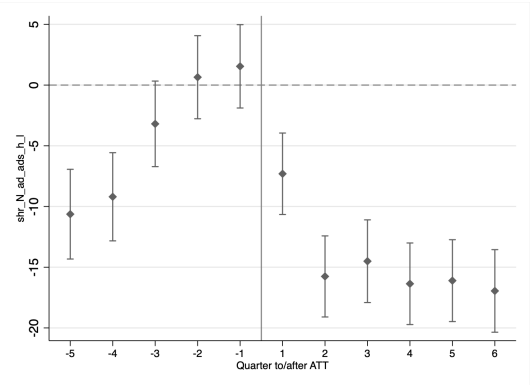
Number of Active Ads



Ad Publisher Concentration



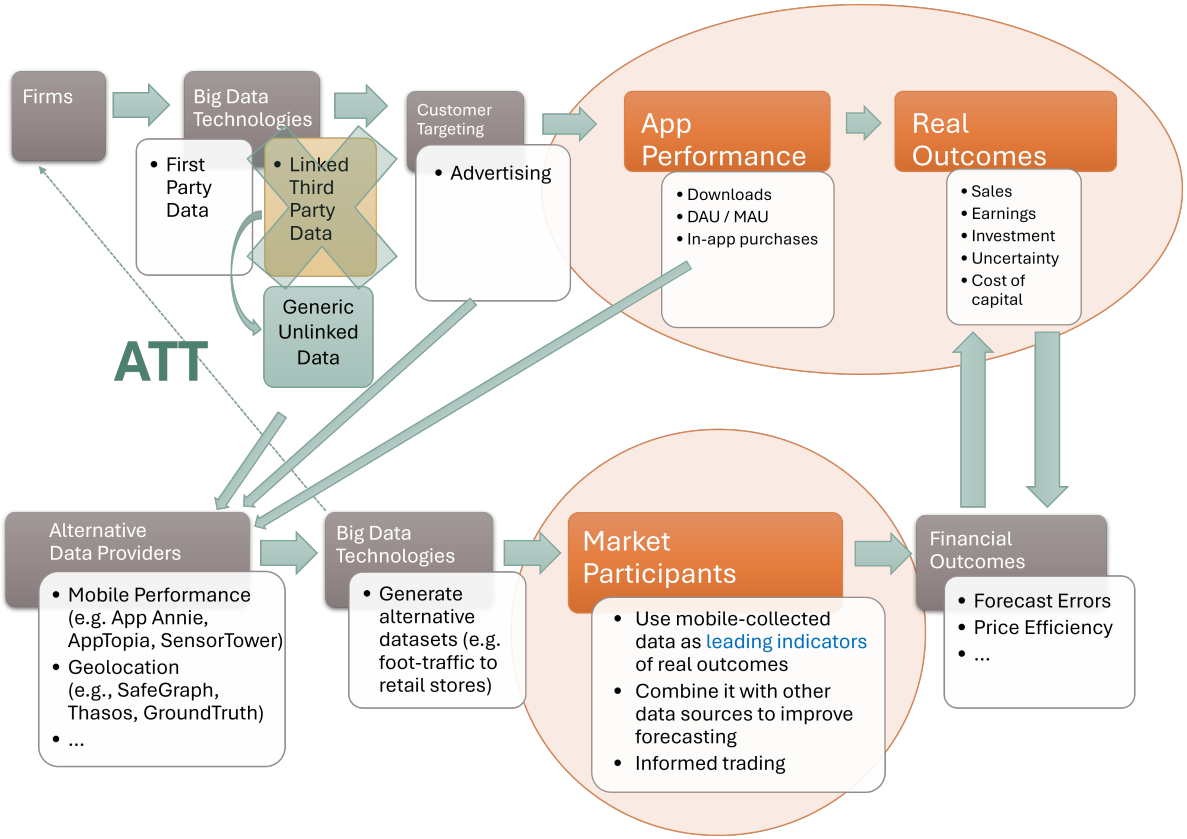
Share of Video Ads



Share of Large Static Ads

Post-ATT: **Number of Active Ads** → does not decrease. **Ad Publisher Concentration** → decreases. **Share of Video Ads** → increases. **Share of Large Static Ads** → decreases. **Overall** → sudden change in mobile advertising strategy, consistent with a reduced targeting ability.

