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Taxation and Global Spillovers in the Digital Advertising Market. Theory and Evidence from Facebook

Abstract

We study the effects of taxation on the international online advertising market, using data on Facebook ad prices, Facebook users product preferences and international trade. Our data encompass a de facto increase in the platform's corporate tax rate in several countries. We show that, due to international trade linkages, tax changes produce global spillovers. Yet, advertisers experience higher prices in countries that directly face the tax increases compared to advertisers in countries that do not. This result is consistent with a theoretical model, which shows that the platform reduces the supply of ads to advertisers from countries where taxation increases.

JEL-Codes: H220, H250, F230.

Keywords: tax incidence, online advertising, Facebook.

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1 Introduction

Rethinking the tax system is one of the most important challenges posed by the digitization of the economy (OECD, 2015, 2018; EU, 2016). Despite the lively policy debate on the topic, the effects of tax instruments designed for the digital market remain an open question. To answer this question, one has to consider a number of issues. First, many of the companies currently at the forefront of the digital economy - such as Google, Facebook and Twitter - are multi-sided platforms, generating practically all of their revenue from advertising.[1] Second, the digital economy has been growing at a much faster rate than any other sector,[2] and the largest platforms have rapidly acquired dominant positions in their respective markets. Third, the sector is populated by multinational firms, operating worldwide but with a business model that requires no permanent establishment, except in very few countries. This paper provides an analysis of taxation in a digital market that accounts for these aspects.

Studying the effect of taxation on the markets that multinational digital platforms (MDPs) dominate is challenging because appropriate data are scarce. Our first contribution is to present new empirical evidence of the incidence of taxation on online advertising prices. We collect a unique database of daily online ad prices on Facebook. This database is novel because digital firms typically provide little information about advertising on their platforms. To measure the tax incidence, we take into account the global nature of the advertising market, in which price spillovers occur

[1] We focus here on ad-financed platforms, such as search engines, social media, blogs, photo and video sharing and social discussion forums. The business model we refer to does not apply to platforms that operate as internet market places, subscription services or transaction intermediaries as a main activity.

[2] The U.S. Bureau of Economic Analysis estimated that real value added in the digital economy annually grew at 9.9 percent per year from 1998 to 2017 on average, compared to 2.3 percent for the overall economy. In 2017, this corresponded to 1.3tr USD in the US alone (equal half of the UK GDP and 6.9 percent of US GDP). See also Figure A1.

across countries. Our analysis suggests that these spillovers arise not only because of a platform's incentive to minimize taxes, but also because of interactions through international trade networks.[3] Our second contribution is to provide a theoretical framework to study the effects on the advertising market of taxing MDPs. The analysis has relevant implications for the design of taxes on digital platforms, and aims to address the current debate on proposed reforms to international corporate tax systems.

Tax instruments directed at digital platforms have been discussed extensively by national as well as international institutions, but their implementation is either very recent or, in most cases, has yet to be finalized. This aspect renders the estimation of the incidence of taxation on the online advertising market difficult. Instead, our study exploits a change in accounting practices recently adopted by the world's largest social media, Facebook.[4] Up to 2016, the firm booked all its non-US advertising sales in Ireland, where it pays comparatively low taxes. In the spring of 2016, Facebook announced that UK advertising sales would be booked locally, and, in late 2017, it indicated that the same change would also apply to all other countries hosting one of the firm's sales offices. Facebook generates 98.5 percent of its revenue through advertising. Thus, these changes imply a substantial increase in the tax rate on the revenue that Facebook collects from advertisers located in such countries. For this reason, these changes

[3]The nature of MDPs allows them to exploit international tax differentials to a larger degree than other multinational enterprise. Typically, MDPs need little in the way of a physical presence in the market in which they operate. They employ novel forms of transactions, facilitating the channeling of royalty payments toward tax heaven-based affiliates. Finally, their business model is based on personal data. The value such data - and the volume of related transactions (e.g. sale of advertising) they generate - are extremely complex to define.

[4]Facebook has a market share of 80 percent in the social media market, according to the Digital Advertising Report 2019 - Social Media Advertising by Statista.com. In 2018, the social media advertising market generated a worldwide revenue of $76.2 billion, representing the second largest digital advertising market. `https://www.statista.com/study/36294/digital-advertising-report-social-media-advertising/`, last consulted on January 17, 2019.

may produce effects similar to the introduction of an ad hoc corporate tax instrument. We collect the median of daily unit prices of all ads targeted at country specific audiences, i.e. the full set of Facebook users located in a particular country. We do this for all countries that are member of the Organisation for Economic Co-operation and Development (OECD) from July 2015 to February 2017, a period encompassing Facebook's accounting change. Time series analysis shows a significant break in the trend of prices for audiences in all countries around the time of the announcement of upcoming accounting changes (March 2016). This effect suggests that Facebook adopted changes in the allocation of ads in all countries, potentially also in anticipation of the upcoming restructuring.

We estimate the effect that an increase in the effective tax rate has on advertising prices, using panel and spatial models. Our approach is motivated by the fact that the market for online advertising is global and dominated by few, very large MDPs. Advertisers from each country target both domestic and foreign Facebook audiences, and changes in tax policy in one country affect the price for reaching audiences also in other countries. For this reason, we deliberately avoid a quasi-experimental setup that compares ad prices in countries with and without taxation of digital platforms. Instead, we directly address the interdependence of prices across countries by considering that users in a country attract both domestic and foreign advertisers. Specifically, we assume that the demand for ads to users in country b by firms from country a depends on which products these users are interested in and on the share of the market for such products in country b that belongs to a-based firms. Our methodology is inspired by recent international trade literature showing that prices and trade flows in digital markets are highly correlated with corresponding figures from traditional markets (Cavallo, 2017, Lendle et al., 2016). Data on prices and on audience preferences, measured by the interests of users

on products and services advertised on Facebook, proxy for advertising demand, while data on bilateral imports of these products account for the market position of foreign advertisers.[5]

Our results show a sizeable effect of increasing the tax rate in sales-office countries on the prices of ads to Facebook audiences. We estimate that the cost-per-mille price (CPM) increased on average by \$0.09 to \$0.29 following Facebook's accounting restructuring, which translates to about 10 to 32 percent of the average price before the restructuring. The impact on prices for audiences located in sales-office countries affected later by the internal accounting reform is stronger (about 35 percent of the initial price). On average, the effect on the prices of ads for audiences in non-sales-office countries is positive but weaker than for audiences in sales-office ones (about 26 percent of the initial price). The evidence is consistent with the hypothesis that the prices paid by advertisers located in sales-office countries increased after the restructuring, contrary to the prices paid by advertisers from non sales-office countries (where Facebook's tax rate did not change).

We provide an approximate calculation of the pass-through of profit taxation in sales-office countries on advertising prices, assuming that Facebook paid an effective tax rate ranging between 0 and 12.5 percent (the statutory rate) in Ireland. The results of this exercise are quite sensitive to the model specification and to the tax rate that the platform pays in Ireland. Our baseline estimates suggest overshifting of taxes on ad prices, with a magnitude that is comparable to previous estimates of VAT pass-through on the prices of consumer goods and services (Benedek et al., 2015).

To interpret our empirical findings, we provide a model of an ad-financed

[5]This methodology accounts for the possibility that producers from a, despite covering a large share of imports into country b, may provide products for which Facebook users of country b show little interest. In this case, producers from country a are likely to account for only a small share of online ads targeted to users of country b.

platform that operates in several countries. In each country, users are exposed to ads from local and foreign advertisers. While users can access the platform for free, they typically dislike advertising. Hence, the platform exposes each user to a limited quantity of ads, and the supply of ads to an audience is effectively limited. When the profit tax in a country increases, the platform reallocates some of this supply from advertisers in this country to the others. Consequently, there is a rise in the prices charged to advertisers from countries in which the tax increases (regardless of the audience they target), whereas prices to advertisers from the other countries decrease. This finding is consistent with our empirical results. Furthermore, our model suggests that similar effects would be at play in the case of indirect taxes on the platform's revenue (e.g., ad valorem taxes on ad sales).

Finally, we calibrate the model using our data, and provide a first pass at the welfare implications of the tax change in several countries. The net effect of the tax change on total welfare is small, but interesting changes surface in the distribution of surplus. Because of the increase in ad prices, taxation tends to penalize advertisers in sales-office countries and benefit advertisers in non-sales-office countries. On the other hand, consumers are slightly better off regardless of their location, given that the platform reduces the provision of ads overall.

This work is a first exploration of the effects of taxation on MDPs. Our analysis suggests that unilateral corporate taxes on digital platforms may influence the price and distribution of ads across countries, even absent tax reform in the countries themselves. Therefore, the effects of taxes may extend beyond the allocation of accounting profits (e.g., through transfer pricing) in ways that signal a departure from the dynamics associated with traditional multinational enterprises. Our analysis addresses the implications of source-based taxation for digital platforms and their users.

Policymakers should carefully evaluate the potential consequences of taxes on digital platforms on i) the *level* and *distribution* of ads and prices across different audiences and ii) the price spillovers due to the global advertising network. In the context of ad hoc tax systems for the digital economy, our paper moves toward the idea of attributing shares of created values to the locations of users who are the targets of online advertising.

We organize the remainder of this paper as follows. In the next section, we briefly describe how our paper relates to the existing literature on the taxation of digital platforms. We then discuss the policy climate and Facebook's accounting restructuring, in section 3. Section 4 introduces our data and illustrates some preliminary evidence. This section also provides a theoretical framework for interpreting our preliminary evidence. This is complemented by the empirical analysis of section 5. Section 6 provides the welfare analysis and the final section concludes.

2 Relation to previous literature

A growing theoretical literature on taxation in two-sided markets underscores that the effects of taxation in such markets are likely to differ from those in traditional ones. Kind et al. (2008) show that ad valorem taxes may result in lower prices and increased service provision by a two-sided platform. Belleflamme and Toulemonde (2018) show that taxes may result in competing two-sided platforms making higher profits. Part of this literature focuses on how taxation may complement regulatory policy regarding data collection by digital platforms. Bourreau et al. (2018) study the implications of taxing data and ads on a digital platform, while Bloch and Demange (2018) consider how taxation may affect a platform's incentives to collect and exploit users' personal data. Most of the literature ignores the presence of multiple jurisdictions, with the exception of Kotsogiannis and

Serfes (2010). However, their approach is significantly different from ours. They model competing jurisdictions as two-sided platforms that strive to attract consumers and shops.

Our paper contributes to the above literature in several ways. First, we analyze profit taxation, rather than commodity taxes. In our model, profit taxes applying to a two-sided multinational platform have similar effects as ad valorem commodity taxes. Secondly, we consider a platform that operates in a multinational context. The platform internalizes the interactions that link not only different markets within a single country (e.g. content and advertising), but also markets in different countries. As a result, the platform can respond to taxation along several dimensions. For instance, it can reallocate the supply of ads, and adjust their price across multiple countries.

Taking a broader perspective, our paper relates to the literature studying the effects of government intervention in two-sided markets. Previous papers include Economides and Hermalin (2012), who analyze the implications of net neutrality regulation for the internet, and Bedre-Defolie and Calvano (2013), who study regulation of payment platforms. Differently from these papers, we focus on fiscal rather than regulatory policy.

The empirical literature on two-sided markets has so far focused on the implications of market power and inter-market externalities, ignoring taxation. Examples include Argentesi and Filistrucchi (2007), who provide an analysis of competition and prices in the Italian newspaper industry. Wilbur (2008) and Boik (2016) analyze the US television industry, whereas Jeziorski (2014) provides evidence from the US radio industry. In a recent survey, Kind and Moen (2015) point out a need for empirical evaluation of the effects of taxes and subsidies in two-sided markets. A key novelty of our paper is to provide this kind of evidence from a dominant MDP in the online advertising market. To our knowledge, the only other paper

providing evidence of the effects of taxation on a digital platform is Bibler et al. (2018). The authors use data from AirBnB listings to investigate the magnitude of hotel and tourism tax evasion and the incidence of these taxes on rental rates.

3 Facebook's accounting restructuring and the policy climate

Our analysis focuses on a recent change in Facebook's accounting regime. Until 2016, the company booked all non-US advertising sales through its Irish subsidiary, irrespective of the advertisers' location and of that of their target audience. At present, Facebook books advertising sales locally in all countries hosting one of its sales offices. That is, Facebook bills advertisers located in sales-office (SO, henceforth) host countries, regardless of the location of the advertisers' target audience. The SO countries are: Australia, Belgium, Canada, France, Germany, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Poland, Spain, Sweden, the UK and the US. This restructuring began in March 2016, when Facebook announced it would start booking its UK advertising sales locally.[6] In December 2017, Facebook revealed that similar changes would take effect in all the other SO countries.

Given the accounting restructuring and the relevance of ad revenues to Facebook's total revenues, changes in advertising revenue collected in an SO country directly affect that country's Facebook tax base. This is relevant, because the marginal tax rate that Facebook pays in SO countries, which matters for the allocation and pricing of ads, is arguably higher

[6]This change affected large advertisers, to which Facebook provides advertising as well as ancillary services. These advertisers are a relatively small share of the total population of advertisers on Facebook, but account for most of the ads and revenue. Small advertisers would instead continue receiving invoices from Facebook Ireland Ltd.

than the tax rate paid in Ireland. The statutory corporate tax rate in SO countries averages 25.9 percent, versus the Irish statutory 12.5 percent. The difference in the effective tax rates may be larger, because Ireland's tax regime is quite favorable to multinational companies. While Facebook may adopt similar practices in other countries as well, the cost of eroding the tax base is arguably higher due to less favorable tax rules.[7] Therefore, Facebook's restructuring corresponds to an increase in the marginal tax rate on its advertising revenue in SO countries. Our analysis of the effects of taxation on advertising prices is based on this premise.[8]

Facebook's accounting changes took place in the midst of several tax policy reforms. The global discussion about possible future multilateral collaboration on taxing digital markets had begun, and it continues to evolve and garner greater policy attention. The OECD recently directed an important discourse on reforming taxation for the digital economy, based on the Base Erosion and Profit Shifting Action Plan.[9] More recently, the European Commission unveiled plans to allow member states to tax profits generated in their territory based on a "digital presence," defined by volume of revenue (larger than 7 million euros), number of users (more than 100,000), or number of business contracts for digital services (more than 3,000). Because this project requires complex reforms, the Commission has also set the short-term goal of an interim tax that "covers the main digital activities that currently escape tax altogether in the EU." This tax would apply to revenue from advertising as well as sales of user data.

