Economic Impact of Opt-in versus Opt-out Requirements for Personal Data Usage: The Case of Apple's App Tracking Transparency (ATT)

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(October 7, 2023)

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Acknowledgment of financial support:
This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement No. 833714).

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Major privacy initiatives allow users to either opt-in or opt-out of a firm's use of their personal data. This article examines one of the world's largest privacy initiatives, Apple's App Tracking Transparency (ATT), introduced with iOS 14.5 in April 2021, to understand the differences in tracking and economic outcomes between both approaches. ATT requires each app to obtain explicit consent to track users across other publishers' apps (tracking if users opted in); before ATT, Apple permitted tracking under implicit consent (tracking unless users opted out). Our analysis of three proprietary daily-level data sets—corresponding to billions of ad impressions ("traffic") across 19 countries—outlines that ATT reduced the share of trackable (versus untrackable) Apple traffic in the United States by 55 percentage points, from 73% to 18%. Given the observed 51% higher prices for trackable (versus untrackable) ad impressions, this decline translates to a 21% fall in ad revenue from Apple users for publishers. In other countries, the decline in tracking rates ranged from 24% to 59%. Cultural differences account for differences in the tracking rates across countries.

Online tracking is the practice of collecting data about users over time to reveal insights into various user characteristics, such as their demographics, interests, brand preferences, or purchase intentions. These insights help firms better target their content and advertising, but tracking also invites privacy concerns (Cui et al. 2021, Martin et al. 2017). As a result, regulators usually require firms to obtain their users' consent to be tracked.

Opt-in and opt-out are two approaches to getting users' consent. Opt-in refers to the user's explicit decision to consent to personal data processing: It stipulates that without action by the user, the user does not consent. Opt-out means a firm can process the user's personal data unless she opts out: Without taking action, a user implicitly consents to her personal data processing.

It is well known that consent rates—defined as the share of users who consent to their personal data processing—are higher under an opt-out approach than an opt-in approach due to the status quo bias (Jachimowicz et al. (2019), Samuelson and Zeckhauer (1988)). Yet, it is unclear how large these differences are, whether and why opt-in consent rates differ across countries, and how large the economic impact is. The latter point is not trivial: Lower profits among firms, particularly media companies, could impact the kind and quality of content that people receive, forcing a trade-off between the right to information and the right to privacy.

Against that backdrop, it is worth considering one of the most significant privacy protection initiatives in recent years: Apple's App Tracking Transparency (ATT), introduced in April 2021 with the iOS 14.5 update. Apple is the world's most valuable company (as measured by market capitalization); thus, its approach to privacy has extensive repercussions in the market. Briefly stated, ATT outlines the conditions under which an app publisher (referred to simply as "publisher" hereafter) gains access to Apple's Identifier for Advertisers (IDFA), which Apple randomly generates and assigns to each Apple device. It is a mobile advertising identification number (MAID), similar to the Google Advertising ID (GAID) on Android devices. ATT essentially prohibited all publishers that run on Apple devices from requesting a user's consent to be tracked via the previously applicable opt-out approach. Instead, it made an opt-in approach obligatory.

ATT has remarkable features for studying differences in the consent rates. First, Apple simultaneously implemented ATT worldwide, facilitating a comparison of consent rates across countries. Second, ATT provides publishers in all countries with little flexibility in how they explicitly ask for consent. In other words, ATT imposes a uniformity of design that does not exist with, e.g., cookie consent banners. For this reason, differences in consent rates across countries would not result from different interpretations of the law and subsequent differences in implementations on how to gather consent (as is the case for cookie consent banners); instead, they result from other causes, such as cultural differences. Third, Apple prevents publishers from “cheating” (i.e., publishers collect a user’s data without the user’s consent). This concurrence of enactment and enforcement contrasts with many privacy laws, such as GDPR, where their enactment (e.g., May 25, 2018 for GDPR) could have a different effect than their enforcement, the latter of which generally happens much later—if at all.

In light of this unique opportunity, we aim to use the introduction of Apple’s ATT to examine the share of trackable users (tracking rate) under the opt-in and opt-out approaches, along with the tracking rate’s antecedents (i.e., culture and opt-in/opt-out appoach) and consequences (i.e., advertising revenue) across 19 countries. Specifically, we answer the following research questions in two empirical studies:

1. How strongly do tracking rates differ when implementing an opt-in instead of an opt-out approach (Study 1)?
2. What is the economic impact when implementing an opt-in instead of an opt-out approach (Study 1)?
3. Do cultural differences impact tracking rates (Study 2)?

Insights from Previous Literature

We proceed with an overview of the previous literature and highlight our work's contribution. We focus on four dimensions, outlining whether studies examine (i) tracking outcomes (i.e., implicit consent rate under opt-out, explicit consent rate under opt-in, tracking rate as a combination of these and other drivers); (ii) tracking value (i.e., prices of ads displayed to trackable and untrackable users); (iii) economic outcomes (i.e., a combination of tracking outcome and tracking value), and (iv) the role of culture as an antecedent. We include studies in our overview that contribute to one of these outcome dimensions by either examining consent requirements in the context of cookie banners (because of their similarity to consent requests under ATT) or specifically studying ATT (see Table 1). Related but not included studies are those about the impact of ATT on publishers' switching behavior toward subscription models and in-app purchases (Kesler 2023) or toward Google's app market (Cheyre et al. 2022).

Earlier work on consent rates focused on cookies banners: Utz et al. (2019) conducted three field experiments on a German e-commerce website with 82,890 users and obtained explicit consent rates ranging from 67% to 83%, conditional upon the user interacting with the cookie banner (i.e., providing some response, either confirming or denying consent). However, there was substantial variation in users' probability of interacting with the cookie banner, ranging from 4% to 42%. Nouwens et al. (2020) found similar results in a field experiment involving 40 participants from the United States who responded to eight cookie banner designs. Specifically, they found an overall explicit consent rate of 55% but a rate of 77% for cookie banners without a button to immediately deny consent. We contribute to this realm of literature by outlining differences in tracking rates for opt-in and opt-out approaches (both directly transferable to cookie banner settings), as well as accounting for how well culture can explain cross-country differences.

More recent studies have also examined ATT: Kollnig et al. (2022) studied the tracking activities of 1,759 apps from Apple's App Store in the UK. The authors showed that the introduction of ATT prevented publishers from using the IDFA; however, many apps could still collect device information, which enabled publishers to track groups of users or apply fingerprinting approaches to track individual users. The authors also assessed how ATT led users to (explicitly or implicitly) deny consent to tracking. Specifically, whereas 50.8% of apps could access the IDFA on pre-ATT devices, only 24.7% of apps could access it on post-ATT devices (iOS versions 14.5 and above). Kim, Andrews, and Schweidel (2022) assessed ATT's effect on the overall extent of mobile tracking, defined by the average number of pings of mobile devices. The authors found that tracking decreased by about 70% after ATT's introduction and that the decrease was largest when Apple rolled out iOS 14.6—probably because Apple placed a red badge on system settings that nudged users to update their devices.

Our study examines how ATT has affected publishers' tracking capabilities—providing a breakdown of the specific channels through which tracking opportunities are lost (e.g., users' explicit denial of consent to track; the loss of implicit consent to tracking)—and quantifies ATT's economic effects. Our work is the first to directly estimate advertising revenue losses attributable to ATT's introduction. Moreover, we examine the impact of culture to explain differences in tracking rates across countries.

Through these contributions, our work also ties into the stream of literature that empirically explores the relationships between ad prices and tracking capabilities. This stream includes the work of Johnson, Shriver, and Du (2020), who examined the domain of tracking cookies in online display advertising. The authors found that the ability to track users enables publishers to command much higher prices for ads (where ads for users who opt out of tracking bring in 52% less revenue compared with ads for trackable users). Laub, Miller, and Skiera (2023) obtained similar results in the same domain. Notably, Marotta, Abishek, and Acquisti (2019), who also examined the domain of tracking cookies in online display advertising, found a much smaller positive effect of tracking (4%).

Table 1: Insights from Previous Studies

Study	**Main Results**	**Tracking Outcomes**			**Tracking Value**	**Economic Outcome**	**Antecedents**
		Implicit Consent	Explicit Consent	Tracking Rate	Ad Prices	Ad Revenue	Role of Culture
Utz et al. (2019)	Cookie banner designs (notice position, type of choice, and content framing) greatly affect explicit consent rates, with effects ranging from 67-83%		Yes				
Nouwens et al. (2020)	Cookie banner designs (no "reject all" button, granular controls) greatly affect explicit consent rates, with effects ranging from 55-77%		Yes				
Kollnig et al. (2022)	ATT reduces app's IDFA usage from 50.8% to 24.7%			Yes			
Kim et al. (2022)	ATT reduces the amount of tracking on mobile devices by 70%			Yes			
Marotta et al. (2019)	Cookie unavailability decreases ad revenue by 4%				Yes		
Johnson et al. (2020)	Cookie unavailability decreases ad revenue by 52%				Yes		
Laub et al. (2023)	Cookie unavailability decreases ad revenue by 20-30%				Yes		
Our Study		**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Overview of Apple's App Tracking Transparency (ATT)

Description of the App Tracking Transparency

Apple introduced ATT with the iOS 14.5 update on April 26, 2021. In a report on the iOS update, Apple (2021a) justified the introduction of ATT by stating that it supports a high standard for privacy, security, and content, and thus helps to maintain users' trust. Apple (2021b) also explicitly stated that other tracking approaches, such as fingerprinting, violate the Apple Developer Program License Agreement.

ATT requires publishers to ask users for tracking consent via the ATT prompt (Figure 1). This prompt functions similarly to a cookie banner that users might encounter on a website but follows a standard format across different apps (see Figure 1). Specifically, it provides the user with the opportunity to accept or deny tracking via IDFA, as well as offers information about how the app uses tracking data (e.g., content personalization, targeting advertising, attribution analytics). If the user has not explicitly consented to being tracked, Apple does not provide the publisher with the IDFA: It does not matter whether the user denied an explicit consent request or whether the publisher never asked the user to provide consent.

Figure 1: Example of App Tracking Transparency Prompt (ATT Prompt)

Notes: This figure provides an example of an ATT prompt. Here, the publisher of a specific app, "App", asks its user for consent to tracking. Tracking helps to personalize content, target advertising, and conduct attribution analytics. The user has to either consent ("Allow Tracking") or deny tracking ("Ask App Not to Track").