Mechanism – Targeting Ability & Signal Precision

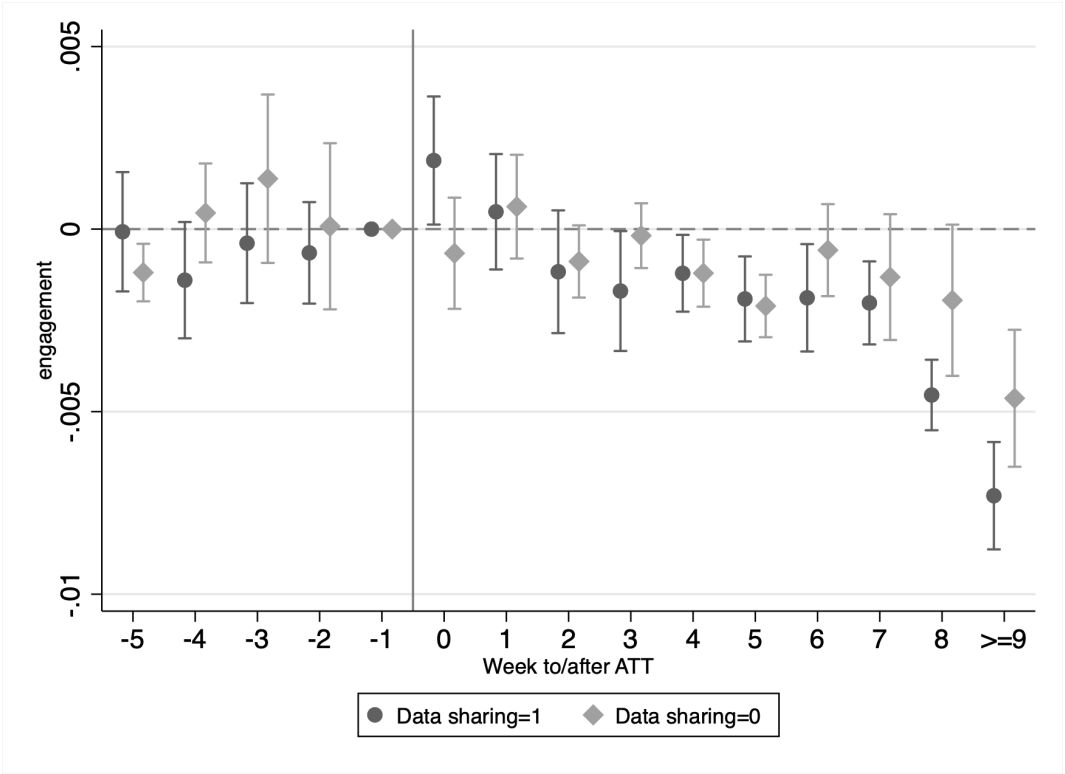


- Reduced targeting ability leads to less efficient marketing strategies (Iyer et al. 2005)
  - App traffic becomes less predictive of user engagement
  - App traffic loses its predictive power over firm performance
- Impact on trading strategies: Trading strategies based on app traffic data become less profitable

Targeting Ability & Signal Precision – App Engagement

$$Engage_{it} = \alpha + \Gamma\Theta \times Traffic_{it-1} + \iota_i + \theta_t + \epsilon_{it} \mid DS{=}0 \text{ or } DS{=}1$$

$Traffic = [Downloads,\ MAU,\ DAU]$; $Engage = \frac{DAU}{MAU}$; $DS = Data\ sharing$;
$\Theta = \left[\theta_{t-5},\ \theta_{-4}, \cdots, \theta_8,\ \theta_9\right] = time\ dummies$



The predictive power of traffic on engagement starts decreasing 4 weeks after ATT, and continues to do so for all weeks following, particularly so for apps that track/share user data.