In addition to ongoing efforts to design multilateral policy instruments,

[7]For instance, Ireland allows the payment of peculiarly large royalty fees to subsidiaries located in tax havens (e.g., the Cayman Islands). See, e.g., *CNN.com* "How Apple paid just 0.005 percent tax on its global profits", August 31, 2016.

[8]Because Facebook's US revenue was booked locally even before the restructuring, we do not include the US in the group of SO countries when we measure the effect of tax changes on the price of ads.

[9]See `https://www.oecd.org/tax/beps/public-consultation-document-secretariat-proposal-unified-approach-pillar-one.pdf`.

a number of individual countries, particularly in Europe, have shown interest in raising taxation on MDPs. Most importantly, effective April 2015, the UK introduced the diverted profit tax, which imposed a punitive 25 percent profit tax rate for companies that shift profit out of the country (in place of the standard rate of 20 percent). Several reports indicate that the establishment of this new tax, which the company would have been liable to pay had it continued booking advertising sales in Ireland, was a relevant factor.[10] The DPT was quickly renamed "Google tax" by the media, despite applying to all multinationals.[11] The Australian government announced the introduction of a similar DPT, effective July 2017, imposing a rate of 40 percent on diverted profits (the standard rate being 30 percent). Italy, France and Germany have opened investigations for the collection of back taxes from MDPs. For example, France approved a "digital services tax" in 2019, and is working with Germany to implement the EU's proposal for an interim tax by 2021. Other countries, including Israel, India and the Slovak Republic, have introduced ad hoc tax rules for firms with "significant economic presence" in their country. See Table 1 for a summary of the policy initiatives.

[10]See *The Financial Times* "Facebook faces profits hit after tax shake-up.", March 4th 2016 and *The Guardian* "Facebook to stop routing ad revenue via Ireland amid pressure over taxes", 12 December 2017. The former article quotes a Facebook staff memo claiming that "In light of changes to tax law in the UK, we felt this change would provide transparency to Facebook operations in the UK". Similar statements were reported in the press also regarding other SO countries. See, e.g., *Politico.eu* "Facebook to overhaul how it pays tax worldwide", December 12, 2017 and *Bloomberg.com* "Facebook to Pay More Tax in France", April 29th 2019. We empirically accommodate potential anticipation of further tax reforms later on.

[11]The declared purpose of the diverted profit tax is "to counteract contrived arrangements used by large groups (typically multinational enterprises) that result in the erosion of the UK tax base." A typical example where liability for such a tax may arise is that of a non-UK company with an Irish subsidiary that provides services to UK customers, while being only partially supported by a UK assisting subsidiary. In this example, the authorities might impose the tax to the Irish principal for diverting profits generated in the UK.

Table 1: Tax reforms affecting digital platforms in OECD countries

Country	Intervention	Year
GER, ITA, FRA, UK	Repayment of Back Taxes	2014/2017
UK, AUS	Diverted Profit Tax (25%)	2015/2016
ISR	Tax for "Significant Economic Presence"	2016
TUR	Withholding Tax on E-payments	2016
HUN	Advertisement Tax	2018
AUT	Online Advertisement Tax	2018
FRA	'YouTube' Tax	2018
SVK	Intermediation Tax	2018
FRA	'Google-Apple-Facebook-Amazon' tax	2019
ITA	New Web Tax (3%)	Ongoing
NZL	Digital Services Tax	Ongoing
EU (Short Term)	Interim Tax on ad revenue and online sales	Ongoing
EU (Long Term)	Tax based on "digital presence"	Ongoing

4 Preliminaries

4.1 Facebook advertising prices

With a base of over 2 billion active users and a global penetration rate of 27 percent, Facebook is the largest social media platform worldwide. The platform gathers practically all of its revenue from the sale of ads (or "impressions").[12] Facebook classifies users based on a set of observable characteristics (e.g., demographics, interests, etc.). A user connecting to the platform generates impression opportunities that are sold to advertisers via online auctions, conducted virtually in real time. Advertisers' bids for these impressions depend on the user's characteristics (see Appendix F for a more detailed description of Facebook's auction system). Advertisers located in any country can send ads to both domestic and foreign Facebook

[12]Figures reported by Nasdaq indicate that between 2016 and 2018, the company generated from $27 billion to $55 billion in worldwide advertising, a contribution to total revenue equal to 97.3 percent and 98.5 percent, respectively, in those years.

users.

Our empirical analysis relies on a panel database of prices for ads directed at Facebook audiences in all OECD countries. We collected these prices from Facebook's Ad Manager website at a daily frequency from July 2015 to February 2017. Specifically, we observe the median of the *range* of prices that, according to Facebook, are currently being paid for ads to the selected audience. Henceforth, we refer to such value as the *median price* for an audience (see Section 5.2 for further details).

In light of the large number of auctions for impressions that take place daily, it is reasonable to think of the median price as a weighted average of prices paid for an audience, with weights given by the relevance of each group of advertisers in the advertising demand for that audience. It is important to note that the median price we observe for each audience is representative of the distribution of prices paid by *all* advertisers that send ads to such audiences, including domestic and foreign ones. Hence, the median prices are interconnected across countries. For instance, the median price for a non-SO country audience may be affected by changes in the way Facebook treats advertisers from SO countries targeting the same audience.

4.2 Preliminary evidence

To identify the effects of taxation on advertising prices, we exploit the change in Facebook's accounting structure described above. We define the break point in the price distribution over time for all countries as March 7, 2016. Facebook's accounting restructuring formally started with the UK, but the company very likely anticipated that it would implement such restructuring in other SO countries as well.

Figure 1 plots the unconditional median prices as measured by cost per thousand or cost per mille (CPM), a marketing term that expresses

the price of 1,000 advertisement impressions on one webpage. The figure shows the median CPM in countries where Facebook has a sales office (red line) and where it does not (blue line).[13] In addition, we separately illustrate the development of ad prices in the UK. The figure shows that after the restructuring the median price increased substantially in both SO and non-SO countries. However, the intensity of the change appears to be weaker in the non-SO countries.

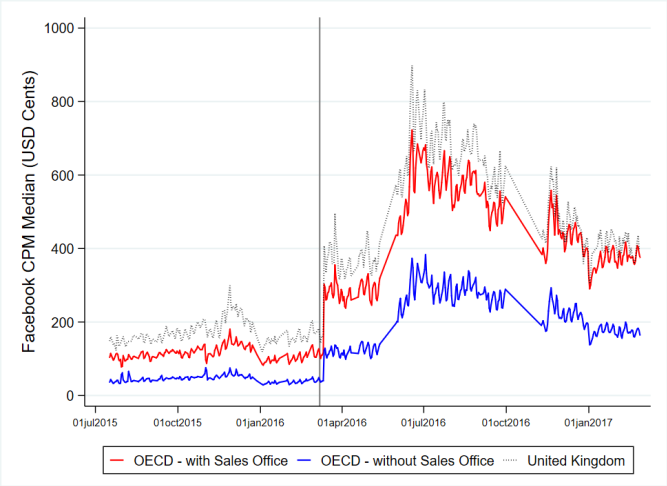

Figure 1: Median cpm, average for oecd countries

An immediate concern is that the observed shift in prices could be due to country- specific characteristics, or events that are unrelated to the tax implications of Facebook's accounting restructuring. To rule out these possible confounding factors, we regress the median prices on country fixed effects and time dummies that account for seasonality and relevant events (e.g., holidays, elections, and relevant global events) that took place in 2016.[14] To capture possible shocks to online advertising prices outside Facebook, we also control for the prices of online ads in the US (averages across the whole internet). Figure 2 plots the residuals of this regression,

[13]CPM stands for Cost-Per-Mille, i.e. price per thousand impressions. This is the most commonly used metric to describe online advertising prices.

[14]Among others, we control for the Brexit referendum, for the US elections, and "Black Friday".

distinguishing between SO countries (red line) and NS countries (blue line). plots the residuals of this regression, distinguishing between SO countries (red line) and NS countries (blue line). The figure shows that the changes observed in Figure 1 are not explained by the above confounding factors for non-SO countries. However, a pronounced difference exists between the behavior of median prices in SO and non-SO countries.

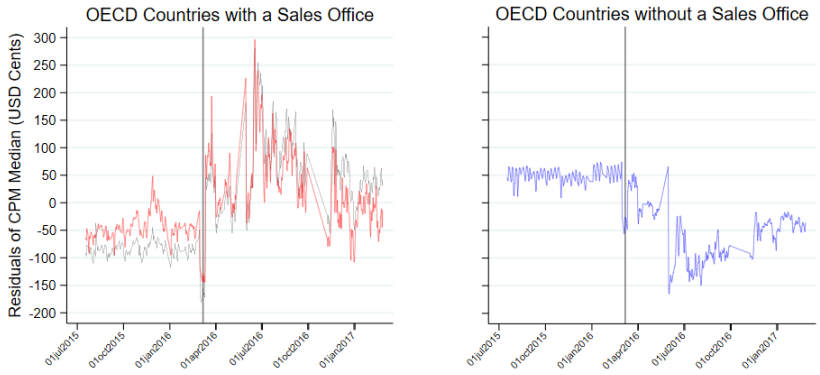

Figure 2: Median cpm (residual), oecd countries
Note: residuals from linear regression of CPM Median levels on country fixed effects, day of the week, holidays, election shopping event dummies and a monthly trend.

In Appendix B, we also show results from a VAR analysis indicating that we can significantly reject the null hypothesis of no break around the date of announcement of Facebook's restructuring. These figures suggest that the effect is not only significant statistically and economically, but it is also heterogeneous across countries.

It is, of course, possible that the change in accounting practices announced on March 7, 2016, coincided with some other change that affected the price of ads on Facebook that we do not observe (e.g., changes in the algorithms that match users to advertisers). An extensive search did not uncover information about any such changes. Facebook formally announced its decision to restructure accounting practices in a press release.

The media extensively covered the decision. To our knowledge, no report about other major modifications to Facebook's ad pricing or allocation took place at the same time.

The evidence presented thus far suggests that (i) the effective increase in taxes on the revenue collected in SO countries coincided with an increase in advertising prices on Facebook and (ii) the change also affected the prices of non-SO audiences, although the effect appears to be substantially smaller than on prices of SO audiences. Our hypothesis is that these price spillovers are caused by the global nature of Facebook's advertising market. We test this hypothesis below and evaluate the implications of these interconnections theoretically and empirically.

4.3 Theoretical model

Consider a digital platform operating in two countries. The platform provides free content to consumers and sells impressions to advertisers. Let n_j be the (exogenous) quantity of advertisers located in country $j = 1, 2$. Advertisers within a country are identical. The platform sells impressions to advertisers in country j via its local subsidiary. We assume the subsidiary in $j = 2$ (the "low-tax" country) is not subject to corporate taxes, whereas that in $j = 1$ (the "high-tax" country) pays a tax $t > 0$. Drawing from our empirical setting, one can think of Country 1 as a SO country and Country 2 as a non-SO country, whereby Facebook's advertising revenue is booked in Ireland and thus is virtually untaxed. Figure 3 provides a graphical representation of our setting.

Let $z_i(q_i)$ be the quantity of users in country i that connects to the platform and q_{ij} the quantity of ads that an advertiser from j sends to a user in country i. A user in country i is exposed to $q_i = \sum_{j=1,2} n_j q_{ij}$ total ads. Throughout the analysis, we shall use the index j to denote the location of *advertisers*, whereas i shall denote the location of *users*.

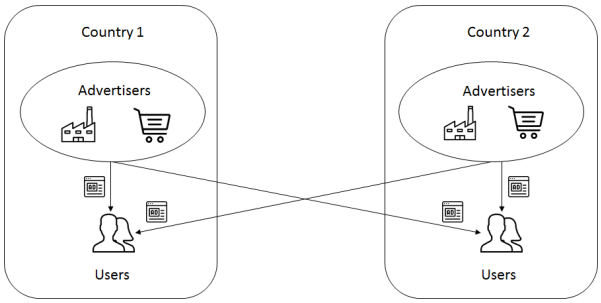

Figure 3: MARKET STRUCTURE

In keeping with previous literature (e.g., Anderson and Coate, 2005), we assume that ads reduce the utility consumers get from browsing the platform's content, hence $z'(.) < 0$.[15] To ensure that sufficient conditions for a unique solution to the platform's profit maximization problem are satisfied, we also assume that $z''(.) \leq 0$.

Let $p_{ij}(q_{ij})$ be the willingness to pay for an additional ad on a consumer located in i by an advertiser located in j, given the advertiser sends q_{ij} impressions to this consumer. We assume $p'_{ij}(.) < 0$, as the marginal value of impressions on a consumer is decreasing.[16] Observe that $p_{ij}(q_{ij})$ does not depend on the quantity of ads the advertiser places on other consumers (in particular, those located in a country different than i).

We assume advertising quantities, q_{ij}, are the platform's decision variables, with $i, j = 1, 2$. In equilibrium, $p_{ij} = p_{ij}(q_{ij})$ holds, where p_{ij} is the price per impression paid by an advertiser in j to reach an audience in i. In other words, the platform adopts third-degree price discrimination, as advertisers from different countries may not pay the same price to reach a

[15] Although digital technologies can improve the relevance of digital ads to users (e.g., through better targeting), these ads are generally annoying. This observation is confirmed by the increasing diffusion of ad blockers and the fact that several digital publishers offer ad-free versions of their websites for a price (e.g., YouTube Red).

[16] For example, one can assume the purpose of ads is to inform consumers about products. The more a consumer is exposed to an ad, the higher the probability that the marginal impression is wasted, because the consumer is already aware of the advertised product. This assumption is in line with the media economics literature. (See, e.g., Ambrus, Calvano and Reisinger, 2016.)

given audience. We discuss these assumptions below.

The platform sustains no variable costs, which is fairly realistic for providers of digital content. Thus, its profit is

$$\pi = \sum_{i=1,2} z_i \left[n_1 q_{i1} p_{i1} (1-t) + n_2 q_{i2} p_{i2} \right]. \tag{1}$$

For simplicity, we ignore the possibility that the platform reduces its tax liability in a country by manipulating accounting profits (e.g., by paying royalty fees to low-tax subsidiaries). This assumption is not crucial. We could model such within-firm payments as lump-sum transfers between subsidiaries, possibly including costs that increase with the size of these transfers (as in, e.g., Devereux et al., 2008). As long as the taxable revenue in the high-tax country is positive, our results are qualitatively unaffected, because the marginal effective tax rate is what matters for the allocation of ads. If the effective tax rate increases with t, the effects on the price and quantity of ads are essentially the same as what we obtain.