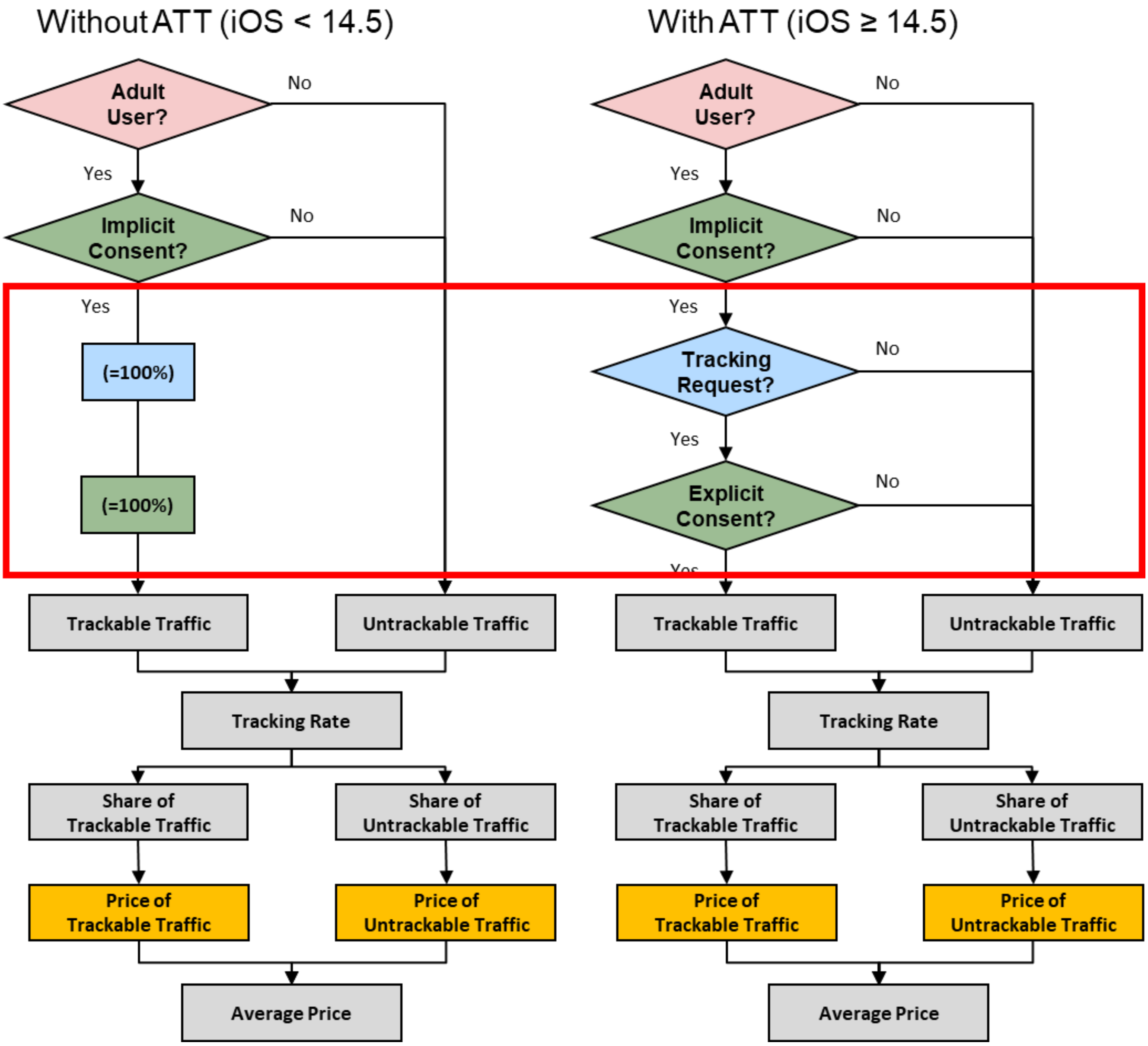
IDFA is an identifier that Apple randomly generates and assigns to each Apple device. Publishers and advertisers with access to a device's IDFA can identify and thereby track a device within—and even more importantly, across—apps. Given that mobile devices typically belong to individual users, this capacity implies that a party with access to a device's IDFA can effectively track the online activities of the individual who uses the device. A publisher might leverage such tracking information, for example, to improve its apps by adapting certain features to users' characteristics or browsing behavior. Crucially, the publisher can also convey a user's IDFA to advertisers, who can use it to better target users and measure ad performance (Goldfarb 2014, Gordon et al. 2021); these capabilities, in turn, usually enable the publisher to realize higher prices for its ad slots (Johnson, Shriver, and Du 2020).

Apple's standardized procedure does not offer publishers much flexibility. In particular, Apple prohibits publishers from showing the ATT prompt to users who have already denied the app's request for tracking, to users under 18 ("minors"), and to users who have denied tracking on a device level. For the remaining eligible users, publishers can effectively only make two choices concerning the consent request: the timing of the presentation of the ATT prompt and the displayed purposes. The publisher does not have to request the user's consent when the user first accesses the App; rather, it can wait for a good moment to ask, e.g., when a user achieves a new level in a game.

Comparison of Situations With and Without the App Tracking Transparency

In Figure 2, we compare the situations before and after the iOS 14.5 update, i.e., the settings with and without ATT. We start with the situation after the iOS 14.5 update (i.e., with ATT), shown in the right panel of Figure 2. As mentioned, publishers cannot track children—or put differently, children cannot choose to be tracked by publishers. Only adults can deny tracking on the device level, which is an opt-out decision because the default setting enables publishers to ask users for their consent to be tracked. The publishers can decide to ask those (adult) users who did not opt-out on the device level for their consent ("request tracking" in Figure 2). The publisher can then track those users who provide their (explicit) consent. Thus, multiplying (i) the number of adult users with the conditional probabilities of (ii) the user implicitly providing consent on the device level, (iii) the publisher requesting consent and (iv) the user providing explicit consent yields the trackable traffic. Combining the trackable traffic with the (remaining) untrackable traffic yields the share of trackable traffic, referred to as the *tracking rate*.

Figure 2: Comparison of Tracking and Economic Outcomes with and without App Tracking Transparency (ATT)



The average price of an ad impression is the sum of (i) the product of the share of trackable traffic and the price for trackable traffic and (ii) the product for the share of untrackable traffic and the price for untrackable traffic.

Before iOS 14.5, Apple used an opt-out approach with its "Limit Ad Tracking" (LAT). Users implicitly consented to a publisher's IDFA access by not toggling the "Limit Ad Tracking" to the "Off" option in the device settings (with the exception of children, who could not be tracked by publishers). Moreover, users who wanted information about the tracking purposes had to search for it (e.g., in the fine print of the app's documentation). Apple did not force providers to request tracking to get IDFA access, which effectively meant that users could not provide explicit consent. The first two metrics in the left panel ("without ATT") of Figure 2 are similar to those on the right panel ("with ATT"). Under ATT, users could still utilize their device settings to prevent apps from displaying the ATT prompt by toggling LAT's replacement "Allow Apps to Request to Track" to the "Off" option. However, the probabilities reflecting the next two metrics are 100% without ATT and usually lower than 100% with ATT.

Notably, a lack of access to a user's IDFA does not entirely prevent the publisher from tracking that user because Apple offers publishers another tracking identifier: the Identifier for Vendors (IDFV). The IDFV is a unique identifier that is both device-specific and publisher-specific. It enables the publisher to track a user's activity within the publisher's own apps. In other words, second-party tracking—here defined as tracking across different properties (e.g., apps) with the same owner (e.g., a publisher)—is feasible via IDFV. Yet, third-party tracking, here defined as tracking across different properties of different owners, is impossible via IDFV.

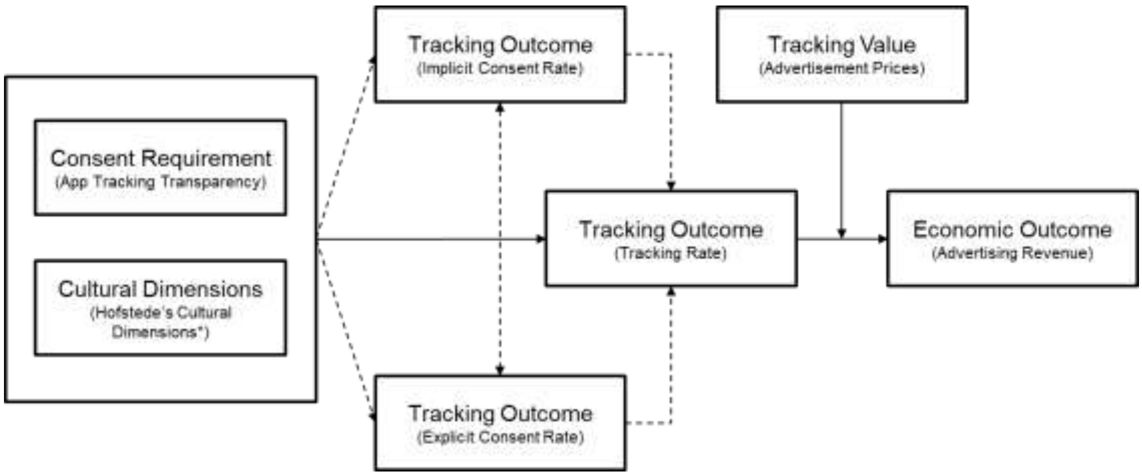
Description of Conceptual Framework

Overview of Conceptual Framework

Figure 3 describes our conceptual framework with three tracking outcomes: the implicit consent rate (i.e., the share of users who do not opt-out), the explicit consent rate (i.e., the share of users who opt-in), and its centerpiece, the tracking rate (i.e., the combination of both consent rates), which represents the share of trackable users. The tracking rate combined with the tracking value (here reflected in the price of an ad impression displayed to a trackable instead of an untrackable user) results in advertising revenue for the publisher. Our empirical analyses in Study 1 focus on estimating the impact of consent requirements—i.e., opt-out approach ("without ATT") versus opt-in ("with ATT")—on tracking outcome (measured by the tracking rate, research question 1) and economic outcome (measured by advertising revenue, research question 2). Moreover, in Study 2, we use the six well-established cultural dimensions of Hofstede, Hofstede, and Minkov (2010) to examine whether cultural differences impact the tracking rate under ATT (research question 3).

Solid lines represent the estimated effects. Explicit and implicit consent rates can act as substitutes for users to guard against being tracked. Specifically, since it is unclear whether users opt-out to avoid subsequent opt-in decisions or do not opt-out because they can decide not to opt-in later, these consent rates are likely interdependent. Hence, endogeneity problems may occur when directly using them as dependent variables. Hence, we estimate the impact on the tracking rates and provide evidence that both consent rates correlate negatively, substantiating our interdependence claim.

Figure 3: Conceptual Framework



Notes: Solid lines refer to estimated effects. Dashed lines refer to mechanisms. The interdependence between the "Implicit Consent Rate" and "Explicit Consent Rate" prevents estimation of the impact of "Consent Requirement" or "Cultural Dimensions" on either rate.

Hypotheses Regarding the Impact of an Opt-In versus Opt-Out Approach on Tracking Outcome, Tracking Value, and Economic Outcome

We outline our hypotheses below. In light of the status quo bias (see Jachimowicz et al. 2019, Samuelson and Zeckhauer 1988) and ATT's essential replacement of an opt-out with an opt-in approach, we hypothesize that ATT reduced the tracking rate (H1a). Since trackable users provide more information to advertisers that enables better ad targeting, we expect (in line with previous literature like Johnson, Shriver, and Du (2020) and Laub, Miller, and Skiera (2023)) an increase in advertisers' willingness to pay and, thus, higher prices for ad impressions displayed to trackable versus untrackable users (H1b). Consequently, we also anticipate a negative impact of ATT on advertising revenue (H1c). Thus, we propose the following three hypotheses:

H1a: Replacing an opt-out approach with an opt-in approach decreases the tracking rate.
H1b: Advertising for trackable traffic is more expensive than for untrackable traffic.
H1c: Replacing an opt-out approach with an opt-in approach decreases advertising revenue.

Hypotheses Regarding the Impact of Cultural Dimensions on Tracking Rates

We used the well-established six cultural dimensions of Hofstede, Hofstede, and Minkov (2010) to formulate and test our hypotheses about the effect of culture on the tracking rate under ATT. Our approach follows previous studies that examined the role of culture on app popularity (Kübler et al. 2018), the value derived from visiting a publisher's website (Steenkamp and Geyskens 2006), and consumers' financial decision-making (Petersen, Kushwaha, and Kumar 2015). We offer a quick description of each dimension and refer to Hofstede, Hofstede, and Minkov (2010) for additional information.

Uncertainty avoidance represents a country's comfort level with ambiguity and risk: Countries with higher uncertainty avoidance value structures and rules. *Power distance* captures the extent to which a society accepts and expects power distribution inequality: In higher power distance societies, there are clearer hierarchies and more respect for authority. *Long-term orientation* measures a country's orientation toward the future: Countries with a higher long-term orientation emphasize perseverance and future rewards. *Individualism* measures a country's preferred balance between individual and group interests: More individualistic countries prioritize personal freedom and autonomy. *Indulgence* captures the extent to which a country values the gratification of human desires: More indulgent countries more strongly value personal enjoyment. *Masculinity* refers to the distribution of roles and values between genders within a country: More masculine countries emphasize assertiveness and more distinct gender roles.

We derive our hypotheses below: Specifically, uncertainty-avoiding users aim to prevent unintended consequences from sharing data. Hence, they will use the opt-in approach to deny the tracking request. Thus, tracking rates should be lower in countries with a higher uncertainty avoidance (H2a).

