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Global Effects of Taxation on Online Advertising**

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* The Networks, Electronic Commerce, and Telecommunications (“NET”) Institute, <http://www.NETinst.org>, is a non-profit institution devoted to research on network industries, electronic commerce, telecommunications, the Internet, “virtual networks” comprised of computers that share the same technical standard or operating system, and on network issues in general.

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Abstract

We study the effects of the taxation of digital platforms on the online advertising market. We exploit novel data on daily unit prices of Facebook ads targeted to country-specific audiences, collected around a major change in the firm's accounting practices following the introduction of the UK Diverted Profit Tax. We show that a substantial increase in ads prices followed such change, although with heterogeneous intensity across countries. These results are in line with a model of a platform operating in the global advertising market. We show that taxation of profits generated in one country makes the price charged to advertisers from that country (resp. other countries) increase (decrease). Accordingly, we demonstrate that aggregate advertising prices in OECD countries increased more, after the policy change, the larger is the market share of UK-based advertisers.

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1 Introduction

The rapid digitalization of the economy poses formidable challenges to policymakers. A major one is rethinking the taxation system (OECD 2015, EU Parliament 2016). Despite the active policy debate on the topic, an open question remains, on what are the real economic effects of introducing ad-hoc tax instruments designed specifically for the digital market. Answering this question requires considering 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 online advertising. Second, these platforms have rapidly acquired dominant positions in their respective markets. Third, they are multinational firms operating worldwide. To our knowledge, we are the first paper to present a formal analysis of taxation in digital markets that accounts for all of these aspects.

Besides providing free access to search engines and social network services, major Internet platforms are dedicated to the refinement of technologies for the elaboration of users' personal data. These technologies have proven extremely profitable, as they allow to improve the accuracy and relevance of users targeting, which is offered to global advertisers. The Interactive Advertising Bureau (IAB) calculated that online advertising revenue in the US alone amounted to 72 Billion USD in 2016, for a growth of over 20% with respect to 2015. The major seven Internet platforms generated 133 Billion USD of ad revenues during the same year, accounting for nearly three-quarters of the 190 Billion USD of global digital ad spending (see Figures 1 and 2). Despite the striking success of these companies, and the interest governments have in collecting tax revenues from their booming profits, there is little evidence of the incidence of taxation on online advertising markets. This lack of evidence is partly due to the fact that most of the profit generated by these businesses remains virtually untaxed, and partly it is due to the scarcity of (freely accessible) statistical data on the subject. Nevertheless, it is, in our view, fundamental to investigate the way that prices and allocation of online advertising (ads) will be affected. Our first contribution is to exploit a novel database of daily ad prices from the World largest social network, Facebook Inc., to provide empirical evidence on the *incidence*

of taxation on online advertising. Besides the lack of empirical evidence, there is very little economic research studying the impact of fiscal policy in markets where MDPs are major players. No existing study considers that, although the markets where MDPs operate are globally integrated, they are actually part of multiple jurisdictions, whose conflicting interests may produce welfare losses. Our second contribution is to build a fairly general theoretical framework that tackles these issues.

Our research is particularly motivated by the fact that taxation of the digital economy is at the top of the agenda of national and multi-lateral bodies, such as the OECD and the EU. MDPs engage in sophisticated accounting practices to minimize local tax bases, which raises concerns of fairness and equality, related to the concentration of high volumes of profits away from their source country.¹ Some governments are taking measures to increase the tax revenue collected from MDPs: many have opened investigations regarding due taxes (see Table 1). Others have introduced, or are considering, new instruments such as the UK's Diverted Profit Tax, Australia's new "Google tax" and the Obama Administration's proposed tax on foreign profits.² Most recently, the European Commission stated its intention to "ensure that corporate profits are taxed where the value is created" (EC, 2017 p.8), and opened discussions on the introduction of an equalization tax on turnover of digital companies, or of a tax on revenues generated from the provision of online advertising services. These policies are seldom supported by formal assessments of their real economic implications and welfare impact.