The first-order conditions (FOCs) of the platform's problem with respect to the quantity of ads directed at country $i = 1, 2$ are

$$\frac{\partial \pi}{\partial q_{i1}} : n_1 \left[(1-t) \left(z_i \left(p_{i1} + \frac{\partial p_{i1}}{\partial q_{i1}} q_{i1} \right) + z_i' n_1 q_{i1} p_{i1} \right) + z_i' n_2 q_{i2} p_{i2} \right] = 0, \tag{2}$$

$$\frac{\partial \pi}{\partial q_{i2}} : n_2 \left[z_i \left(p_{i2} + \frac{\partial p_{i2}}{\partial q_{i2}} q_{i2} \right) + z_i' n_2 q_{i2} p_{i2} + (1-t)\, z_i' n_1 q_{i1} p_{i1} \right] = 0. \tag{3}$$

The left hand sides of the expressions in (2) and (3) are the marginal revenues from impressions sold to advertisers from country $j = 1, 2$, respectively, that target users in country i. These expressions include the mechanical effect due to the expansion in the volume of ads and the ensuing reduction in the equilibrium price. Furthermore, there is a negative effect on revenue due to the reaction of i's consumers to the change in the level of advertising they are exposed to. Note that this effect reduces the

revenue generated by advertisers located in j as well as in the other country, as captured by the last term in (2) and (3). Thus, there is an implicit cost of exposing an audience to a greater quantity of ads. Notice that, as taxation affects only the revenue collected from advertisers of country 1, it makes the implicit cost of ads allocated to such advertisers relatively larger.

Observe that the FOCs in (2) and (3), that refer to country i's audience, are independent of the quantity of ads the platform shows to the audience in the other country. The reason is twofold. First, users in country i only care about the total quantity of ads, q_i they are exposed to, but not about the quantity of ads the platform shows to users in the other country. Furthermore, an advertiser's demand for ads to i's audience does not depend on the quantity of ads the advertiser sends to the other audience.

We now analyze the effect of changes in t on the quantity and price of ads carried by the platform. Using (2) and (3), we can show (see Appendix C) that

$$\frac{\partial q_{i1}}{\partial t} < 0, \frac{\partial q_{i2}}{\partial t} > 0, \; i = 1, 2, \tag{4}$$

which implies directly that

$$\frac{\partial p_{i1}}{\partial t} > 0, \frac{\partial p_{i2}}{\partial t} < 0, \; i = 1, 2. \tag{5}$$

Therefore, the quantity of impressions per consumer sold to advertisers from country 1 decreases with the tax rate applied in country 1, while the price of these impressions increases. The opposite applies to impressions sold to advertisers from country 2. The intuition is easily grasped from (2) and (3). Consumers dislike advertising, so the platform must limit the quantity of ads it exposes each consumer to. That is, the supply of ads on each consumer is effectively limited. Therefore, the platform has to allocate this supply between advertisers from country 1 and 2. When the profit tax

in 1 increases, the marginal revenue from ads sold to advertisers therein decreases. Hence, the platform reallocates the supply of ads to advertisers in 2: q_{i1} decreases while q_{i2} increases. Advertisers from country 1 thus pay a higher price following the tax increase, contrary advertisers from country 2.

Notice that this outcome is a consequence of the two-sided nature of this market. If users did not care about being exposed to ads (i.e. $z' = 0$), taxation would have no effect on prices and quantities, as (2) and (3) show.

Proposition 1 *An increase in profit taxation in one country causes higher prices to advertisers located therein and lower prices to advertisers in the other country, regardless of the audience they target.*

Before proceeding, we briefly discuss the assumption that the platform controls the allocation of ads to advertisers of different countries, q_{ij}. The sale of ads on Facebook takes place via auctions, but there are ways for the platform to influence their allocation. For example, Facebook assigns scores to advertisers based on the relevance of their message to the audience they target. This scoring affects their probability of winning the auctions. The score depends on the advertiser's location, among other things.[17] Hence, adjusting such a score allows the platform to influence the allocation of impressions across countries. By the same token, the platform can influence the equilibrium prices paid by advertisers from different countries. Therefore, advertisers in different countries can pay systematically different prices for reaching the same audience. See Appendix F for details on Facebook advertising auctions.

Proposition 1 suggests that advertisers from SO countries (i.e., those where Facebook's revenue is taxed at higher rate following the restruc-

[17] See `https://www.facebook.com/business/help/430291176997542?helpref=faq_content`.

turing) should pay higher prices regardless of which audience they target, contrary to the situation faced by advertisers from non-SO countries. To connect this result to the preliminary evidence of Section 4.2, recall that the median prices we observe are defined by location of the *audience*. Specifically, they are the median of the range of prices for audience i paid by advertisers from each country j. We treat them as a weighted average of the prices, p_{ij}, paid by such advertisers.

Given Proposition 1, the increase in the median price for audience i following the restructuring is more likely to be positive the larger the share of the demand for ads to such audience that originates from SO countries. If an audience is exposed primarily to domestic ads, one can expect the median price to increase when the audience is located in a SO country, and to decrease if the audience is in a non-SO country. However, a larger share of demand coming from foreign advertisers located in SO countries should make a positive effect more likely. This reasoning is consistent with our preliminary evidence, which shows that Facebook's accounting restructuring coincided with an increase in advertising prices to all audiences (Figure 1), but that the effect for the prices to SO audiences was significantly different than that for audiences in non-SO countries (Figure 2). Section 5 provides a more formal treatment of this issue.

5 Empirical analysis

5.1 Empirical Strategy

Section 4.2 suggests that changes in taxation within one country can affect the price of ads targeted at audiences located in other countries, consistently with our theoretical model. The key reason for the interaction between the median ad prices is that they are defined by location of the

audience, but a country's audience is typically exposed to ads from domestic as well as foreign advertisers. Consequently, to identify the response of our median ad prices to the increase in taxation on Facebook's revenue in SO countries, we need to address spillovers across countries.[18] To model the international network of ad markets, we rely on the link between digital and physical markets. Our approach is inspired by recent macroeconomic and international economics literature, showing that prices and trade flows in digital and traditional markets are highly correlated (Cavallo, 2017; Lendle et al., 2016).

Our strategy can be described as follows. Consider a group of N countries. The share that advertisers from country $j=1,...,N$ have in the demand for ads sent to an audience in country $i=1,...,N$ should be explained by the share that firms from country j have in country i's market for products and services that are likely to be advertised on Facebook. More precisely, we assume advertisers from j account for a share of the demand for ads directed at i's audience that depends on two factors: The first is which products the audience in i cares about. Such product preferences proxy for the likelihood that a product is advertised to audience i on Facebook given the international trade network.[19] For instance, electronic devices are probably more likely to be advertised on Facebook than lumber or natural gas. The second factor is the share of the market for such products in country i accruing to suppliers from j. To capture these factors, we combine data on Facebook user interests with international trade data.

Formally, we assume that the price for an audience in country i at date

[18]Previous literature has shown that fiscal policy changes may affect outcomes in other countries through international trade (e.g., Beetsma et al., 2006; Auerbach and Gorodnichenko, 2013; Goujard, 2017). More generally, this idea is also consistent with fiscal shocks being transmitted through the current account at the macroeconomic level.

[19]The measurement of these is also consistent with the demand-side focus of this paper. Note that we take the trade network as given in this paper, i.e. we are not interested in the prediction of trade flows (e.g., Linder, 1961).

d can be expressed as a weighted average

$$p_{id} = \sum_{j \neq i} w_i^j p_{ijd} + w_i^i p_{iid}, \qquad i = 1, ..., N. \tag{6}$$

where p_{iid} and p_{ijd} indicate the price that, respectively, domestic and foreign advertisers pay at d to target audience i. The weight of advertisers from any country, w_i^j, is time invariant and approximated by the share of the demand for ads targeting audience i from advertisers located in country j, Ads_i^j:

$$w_i^j \sim Ads_i^j. \tag{7}$$

Although we do not observe Ads_i^j directly, we can proxy for these variables using international trade flows averaged across sectors. To compute proxies for the weights of *foreign* advertisers in country i, we average manufacturing imports into i from each country j across product categories, $Trade_{ijk}$ (where k is the index for an HS 4-digit category), weighted by product penetration rates, FCBKPen_{ik}.[20] In a nutshell, these penetration rates measure the share of the audience in i that is interested in product k. We derive this information from data reported by Facebook (see Section 5.2 for a more detailed description). We thus approximate the weights in eq. (7) as follows. Let $g(\cdot)$ be a continuously differentiable and increasing function. Then

$$w_i^j \sim \omega_i^j = g\left(\widetilde{Trade}_{ij} / \textstyle\sum_j \widetilde{Trade}_{ij}\right), \quad j = 1, ..., N, \tag{8}$$

[20]For a similar approach see Caporale and Girardi (2013). We focus on manufacturing data due to greater coverage of countries. However, we have estimated the model also including trade in services and found no major changes in the results, see Section 5.4.

where

$$\widetilde{Trade}_{ij} = \sum_k \text{FCBKPen}_{ik} \times Trade_{ijk}.$$

We do not construct the same proxy for the weight of *domestic* advertisers in country i, w_i^i. Standard international trade data do not report information on domestic consumption by product category in each country.[21] Consequently, we do not control directly for an audience's exposure to domestic advertisers in the empirical model. However, we account for such exposure in the analysis, see the next section.

5.1.1 Estimating the Effect of the Accounting Restructuring on Advertising Prices

We estimate the effect of the change in Facebook's accounting practices on the (median) advertising prices in OECD countries, by means of a reduced-form panel model. We account for spillovers across countries by exploiting the variation in country-level exposure to foreign advertisers from SO countries described previously. This variation is meant to explain the differences in the effect on prices across the different audiences. We postulate the following regression model:

$$\begin{aligned} p_{id} = \beta_0 + \beta_1 T_d + \beta_2 \widetilde{Trade}_i^{\text{SO}} + \beta_3 T_d \times \widetilde{Trade}_i^{\text{SO}} + \beta_4 CPM_{d-1}^{US} + \beta_5 lnGDP_{iq} \\ + \mathbf{X}'_{iy}\Gamma + Hol_{id} + DW_d + Q_q + M_{m(y)} + B_d + \text{USelec}_d + \varepsilon_{id}, \end{aligned} \tag{9}$$

where T_d is a dummy equal to one for each day on and after the 7th of March 2016. The variable $\widetilde{Trade}_i^{\text{SO}}$ measures the share of imports with SO countries, weighted by the relevance of products for country-i's audience,

[21] It would be possible to use international input-output tables incorporated for example in the TiVA or WIOD databases. Besides the lack of data at sufficiently disaggregated product level, issues of collinearity between w_i^i and w_i^j may arise.

as described above:

$$\widetilde{Trade_i}^{SO} = \sum_{j \in SO} \widetilde{Trade_{ij}} / \sum_j \widetilde{Trade_{ij}}. \tag{10}$$

Equation (9) also includes an interaction term between T_d and $\widetilde{Trade_i}^{SO}$. This term accounts for the possibility that the effect of the accounting restructuring varies by country i, depending on the country's exposure to foreign advertisers from SO countries. Note that including $\widetilde{Trade_i}^{SO}$ also takes into account exposure to foreign NS advertisers, given that $\widetilde{Trade_i}^{non-SO} = 1 - \widetilde{Trade_i}^{SO}$. Recall however that we do not control for exposure to domestic advertisers. Nonetheless, we estimate the model distinguishing the effects of the restructuring on p_{id} between SO and non-SO audiences. Given that we control for exposure to foreign advertisers, we can use the difference in the marginal effects of T_d on the median price for SO and non-SO audiences to obtain an indication of the sign of the effect of exposure to domestic ads. We return to this point when discussing the results (Section 5.3).

We include several controls to capture the fact that differences in advertising prices across countries may depend on the size of the digital market in each country. We account for possible shocks to the digital advertising market that may have caused fluctuations in Facebook ad prices independently of changes in taxation. To this end, we include the variable CPM^{US}_{d-1}, which is the weekly average CPM for a sample of internet ads in the US in the week before d. The US share of the global digital advertising market is by far the largest of all countries. Hence, this variable is a reasonable proxy for online ad prices.[22] We also include log quarterly GDP as a measure for market size. The vector $\mathbf{X}_{iy}$ contains country-specific variables that proxy for the degree of digitization of the country's economy. This includes the

[22]EMarketer statistics report that the US spent 107 Billion US Dollars in digital advertising for the year 2018 alone.

penetration of e-commerce and the OECD's Services Trade Restrictiveness Index (STRI) for electronic transactions, which accounts for possible differences in regulatory restrictions on digital commerce and transactions. We provide a more detailed description of these variables in Section 5.2.

Finally, we include a set of time controls, to account for trends and cyclicalities: DW_d, Q_q, Hol_{id} and $M_{m(y)}$ are day of the week, quarterly, holiday and monthly dummies, respectively. Furthermore, we include a dummy for the post-Brexit period (B_d) and a dummy that equals one at the time of the US elections (USelec_d). The ε_{id} refer to idiosyncratic error terms.

To benchmark the results, we first estimate (9) to solely address the accounting policy change. For this, we first test the series for unit root using the Im-Pesaran-Shin panel-data unit-root test for unbalanced panels. The results on the unit-root tests are shown in Appendix A (Table A1). We partly reject the null hypothesis of a unit root, and we clearly reject it for the demeaned series. Consequently, we use a fixed effects model as a benchmark.

Two additional issues are relevant to our data. First, autocorrelation is present in the error term, and second, daily advertising prices are autocorrelated. We thus re-estimate (9) by pooled OLS, using 8 lags of the dependent variable as chosen by the AIC, as well as by GLS.[23] The latter accounts for AR(1) autocorrelation within panels, cross-sectional correlation and heteroskedasticity across panels.

[23]Dynamic models are not appropriate in this context: The time-series is long ($T > N$) and thus the bias due to a dynamic structure becomes small. Additionally, dynamic models usually assume no autocorrelation in the errors. This autocorrelation was rejected by tests for serial correlation in the idiosyncratic errors (Wooldridge, 2002).

5.2 Data

Facebook's Ad Manager website is our main source of information.[24] By scraping this website, we collected the upper bound, lower bound and median of the *range* of ad prices (CPM) that, according to Facebook, advertisers targeting users in a given country should expect to pay. This is the range of prices advertisers pay for ads to reach that country's audience at a given time. We collected this information for each OECD country at a daily level, defining the audiences based only on country of residence (i.e., without specifying any additional characteristic). See Appendix G for more details on our data collection procedure. In the empirical analysis, we focus on the median of the range of prices for each audience, referring to them as the *median prices* for each audience. These prices constitute the outcome variable of our analysis.[25]

Summary statistics for the median prices in our panel are reported in Table 2. The median CPM is \$2.57 on average for all countries. Note that such price has increased from 0.91 before the accounting restructuring, to \$3.91 after this change. We also report the same information for the UK, which was the first country where Facebook's accounting reform was announced. The average of the median CPM before the restructuring in SO countries was \$1.37 before and about \$5.34 after the restructuring. The corresponding averages for non-SO countries are \$0.52 and \$2.62.