In contrast, users who accept the power of superiors may follow the ATT prompt's tracking request more often. Thus, tracking rates should be higher in countries with a higher power distance (H2b).

Long-term-oriented users may wish to avoid a situation where publishers must switch to paid business models because of low tracking rates. Thus, countries with a higher long-term orientation should be more willing to provide consent under ATT and exhibit higher tracking rates (H2c).

Individualistic users are less prone to that kind of supportive behavior and will instead focus on their own benefits. Thus, they may have less incentive to share data, leading to lower tracking rates in countries with higher individualism (H2d).

Indulgent users may prefer personalization to help satisfy their needs and desires instead of focusing on the potential downsides of sharing data. Thus, tracking rates should be higher in countries with higher indulgence (H2e).

We did not find convincing arguments to derive a hypothesis for the impact of the sixth cultural dimension, masculinity. Hence, we only tested the following five hypotheses:

H2a: Uncertainty-avoiding users aim to prevent unintended consequences from sharing data, which decreases their tracking rates.

H2b: Users accepting the power of superiors more often follow the ATT prompt's tracking request, which increases their tracking rates.

H2c: Long-term-oriented users wish to avoid a situation where publishers must switch to paid business models because of low tracking rates, which increases their tracking rates.

H2d: Individualistic users focus on their benefits, lowering the incentives to share data to support publishers, which decreases their tracking rates.

H2e: More indulgent users prefer personalization to help satisfy their needs and desires, which increases their tracking rates.

Description of Data Sets in Empirical Studies

Source of the Data Sets

Our empirical study used three proprietary data sets of a demand-side platform in the programmatic mobile online advertising market. The demand-side platform helps advertisers buy advertising inventory on mobile devices by bidding on their behalf in real-time auctions on ad exchanges and supply-side platforms. For each ad impression offered for sale, the demand-side platform receives a bid request with the following features (among others): (i) the operating system of the device on which the ad impression is being offered (i.e., Apple or Android); (ii) the version of the operating system (e.g., iOS 14.6); (iii) the device's tracking information to identify the four different rates outlined in Figure 2 (for Apple devices); (iv) the availability of a device ID (for Android devices); (v) the country of the user; and (vi) the date and time of the bid request. The demand-side platform then decides on whether to submit a bid for the bid request or not. Therefore, the number of bids is lower than the number of bid requests. For all non-winning bids (>95% of all bids), the demand-side platform received information about the winning price, representing the expense for displaying the ad impression.

Description of Tracking Data Set

In our first data set ("tracking data set"), we have access to daily-level aggregate information for each feature, corresponding to about 30 billion ad impressions daily. For any particular day, we know the number of ad impressions offered for Apple users in the United States who are trackable, i.e., who are (i) adults, (ii) did not opt-out on the device level, (iii) were asked for consent and (iv) opted-in. This value enables us to calculate the daily share of trackable users.

We used this “tracking data set” to estimate the impact of ATT on the tracking rate. This data set covers 19 countries from April 1 to April 25, 2021, and from October 1, 2021, to March 31, 2022, i.e., the month preceding ATT’s introduction (April 26, 2021) and six months after most Apple users adopted iOS 14.5 or higher.

Description of Price Data Set

Our second data set (“price data set”) includes the price (in $ CPM) of ad impressions on an Apple device for which our demand-side platform submitted a bid and other information, such as the app that displays the ad impression and whether the device ID (i.e., the IDFA) was available. The data set still covers our 19 countries but only supplies monthly data (specifically February 2022). We used this price data set to assess, for each country, price differences between ad impressions corresponding to trackable versus untrackable devices, while partialling out app-specific characteristics.

Description of App Data Set

Our third data set (“app data set”) shares similarities with the tracking data set but is more recent (covering daily data from April 1 to April 30, 2023) and contains all information on the country-app level instead of the country level. In other words, it is more disaggregated and allows us to compare the tracking rates of one app across multiple countries; for some apps, up to all 19 countries. These comparisons are unlikely to suffer greatly from users’ self-selection. Instead, differences across countries, particularly cultural differences, should primarily impact the resulting differences in tracking rates.

We used the following criteria to select our 986 iOS apps: (i) only apps with >100mm monthly ad impressions across all countries, (ii) only country-app observations with >1mm monthly ad impressions and (iii) only apps operating in at least two countries. Again, we have this information for our 19 countries.

Empirical Study 1:
Impact of ATT on Tracking and Economic Outcome

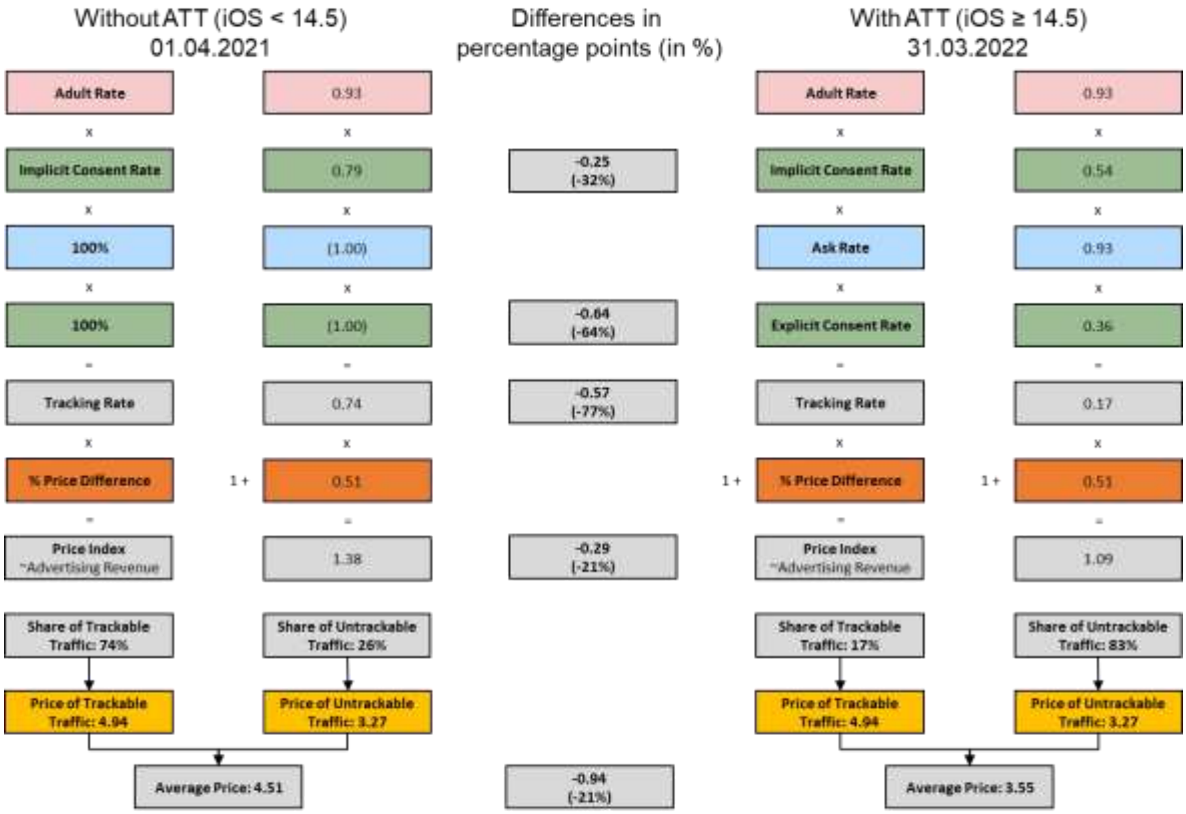
Study 1 focuses on the impact of ATT on the tracking outcome (measured by the tracking rate) and the economic outcome (measured by the decrease in advertising revenues). It enables us to test hypotheses 1a-1c and uses the tracking data set and the price data set.

Procedure to Derive Results and Illustration of Results

In what follows, we refer to a "share" of trackable traffic; this value captures the share of ad impressions corresponding to trackable Apple devices out of all ad impressions offered to Apple devices. These shares might differ from the shares of Apple devices because our focus is on the number of ad impressions rather than on individual devices. In adopting this approach, we effectively weight each user by economic importance, i.e., by the number of ad impressions the user generates. For simplicity, we subsequently refer to weighted users as users.

In presenting our results, we first focus on how we derive the results for the United States for the first and last day of our tracking data set. The first day, Thursday, April 1, 2021, represents the situation without ATT. The last day, Thursday, March 31, 2022, represents the situation with ATT. Figure 4 presents the results of each step in the procedure outlined above in Figure 2.

Figure 4: Comparison of Tracking and Economic Outcomes with and without App Tracking Transparency (ATT) in the United States



Seven percent of all Apple users were children on both April 1, 2021 ("without ATT") and March 31, 2022 ("with ATT"), which means the adult rates were equal. We observed major differences for the implicit and explicit consent rates. With ATT, more users opted-out on the device level (46% versus 21%), which is remarkable considering that users could grant access to individual Apps rather than entirely opt-out on the device level.

Of those who did not opt-out (54%) and were asked (93%), 64% denied consent. So, the tracking rate with ATT is 17%, compared to 74% without ATT (i.e., it is 57 percentage points (%p), or 77%, lower). The price for trackable traffic in the United States is 51% higher than for untrackable traffic, as we will detail below. Weighted by the respective shares of trackable and untrackable prices, we found a 21% lower average price with ATT than without ATT. We used this decrease to signify the loss of online advertising revenue.

So far, we have used a before–after comparison to derive our results. For robustness, we also calculated the percentage difference using a difference-in-differences approach, with Android users as the control group. The tracking rate of Android users was 93.68% on April 1, 2021, and 93.78% on March 31, 2022. Android users' (rounded) tracking rate did not change (the unrounded difference was 0.1 %p); thus, the difference-in-difference approach yielded similar results.

Impact of App Tracking Transparency (ATT) on Tracking Outcome

Instead of just looking at two points in time (i.e., the first and the last day of our observation period), we now consider all days of our observation period, i.e., all days before the treatment (25 days: April 1 to April 25, 2021) and the days after the treatment (182 days: October 1, 2021, to March 31, 2022). We ran a regression analysis with the tracking rate as the dependent variable and the binary variable ATT as the independent variable (0 before the introduction of ATT (April 26, 2021) and 1 afterward). The left panel of Figure 5 displays the results. The introduction of ATT reduced the tracking rate by 55 %p, which is only slightly lower than our results when comparing just two days (57 %p).

Figure 5: Impact of the Introduction of ATT on Tracking Outcome

Regression Results for the USA

Model	**1a**
ATT	-0.55*** (-268.27)
	Model Statistics
Dependent Variable	Tracking Rate
Mean (Before ATT)	0.73
Mean (After ATT)	0.18
R-Squared Within in %	99.43
Number of Countries	1
Number of Days	207
Number of Observations	207
Starting Date (Before ATT)	2021-04-01
Ending Date (Before ATT)	2021-04-25
Starting Date (Before ATT)	2021-10-01
Ending Date (Before ATT)	2022-03-31

Notes: t-statistics are in parentheses and based on robust standard errors. ***: $p<0.001$.

Distribution of Impact across 19 Countries

We present the results of the regressions of the 18 remaining countries in Web Appendix C and summarize them in the right panel of Figure 5. The findings illustrate that ATT had a stronger effect in the United States than in most other countries. Still, the average decrease in the tracking rate was 46.17%, with the lowest decrease being 23.65% (in Indonesia). Thus, we find support for our hypothesis H1a that replacing an opt-out approach with an opt-in approach, as ATT does, decreases the tracking rate.

To determine whether these changes were indeed attributable to the introduction of ATT and not merely a result of time trends, we also estimated a difference-in-differences approach, with Android users as the control group (see Web Appendix C). The estimated decrease in the tracking rate for Apple users was -56 pp and, thus, very similar. Still, just as a straightforward before–after comparison assumes that there are no confounding time effects, a difference-in-differences approach also requires assumptions—namely, parallel time trends before the treatment and the absence of spillover effects from the treatment group to the control group, often referred to as “Stable-Unit-Treatment-Value-Assumption” (i.e., SUTVA). In our setting, it is not clear which assumption is stronger. Given that the substantive results are almost identical between the two approaches, we treat the before—after approach as our main results and use a difference-in-difference approach to support their robustness.