Targeting Ability & Signal Precision – Firm Performance

$$Performance_{it} = \alpha + \beta_1 Downloads_{it} + \beta_2 Data\ \ Sharing_i \times Downloads_{it} + \beta_3 Post^{ATT} \times Downloads_{it} +$$

$$\beta_4 Post^{ATT} \times Data\ \ Sharing_i \times Downloads_{it} +$$

$$\beta_5 Data\ \ Sharing_i + \beta_6 Post^{ATT} \times Data\ \ Sharing_i + \beta_7 Downloads_{it-1} + \Gamma X_{it-4} + \iota_i + \theta_t + \epsilon_{it}$$

	Sales growth	Sales growth	SUE	SUE
Downloads	0.040***	0.036***	0.253**	0.266***
	(0.01)	(0.01)	(0.10)	(0.10)
Data sharing × Downloads	0.029**	0.031***	0.214*	0.188*
	(0.01)	(0.01)	(0.12)	(0.11)
ATT × Downloads	-0.002	0.004	0.077	0.079
	(0.01)	(0.01)	(0.06)	(0.06)
ATT × Data sharing × Downloads	-0.018*	-0.020**	-0.246**	-0.235**
	(0.01)	(0.01)	(0.11)	(0.10)
Controls	N	Y	N	Y
Firm & YQ FEs	Y	Y	Y	Y
Observations	13,484	13,051	13,671	13,087
R-sq	0.229	0.282	0.069	0.074

Controls: size, and cash, tangibles and debt over assets, at (t-4)
Variables: *Downloads*=ln(downloads); *Performance*=[Sales growth, SUE]; *Sales growth*=yearly sales growth; *SUE*=yearly change in EPS, scaled by price; *Data Sharing*=firms tracking users through mobile apps

An increase in downloads of 1 st.dev. **Pre & Post-ATT (non-DS)** → increases SG of 8.65%; SUE of 0.67, 11.4% of its st.dev. **Pre-ATT (DS)** → increases SG of 16.75%; SUE of 1.14, 19.4% of its st.dev. **Post-ATT (DS)** → increases SG of 11.75%; SUE of 0.548, 9.3% of its st.dev.

Targeting Ability & Signal Precision – Portfolio Analysis

- Monthly trading strategy:
  - Sort stocks into quintiles based on on abnormal downloads at $t-1$
  - Long-short (LS) portfolio: buy top quintile of stocks, short-sell bottom
  - Compute risk-adjusted returns of LS portfolio (Fama-French-Carhart 6-factor model over the past 12m)

Pre-ATT → Strong upward CAR trend: portfolios sorted by downloads show significant CAR from 2017 to 2021 (35% VW, 80% EW no micro cap, 120% MAUW no micro cap).
Post-ATT → No additional CAR: app downloads lose relevance for trading strategies

Roadmap

Next Steps

- Expand the study of market efficiency beyond ST price informativeness
- Extend the analysis of analyst forecast errors by levering granular information from analyst reports
- Explore the impact of ATT on investor portfolios?
- Provide a more direct connection between ad targeting and capital market effects by levering creative-level advertising data?

Roadmap

Conclusion

- Privacy vs. Data Utility: Privacy regulations like Apple's ATT policy reduce the availability of alternative data, increasing forecast errors and reducing price informativeness in financial markets
- Implications for Policy Makers: Policymakers must balance protecting privacy with minimizing disruptions to data-driven insights. Developing standardized frameworks for anonymized data sharing could help mitigate these effects
- Future Work: Research should explore long-term impacts on market efficiency and how privacy regulations create unequal access to alternative data among investors

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