We also queried the Ad Manager to collect Facebook penetration rates per each audience and product category. Specifically, we collect vectors of product interests for each audience. Each vector has $k = 1, .., K$ entries,

[24]The Ad Manager is the website advertisers use to acquire ads on Facebook. We briefly describe this website and the process advertisers follow to place bids on it in Appendix G.

[25]Our results remain qualitatively unchanged when focusing on either the lower or the upper bound of the range reported by Facebook. The results also do not appear to change when focusing on other ad pricing metrics, namely CPC (Cost-Per-Click) and CPA (Cost-Per-Action).

where K is the number of product categories and the k-th entry corresponds to the share of users in country i that, according to Facebook, has shown interest in a product within category k. We classify products using the HS 4-digit product list, to ensure categories can be mapped to products and are comparable across countries. To calculate country-specific imports from SO countries as a share of total (OECD country) imports, we combine information on product penetration rates on Facebook with information on bilateral trade between the country of the advertiser j and the country of the audience i. Specifically, we use manufacturing imports data between 2015 and 2017 from the UN Comtrade database by goods category based on the HS classification (at the 4 digit-level), averaged across years. In order to account for the selection of products that are more likely to be advertised on Facebook in country i, when computing the trade shares we weigh the import volumes for each product category k by the penetration rates in country i, as described in section 5.1.

Table 2 shows that, on average, a country in our sample receives about 81 percent of goods imports likely to be advertised on Facebook from SO countries (as captured by the variable $\widetilde{Trade_i}^{\text{SO}}$). This share is slightly higher for SO countries on average (84 percent), but it is substantial for non-SO ones as well (79 percent).

The weekly average CPM for online advertising in the US is obtained from Nielsen's Ad Intel dataset. The firm reports that, up to 2017, the sample of impressions in this dataset focuses on large national publishers and advertisers. Hence, it is likely that the average CPM actually overestimates the average for the universe of US ad-financed websites. Indeed, the average CPM for all digital ads (outside Facebook) in the US exceeds the CPM we observe for Facebook, at around 11 USD. In itself, the level of this variable is not important for our analysis. What matters is that there is no noticeable discontinuity in the price of ads on the US market around

the announcement of Facebook's restructuring. This suggests that the restructuring did not coincide with a major change on the online advertising market in general.

Finally, to account for market size, we use the log quarterly GDP in million 2010 USD as well as yearly data on the digital STRI for electronic transactions.[26] We also use data on the use of e-commerce for private individuals (*Share of individuals who e-buy in percent*). These data are provided by the OECD.[27] Table 2 shows that the average for this variable in our sample amounts to 38 percent.[28]

[26]This index is computed yearly by the OECD for all member countries and provides information on regulations affecting trade in services for multiple sectors. See `https://qdd.oecd.org/subject.aspx?Subject=063bee63-475f-427c-8b50-c19bffa7392d`

[27]We have also collected other indicators of ICT usage by the OECD, which proved relevant in the regressions (in the sense of increasing the R-squared). As they were missing for a host of countries, in particular the US, we abstained from including them in our regressions. Note that this leads to a very slight downward bias of the coefficient for T_d.

[28]Appendix A (Figure A2) indicates a positive correlation between CPM prices and trade shares with sales office countries, as well as with individuals' use of e-commerce across OECD countries.

Table 2: SUMMARY STATISTICS

	All				Before Change				After			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
	A. All countries											
Median CPM (USD)	2.57	2.75	0.09	19.29	0.91	0.71	0.09	3.94	3.91	3.04	0.13	19.29
UK CPM (USD)	3.74	2.10	1.19	8.98	1.72	0.29	1.19	3.00	5.37	1.40	1.43	8.98
CPM_{d-1}^{US}	10.84	0.23	10.05	11.23	10.86	0.19	10.40	11.16	10.82	0.25	10.05	11.23
$\widetilde{Trade}_i^{SO}$	0.81	0.10	0.48	0.97	0.81	0.10	0.48	0.97	0.81	0.10	0.48	0.97
Digital STRI	0.03	0.01	0.02	0.04	0.03	0.01	0.02	0.04	0.03	0.01	0.02	0.04
Log GDP	13.03	1.51	9.56	16.66	13.02	1.51	9.59	16.64	13.04	1.51	9.59	16.65
Individuals who e-buy (%)	37.95	19.42	1.71	68.86								
Observations	18,900				8.424				10,476			
	B. Sales office countries											
Median CPM (USD)	3.55	3.07	0.13	19.29	1.37	0.65	0.13	3.64	5.36	3.06	0.24	19.29
$\widetilde{Trade}_i^{SO}$	0.84	0.08	0.72	0.96	0.84	0.07	0.72	0.96	0.84	0.08	0.72	0.96
Observations	8,952				3,978				4,947			
	C. Non Sales office countries											
Median CPM (USD)	1.71	2.07	0.09	13.08	0.52	0.59	0.09	3.94	2.62	2.37	0.13	13.08
$\widetilde{Trade}_i^{SO}$	0.79	0.12	0.48	0.97	0.79	0.12	0.48	0.97	0.79	0.12	0.48	0.97
Observations	9,975				4,446				5,529			

Notes: Sources: CPM_{d-1}^{US} (weekly average CPM from US websites), Nielsen; $\widetilde{Trade}_i^{SO}$ (yearly final goods trade volume share with all sales office countries, 2015-2017, weighted by industry-specific penetration rates), Comtrade and own calculations; Digital STRI, electronic transactions subindex, OECD: the index lies in the unit interval, taking the value of zero in the absence of restrictions and 1 when the component is fully restrictive, and covers restrictions on electronic transactions (e.g., licenses, online tax registration, deviations from internationally accepted rules on electronic contracts, dispute settlement mechanisms); log GDP, OECD in million 2010 USD; (share of) individuals who e-buy, OECD.

5.3 Results

We summarize the results in Table 3. The effect of the increase in taxation in SO countries on the median CPM of advertising is approximately 1.1 USD on average according to the fixed effects (Column 1) and the pooled OLS model (Column 2).[29] Including lags of the dependent variable accounts for autocorrelation in advertising prices and reduces the coefficient

[29]The fixed effects model captures potentially time-invariant factors subsumed in $\tilde{w}_i^j$ and further accounts for cyclical variations, but not for potentially simultaneous shocks. The demeaned series also clearly rejected the null hypothesis of a unit root.

of interest significantly to 0.136, indicating a substantial upward bias in the previous results. Taking into account serial correlation in the idiosyncratic errors and and cross-sectional dependence by way of a GLS model (Column 4) results in a coefficient of 0.277. Note that including lags of the dependent variable may lead to substantial bias in the presence of serial correlation, and thus the true effect may lie somewhere between those found in Columns 3 and 4.[30]

Next, we account for import shares from SO countries, which we include in Columns 5 to 7. These suggest that the effect of the increase in taxation on the median price of advertising to a country not exposed to foreign SO advertisers is negative on average and very small. However, higher exposure to such advertisers has a positive and mostly significant effect on the price following the break. Thus, each additional unit of exposure to foreign SO advertisers (captured by interest-weighted import shares) strengthens the effect of taxation on the median price of advertising, which is in line with our conjecture that prices depend on the exposure of audiences to foreign advertisers, whereby the exposure is proxied by import demand. Given the substantial share of SO countries imports – roughly 80 percent on average (see Table 2) – the marginal effect of the increase in taxation evaluated at the average level of exposure to foreign SO advertisers is also positive; it ranges from 0.136-0.293, according our models (the POLS model estimated with LDV and the model estimated by GLS). The overall effects are thus unchanged compared to the results shown in Columns 2 to 4.[31]

To shed more light on the role of an audience's exposure to SO and non-SO ads for the effect of taxation on the median price, we break down the previous estimates distinguishing between audiences located in SO versus

[30]This argument may be further supported by the observation that the lagged variables amount to about 1 and the R^2 approaches 1 as well.

[31]We also used services import shares from the OECD instead of goods import shares. Using this formulation, the total (POLS) effects amount to 1.118 (standard error 0.079).

non-SO countries in Columns 8 and 9 of Table 3. We exclude the US as an observation in both groups because Facebook's US revenue was taxed at the local rate before and after the accounting change. Note that this does not affect the exposure to sales-office countries as measured by $\widetilde{Trade_i}^{SO}$, because the local selling structure applies to the aggregate of these countries.

To interpret the differential effect the accounting restructuring had across SO and non-SO countries, we look at what happens at the average exposure to incoming trade from SO countries (bottom row, Columns 8 and 9). The effect on the median price of ads is positive and significant for both SO and non-SO audiences. However, the size of this effect is substantially larger in the former ($0.455) than in the latter ($0.137). That is, given the average exposure to foreign SO (and non-SO) advertisers, and conditional on other controls, the effect of taxation on the median price of ads is larger for audiences in SO countries. Recall, however, that we do not control for exposure to domestic advertisers directly. Therefore, this finding suggests that exposure of non-SO audiences to domestic advertisers is likely to decrease the median price of ads to such audiences, whereas exposure to foreign SO ads tends to increase the price. In all, the results appear to be consistent with the predictions of our theoretical model, which shows that, after the increase in tax rates in SO countries, the prices paid by advertisers from SO countries should increase, unlike the prices paid by advertisers from non-SO countries.

As a robustness check, we report findings akin to ones reported in Table 3, for a sample that we have trimmed before June 2016 instead of for all data up to February 2017 in Table A3. The reason is that several breaks have occurred in the data after that date. For example, the scraping algorithm has paused on two occasions after that date and prices have decreased after July 2016 but settled on an overall higher level than before 7 March 2016

(see Figure 1). The results remain qualitatively robust at large and are quantitatively just slightly below the ones presented in Table 3.

Table 3: Effect of facebook accounting restructuring on online ad prices

	(1) FE	(2) POLS	(3) POLS	(4) GLS	(5) POLS	(6) POLS	(7) GLS	(8) non-SO	(9) SO
T_d	1.137	1.116	0.136	0.277	-2.715	0.092	-0.074	0.233	-2.575
	(0.140)	(0.137)	(0.016)	(0.026)	(0.175)	(0.029)	(0.193)	(0.185)	(0.555)
$\widetilde{Trade_i}^{SO}$					-2.495	-0.032	1.377	-1.729	2.039
					(0.126)	(0.020)	(0.489)	(0.545)	(1.163)
$T_d \times \widetilde{Trade_i}^{SO}$					4.762	0.055	0.456	-0.059	3.879
					(0.191)	(0.034)	(0.244)	(0.235)	(0.673)
Obs.	18,900	18,900	18,612	18,900	18,900	18,612	18,900	9,975	8,925
R^2	0.657	0.666	0.992		0.672	0.992			
Effect at Avg($\widetilde{Trade_i}^{SO}$)					1.115	0.136	0.293	0.137	0.455
					(0.080)	(0.015)	(0.027)	(0.027)	(0.056)

Notes: Model [1] is estimated using a fixed effects panel model, models [2] and [3] by pooled OLS – where model [3] includes 8 lags of the dependent variable in addition (as suggested by the AIC) – and model [4] by GLS. Models [5]–[7] include goods imports from countries with a sales office, weighted by country specific product interests, whereby [5] is estimated by POLS, [6] includes 8 lags of the dependent variable, and [7] is estimated by GLS. [8] and [9] are estimated by GLS for non-SO and SO countries, respectively. All models control for the average weekly CPM of the US national internet market (not reported) and further include day-of-the-week dummies, quarterly dummies, holiday dummies, month-year dummies, a dummy for brexit, a dummy for the US elections. Models in [2]-[9] also include the digital STRI, quarterly log GDP, and ICT usage (all OECD). Standard errors clustered at the country level in parentheses.

5.4 Spatial Price Interdependence

To test the robustness of our results, we account for the interdependence of prices, or more precisely, for the role of price spillovers across countries, by a spatial estimation approach. This allows for a more complex structure for the network between an audience and the different countries where all advertisers targeting that audience are located. It also represents a more flexible approach regarding the sources of spillovers than the approach described in 5.1.1. The latter could include for instance anticipation effects of tax reforms in other countries than the UK, which have not been explicitly

accounted for in the previous section. We build an $n \times n$ spatial weighting matrix $\mathbf{W}$ with elements w_{ij} capturing the strength of the relationship between the audience of country i and the advertisers from country j.

Consistent with the previous section, we construct a weighting matrix based on $\widetilde{Trade}_{ij}$, trade of i and j, weighted by the interests of i's audience in the products traded with j (corresponding to eq. (7)). Thereby we focus on total trade (the sum of exports and imports) to capture patterns of interdependence through trade between countries in a more appropriate way than when using imports only. Since we now exploit a bilateral structure for w_{ij}, we propose different alternative matrices that account for patterns of trade between countries. Note that the matrix has a zero diagonal but has non-zero trade in the off-diagonal elements of the matrix, and is min-max normalized.[32] Alternative spatial weighting matrices are based on geographical distance between countries (inspired by the gravity model of trade), and the number of flight connections between countries as a second weighting matrix taking into account the social network between countries.[33]

[32]Note that we also set trade with non-SO countries to zero.

[33]For related approaches see e.g., Behrens et al. (2012); Lee and Pace (2005); LeSage and Pace (2008). The use of distance is common in the trade literature to proxy for trade costs. The limitations of the distance matrix is that it may not be appropriate for proxying a network of online advertising, because this often pertains services that are distributed at nearly zero trade cost. Our last approach moves on to collecting data on the number of flights between the countries in our sample. The source is `https://openflights.org/`. For each airport, this database collects all connections from that airport to other airports by country. This spatial weighting matrix based on flight connections represent an alternative way of capturing the cultural vicinity among countries, something that is particularly relevant for the distribution of advertising. We also tested bilateral trade predicted from a gravity equation estimated by PPML, with ij-imports from the UN Comtrade database as the dependent variable, and log distance, contiguity, common official language, colonial history (all from CEPII), as well as importer and exporter fixed effects as independent variables, with similar results.