Finally, we calculated the correlation between the implicit and explicit consent rates across all countries and days to determine whether these decisions impact each other. The correlation was significantly negative (-0.33, $p<0.001$), indicating that an increase in the implicit consent rate accompanies a decrease in the explicit consent rate (or vice versa). The correlation across all countries and apps was also significantly negative (-0.44, $p<0.001$) in our app data set used in the second empirical study.

An explanation for these negative correlations could be that privacy-sensitive users deny tracking on the device level so that publishers can no longer ask for their explicit consent (via the ATT prompt). Thus, providers can only get explicit consent from less privacy-sensitive users, who more often provide this consent. Another explanation could be that responding to so many ATT prompts (by denying explicit consent) annoys users, who then decide to deny consent on the device level. In any case, the negative correlation outlines that we cannot compare explicit consent rates across countries and apps without controlling for differences in implicit consent rates.

Price Differences between Trackable and Untrackable Traffic

The change in the average price of an ad shown on an Apple device serves to reflect ATT's impact on advertising revenue from Apple users. We can derive the average price (with and without ATT) by (i) multiplying the share of trackable users with the average ad price for trackable users, (ii) multiplying the share of untrackable users with the average ad price for untrackable users, and (iii) adding the result of (i) to the result of (ii) (see Figure 2 and Figure 4). Given that the previous section outlined the change in tracking rates, we now use our price data set to derive the differences in prices for trackable and untrackable traffic (in February 2022).

We ran a regression for each country, with the logged price of an ad impression as the dependent variable. The main independent variable was IDFA. We used app fixed effects to control for app-specific characteristics. Figure 6 (left panel) presents the results for the United States. The parameter of IDFA had a value of 0.41 for the United States, reflecting a 51% increase in ad prices for trackable users (=exp(0.41)-1).

Figure 6: Estimation of Price Differences for Ads for Trackable versus Untrackable Users

Regression Results for the USA

Model	**1b**
IDFA	-0.41*** (11.48)
	Model Statistics
Dependent Variable	Log(CPM)
Country	United States
Impact of IDFA in %	51
R-Squared Within in %	82.69
Mean (without IDFA)	3.27
Mean (with IDFA)	4.18
App Fixed Effects	Yes
Number of Apps	6,985
Number of Days	28
Number of Observations	15,578,926
Starting Date	2022-02-01
Ending Date	2022-02-28

Notes: t-statistics are in parentheses and based on app-level clustered standard errors. ***: p<0.001.

Distribution of Impact across 19 Countries

The right panel of Figure 6 outlines that the price increase in the United States was slightly lower than the average price increase across our 19 countries. The increase was lowest in Switzerland (14.39%) and Poland (15.75%), while highest in Brazil (85.73%) and Mexico (96.50%). In short, we found support for our hypothesis H1b that advertising for trackable traffic is more expensive than for untrackable traffic.

Impact of App Tracking Transparency (ATT) on Economic Outcome

As outlined, the price for trackable traffic in the United States was 51% higher than for untrackable traffic. Meanwhile, the share of trackable traffic after ATT decreased from 74% (April 1, 2021) to 17% (March 31, 2022); respectively, the share of untrackable traffic increased from 26% to 83%. Multiplying the respective values yields a 21% lower average price in the United States with ATT than without ATT (=(17% x 1.51 + 83% x 1.00) / (74% x 1.51 + 26% x 1.00)-1).

Next, we calculated the average price for all days of our observation period (25 days before and 182 days after the introduction of ATT) and then ran a regression for each country. The dependent variable is the logged daily average price (i.e., "Price Index" in Figure 4). As in the analysis shown in Figure 5, the binary variable ATT is the main independent variable. Figure 7 (left panel) outlines that the average price for an ad impression on an Apple device decreased by 23%, which signals a decrease in advertising revenue from Apple users.

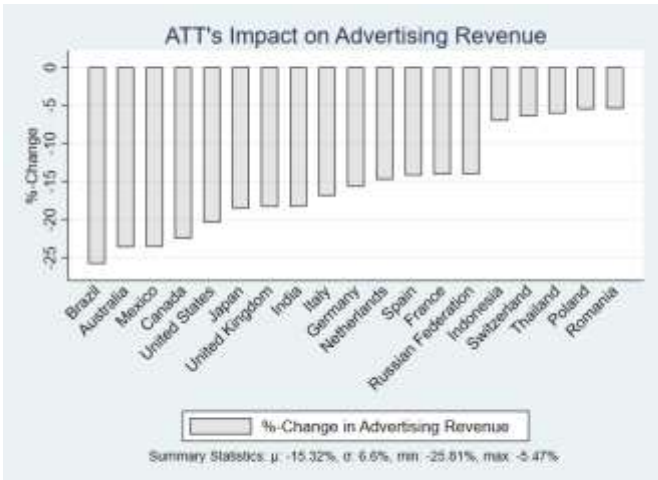
Figure 7: Impact of Apple's App Tracking Transparency (ATT) on Economic Outcome

Regression Results for the USA

Model	**1c**
ATT	-0.23*** (-279.73)
	Model Statistics
Dependent Variable	Log(Price Index)
Mean (Before ATT)	0.32
Mean (After ATT)	0.09
R-Squared Within in %	99.30
Number of Countries	1
Number of Days	207
Number of Observations	207
Starting Date (Before ATT)	2021-04-01
Ending Date (Before ATT)	2021-04-25
Starting Date (Before ATT)	2021-10-01
Ending Date (Before ATT)	2022-03-31

Notes: t-statistics based on robust standard errors in parentheses. ***: p<0.001.

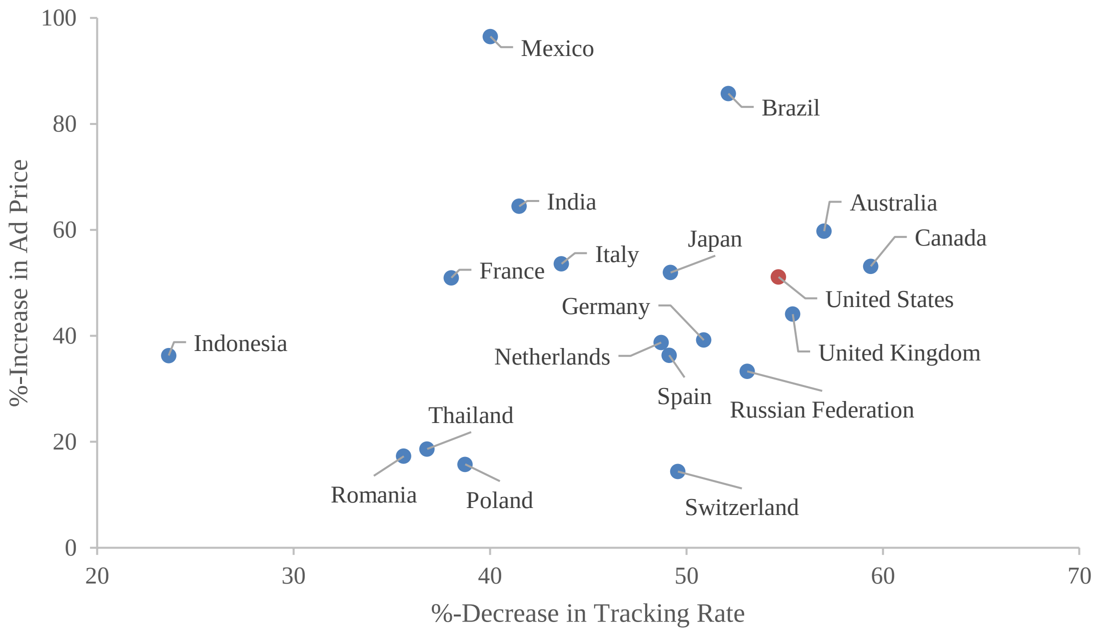
Distribution of Impact across 19 Countries



Web Appendix E presents the regression results for the other countries (summarized in the right panel of Figure 7). The decrease in advertising revenue of 20.55% (=(exp(-0.23)-1)*100) in the United States was higher than the average decrease (-15.32%) and close to the largest decrease across our 19 countries (Brazil: -25.80%). The lowest decrease occurred in Romania (-5.47%), but even that was notable. In short, we found support for our hypothesis H1c that replacing an opt-out approach with an opt-in approach (such as with ATT) decreases advertising revenue.

As the decrease in advertising revenue resulted from the increase in untrackable traffic (Figure 5) alongside the decrease in prices for ads for untrackable traffic (Figure 6), we contrasted both effects in Figure 8.

Figure 8: Scatter Plot with Decreases in Tracking Rate and Price Increases for Trackable versus Untrackable Ads



Validity of Meta's Claim of an Annual $10 Billion Loss Due to ATT

Apple claims that ATT improves users' privacy, while publishers complain that such privacy has come at a considerable cost. For example, Meta (2022a)—which publishes apps such as Facebook, Instagram, and WhatsApp—claimed that its advertising revenues would drop by $10 billion in 2022 because of ATT's impact on the ability to conduct tracking. As Meta (2022a) did not publicize how it reached that figure, we used our results to examine the validity of its claim.

Therefore, we multiplied Meta's 2021 ad revenue in their four regions (United States & Canada, Europe, Asia-Pacific and Rest of World), equal to $114.9 billion (Meta 2022b), by the following factors: its share of mobile advertising revenue (≈90%); our estimated percentage decrease for the ad revenue with Apple devices in these four regions (represented by the United States: 20.55%, by Germany: 15.70%, by Australia: 23.63% and by Mexico: 23.57%), and the share of Apple devices among all devices in these four regions (again represented by the United States: 54.33%, by Germany: 27.49%, by Australia: 59.05% and by Mexico: 13.58%; all values according to our tracking data set). We obtained an estimated decline of $9.5 billion, thereby supporting the validity of Meta's $10 billion claim.

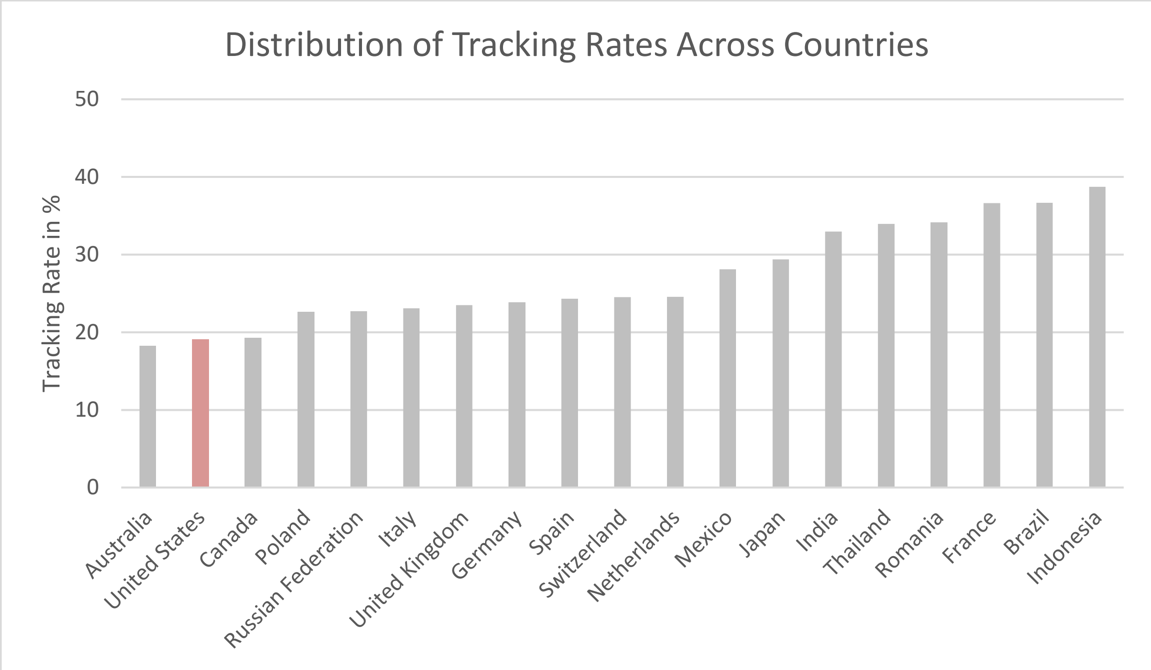
Empirical Study 2: Impact of Cultural Dimensions on Tracking Rates

We used our app data set for our second empirical study, which covers more recent data from April 2023 on the country-app level. This way, when comparing tracking rates across countries, we can control for the effect of tracking rate differences due to the usage of different Apps across countries.

Distribution of Tracking Rates Across Countries (April 2023)

To gain insights into the tracking rates in our 19 countries after controlling for differences in app usage, we ran a regression that used the tracking rate as the dependent variable and country and app fixed effects as independent variables. In Figure 9, we display the estimated fixed effects for the countries (plus the intercept), representing the tracking rates of countries after partialling out app-specific usage differences.

Figure 9: Distribution of Tracking Rates after Apple's Introduction of App Tracking and Transparency (ATT) Across 19 Countries (April 2023) and After Controlling for App Fixed Effects



Tracking rates varied from 18.26% (in Australia) to 38.71% (in Indonesia), with an average value of 28.18% (approximately the tracking rate in Mexico).

Impact of Cultural Dimensions on Tracking Rates Across Countries

These differences suggest that cultural differences (reflecting country-specific disparities) could impact the results, as hypotheses H2a-H2e also propose. Therefore, we examined the role of cultural differences in greater detail in our second empirical study by employing the cultural dimensions of Hofstede, Hofstede, and Minkov (2010).

We ran linear regressions with the tracking rate as the dependent variable and the six cultural dimensions of Hofstede, Hofstede, and Minkov (2010) as our main independent variables (Table 2). We used fixed effects in Models 2a and 2b. Model 2b also considered GDP per Capita to account for the economic environment (see Tang and Koveos 2008), a typical control variable in cultural impact studies (e.g., Datta et al. 2022). This difference, however, did not substantively impact our results. Since both models of Table 2 yielded similar insights, we used Model 2a as our main model because it mimics the conceptual model outlined in Figure 3.

The results shown in Table 2 signal that a unit increase in uncertainty avoidance (μ=64.12; σ=19.71), individualism (μ=64.85; σ=22.38), and masculinity (μ=56.93; σ=16.739) yielded a 0.06, 0.09, and 0.02 percentage point decrease in the tracking rate (μ=25.71; σ=13.61). In contrast, a unit increase in power distance (μ=53.33; σ=18.61), long-term orientation (μ=51.50; σ=21.48), and indulgence (μ=54.97; σ=19.73) led to a 0.16, 0.10, and 0.04 percentage point increase in the tracking rate. All results are consistent with our hypotheses H2a – H2e in sign and statistical significance, and consistent with model 2b. They indicate that cultural dimensions explain the differences in tracking rates across apps under ATT.

Table 2: Impact of Cultural Dimensions on the Tracking Rate with ATT

Model	**2a**	**2b**
Uncertainty Avoidance	-0.06*** (-9.25)	-0.04*** (-5.97)
Power Distance	0.16*** (20.76)	0.12*** (13.35)
Long-Term Orientation	0.10*** (22.80)	0.11*** (24.28)
Individualism	-0.09*** (-13.18)	-0.05*** (-6.25)
Indulgence	0.04*** (-4.66)	-0.03*** (-5.24)
	Control Variables	
Masculinity	-0.02*** (-4.66)	-0.03*** (-5.24)
GDP per Capita in $100k		-0.07*** (-12.50)
App Fixed Effects	Yes	Yes
	Model Statistics	
Dependent Variable	Tracking Rate	Tracking Rate
Average in %	25.72	25.72
R-Squared Within in %	24.94	25.82
Number of Countries	19	19
Number of Apps	986	986
Number of Observations	10,555	10,555

Notes: t-statistics are in parentheses and based on app-level clustered standard errors. ***: p<0.001.

Summary, Conclusions and Implications

Summary

We used three data sets—covering 19 countries and one of the world's largest privacy initiatives, Apple's App Tracking Transparency (ATT)—to examine two kinds of hypotheses concerning the effects of an opt-in (versus an opt-out) approach to obtaining users' consent for being tracked. The first kind (H1a-H1c) refers to the tracking and economic outcome; the second (H2a-H2e) refers to the role of cultural differences in said outcomes.

We found support for all our hypotheses. For example, the results for the United States support that ATT strongly decreases the share of trackable users (-55%p, supporting H1a) and the resulting revenues (-21%, supporting H1c) because advertising for trackable traffic yields much higher prices (+51% in the United States, supporting H1b). To provide a rough estimate of the absolute dollar loss in the United States corresponding to this effect, we multiplied the percentage decrease (20.55%) for Apple devices by the level of mobile online advertising revenue in the United States in 2021 ($135.1 billion according to IAB (2022)) and the share of Apple users (54.33%), yielding an overall monetary loss of $15.08 billion in the United States.

The effect of ATT on tracking rates in other countries was lower (-23.65 %p on average), as was the effect on advertising revenue (-15.32% on average). Still, these effects entail substantial losses for companies. For example, our results predict an annual (worldwide) revenue loss of $9.5 billion for Meta.

The tracking rates two years after the introduction of ATT (April 2023) differed strongly across our 19 countries: from 18.26% (in Australia) to 38.71% (in Indonesia), with an average value of 28.18%. The cultural dimensions of Hofstede, Hofstede, and Minkov (2010) explain those differences, in support of our five hypotheses:

- Uncertainty-avoiding users have lower tracking rates (H2a).
- Users accepting the power of superiorities have higher tracking rates (H2b).
- Long-term-oriented users have higher tracking rates (H2c).
- Individualistic users have higher tracking rates (H2d).
- More indulgent users have higher tracking rates (H2e).

Conclusions

Our results enable us to draw the following conclusions.

Roll-out of Privacy Policies. The update rate represents the share of users to which ATT applies. Notably, this rate is consistently high and similar across countries, suggesting that

Apple did not push the update differently across countries but instead implemented similar tracking requirements (see Figure W2 in Web Appendix B). This roll-out suggests that it is feasible to simultaneously implement a worldwide change in the privacy policy. The update rate attained its high level less than five months after ATT's introduction, which suggests that privacy policies can be rolled out quickly. The update rate remained stable thereafter, indicating that ATT's economic impact in those 19 countries should not change much because ATT already applies to almost all users.

Design of Privacy Policies. How one gathers users' consent to be tracked is an important design question. For example, the tracking rates on Android devices between April 2021 and March 2022 remained almost constant at around 94% in the USA. Even before the introduction of ATT, tracking rates on Apple devices were already much lower at around 74%. Part of this disparity may stem from the privacy preferences of both platforms' users, but some differences likely follow from Apple's approach to gaining users' consent compared to Google (the owner of Android). For example, Apple did not even allow minors to decide upon being tracked (Figure 2).

Our results demonstrate that replacing an opt-out with an opt-in approach greatly affects the share of Apple users providing consent to being tracked. The opt-in (versus opt-out) approach makes the no-tracking (versus tracking) alternative the default option. Our results emphasize that this design decision matters tremendously, which aligns with previous studies on choice architecture for app adoption (Reeck et al. 2023), health insurance decisions (Dellaert et al. 2022), and default options in other areas (Jachimowicz et al. 2019) and

What differentiates our setting from previous studies on default options is that consent questions on Apple's devices occur repeatedly. For example, individuals are usually only asked once for their organ donations over a longer period of time, which is the setting that Shepherd, O'Carroll, and Ferguson (2014) examined. With ATT, whenever a user starts using a new App, the app has to ask the user (via the ATT prompt) for her consent to be tracked. Since users often interact with new Apps, they are often confronted with the ATT prompt unless they decide to deny consent on the device level.

Our results show a negative correlation (-0.33 in Study 1 and -0.44 in Study 2) between the explicit consent rate (i.e., the “ATT prompt consent rate”) and the implicit consent rate (i.e., not denying on the device level). Thus, a higher share of users opting out on the device level goes along with a higher sharing of users providing consent when showing the ATT prompt, i.e., when providing consent to being tracked by a specific App. We could only speculate about the possible reasons, such as privacy-sensitive users self-selecting out of opt-in decisions by opting out and users being annoyed by having to respond to too many ATT consent prompts. Yet, this result indicates we cannot deduce different privacy preferences by comparing explicit consent rates across different settings (e.g., demographic groups, Apps, countries) without controlling for differences in implicit consent rates.

Comparison of Tracking Rates between Apple and Android devices. The tracking rates on Apple devices were much lower than on Android devices before ATT and even more after. Two major reasons for those differences are that (i) Apple takes actions that lead to more privacy than Android (i.e., Google) and (ii) Apple users are more privacy-sensitive than Android users. Our data do not allow us to disentangle these two reasons. Yet, the huge differences in tracking rates of Apple users with and without ATT indicate that Apple’s actions had a strong impact on privacy rates. Thus, it is unlikely that differences between Apple and Android users represent the only reason that we observed such large differences in tracking rates.

Is it Worth Bothering Users? No matter whether users provide or deny consent to being tracked, they must invest time into making these decisions, which can be substantial. For example, Skiera et al. (2022) found that even the least granular cookie consent banner decisions take 22 seconds of the average user’s day. For more granular decisions, this time goes up to more than 15 minutes and more than one hour per day if the user wants to customize every possible data processing detail.

In short, the question is whether we must bother the user with making these decisions. It would not be necessary if the resulting tracking rates were close to 0% or 100%, but that is not the case. For example, in the US, the tracking rate is about 27% with ATT, which differs substantially from 0%. In other words, a sizable share of consumers are fine with being tracked. The tracking rate for Android users was about 94%, which indicates that a setting with "allow tracking all users" is only incorrect for 6% of all users. Yet, the "without ATT tracking rate" of Apple users (i.e., the situation before ATT) was considerably lower at 74%. So, concluding that an opt-out approach mimics a setting where all users consent to being tracked is incorrect.

Instead, our results indicate that the type of approach is important. Our observed difference between Android (i.e., Google) users and Apple users of 20 %p (=94%-74%) is considerable and raises some doubts about whether privacy laws (e.g., GDPR) should remain vague regarding the precise implementation of consent approaches. Stated differently, firms can end up with different tracking rates when interpreting privacy laws differently, as was observed for cookie consent banners. Apple's ATT does not offer publishers much flexibility in requesting users' consent. So, the playing field is more level among firms under Apple's ATT than under GDPR.

Scope of Application of ATT. However, a level playing field might not exist between Apple and all other firms because ATT essentially applies to all firms apart from Apple. A crucial question is whether it would be more appropriate if ATT applied to all providers operating on the platform, including Apple's services like Apple News. Apple maintains that its services respect user privacy, their data collection is minimal, and Apple's ecosystem is tightly integrated (e.g., some of its services rely on data sharing for functionality like Handoff between devices or Siri suggestions). Still, there is an argument for having the same consent standards apply universally (UK Competition and Markets Authority (CMA) 2022).

Apple's Other Reasons for Introducing ATT. Apple claimed that it introduced ATT to increase its users' privacy. Yet, Apple also strengthened its position in the digital advertising market after the introduction of ATT. According to Statista, Apple's global advertising business reached revenues of $1.09 billion in 2020. These revenues increased to $3.7 billion in 2021 and $4.7 billion in 2022. Within two years, Apple quadrupled its advertising revenue. Our results indicate that publishers suffered from a 20% loss in advertising revenues in the United States. The advertisers likely spent their money elsewhere. It is unclear where, but it could be that advertisers increased their advertising spending on Apple's App Store.