We formulate the spatial model as follows:

$$p_{id} = \gamma_0 + \gamma_1 p_{id-1} + \rho \sum_{j=1}^{n} w_{ij} p_{jd} + \gamma_2 T_d + \gamma_3 CPM_{d-1}^{US} + \gamma_4 STRI_{iy} + \gamma_5 lnGDP_{iq} + Hol_{id} + DW_d + Q_{iq} + M_{m(y)} + B_d + \text{USelec}_d + \nu_{id}, \tag{11}$$

where $\nu_{id} = \lambda \sum_{j=1}^{n} w_{ij} v_{jd} + u_{id}$. The equation is estimated by maximum likelihood using different spatial panel models. We rely on fixed effects spatial autoregressive (SAR) models, assuming that $\lambda = 0$, as well as an autoregressive model with autoregressive disturbances (SAC). Adding p_{id-1} to eq. 11 allows for a dynamic structure, yet we additionally estimate models excluding the lagged dependent variable.

Two results stand out.[34] First, we find that the estimates on both ρ and λ are mostly significant, indicating that the concern of spatial interdependence is valid.[35] Second, the main effects on the break are quantitatively and qualitatively similar to the ones shown in Table 3. Also in line with previous findings, using a dynamic model substantially changes these results (Columns 1 and 4), as the inclusion of a lag of the dependent variable decreases the coefficients to about 0.1 at best when using a dynamic model.

Additionally, direct, indirect and total effects are reported. The direct effect indicates the effect of the accounting restructuring in country i on prices in country i, averaged over all countries, and the total effect can be interpreted as the effect of the policy change in i on prices in all countries, averaged over all countries. The indirect effect is the difference between

[34]Table A2 in Appendix A summarizes the results from the estimation of eq. (11). The table is organized such that the main effect is displayed in panel A. Since the accounting restructuring for the UK, interpreting this coefficient is straightforward.

[35]Since $\rho, \lambda \neq 0$, either a spatial autoregressive model (SAR) or a spatial autoregressive model with autoregressive disturbances (SAC) is preferred compared to the spatial Durbin (SDM) – which assumes that $\lambda = 0$ – or the spatial error model (SEM), which assumes that $\rho = 0$.

the two (total minus direct). The estimates of the indirect effect are positive and statistically significant when using our preferred version of **W**, indicating that there is feedback from neighbours' prices. What we would be interested in is thus the total effect, which amounts to about 1.1 when we exclude the lagged dependent variable, and to 0.1 when we include the lagged dependent variable.

5.5 Implied Tax Pass-through rates

To put our estimates in perspective, we evaluate the pass-through rate of profit taxes on advertising prices implied by our estimates. Estimates indicate that the median price to reach audiences in OECD countries rose on average by \$0.29 due to the increase in taxes Facebook pays in SO countries (Table 3, Column 7). However, the lower bound of our estimates (Table A2, column 4) shows an effect of \$0.09. Given an average CPM in the period before the tax change of \$0.91, the price thus increased by about 10 to 32 percent. The average price increase for the subset of audiences located in SO countries is about 35 percent and 26 percent in non-SO countries (based on the estimates in Table 3, Columns 8 and 9).[36]

The average statutory corporate tax rate in OECD countries where Facebook has a sales office is 25.9 percent.[37] Because Facebook's advertising revenue was booked in Ireland before the tax change, the initial corporate tax rate of reference is the Irish one, equal to 12.5 percent. However, it is conceivable that the effective tax rate paid by Facebook in Ireland is substantially lower. Assuming an unchanged effective OECD average tax rate, we consider 12.5 percent as the upper bound of the initial tax rate

[36]Given estimates based on pooled models which do not include a lagged dependent variable (amounting to \$1.1), the price increase even amounts to up to 150 percent. However, our preferred estimates are from models including lagged dependent variables or control for serial correlation, and we concentrate on those estimates here.

[37]This is the average of the combined tax rate reported in the OECD Stats Database (Table II.1). See `https://stats.oecd.org/index.aspx?DataSetCode=Table_II1`.

and zero percent as the lower bound. The lower bound on the average tax increase in SO countries is thus 13.4 percent, and the upper bound is 25.9 percent. Table 4 reports the profit tax pass-through on the median advertising prices for OECD audiences on average. We also report the results distinguishing between audiences in SO and non-SO countries.[38]

The results of this exercise are quite sensitive to the model specification as well as the effective Irish tax rate. Given our preferred (GLS) estimates, the effect on ad prices ($0.29) suggests overshifting of taxes on ad prices (pass-through rate between 1.23 and 2.68). However, the lower bound of our estimates would suggest undershifting (pass-though rate between 0.38 and 0.83).[39]

In the last two columns of Table 4 we distinguish the effect between prices for audiences in sales-office (SO) and non-sales-office (non-SO) countries (based on the estimates from Table 3, columns 8 and 9). Notably, pass-through tends to be higher in non-sales-office countries, primarily because the initial CPM for audiences in such countries tends to be substantially smaller than for sales-office countries (we report disaggregate results by country in Appendix D).

[38]We use the following formula for pass-through: $\frac{\Delta p}{p} / \frac{\Delta t}{1+t}$, where Δp is the estimated increase in the average CPM ($0.09 and $0.29 overall, $0.45 for sales-office and $0.14 for non-SO), p is the average CPM in the period up to March 2016 ($0.91 overall, $1.37 for SO and $0.52 for non-SO), t is the Irish tax rate (assumed between 12.5 percent and zero) and Δt is the difference between the average corporate tax rate in OECD countries where Facebook has a sales office (25.9 percent) and t.

[39]The theoretical literature shows that overshifting of commodity taxes on goods prices can occur in imperfectly competitive markets, even with a monopolist supplier (Weyl and Fabinger, 2013).

Table 4: Average pass-through in oecd countries, sales-office and non sales-office countries

	Pass-through			
Tax rate IRL	ALL (0.09)	ALL (0.29)	SO	non-SO
12.50%	0.83	2.68	2.21	3.16
6.25%	0.53	1.72	1.42	2.03
0%	0.38	1.23	1.02	1.45

Notes: We compute the pass-through in each country using the upper and lower bound of the estimated effect on CPM (see Tables 3 and A2) and considering as the pre-reform tax rate the tax rate in Ireland (IRL), allowed to range between 12.5 and 0 percent. The post-reform tax rate is the average tax rate in Sales-Office countries, 25.9 percent.

To our knowledge, there are no previous estimates of tax pass-through rates on digital advertising prices. However, we can compare our results to existing estimates of VAT pass-through on the prices of consumer goods and services. The VAT literature typically estimates pass-through rates from 0.2 to 1.6 (Benedek et al., 2015). Given the highly plausible scenario that Facebook pays a tax rate close to zero in Ireland, our preferred estimates of pass through are at the high end of this spectrum. However, given the (less plausible, in our view) assumption that Facebook pays the full statutory tax rate in Ireland, our estimates suggest that pass-through is greater than previous estimates for VAT.

There are many differences between markets for consumer goods and services and the market we consider. For instance, the former are typically not dominated by two-sided platforms, unlike the market for advertising on social media. Given these differences, one should take the comparison of pass-through rates between the markets for social media ads and consumer goods with some caution.

6 Welfare Analysis

We provide a basic evaluation of the effects on welfare of the tax changes considered above by comparing welfare before and after the tax increase. These scenarios are referred to as pre-tax and post-tax scenario in the following. The analysis is based on the theoretical model of Section 4.3, that we extent to account for six countries. Furthermore, we specify consumer utility and advertiser profits in order to compute the respective surpluses. We calibrate the model using data from the following countries: Germany, France, UK, Japan, Mexico and the US. The first four are SO countries where Facebook revenue was taxed at the local rate only after the restructuring. The US is an SO country, but the ad revenue therein was booked locally before the accounting change. Finally, Mexico is a non-SO country. We focus on a restricted number of six countries for computational reasons. For reasons of space, we relegate the description of the model, data and calibration to Appendix E.

In the initial (pre-tax) scenario, we assume the platform does not pay any tax, except in the US. As for the post-tax scenario, we assume the platform pays no taxes in Mexico, which is a NS country, and pays the statutory corporate tax rate in Germany, France, UK, Japan and the US (SO countries). Details about the data used, results for the quantity of ad impressions to users as well as the prices of ads in the two scenarios are in Appendix E.

Table 5 summarizes the effects of the tax change on welfare, distinguishing between consumers, advertisers, the platform and the government. We find relatively small effects on total welfare, which decreases slightly, by 1 to 2 percent in the countries where the tax rate increased. By contrast, total welfare rises in Mexico and the US. However, the model suggests that taxation has relevant distributional effects. Specifically, there is a substan-

tial decrease of about 10 percent on average in advertiser surplus in the countries where the tax rate went up, due to the increase in ad prices. On the other hand, advertisers from Mexico and the US are better off because ads are cheaper for them. Furthermore, we find an increase in consumer surplus in all countries, due to the overall reduction in the exposure to ads due to the increase in taxation. However, given the rather small reduction in the total provision of ads, the effect on consumer surplus is small. Finally, a significant share of the platform's profits are taxed away in SO countries.

Table 5: Welfare changes

Pre-Tax Scenario						
	GER	FRA	UK	JPN	MEX	USA
Dailly users ('000)	20,884	22,215	29,062	13,715	44,559	177,009
Advertiser Surplus ($M)	5,341	1,579	9,628	7,124	731	12,072
Consumer Surplus ($M)	11,331	11,497	16,482	7,007	19,356	78,521
Tax Revenue ($M)	0	0	0	0	0	25,002
Platform Profit ($M)	8,017	3,407	13,450	8,903	1,724	43,511
Welfare ($M)	24,689	16,483	39,560	23,034	21,811	159,107
Post-Tax Scenario						
	GER	FRA	UK	JPN	MEX	USA
Dailly users ('000)	20,921	22,273	29,077	13,881	44,964	177,156
Advertiser Surplus ($M)	4,921	1,289	8,956	6,602	836	12,467
Consumer Surplus ($M)	11,363	11,546	16,495	7,130	19,659	78,651
Tax Revenue ($M)	2,355	1,131	2,564	2,614	0	23,945
Platform Profit ($M)	5,766	2,196	10,929	6,399	1,754	44,348
Welfare ($M)	24,405	16,162	38,944	22,745	22,248	159,411

7 Conclusion

We have provided a first exploration of the effects of taxation on MDPs. We show novel evidence on the incidence of taxation of digital platforms on the online advertising market. We study the effect of a change in Facebook's

accounting practices that took place in March 2016. We show that advertising prices increase substantially not only in the countries where taxation on the platform's revenue increased, but also in other countries. We find generally starker effects for countries that exhibit larger market shares of advertisers based in countries where taxation increased. Our findings are consistent with a theoretical model of a two-sided platform operating in the global advertising market.

These results highlight the relevance of international spillovers among advertising prices, in a market dominated by a large multinational digital platform. In particular, we show that these spillovers relate to pre-existing international trade patterns. This implies that unilateral corporate taxes on digital platforms may influence the price and distribution of ads across countries, even absent tax reform in the countries themselves. Therefore, the effects of taxes may extend beyond the allocation of accounting profits (e.g., through transfer pricing) in ways that signal a departure from the dynamics associated with traditional multinational enterprises.

The analysis has relevant implications for the design of taxes on digital platforms, and aims to address the current debate on proposed reforms to international corporate tax systems. Our results suggest that policymakers should carefully evaluate the potential consequences of taxes on digital platforms on i) the *level* and *distribution* of ads and prices across different audiences and ii) the price spillovers due to the global advertising network. In the context of ad hoc tax systems for the digital economy, our paper moves toward the idea of attributing shares of created values to the locations of users who are the targets of online advertising.

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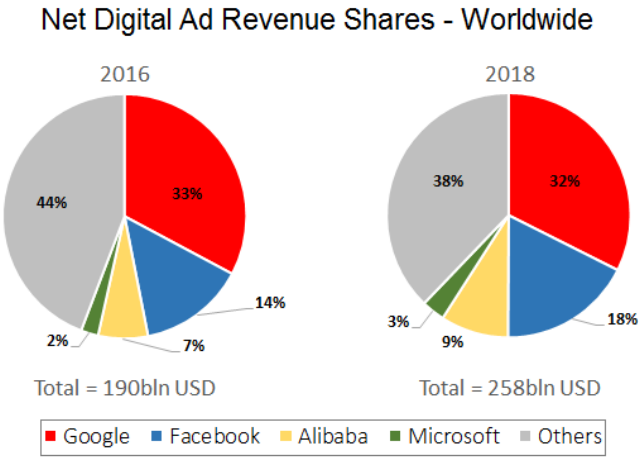
Appendix for online publication

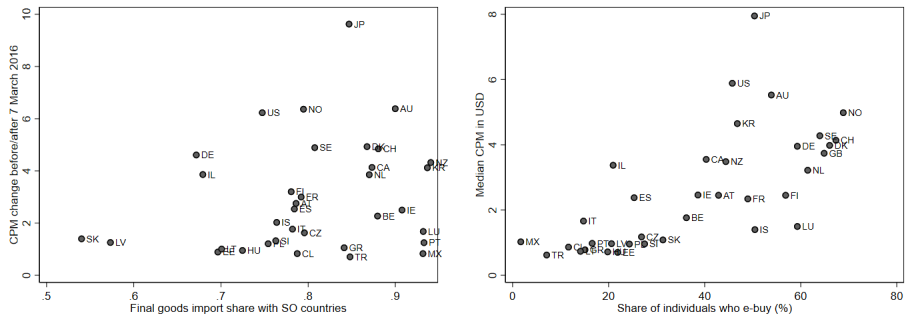
A Supplementary Figures and Tables

Figure A1: Online advertising market share of dominant platforms



Source: Statista, 2019

Figure A2: CPM prices, trade shares with SO countries, and ICT usage



Note: $\widetilde{Trade_i^{SO}}$ is yearly final goods import volume share with all sales office countries, 2015-2017, weighted by industry-specific penetration rates); (share of) individuals who e-buyOECD countries only. *Source*: Comtrade and own calculations; OECD.

Table A1: Test for unit root of median cpm

Statistic	(1) DF	(2) IPS	(3) IPS
Z(t)	-1.873	-3.738	-11.5353
p-value	0.345	0.0001	0.000

Column (1) uses the augmented Dickey-Fuller test for the UK only. Columns (2) and (3) are based on the Im-Pesaran-Shin (2003) test for unbalanced panels. Z(t) denotes the test statistic. The null hypothesis is that all the panels contain a unit root. Column (3) subtracts cross-sectional means.

Table A2: Effect of facebook accounting restructuring on online ad prices for spatial models

	(1) SAR	(2) SAR	(3) SAC	(4) SAR	(5) SAR	(6) SAC	(7) SAR	(8) SAR	(9) SAC
		$\widetilde{Trade}_{ij}$			Distance			No. flights	
A. Main effect									
T_d	0.110	0.897	0.922	0.087	0.674	0.632	0.108	0.995	0.990
	(0.013)	(0.140)	(0.148)	(0.014)	(0.214)	(0.276)	(0.013)	(0.164)	(0.164)
p_{id-1}	0.969			0.970			0.974		
	(0.006)			(0.006)			(0.005)		
B. Direct effect									
T_d	0.108	0.907	0.937	0.085	0.678	0.641	0.106	1.000	0.999
	(0.014)	(0.140)	(0.147)	(0.014)	(0.204)	(0.259)	(0.013)	(0.161)	(0.159)
C. Indirect effect									
T_d	0.001	0.220	0.183	0.002	0.457	0.568	0.001	0.138	0.147
	(0.0002)	(0.061)	(0.077)	(0.001)	(0.283)	(0.464)	(0.0002)	(0.110)	(0.115)
D. Total effect									
T_d	0.109	1.127	1.121	0.087	1.135	1.210	0.107	1.138	1.146
	(0.014)	(0.164)	(0.184)	(0.014)	(0.270)	(0.381)	(0.013)	(0.175)	(0.185)
ρ	0.041	0.829	0.698	0.082	1.106	1.256	0.027	0.465	0.479
	(0.006)	(0.155)	(0.194)	(0.033)	(0.531)	(0.670)	(0.011)	(0.253)	(0.290)
λ			0.742			-1.061			0.352
			(0.200)			(1.426)			(0.317)
Obs.	18,864	18,900	18,900	18,864	18,900	18,900	18,864	18,900	18,900
R^2	0.990	0.391	0.412	0.990	0.356	0.344	0.990	0.335	0.330

Notes: Models [1] and [2] are estimated based on a panel fixed effects spatial autoregressive (SAR) – [1] with lagged dependent variable –, model [3] is based on a spatial autoregressive model with auto regressive disturbances (SAC). The spatial weighting matrix for these models is based on bilateral trade between OECD countries (weighted by audience-specific interests), with zero diagonal. This corresponds to $\widetilde{Trade}_{ij}$, as expressed in eq. (7), replacing imports by total trade. Columns [4]–[6], and [7]–[9] are estimated analogously, using geographic distance and the number of flight connections as weighting matrices, respectively. All regressions control for the average weekly CPM of the US national internet market and the digital STRI for electronic transactions, and include day-of-the-week dummies, country-quarter dummies, holiday dummies, monthly dummies, a dummy for brexit, a dummy for the US elections and country-specific dummy for local general elections. Robust standard errors in parentheses.

Table A3: Effect of facebook accounting restructuring on online ad prices (trimmed sample)

	(1) FE	(2) POLS	(3) POLS	(4) GLS	(5) POLS	(6) POLS	(7) GLS	(8) non-SO	(9) SO
T_d	1.093	1.077	0.094	0.211	-1.960	0.031	-0.113	-0.011	-2.436
	(0.134)	(0.132)	(0.011)	(0.021)	(0.200)	(0.034)	(0.155)	(0.136)	(0.475)
$\widetilde{Trade_i}^{SO}$					-0.908	-0.029	1.787	-1.244	0.513
					(0.078)	(0.014)	(0.460)	(0.376)	(1.038)
$T_d \times \widetilde{Trade_i}^{SO}$					3.775	0.079	0.431	0.162	3.635
					(0.241)	(0.042)	(0.197)	(0.174)	(0.574)
Obs.	12,600	12,600	12,312	12,600	12,600	12,312	12,600	6,650	5,950
R^2	0.642	0.659	0.990		0.667	0.990			
Effect at Av($\widetilde{Trade_i}^{SO}$)					1.077	0.094	0.234	0.116	0.572
					(0.059)	(0.011)	(0.022)	(0.020)	(0.048)

Notes: All columns are based on a trimmed sample, restricted to all observations before 1st of June 2016. Model [1] is estimated using a fixed effects panel model, models [2] and [3] by pooled OLS – where model [3] includes 8 lags of the dependent variable in addition (as suggested by the AIC) – and model [4] by GLS. Models [5]–[7] include goods imports from countries with a sales office, weighted by country specific product interests, whereby [5] is estimated by POLS, [6] includes 8 lags of the dependent variable, and [7] is estimated by GLS. [8] and [9] are estimated by GLS for non non-SO and SO countries, respectively. All models control for the average weekly CPM of the US national internet market (not reported) and further include day-of-the-week dummies, quarterly dummies, holiday dummies, month-year dummies, a dummy for brexit, a dummy for the US elections. Models in [2]-[9] also include the OECD digital STRI, quarterly log GDP, and ICT usage. Standard errors clustered at the country level in parentheses.

B Structural Break Test and VAR analysis of Facebook Ad CPM Prices

Table B1: Structural break test for weekly oecd cpm prices

Country	Test I		Test II		Country	Test I		Test II	
Australia	297.66	0.0000	35.42	0.0000	Latvia	327.26	0.0000	26.54	0.0000
Austria	369.67	0.0000	6.06	0.1086	Lithuania	290.89	0.0000	32.07	0.0000
Belgium	282.11	0.0000	37.36	0.0000	Luxembourg	330.77	0.0000	16.55	0.0009
Bulgaria	296.00	0.0000	32.17	0.0000	Malta	416.62	0.0000	43.02	0.0000
Canada	313.59	0.0000	1.27	0.7351	Mexico	233.03	0.0000	48.87	0.0000
Chile	290.22	0.0000	3.99	0.2621	Netherlands	277.84	0.0000	41.37	0.0000
Croatia	280.79	0.0000	31.53	0.0000	New Zealand	339.08	0.0000	22.67	0.0000
Cyprus	287.19	0.0000	0.45	0.9308	Norway	283.16	0.0000	16.04	0.0011
Czech Republic	285.51	0.0000	9.78	0.0205	Poland	312.74	0.0000	3.53	0.3171
Denmark	289.38	0.0000	46.02	0.0000	Portugal	245.44	0.0000	9.87	0.0197
Estonia	352.89	0.0000	18.77	0.0003	Romania	343.62	0.0000	20.46	0.0001
Finland	307.04	0.0000	23.96	0.0000	Slovakia	287.73	0.0000	8.13	0.0433
France	328.98	0.0000	35.24	0.0000	Slovenia	255.78	0.0000	39.36	0.0000
Germany	340.70	0.0000	8.62	0.0348	South Korea	471.39	0.0000	15.98	0.0011
Greece	260.35	0.0000	14.57	0.0022	Spain	335.71	0.0000	8.66	0.0342
Hungary	313.42	0.0000	12.08	0.0071	Sweden	382.05	0.0000	7.00	0.0719
Iceland	240.55	0.0000	88.77	0.0000	Switzerland	289.68	0.0000	13.55	0.0036
Ireland	375.31	0.0000	7.05	0.0493	Turkey	327.04	0.0000	4.60	0.2034
Israel	278.19	0.0000	9.63	0.0220	United Kingdom	298.03	0.0000	17.68	0.0005
Italy	458.96	0.0000	26.92	0.0003	United States	326.85	0.0000	109.59	0.0000
Japan	383.45	0.0000	21.90	0.0001					

Table reports χ^2 test statistic results and significance level for the test of the null hypothesis that the CPM do not vary over the subsamples defined by the break date, specified as on the 7th of March 2016 (day of the announcement of Facebook UK's accounting restructuring). Test I is based on a simple regression of the CPM weekly level on a constant, whereas Test II is based on a regression of the CPM weekly level on a constant, its own first lag and on the contemporaneous level of OECD CPM weighted average. Weights are given by the share of Facebook users registered as resident in a given country.

To test the validity of the structural break hypothesis around the 7th of march 2016, we conduct a series of tests, on the country-specific time series of Facebook weekly CPM prices. Inspired by the narrative approach method introduced by Romer and Romer (1989), we proceed with a reduced-form VAR estimation of the CPM for country-specific audiences around the date of the announcement, where we use weekly averages instead of daily data. This takes into account the potential interdependence of country-specific advertising prices as suggested by the co-movement of the CPMs across different countries shown in Figure 2, as well as the time series nature of our data. The effects of the change in accounting practices can be illustrated by the corresponding impulse-response functions.

Specifically, we account for exogenous stock prices, endogenous prices and the effect of (the lead of) $After_d$. We follow the AIC, and include only one lag. Thereby we constrain the lag parameter on the equation for $After_d$ to zero, and make a small-sample degrees-of-freedom adjustment. The impulse response functions (IRF) for the effect of the accounting restructuring on median CPM prices across all OECD countries (see Figures B2, B3 and B4) are reported subsequently. As suggested by these figures and by the results on structural break tests, we find significant jumps after the announcement in March 2016, conditional on the series' lags, stock prices, and quarterly dummies. In order to be able to compare the intensity of the effect, we scale the axes homogeneously. Two things become evident from the figures: the announcement effect is not only significant statistically and economically, but it is also heterogeneous across different countries. For instance, we find very strong effects for the majority of EU countries with a sales office (see France, Germany, the Netherlands and Spain, from figure B2), and very small effects for the EU countries without a Sales Office. We also find that the effects are generally small for many countries which are a) smaller and/or less developed, and that b) levy lower corporate taxes.

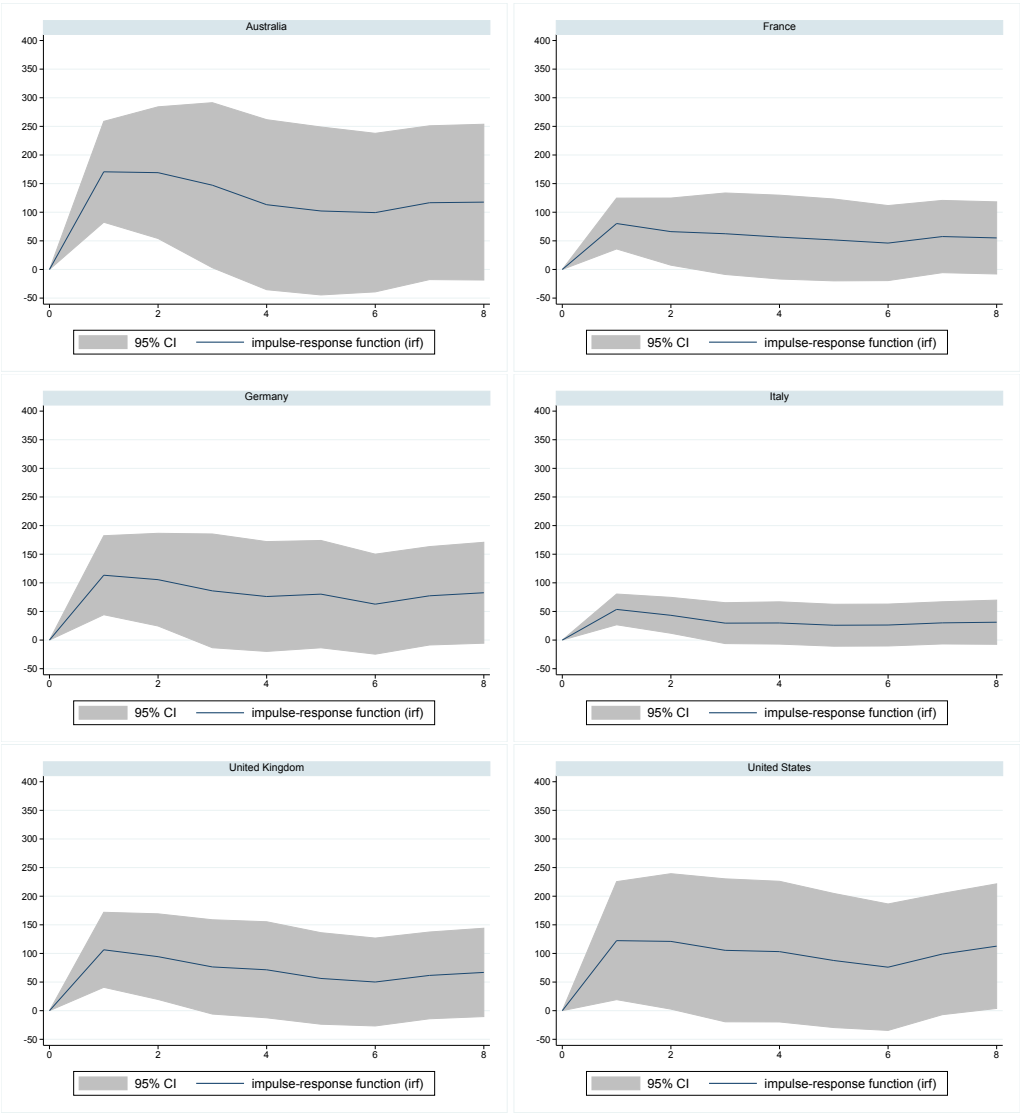


Figure B1: Impulse response functions for the effect of tax announcement on median CPM prices for selected OECD countries

Note: We estimate a reduced-form VAR model including one lag (chosen by AIC) as well as Facebook stock price and quarterly dummies as exogenous variables. The standard errors are corrected for small sample and degree-of-freedom adjusted. Data are based on weekly median CPM prices for all OECD countries. We model the tax announcement with one lead as an endogenous variable and constrain its lag parameter to zero.