Trackable Traffic is more Valuable than Untrackable Traffic. Our results indicate that advertising prices for trackable traffic were substantially higher than for untrackable traffic (14% to 97%) in our 19 countries. Thus, publishers who rely on advertising revenues suffer from privacy initiatives that decrease the share of trackable traffic.

Implications for Publishers

Publishers must recognize that most users quickly updated their device to iOS 14.5 or higher, implying that it is currently rare for publishers to track users via the IDFA without their explicit consent. In addition, among all adult users, the share of users opting out on the device level is high: 46% in the US, for example (Figure 4). As publishers cannot ask minors (about 7% of their users), they can only ask about half of their users (50.22% = 93% x 54%) for their explicit consent (via the ATT prompt). Most of them deny consent (64%). The result is a low share of users who can be tracked via their IDFA.

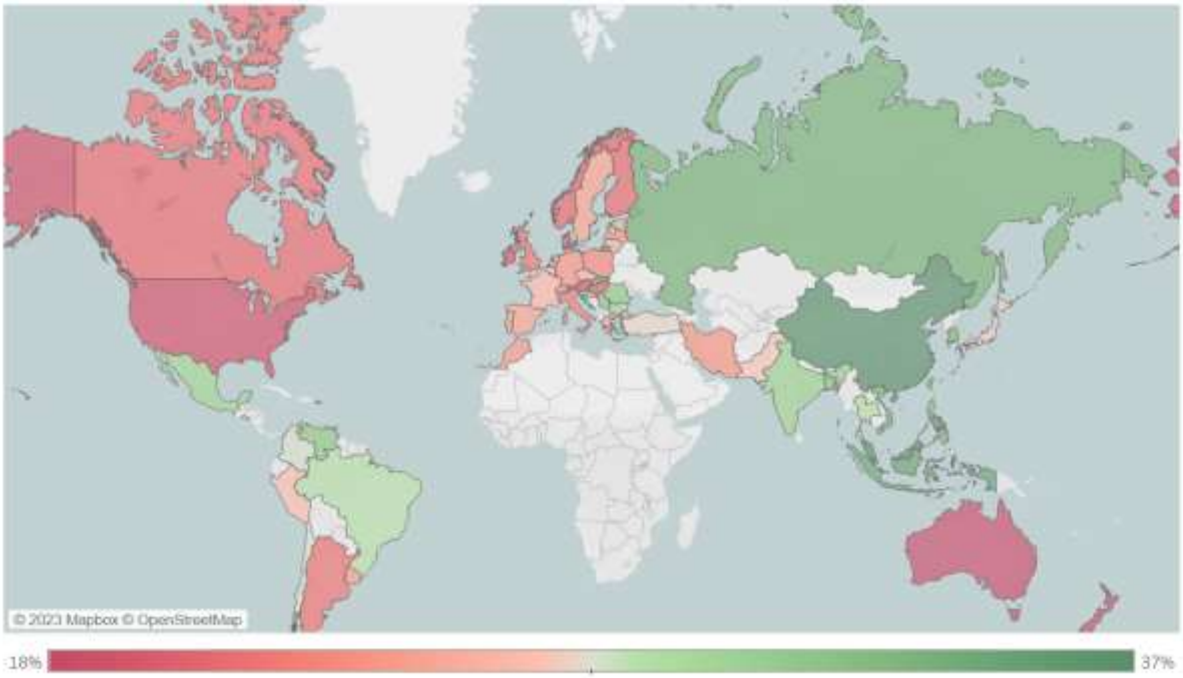
As advertising prices are much higher for trackable than for untrackable traffic (+51% in the USA), the question is what publishers can do to increase the share of trackable traffic, i.e., their tracking rate. Rescinding ATT would help because the tracking rates under an opt-out approach are much higher than under an opt-in approach; of course, it is unlikely that Apple will revert its stance. Still, the lesson from ATT for other settings (e.g., Android users) is that an opt-out approach yields higher tracking rates.

Very likely, an individual publisher can do little to increase the implicit consent rate (i.e., the share of users who do not opt-out on the device level). Being a “good App” (in a privacy sense) certainly does not hurt the implicit consent rate, but its impact is probably far lower than being a “bad App”. Indeed, one “bad App” might sufficiently incentivize the user to disable tracking on the device level. Even without being a “bad app”, each app must confront users with the ATT prompt in order to access the user’s IDFA. Users who constantly have to answer the ATT prompts might become annoyed and decide to opt-out on the device level. Once this setting is in place, it becomes difficult to reach the user and persuade them differently.

In short, publishers can only use the ATT prompt to “nudge” the user into consenting to be tracked. Apple does not provide much flexibility in designing this prompt (see Figure 1); however, publishers can use a “pre-prompt”, i.e., a custom message or screen that publishers display before the ATT prompt. Publishers can use this pre-prompt to explain why they should allow tracking in order to increase the chances of consent to the ATT prompt itself. In this vein, publishers can use our insights from hypotheses H2a-H2e to design these pre-prompts. For example, they could reduce the perceived uncertainty that comes with tracking (H2a), e.g., by emphasizing the security and aims of data processing. They could also highlight the long-term consequences of the publisher’s inability to track users (H2c), e.g., the lack of financial resources to generate high-quality content (Shiller, Waldfogel, and Ryan 2018) or remind users that their consent enables the publisher to offer the app free of monetary charges (Schumann, von Wangenheim, and Groene 2014). They could also clarify that tracking offers more user-specific indulgences, e.g., more personalized recommendations (H2e).

Publishers who rely on tracking can also use our insights from hypotheses H2a-H2e to evaluate countries in terms of their tracking abilities. Figure 10 uses Model 2a of Table 2 to predict the tracking rates of the 62 countries for which Hofstede, Hofstede, and Minkov (2010) measured their six cultural dimensions. It outlines that the predicted tracking rates are, in general, higher in Asia and South America.

Figure 10: Predicted Tracking Rates Across 62 Countries Based On Cultural Dimensions



Additionally, publishers may seek to leverage the Identifier for Vendors (IDFV) to mitigate the decrease in tracking rate. As discussed above, the IDFV enables a publisher to track a user within the network of apps that the publisher owns. Thus, ATT (via IDFV) incentivizes publishers to increase the number of apps they own—whether by developing news apps or merging with other publishers.

Implications for Advertisers

Our results indicate that ATT substantially decreased the opportunities for targeted advertising, e.g., via behavioral advertising or retargeting, among Apple users. While 73% of

Apple users were reachable before the introduction of ATT, only 18% were reachable afterward (55%p less). In addition, advertisers can rely less on data brokers for improving targeted advertising because said data brokers also suffer from more limited opportunities under ATT to collect user data. Advertisers relying on targeted advertising must implement other forms that do not rely on access to the users' IDFA (particularly contextual targeting) or increase their activities with users on other devices (particularly Android devices or other media).

Furthermore, advertisers on Apple devices must realize that measuring advertising performance is more limited because their attribution models can no longer rely on having access to the IDFA of most of their users. In other words, attributing conversions to specific ads or campaigns becomes more difficult. Apple's introduction of the SKAdNetwork (i.e., an opportunity to measure the success of ad campaigns under ATT) is helpful but only reports at a campaign level, not at a user level. As a result, advertisers only get data for the whole campaign, making it hard to understand how differences in users' characteristics impact their responses to ads. In addition, the SKAdNetwork also introduces delays in conversion reporting so advertisers no longer receive near-real-time feedback on their campaigns' performances, complicating the optimizations of their campaigns on Apple devices.

Implications for Users

For users, our results make clear that an opt-in approach yields lower tracking rates than an opt-out approach, and is thus better for privacy. Additionally, users can rest assured that publishers are not lying when telling users that "allow tracking" helps them generate higher revenues. Our data is not suitable for testing the claim that "higher revenues help them [Apps] to create better content", but other studies have substantiated this point (Shiller, Waldfogel, and Ryan 2018). That finding aligns with intuition and the results of our hypotheses H2c. In short, users should realize that never consenting to tracking can have negative consequences in terms of an app's future offerings.

Implications for Regulators

Regulators across several countries have recognized the need to implement regulations to improve user privacy on the internet (e.g., Europe's GDPR, California's California Consumer Privacy Act (CCPA), and China's Personal Information Protection Law (PIPL)). However, there is uncertainty about how to achieve this privacy improvement. For example, GDPR and PIPL generally require firms to implement an opt-in approach, whereas the CCPA only requires an opt-out approach (Jin and Skiera 2022). Our findings illustrate that an opt-in approach yields higher privacy (as measured by the share of non-trackable traffic), but decreases publishers' advertising revenues and, by extension, their profit. Thus, regulators must trade-off between users' privacy and publishers' profit. This trade-off is not an easy task: privacy and profit are hard to compare (e.g., because they are not usually measured on the same scale), akin to "comparing apples with oranges". Furthermore, publishers' lower profits can indirectly hurt users, e.g., by leading to less or lower-quality content.

Our results outline that, before ATT, users had the opportunity to adjust their system settings to opt out of IDFA tracking—yet most chose not to do so. They only did it after ATT. Several reasons could explain this behavior: For example, in the pre-ATT period, users might have perceived the effort to turn off tracking as too high. In that case, the regulator might conclude that users do not attribute high value to increased user privacy—even if they claim to do so (a situation referred to as the privacy paradox; Kokolakis 2017; Gerber, Gerber, and Volkamer 2018). Alternatively, users might not have been aware that they could disable tracking via their system settings. In that case, ATT can bypass users' privacy illiteracy (Trepte et al. 2014), thus benefitting users significantly. It is also possible that users were simply unaware of the potential harm that tracking might cause them. In that case, moving from an opt-out to an opt-in approach does not help much unless such a move comes with additional information that addresses users' lack of awareness.

Our results indicate that the high share of trackable users on Android devices (95% in the US) remained fairly constant during the observation period of our first empirical study (1 month before and 11 months after ATT). In contrast, the share of trackable Apple users dropped strongly (from 73% to 18% in the USA). A regulator might wonder if there are spillover effects between Apple and Android users—wherein the less trackable Apple users incentivize Android users to also opt out of tracking. But our results do not lead us to draw such a conclusion.

Regulators must also recognize that ATT can have other consequences beyond a decrease in publishers' revenues. First, publishers may try to leverage the Identifier for Vendors (IDFV) as a means of mitigating the decrease in tracking rate. As discussed above, the IDFV enables a publisher to track a user within the network of apps that the publisher owns. Thus, ATT, via IDFV, incentivizes publishers to increase the number of apps they own. This incentive might also lead to publisher consolidation in Apple's app market. Such consolidation might raise new privacy concerns and reduce competition in the app market.

Second, regulators must be aware that a firm's privacy initiatives—in this case, Apple—may have economic motivations. As stated before, Apple implemented ATT in April 2021 and increased its advertising revenues from $1.09 billion in 2020 to $3.7 billion in 2021 and $4.7 billion in 2022. Because of ATT, publishers suffered from a 20% loss in advertising revenues in the Untied States. We did not examine whether Apple's increase in advertising revenue occurred because of ATT, but it is a remarkable coincidence. Thus, regulators should carefully examine the major motivations behind firms' privacy initiatives: Is that decision made for users' privacy or the firm's competitive position?