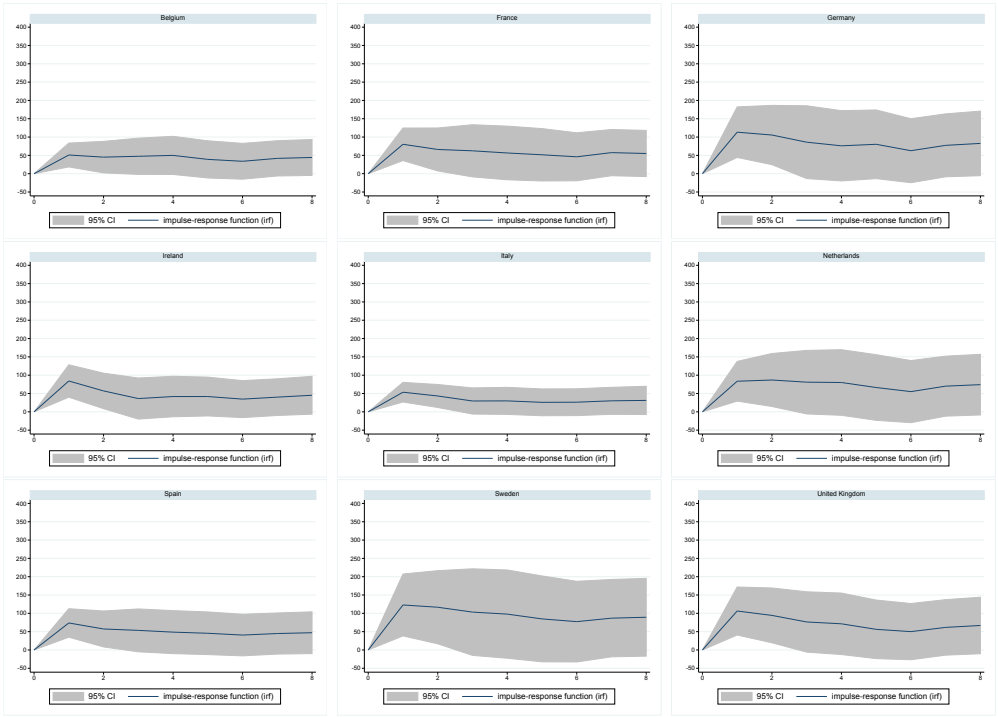


Figure B2: Impulse response functions for the effect of tax announcement on median cpm prices across eu countries with a Sales Office

Figure B3: Impulse response functions for the effect of tax announcement on median cpm prices across eu countries without a sales office

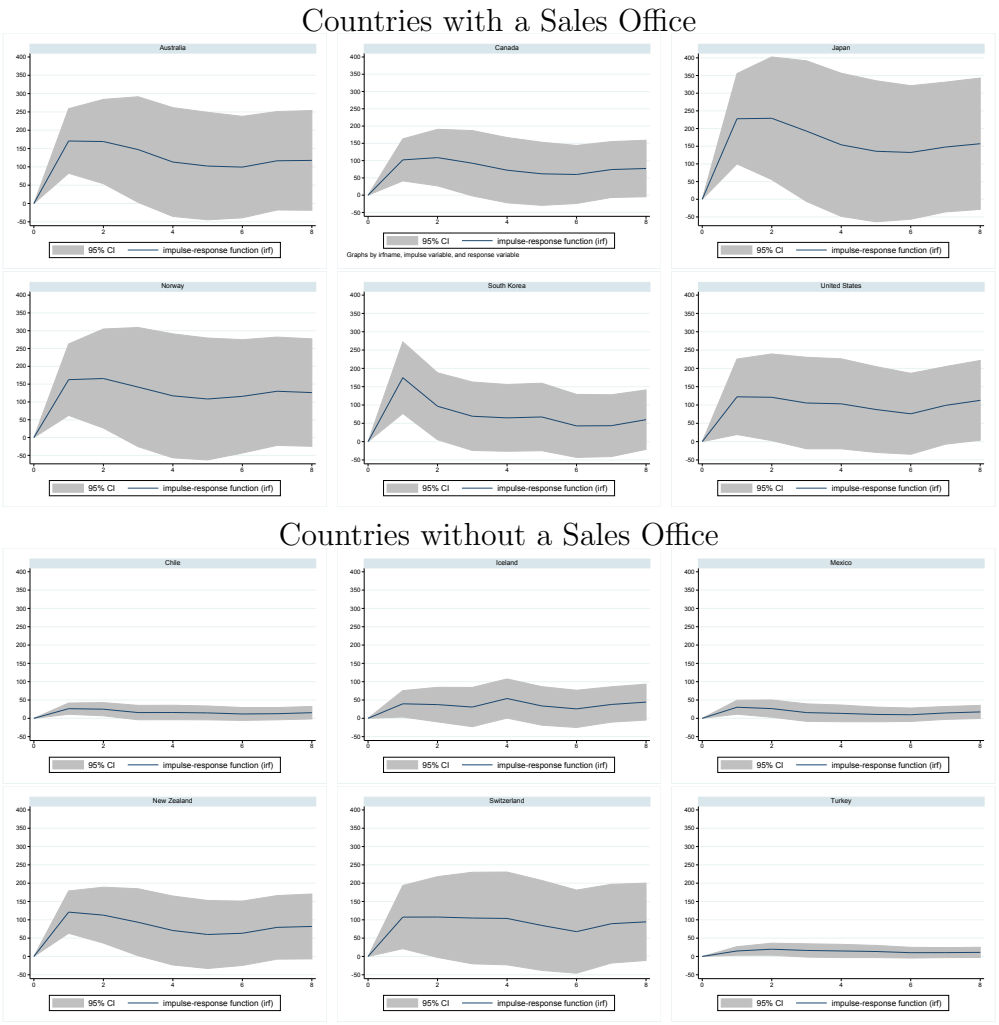


Figure B4: Impulse response functions for the effect of tax announcement on median cpm prices across non eu members of the oecd

Note: We estimate a reduced-form VAR model including one lag (chosen by AIC) as well as Facebook stock price and quarterly dummies as exogenous variables. The standard errors are corrected for small sample and degree-of-freedom adjusted. Data are based on weekly median CPM prices for all OECD countries. We model the tax announcement with one lead as an endogenous variable and constrain its lag parameter to zero.

C Proofs not given in the text

Totally differentiating (2) and (3), we get, for , $i = 1, 2$,

$$\frac{\partial q_{i1}}{\partial t} = -\frac{\frac{\partial^2\pi}{\partial q_{i1}\partial t}\frac{\partial^2\pi}{\partial q_{i2}^2} - \frac{\partial^2\pi}{\partial q_{i2}\partial t}\frac{\partial^2\pi}{\partial q_{i1}\partial q_{i2}}}{\frac{\partial^2\pi}{\partial q_{i2}^2}\frac{\partial^2\pi}{\partial q_{i1}^2} - \frac{\partial^2\pi}{\partial q_{i1}\partial q_{i2}}\frac{\partial^2\pi}{\partial q_{i1}\partial q_{i2}}}, \quad \frac{\partial q_{i2}}{\partial t} = -\frac{\frac{\partial^2\pi}{\partial q_{i2}\partial t}\frac{\partial^2\pi}{\partial q_{i1}^2} - \frac{\partial^2\pi}{\partial q_{i1}\partial t}\frac{\partial^2\pi}{\partial q_{i1}\partial q_{i2}}}{\frac{\partial^2\pi}{\partial q_{i2}^2}\frac{\partial^2\pi}{\partial q_{i1}^2} - \frac{\partial^2\pi}{\partial q_{i1}\partial q_{i2}}\frac{\partial^2\pi}{\partial q_{i1}\partial q_{i2}}}. \tag{C.1}$$

We have $\frac{\partial^2\pi}{\partial q_{i1}^2}, \frac{\partial^2\pi}{\partial q_{i2}^2} < 0$ and $\frac{\partial^2\pi}{\partial q_{i2}^2}\frac{\partial^2\pi}{\partial q_{i1}^2} - \frac{\partial^2\pi}{\partial q_{i1}\partial q_{i2}}\frac{\partial^2\pi}{\partial q_{i1}\partial q_{i2}} > 0$ by the assumption that second order conditions are satisfied at equilibrium. Furthermore, we have

$$\frac{\partial^2\pi}{\partial q_{i1}\partial q_{i2}} = z_i' n_2 n_1 \left[\left(p_{i2} + \frac{\partial p_{i2}}{\partial q_{i2}} q_{i2}\right) + (1-t)\left(p_{i1} + \frac{\partial p_{i1}}{\partial q_{i1}} q_{i1}\right)\right] + \\ + z_i'' n_2 n_1 \left[(1-t)\, n_1 p_{i1} q_1 + n_2 p_{i2} q_{i2}\right] < 0,$$

The inequality follows from (2) and (3). Specifically, (2) and (3) equal zero in equilibrium. Given this, and because the terms $z_i' q_{ij} p_{ij} n_j$ are negative, the terms in round parentheses above are positive. Furthermore, we have

$$\frac{\partial^2\pi}{\partial q_2 \partial t} = -z_i' q_{i1} p_{i1} n_1 n_2 > 0, \quad \frac{\partial^2\pi}{\partial q_{i1}\partial t} = -n_1\left[z_i' n_1 q_{i1} p_{i1} + z_i\left(\frac{\partial p_{i1}}{\partial q_{i1}} q_{i1} + p_{i1}\right)\right] < 0.$$

The last of these inequalities follows from (3). Given that $z_i' q_{i2} p_{i2} n_2 < 0$ and $(1-t) > 0$, we must have $z_i' n_1 q_{i1} p_{i1} + z_i\left(\frac{\partial p_{i1}}{\partial q_{i1}} q_{i1} + p_{i1}\right) > 0$.

Given the above expressions, we get

$$\frac{\partial q_{i2}}{\partial t} > 0 \iff \frac{\partial^2\pi}{\partial q_{i2}\partial t}\frac{\partial^2\pi}{\partial q_{i1}^2} < \frac{\partial^2\pi}{\partial q_{i1}\partial t}\frac{\partial^2\pi}{\partial q_{i1}\partial q_{i2}}.$$

and we find $\frac{\partial q_{i2}}{\partial t} > 0$ because $\frac{\partial^2\pi}{\partial q_{i1}\partial t} < 0$. Furthermore, we have

$$\frac{\partial q_{i1}}{\partial t} < 0 \iff \frac{\partial^2\pi}{\partial q_{i1}\partial t}\frac{\partial^2\pi}{\partial q_{i2}^2} > \frac{\partial^2\pi}{\partial q_{i2}\partial t}\frac{\partial^2\pi}{\partial q_{i1}\partial q_{i2}}.$$

Again, $\frac{\partial q_{i1}}{\partial t} < 0$ because $\frac{\partial^2\pi}{\partial q_{i1}\partial t} < 0$.

D Effect of tax change and pass-through by country

Table D1: Effect and pass-through by country

Countries with Sales Office

	Initial CPM	Effect Td	Pass-through with IRE tax rate (%) 0	6.25	12.5
AUS	2.12	0.74	0.93	1.30	2.01
BEL	0.73	0.29	1.06	1.49	2.31
CAN	1.36	0.45	1.01	1.41	2.19
DEU	1.50	0.56	0.99	1.39	2.16
ESP	1.07	0.34	0.85	1.18	1.84
FRA	0.78	0.33	1.12	1.57	2.44
UK	1.82	0.40	0.59	0.82	1.28
ISR	1.33	0.35	0.83	1.16	1.81
ITA	0.78	0.16	0.77	1.08	1.68
JPN	2.72	1.09	1.07	1.49	2.32
KOR	2.37	0.65	0.85	1.19	1.84
NLD	1.00	0.47	1.24	1.74	2.70
NOR	1.46	0.80	1.46	2.04	3.17
NZL	1.09	0.40	1.40	1.96	3.05
POL	0.29	0.12	1.67	2.34	3.64
SWE	1.57	0.29	0.72	1.01	1.57
USA	2.43	0.57	0.74	1.03	1.61
Average	1.37	0.46	1.03	1.42	2.22

Countries without Sales Office

	Initial CPM	Effect Td	Pass-through with IRE tax rate (%) 0	6.25	12.5
AUT	0.93	0.26	1.08	1.52	2.35
CHE	1.45	0.30	0.79	1.11	1.72
CHL	0.40	0.07	0.68	0.95	1.48
CZE	0.27	0.17	2.38	3.33	5.17
DNK	1.25	0.33	1.02	1.42	2.21
EST	0.21	0.12	2.28	3.20	4.96
FIN	0.68	0.27	1.55	2.17	3.38
GRC	0.20	0.06	1.27	1.78	2.77
HUN	0.19	0.07	1.51	2.11	3.28
IRL	1.07	0.21	0.76	1.06	1.65
ISL	0.28	0.22	3.07	4.30	6.67
LTU	0.18	0.09	1.98	2.77	4.30
LUX	0.57	0.13	0.86	1.21	1.87
LVA	0.27	0.13	1.77	2.48	3.85
MEX	0.57	0.08	0.54	0.75	1.17
PRT	0.29	0.12	1.63	2.28	3.53
SVK	0.31	0.12	1.50	2.10	3.26
SVN	0.23	0.11	1.88	2.64	4.09
TUR	0.23	0.06	0.96	1.34	2.08
Average	0.52	0.14	1.42	2.03	3.15

E Model, calibration and data for the welfare analysis

We consider the setup of Section 4.3, with $N > 2$ countries. Let M_i be the population of potential users in country i. A user in i gains the following

utility from browsing the platform

$$U_i(m) = 1 - \alpha_i q_i - m, \tag{E.1}$$

where m is distributed uniformly on the $[0, 1]$ interval. Recall that $q_i = \sum_{j=1..N} n_j q_{ij}$ is the total quantity of ads the consumer is exposed to. Users connect to the platform only if they get a positive utility. Given our assumptions, the quantity of users in i who connect is $M_i z_i = M_i(1 - \alpha_i q_i)$. It follows that the aggregate surplus of i's consumers is

$$CS_i = M_i(1 - \alpha_i q_i)^2/2. \tag{E.2}$$

We specify the inverse demand for impressions to a consumer in i by an advertiser in country j as

$$p_{ij}(q_{ij}) = \beta_j - \gamma_j q_{ij}. \tag{E.3}$$

The aggregate surplus of advertisers from country j is

$$AS_j = n_j \sum_{i=1..N} M_i z_i \frac{(\beta_j - p_{ij})q_{ij}}{2}. \tag{E.4}$$

We denote by t_j the tax rate set by country j on the revenue the platform collects in its jurisdiction. The platform's tax payment in country j is therefore

$$T_j = n_j t_j \sum_{i=1..N} M_i z_i p_{ij} q_{ij}, , \tag{E.5}$$

and the platform's profit in country j is

$$\pi_j = (1 - t_j) n_j \sum_{i=1..N} M_i z_i q_{ij} p_{ij}. \tag{E.6}$$

We define welfare in country i as the sum of consumer and advertiser

surplus, the platform's profit and tax revenue:

$$W_i = \pi_i + CS_i + AS_i + T_i. \tag{E.7}$$

We use data from the period before Facebook's accounting change, i.e. from July 2015 to March 2016. The data described in the previous sections are enhanced with information on the exposure to ads on Facebook stemming from an experimental dataset (Cabañas et al., 2017). The latter reports information about the average number of impressions that a sample of Facebook users in each country is exposed to while browsing the social media website.[40] As Table E1 reports, each user sees about two ads per minute on average, with users in Mexico being exposed to the lowest quantity of ads, and users in Germany, the UK and the US being exposed to the largest quantity. We use these quantities to approximate the exposure to ads, q_i, in the model. (Note that we do not observe the advertisers' location.)

To obtain the disutility parameter α_i in expression (E.1), we combine information on the share of daily active users in each country with information on exposure to ads. Specifically, we approximate the share of platform users, z_i, by the ratio of daily users and the total number of users in each country, as reported by Facebook's Ad Manager. We then combine this information with q_i to obtain α_i, based on (E.1).

We calibrate the parameters of the demand function in expression (E.3) given the assumption that they do not vary according to which audience advertisers from country j target. It is not possible to differentiate such parameters by target country because, recall, we do not observe the quantities q_{ij} and the prices p_{ij}. We compute the slope, $\gamma_j = {}^{\partial p_{ij}}/_{\partial q_{ij}}$, starting

[40]The dataset was collected through a Facebook plugin, the FDVT (`https://fdvt.org/`).

from the elasticity of demand for ads ϵ_{qp}^{ij}

$$\epsilon_{qp}^{ij} = \frac{\partial q_{ij}}{\partial p_{ij}} \frac{p_{ij}}{q_{ij}} \implies \gamma_j = (1/\epsilon_{qp}^{ij}) \frac{p_{ij}}{q_{ij}}. \tag{E.8}$$

We approximate q_{ij} by taking the quantity of ads that users in country j are exposed to (described above) and dividing it by the total number of advertisers. For each country j, we approximate for q_{ij} using information about the total number of advertisers on Facebook and each country's share of global GDP in 2015 as well as businesses' propensity to advertise online.[41] We approximate for target-specific ad prices, p_{ij}, by the median price for advertising to country j, p_j. This assumption is consistent with the idea that domestic advertisers should have a large weight in determining the price of ads in country j. As we report in Table E1, there is substantial variation in such prices across the countries we consider. The highest price is for ads targeting audiences in Japan (CPM \$2.58) and lowest to Mexico (CPM \$0.58). Finally, because we lack information on the elasticity of demand by advertisers on Facebook, we use the average of the estimates in Argentesi and Filistrucchi (2007, Table 4) for newspaper advertising, i.e. -0.84. Having obtained the estimate for γ_j, we compute β_j based on (E.3).

[41] According to Statista.com, the total number of advertisers on Facebook at the end of 2015 was approximately 3 million globally. We calculate the approximate share of such advertisers from each country based on each country's share of global GDP, weighted by the average of four variables that describe a country's firms' propensity to operate (and, thus, advertise) online. These variables are: (i) the share of businesses with a website or home page, (ii) the share of businesses with a website allowing for ordering or reservation (iii) the share of businesses receiving orders through the internet and (iv) the share of businesses using social media. This information is available from the OECD (`https://stats.oecd.org/`).

Table E1: Data and parameters for welfare analysis

	Daily users ('000)	Ads per user-hour	Median CPM ($cent)	Advertisers
GER	20,884	134.6	142.5	91,700
FRA	22,215	115.2	70.0	53,600
UK	29,062	138.4	174.5	84,600
JPN	13,715	100.4	258.9	167,400
MEX	44,559	85.9	58.5	30,800
USA	144,871	131.5	246.8	801,200
	Tax rate (%)	α	β	γ
GER	29.8	0.14	0.31	0.08
FRA	34.4	0.17	0.15	0.04
UK	19.0	0.08	0.38	0.07
JPN	29.7	0.34	0.57	0.22
MEX	30.0	0.32	0.13	0.06
USA	25.8	0.11	0.54	0.12

The total quantity and median prices of ads we obtain in the pre-tax scenario are very close to the observed ones, see the last columns (TOT) of the top panels of tables E2 and E3. The majority of ads consumers are exposed to come from the US and UK. These countries are also the ones where advertisers tend to pay the highest prices, together with Japan.

In the post-tax regime, the platform pays the corporate tax rate on revenue generated in all SO countries. We obtain an increase of about 20 percent in the prices paid by advertisers from countries where the tax rate increased, while the quantity of ads mildly decreases, by about two to three percent. The model also predicts a decrease in the prices paid by advertisers from US and Mexico, although this decrease is rather small in magnitude. Overall, the median price per audience (computed as the weighted average of the ad prices to reach a given audience) increases by about 20 percent to target audiences in SO countries where the effective tax rate goes up, and by a smaller extent for audiences in the US and Mexico. See the bottom panels of tables E2 and E3.

Table E2: Ad impressions per user

Ad impressions (per user-hour), Pre-Tax Scenario							
to/from	GER	FRA	UK	JPN	MEX	USA	TOT
GER	22.0	16.3	31.1	14.6	9.2	35.0	128.2
FRA	21.4	15.2	30.4	14.4	8.5	34.4	124.2
UK	23.2	18.4	32.4	15.0	10.7	36.0	135.8
JPN	17.7	8.7	26.2	13.1	4.0	31.2	100.9
MEX	18.1	9.5	26.7	13.2	4.6	31.6	103.6
USA	22.6	17.4	31.8	14.8	10.0	35.5	132.1

Ad impressions (per user-hour), Post-Tax Scenario							
to/from	GER	FRA	UK	JPN	MEX	USA	TOT
GER	21.2	14.8	30	13.6	10.2	36.4	126.2
FRA	20.2	12.4	29.6	13	9.8	36	121
UK	21	16.4	31.6	14.2	11.4	36.8	131.4
JPN	15.4	4.8	25.2	12	5.8	34	97.2
MEX	17.1	6.6	26.4	11.0	5.9	32.6	99.6
USA	20.8	15.2	30.2	13.4	10.4	37.0	127.0

Table E3: Ad prices

Ad prices (CPM, $cent), Pre-Tax Scenario							
to/from	GER	FRA	UK	JPN	MEX	USA	AVG
GER	119.5	68.1	132.2	175.2	57.2	180.4	140.6
FRA	67.9	51.9	74.9	93.9	49.9	90.9	70.4
UK	120.1	64.1	165.2	211.1	57.1	200.6	168.0
JPN	176.5	112.5	204.5	280.5	104.5	268.5	254.8
MEX	65.2	78.8	67.3	57.8	76.2	55.1	59.7
USA	160.5	84.5	193.8	284.0	75.0	269.8	246.1

Ad prices (CPM, $cent), Post-Tax Scenario							
to/from	GER	FRA	UK	JPN	MEX	USA	AVG
GER	184.2	105.8	195.2	230.4	51.2	171.5	171.3
FRA	95.1	78.4	102.6	140.2	42.3	78.4	82.5
UK	175.4	79.6	225.1	271.3	51.0	190.4	207.5
JPN	235.1	142.1	275.6	361.3	94.2	262.1	308.4
MEX	80.4	93.2	96.1	80.4	62.3	48.2	60.9
USA	220.5	110.5	245.6	369.4	72.9	252.3	251.9

F Advertising Auctions on Facebook

To allocate advertising opportunities on its website, Facebook adopts an auction system based on the Vickrey-Groves-Clark (VCG) mechanism. We present this mechanism in an informal way. Consider an auction where a set of goods is being sold. In the case of Facebook, these goods correspond to advertising space on the "wall" of a set of users defined by certain characteristics (e.g., demographics, interests, etc.), i.e. an *audience*. For each of these goods, bidders (advertisers) announce the maximum price they are willing to pay. Bidders cannot see other participants' bids (sealed-bid auction). The auction closes once all the bids are in.

In the standard VCG auction, the auctioneer calculates for each bid the marginal loss to the other bidders if the bid were successful. For those who would have obtained the goods if the bid in question were ignored, the loss is equal to the bid they placed (i.e., their declared willingness to pay). The loss is instead zero to all bidders who would not have obtained the good, even if the bid considered were ignored. The auctioneer allocates the good to the highest bidders and charges them the marginal loss their bid has caused to others.

To fix ideas, suppose there is only one good to be allocated. In this case, the auction system would allocate the good to the highest bidder, and charge the second-highest bid (i.e., the loss to the bidder who would have received the good otherwise) to the winner. That is, the mechanism reduces to a second-price auction when a single good is for sale.

It can be shown that this mechanism maximizes the aggregate utility of bidders, since all the goods are attributed to the participants with the highest willingness-to-pay. Furthermore, if agents are fully rational and in the absence of collusion, the willingness to pay is reported truthfully. This is because only the marginal harm to other bidders will be charged to each

participant, making truthful bidding a (weakly) dominant strategy. However, this type of auction does not maximize the seller's revenue. According to Facebook, though, this disadvantage is unimportant. The reason is that, although some revenue may be sacrificed in the short run, in the long run the mechanism improves the relevance of the ad to the selected audience and, therefore, the effectiveness of advertising on the platform.

Facebook's auction system is in fact more complex than the standard VCG auction, because it considers not only the marginal loss to other bidders (advertisers), but also the loss to the users who get exposed to the ads. Although the company does not disclose the details of this procedure, we can summarily describe it as follows. For a given audience, Facebook calculates a *relevance score* associated to each ad proposed by the respective bidders. The higher this score, the higher the imputed loss to the audience when that advertiser's bid is unsuccessful. The score captures the cost to the audience of not seeing the ad. Facebook uses the relevance score to determine which bids are successful and how much the winners should be charged (that is, the size of the combined loss on users and other advertisers). This process is controlled by a Facebook automated algorithm, which is not observed by the researcher nor by the advertiser.[42]

According to Facebook, this system minimizes the probability that ads are shown to uninterested audiences. Furthermore, it increases the price advertisers should expect to pay when attempting to reach an audience that is also targeted by other relevant ads. Furthermore, less relevant ads cause higher "social" harm, so the price the advertiser pays increases as well.

[42]see https://www.facebook.com/business/help/430291176997542?helpref=faq˙content

G Collection of Facebook data

Our main source of information is Facebook's Ad Manager website.[43] This website provides an interface that advertisers can use to place ads on Facebook.

An advertiser using the Ad Manager selects an audience, defined by any combination of geographical location, demographical characteristics, personal interests and behaviors. The advertiser also selects a compensation method: CPM, CPC or CPA. Cost per Mille (CPM), is the unit price paid every time the ad is shown a thousand times to users in the selected audience. Advertisers who care for driving traffic to a specific web-page generally prefer to pay per click by the selected audience. This compensation method is referred to as Cost per Click (CPC). Finally, Cost per Action is a price paid every time a consumer adopts a certain action (e.g., visiting the advertiser's webpage).

The advertiser can then choose a maximum bid for impressions on that audience. In the latter case, Facebook displays a suggested *bid range*. The range of suggested bids indicates a minimum, a median and a maximum bid. According to Facebook, this is the range of prices that are currently being paid by advertisers winning auctions for the selected audience.[44] See Figure G2 for a screenshot of the page reporting the bid range. We queried the Ad Manager to collect the bid range for audiences defined exclusively by country of residence, for all OECD countries, using CPM, CPC and CPA metrics. The queries took place for every 15 minutes during our period of observation. We averaged the data at daily level.

The Ad Manager also provides advertisers with information about the expected size of the audience they intend to reach. Specifically, the website reports the expected number of daily active users that belong to the

[43] https://www.facebook.com/business/learn/facebook-ads-reporting-ads-manager
[44] See https://www.facebook.com/help/213140778716849.

selected audience. See Figure G1. We also queried the website to collect information about the number of users in each country that are interested in certain products. Specifically, based on Comtrade's HS8-classification for categories of goods, we select audiences based on country of location and interest in each category, and collect the number of users within the audience so defined. Because our trade data is available at the yearly level, we average our information about country-product audiences yearly as well. We then compute the share of Facebook users within a country that are interested in each product category, thereby obtaining our vectors of penetration rates.

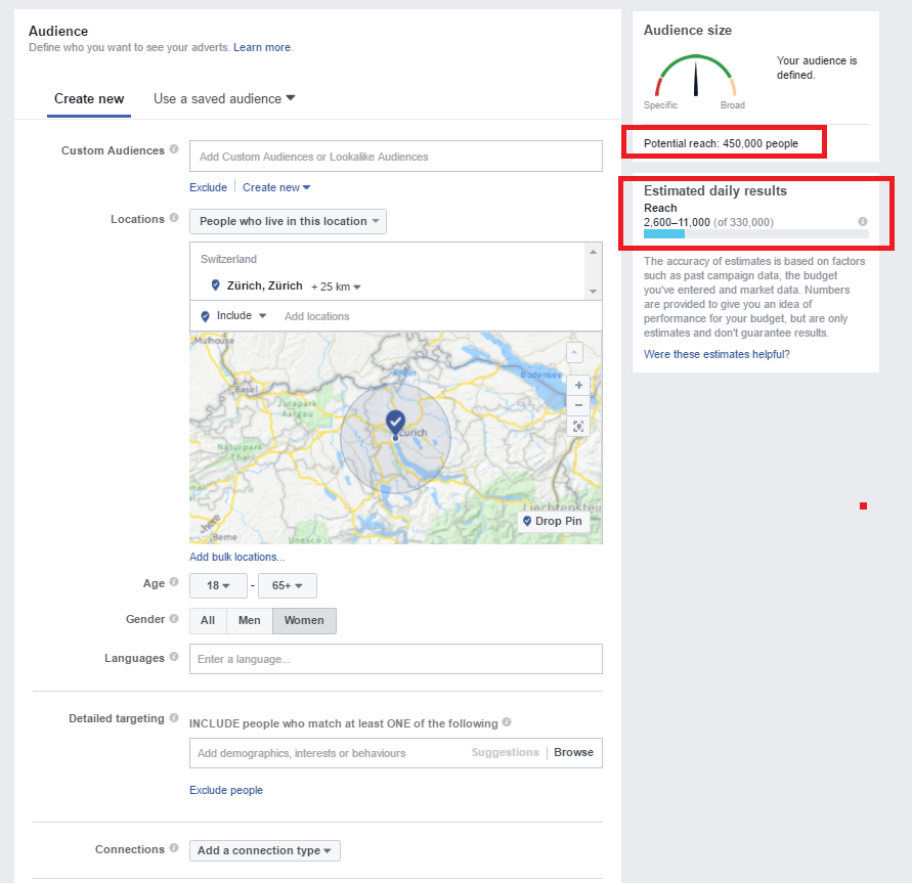


Figure G1: Facebook ad manager - screenshot

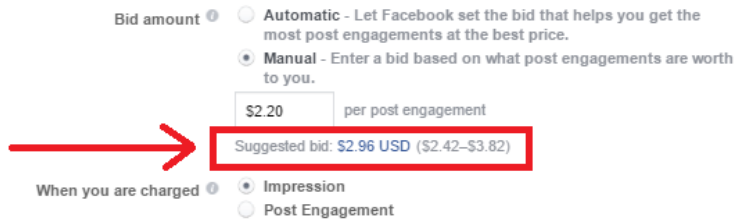


Figure G2: Facebook ad suggested bid - screenshot