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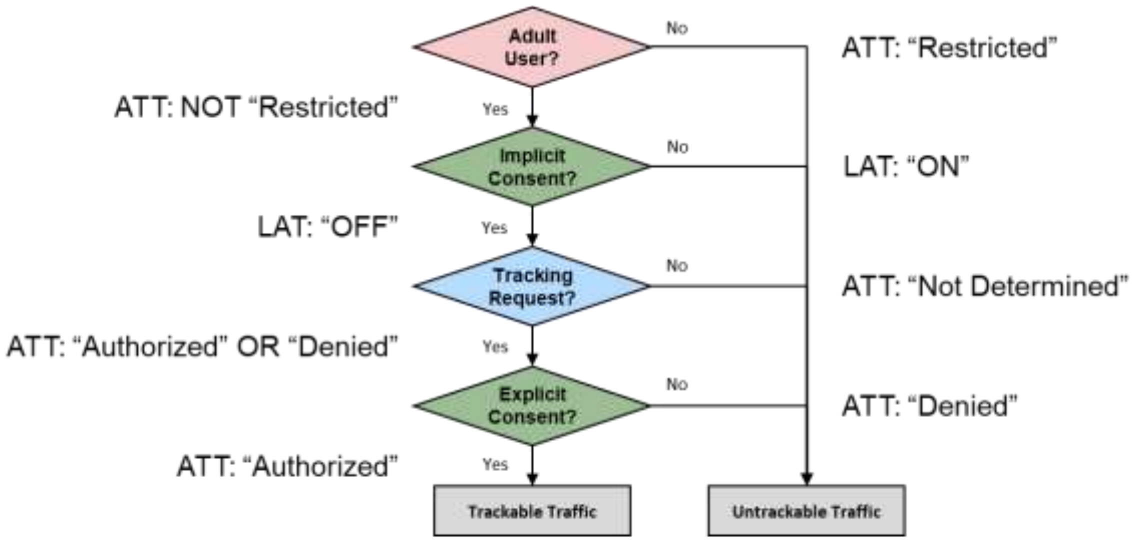
Web Appendix

Web Appendix A: Description of Procedure to Derive Consent Rates

We use Figure W1 to outline how we use our data, specifically our observation of LAT and ATT status, to measure trackable and untrackable traffic. Before iOS 14.5, Apple used an opt-out approach with its "Limit Ad Tracking" (LAT). Starting with iOS 14.5, Apple changed the name "Limit Ad Tracking" to "Allow Apps to Request to Track" and added the opt-in approach (via the ATT Prompt). For ease of simplicity, however, we continue to refer to "Allow Apps to Request to Track" as "Limit Ad Tracking".

LAT measures the opt-out rate on the device level. If LAT is "ON", publishers cannot request the user (via the ATT prompt) whether they can track the user. As they cannot ask, they cannot get the user's (explicit) consent for tracking, i.e., the ability to access the user's IDFA. So, publishers can only request the user if LAT is "OFF".

Figure W1: Relation of Trackable and Untrackable Traffic with LAT and ATT Status



Across all iOS versions, Apple uses the following four labels to define a user's tracking status for a particular app:

- *Authorized* represents Apple users from whom the app has obtained explicit consent to use the IDFA for tracking. For post-ATT versions of iOS, this status refers to users who saw the app's ATT prompt and tapped "Allow Tracking".
- *Denied* represents two groups of Apple users, which Apple does not distinguish: (i) users who were asked by publishers to provide explicit consent to tracking and denied their consent (e.g., users who saw the ATT prompt and tapped "Ask App Not to Track"); and (ii) users who accessed iOS's privacy settings and toggled an individual app's tracking setting or the "Allow Apps to Request to Track" setting to the "OFF" option.
- *Not Determined* represents Apple users who have toggled the "Allow Apps to Request to Track" setting to the "on" option but whom the app has not asked for explicit consent to track (e.g., users who have not seen the app's ATT prompt, for iOS versions 14.5 and above).
- *Restricted* represents non-adult users. For those users, the setting "Allow Apps to Request to Track" is disabled (and, consequently, permanently toggled "off"). So, publishers cannot access their IDFA.

As Figure W1 outlines, we use the ATT status "Restricted" to differentiate between adult and non-adult users. For adult users, we use the LAT status "OFF" and "ON" to differentiate between users who do not opt-out (implicit consent) and opt-out. Next, the ATT statuses "Authorized" and "Denied" define users who received a tracking request and, thus, saw an ATT prompt. In contrast, the ATT status "Not Determined" represents the remaining users who have not seen an ATT prompt (yet). Finally, the ATT status "Authorized" establishes users who opted-in (explicit consent) and yield "Trackable Traffic", whereas users with ATT status "Denied" represent users who did not opt-in, and, together with users having the ATT status "Restricted" or "Not Determined" or LAT status "ON", yield "Untrackable Traffic".

We then define our five rates as follows:

- The tracking rate is the share of “Trackable Traffic” at the sum of “Trackable Traffic” plus “Untrackable Traffic”.
- The explicit consent rate is the share of users with ATT status “Authorized” among all users with ATT status “Authorized” or “Denied” .
- The ask rate is the share of users with ATT status “Authorized” or “Denied” among those with LAT “OFF”.
- The implicit consent rate is the share of users with the LAT status “OFF” among users without ATT status “Restricted”.
- The “adult rate” rate is the share of users without ATT status “Restricted” among all users.

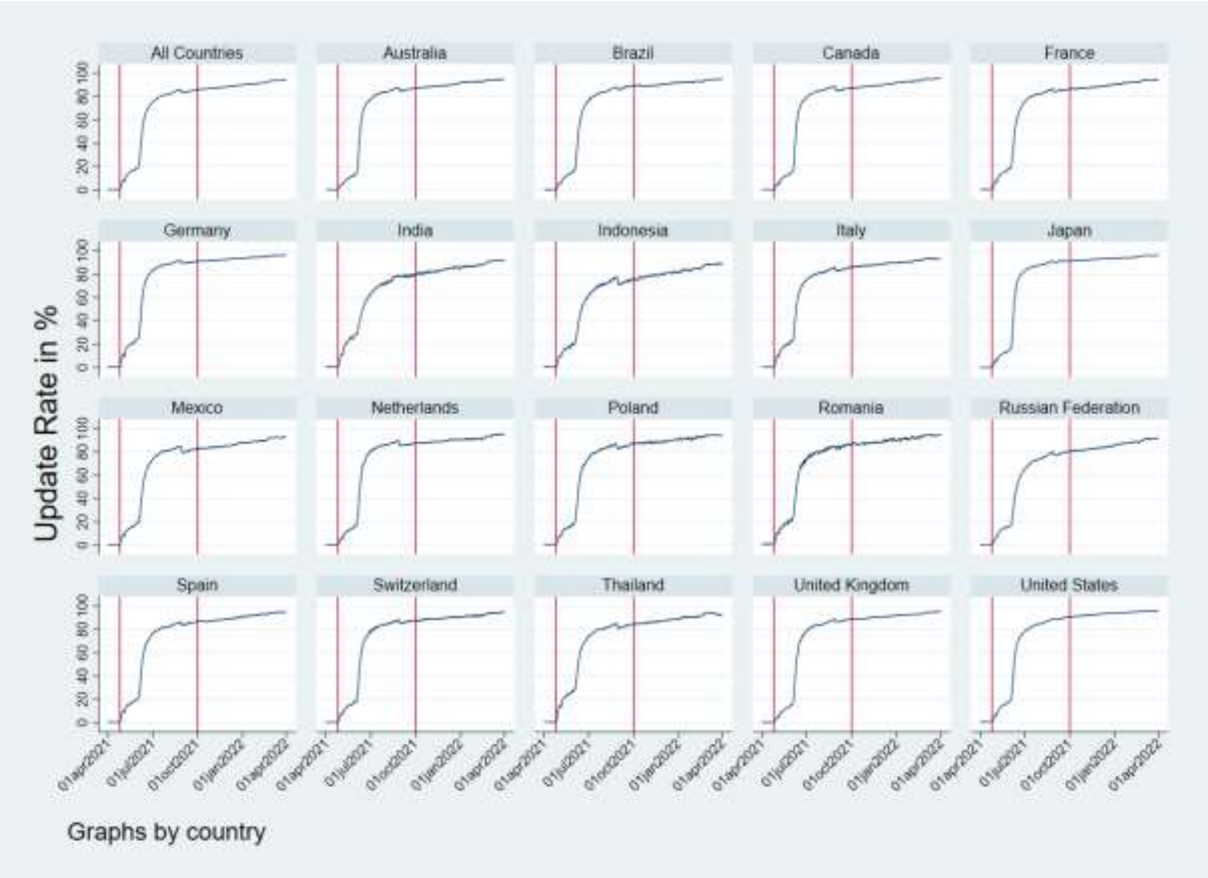
Web Appendix B: Adoption of Apple's App Tracking Transparency (ATT) (≥iOS 14.5)

ATT's roll-out started on April 26, 2021, when the company released an updated version of its operating system (iOS 14.5). So, a user adopted ATT whenever they installed an operating system with version 14.5 or higher. The update rate reflects the percentage of Apple users who have updated their devices to a post-ATT iOS version. Users who purchase new devices or update old devices impact the update rate. Apple influences these users because it determines how attractive the update is (i.e., by the degree of improvement in the new version compared to the previous one) and decides how strongly it communicates to users that an update is available.

Figure W2 outlines the update rates for each of our 19 countries and all 19 countries together (labeled as "all countries"). The first vertical red line represents April 25, 2021, a day before ATT's implementation. The second vertical red line represents October 1, 2021, approximately five months after ATT's implementation. Empirical study 1 uses all observations to the left of the first vertical red line and all observations to the right of the second vertical red line. The update rates across all countries on April 25, 2021, are close to 0% (e.g., United States: 0.50%, average across all countries: 0.38%). On October 1, 2021, update rates are much higher (e.g., United States: 90.74%, average across all countries: 85.94%). So, most of the updates to ATT occurred before October 1, 2021, which motivates us to use October 1, 2021, as the start of our observation period after ATT. On March 31, the last day in our observation period, update rates increased further (e.g., United States: 95.86%, average across all countries: 94.12%).

Regarding the dynamics in the United States, Figure W2 shows that immediately after ATT's introduction, the update rate increased only slightly to 20%. A substantial increase in the update rate, to about 80%, quickly occurred after Apple introduced iOS 14.6 (on May 24, 2021). The second increase probably occurred because Apple pushed the update of iOS 14.6 by showing a red badge on the devices' system settings icon, firmly nudging users to update their devices.

Figure W2: Overview of Update Rate Across Countries



Web Appendix C: Results of Regressions with the Impact of the Introduction of ATT on Tracking Outcome

In Table W1 and Table W2, we present the regressions for our 19 countries (in alphabetical order) that belong to the results in Figure 5. The Model 3s (USA) repeats the result shown in Figure 5.

Table W1: Impact of the Introduction of ATT on Tracking Outcome (First Table – Before and After)

Model	**3a**	**3b**	**3c**	**3d**	**3e**	**3f**	**3g**	**3h**	**3i**	**3j**
ATT	-0.57***	-0.52***	-0.60***	-0.37***	-0.50***	-0.41***	-0.24***	-0.43***	-0.49***	-0.40***
	(-483.06)	(-192.68)	(-518.88)	(-157.35)	(-148.35)	(-202.71)	(-44.46)	(-133.76)	(-173.86)	(-128.54)
	Model Statistics									
Country	Australia	Brazil	Canada	France	Germany	India	Indonesia	Italy	Japan	Mexico
Dependent Variable	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate
Mean (Before ATT)	0.73	0.85	0.75	0.74	0.69	0.72	0.62	0.72	0.73	0.66
Mean (After ATT)	0.16	0.33	0.16	0.36	0.18	0.3	0.37	0.28	0.24	0.25
R-Squared Within in %	99.87	98.73	99.91	96.14	97.34	98.7	95.04	97.29	97.11	99.49
Number of Countries	1	1	1	1	1	1	1	1	1	1
Number of Days	207	207	207	207	207	207	207	207	207	207
Number of Observations	207	207	207	207	207	207	207	207	207	207
Starting Date (Before ATT)	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01
Ending Date (Before ATT)	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25
Starting Date (Before ATT)	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01
Ending Date (Before ATT)	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31

Notes: t-statistics are in parentheses and are based upon robust standard errors. ***: p<0.001.

Table W2: Impact of the Introduction of ATT on Tracking Outcome (Second Table – Before and After)

Model	**3k**	**3l**	**3m**	**3n**	**3o**	**3p**	**3q**	**3r**	**3s**	**3t**
ATT	-0.49***	-0.38***	-0.35***	-0.53***	-0.49***	-0.49***	-0.37***	-0.55***	-0.55***	-0.46***
	(-192.30)	(-62.08)	(-59.61)	(-312.82)	(-242.99)	(-168.26)	(-189.69)	(-224.22)	(-268.27)	(-125.67)
					Model Statistics					
Country	Netherlands	Poland	Romania	Russian Federation	Spain	Switzerland	Thailand	United Kingdom	United States	All countries
Dependent Variable	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate
Mean (Before ATT)	0.72	0.68	0.72	0.78	0.71	0.74	0.72	0.76	0.73	0.73
Mean (After ATT)	0.23	0.3	0.38	0.25	0.22	0.25	0.35	0.2	0.18	0.27
R-Squared Within in %	97.76	76.91	77.11	99.65	98.95	95.9	98.71	98.52	99.43	93.25
Number of Countries	1	1	1	1	1	1	1	1	1	19
Number of Days	207	207	207	207	207	207	207	207	207	207
Number of Observations	207	207	207	207	207	207	207	207	207	3933
Starting Date (Before ATT)	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01
Ending Date (Before ATT)	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25
Starting Date (Before ATT)	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01
Ending Date (Before ATT)	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31

Notes: t-statistics are in parentheses and are based upon robust standard errors. ***: p<0.001. All countries' estimation (model 3t) with country-level fixed effects.

Table W3 and Table W4 display the results for a difference-in-difference approach. They should document that the results remain similar when we use a difference-in-differences approach instead of a before-after approach (as Figure 5, Table W1 and Table W2 present).

Table W3: Impact of the Introduction of ATT on Tracking Outcome (First Table – Difference in Differences)

Model	**3a-r**	**3b-r**	**3c-r**	**3d-r**	**3e-r**	**3f-r**	**3g-r**	**3h-r**	**3i-r**	**3j-r**
ATT	-0.58***	-0.42***	-0.60***	-0.33***	-0.34***	-0.41***	-0.24***	-0.46***	-0.48***	-0.39***
	(-411.50)	(-83.57)	(-440.49)	(-57.71)	(-65.93)	(-195.39)	(-43.30)	(-59.15)	(-169.57)	(-122.80)
	Model Statistics									
Country	Australia	Brazil	Canada	France	Germany	India	Indonesia	Italy	Japan	Mexico
Dependent Variable	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate
ATT Effect (Before-After Approach)	-0.57	-0.52	-0.60	-0.37	-0.50	-0.41	-0.24	-0.43	-0.49	-0.40
Difference in ATT Effects (DiD – Before-After Approach)	-0.01	0.10	0.00	0.04	0.16	0.00	0.00	-0.03	0.01	0.01
Mean (Before ATT)	.84	.91	.85	.71	.7	.84	.79	.67	.85	.81
Mean (After ATT)	.56	.6	.55	.5	.36	.63	.67	.47	.6	.6
R-Squared Within in %	99.97	97.85	99.98	91.15	97.08	99.87	99.79	89.75	99.69	99.96
Number of Countries	1	1	1	1	1	1	1	1	1	1
Number of Days	207	207	207	207	207	207	207	207	207	207
Number of Observations	414	414	414	414	414	414	414	414	414	414
Starting Date (Before ATT)	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01
Ending Date (Before ATT)	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25
Starting Date (Before ATT)	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01
Ending Date (Before ATT)	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31

Notes: t-statistics are in parentheses and are based upon robust standard errors. ***: p<0.001.

Table W4: Impact of the Introduction of ATT on Tracking Outcome (Second Table – Difference in Differences)

Model	3k-r	3l-r	3m-r	3n-r	3o-r	3p-r	3q-r	3r-r	3s-r	3t-r
ATT	-0.49***	-0.40***	-0.38***	-0.52***	-0.39***	-0.47***	-0.36***	-0.58***	-0.56***	-0.44***
	(-58.37)	(-47.91)	(-41.00)	(-297.98)	(-83.03)	(-91.63)	(-169.71)	(-90.46)	(-232.18)	(-70.33)
	Model Statistics									
Country	Netherlands	Poland	Romania	Russian Federation	Spain	Switzerland	Thailand	United Kingdom	United States	All countries
Dependent Variable	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate	Tracking Rate
ATT Effect (Before-After Approach)	-0.49	-0.38	-0.35	-0.53	-0.49	-0.49	-0.37	-0.55	-0.55	-0.46
Difference in ATT Effects (DiD – Before-After Approach)	0.00	-0.02	-0.03	0.01	0.10	0.02	0.01	-0.03	-0.01	0.02
Mean (Before ATT)	.67	.67	.69	.87	.69	.75	.84	.69	.83	0.78
Mean (After ATT)	.43	.49	.54	.6	.39	.49	.65	.42	.56	0.54
R-Squared Within in %	89.43	89.05	81.22	99.94	96.89	97.58	99.85	94.79	99.91	55.27
Number of Countries	1	1	1	1	1	1	1	1	1	19
Number of Days	207	207	207	207	207	207	207	207	207	207
Number of Observations	414	414	414	414	414	414	414	414	414	7866
Starting Date (Before ATT)	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01
Ending Date (Before ATT)	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25
Starting Date (Before ATT)	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01
Ending Date (Before ATT)	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31

Notes: t-statistics are in parentheses and are based upon robust standard errors. ***: p<0.001. All countries' estimation (model 3t-r) with country-level fixed effects.

Web Appendix D: Regression Results with Price Differences of Trackable and Untrackable Traffic

In Table W5 and Table W6, we present the regressions for our 19 countries (in alphabetical order) that belong to the results in Figure 6. The Model 4s (USA) repeats the result shown in Figure 6.

Table W5: Estimation of Price Differences for Ads for Trackable versus Untrackable Users (in $ CPM) for All Countries

Model	**4a**	**4b**	**4c**	**4d**	**4e**	**4f**	**4g**	**4h**	**4i**	**4j**
IDFA	0.47***	0.62***	0.43***	0.41***	0.33***	0.50***	0.31	0.43***	0.42***	0.68***
	(8.08)	(13.23)	(11.18)	(14.17)	(7.50)	(12.55)	(1.19)	(13.51)	(7.20)	(6.87)
					Model Statistics					
Country	Australia	Brazil	Canada	France	Germany	India	Indonesia	Italy	Japan	Mexico
Dependent Variable	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM
Mean (Without IDFA)	4.00	0.59	3.86	2.67	2.96	1.01	19.2	3.75	0.27	1.15
Mean (With IDFA)	7.70	1.22	7.69	2.74	6.29	1.42	32.1	4.29	0.52	2.19
Impact of IDFA in %	60	86	53	51	39	64	36	54	52	97
R-Squared Within in %	30.51	67.92	36.28	28.24	23.69	48.15	4.180	23.78	48.87	43.25
Number of Apps	2072	1809	2627	1795	2116	677	1556	1438	713	1533
Number of Days	28	28	28	28	28	28	28	28	28	28
Number of Observations	145,190	273,515	295,333	168,214	197,777	19,306	31,393	43,610	136,864	76,465
App Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Starting Date	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01
Ending Date	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28

Notes: t-statistics are in parentheses and based on App-level clustered standard errors. ***: $p<0.001$.

Table W6: Estimation of Price Differences for Ads for Trackable versus Untrackable Users (in $ CPM) for All Countries

Model	**4k**	**4l**	**4m**	**4n**	**4o**	**4p**	**4q**	**4r**	**4s**	**4t**
IDFA	0.33***	0.15+	0.16*	0.29***	0.31***	0.13**	0.17**	0.37***	0.41***	0.42***
	(7.99)	(1.91)	(2.22)	(5.54)	(3.38)	(3.17)	(3.02)	(8.54)	(11.48)	(11.11)
	Model Statistics									
Country	Netherlands	Poland	Romania	Russia	Spain	Switzerland	Thailand	UnitedKingdom	USA	All countries
Dependent Variable	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM	Log of CPM
Mean (Without IDFA)	4.74	3.07	3.87	2.56	1.23	3.59	0.810	5.55	3.27	3.27
Mean (With IDFA)	5.76	2.50	2.98	3.41	3.30	5.79	1.63	6.44	4.18	4.27
Impact of IDFA in %	39	16	17	33	36	14	19	44	51	52
R-Squared Within in %	10.34	1.95	1.83	27.95	8.81	1.72	4.68	31.50	82.69	35.97
Number of Apps	1113	633	516	2085	1084	1847	466	2827	6985	9795
Number of Days	28	28	28	28	28	28	28	28	28	28
Number of Observations	21,326	9,521	6,764	156,633	42,010	25,694	16,781	363,365	15,578,926	17,635,535
App Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Starting Date	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01	2022-02-01
Ending Date	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28	2022-02-28

Notes: t-statistics are in parentheses and based on App-level clustered standard errors. +: p<0.10, *:p<0.05, **:p<0.01, ***: p<0.001.

Web Appendix E: Results of Regressions with the Impact of the Introduction of ATT on Economic Outcome

In Table W7 and Table W8, we present the regressions for our 19 countries (in alphabetical order) that belong to the results in Figure 7. The Model 5s (USA) repeats the result shown in Figure 7.

Table W7: Impact of the Introduction of ATT on Tracking Outcome (First Table)

Model	**5a**	**5b**	**5c**	**5d**	**5e**	**5f**	**5g**	**5h**	**5i**	**5j**
ATT	-0.27***	-0.30***	-0.26***	-0.15***	-0.17***	-0.20***	-0.07***	-0.18***	-0.20***	-0.27***
	(-516.86)	(-199.47)	(-560.57)	(-153.24)	(-150.10)	(-206.48)	(-45.98)	(-137.17)	(-168.96)	(-145.49)
	Model Statistics									
Country	Australia	Brazil	Canada	France	Germany	India	Indonesia	Italy	Japan	Mexico
Dependent Variable	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)
Mean (Before ATT)	0.36	0.54	0.33	0.32	0.23	0.38	0.2	0.32	0.32	0.49
Mean (After ATT)	0.09	0.25	0.08	0.17	0.07	0.17	0.12	0.14	0.11	0.22
R-Squared Within in %	99.83	98.32	99.89	95.58	96.90	98.43	94.85	96.82	96.51	99.42
Number of Countries	1	1	1	1	1	1	1	1	1	1
Number of Days	207	207	207	207	207	207	207	207	207	207
Number of Observations	207	207	207	207	207	207	207	207	207	207
Starting Date (Before ATT)	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01
Ending Date (Before ATT)	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25
Starting Date (Before ATT)	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01
Ending Date (Before ATT)	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31

Notes: t-statistics are in parentheses and are based upon robust standard errors. ***: p<0.001.

Table W8: Impact of the Introduction of ATT on Tracking Outcome (Second Table)

Model	**5k**	**5l**	**5m**	**5n**	**5o**	**5p**	**5q**	**5r**	**5s**	**5t**
ATT	-0.16***	-0.06***	-0.06***	-0.15***	-0.15***	-0.07***	-0.06***	-0.20***	-0.23***	-0.17***
	(-189.40)	(-61.48)	(-59.31)	(-324.94)	(-245.18)	(-164.91)	(-191.85)	(-222.48)	(-279.73)	(-54.73)
					Model Statistics					
Country	Netherlands	Poland	Romania	Russian Federation	Spain	Switzerland	Thailand	United Kingdom	United States	All countries
Dependent Variable	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)	Log(Price Index)
Mean (Before ATT)	0.24	0.1	0.11	0.23	0.23	0.1	0.12	0.28	0.32	0.28
Mean (After ATT)	0.08	0.04	0.06	0.08	0.07	0.03	0.06	0.08	0.09	0.11
R-Squared Within in %	97.40	76.18	76.46	99.56	98.80	95.64	98.64	98.22	99.30	81.67
Number of Countries	1	1	1	1	1	1	1	1	1	19
Number of Days	207	207	207	207	207	207	207	207	207	207
Number of Observations	207	207	207	207	207	207	207	207	207	3933
Starting Date (Before ATT)	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01	2021-04-01
Ending Date (Before ATT)	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25	2021-04-25
Starting Date (Before ATT)	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01	2021-10-01
Ending Date (Before ATT)	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31	2022-03-31

Notes: t-statistics are in parentheses and are based upon robust standard errors. ***: $p<0.001$. All countries' estimation (model 5t) with country-level fixed effects.