The empirical analysis presented in this paper exploits a variation in Facebook's internal accounting practices related to the UK market. There is speculation that this restructuring was triggered by changes in the UK corporate tax policy, specifically by the introduction of the Diverted Profit Tax (DPT) designed to collect tax

¹Although these practices are common to all multinationals, MDPs are particularly suited to adopt them. First, they require little to no physical presence in the market where they operate; second, they employ novel forms of transactions, simplifying the channeling of royalty and fee payments toward tax heaven affiliates; finally, their business model is based on personal data, the value of which is extremely complex to define, as is the volume of transactions (e.g. sale of advertising) generated from this data. See, e.g., European Commission (2017)

²See the Washington Post, "How US companies are avoiding 695\$ billion in taxes", March 4th 2016.

revenue from digital companies.³ According to the new accounting arrangements, the revenue collected from UK advertisers is booked (and thus taxed) locally, rather than in Ireland (as is the revenue from all other countries). Because Ireland has a favorable tax regime, the restructuring corresponds to an increase in taxes on UK-generated revenue. We collect daily unit prices of Facebook ad impressions targeted to *country-specific audiences*, for a period of approximately eighteen months, going from July 2015 to February 2017. We use the sample to estimate the effect that the change in Facebook UK accounting practices had on advertising prices. We employ time series analysis to show the significance of the break in the trend of Facebook UK advertising prices, around the time of the announcement of the new accounting practices. Furthermore, we show that the break had spillover effects over all other OECD countries. We use panel data and spatial models to show that the unit price of ads directed to foreign audiences also increased, but the intensity of the increase was stronger the larger the market share of UK-based advertisers in the country of the targeted foreign audience.

We reconcile our empirical findings in a theoretical model of a two-sided platform that operates in the global advertising market. Users access free online services, while receiving targeted ads from local and foreign advertisers. Through the effects of advertising on users demand, our model shows that an increase in profit tax rates of one of the countries, will cause ad prices to raise for local advertisers and to drop for foreign ones. This explains the mechanism behind our empirical finding of cross-country spillover effects, because it shows that higher taxes in one country are associated with higher average ad prices in that country, as well as in all other countries where directly affected advertisers have a substantial market share.

Motivated by the current policy landscape, with several countries looking to increase taxes on locally-generated MDP profits, we extend our theoretical framework and consider a multilateral setting, where each country sets independent tax rates, enforced on the revenue collected by local advertisers. We find that revenue-maximizing governments would ignore the spillover effect on foreign markets, and coordinate on taxes below the jointly revenue-maximizing level. We then consider

³See the Financial Times “Facebook faces profits hit after tax shake-up.”, March 4th 2016.

the case of local welfare maximizing governments, and also find that taxes are set at exceedingly low levels. Overall, these results suggest that there is scope for international cooperation on tax rules to improve welfare. They also provide some support for initiatives by supra-national bodies intended to reduce tax loopholes that may be exploited by MDPs, such as the OECD’s BEPS initiative (OECD, 2015).

– Insert Figures 1 and 2 and Table 1 here–

We organize the remainder of this paper as follows. In the next section, we describe Facebook’s accounting restructuring and the data used subsequently. This is complemented by an empirical analysis that studies the effect of the change on on-line advertising prices along various lines. Section 4 outlines a theoretical framework that extends beyond the explanations of the empirical patterns. The final section concludes.

2 Effect of Corporate Taxes on Facebook Online Ad Prices

2.1 Facebook UK accounting restructuring

As of today, no country has enforced any legislation regarding ad-hoc fiscal instruments for the collected of tax revenue from digital companies. This is one of the reasons behind the lack of empirical evidence on the topic. In order to identify the effects of taxation on online advertising prices, we therefore exploit a change in Facebook’s accounting structure. Facebook is a digital platform providing free services to global users, while selling impressions to advertisers who are able to select a desired target audience. The market structure is depicted in Figure 3.

– Insert Figure 3 here–

As clearly explained on their “Adverts-Help” page⁴, Facebook ads purchases

⁴see the “Currencies and Taxes” section of the “Advertisers Help Center” at https://www.facebook.com/business/help/735697126483994?helpref=uf_permalink

are made through the European Headquarters in Dublin.⁵ The revenue generated through advertising purchases goes under Facebook Ireland Ltd, who later pays royalty fees to Facebook Ireland Holdings, located in the Cayman Islands. Up until the end of the fiscal year 2015-2016, all advertisements booked by UK advertisers followed the same scheme. On the 7th of March 2016 Facebook UK Ltd. announced that it would operate a change in its accounting practices. Starting from the 1st of April 2016, large UK advertisers would start being billed locally, whereas small advertisers would continue receiving their bills from Facebook Ireland Ltd..⁶ The Financial Times reported that accounts published at the beginning of October 2016, show that the company paid 4.2mln GBP in corporate tax for 2015, nearly 1,000 times more than the 4,300 GBP paid in the previous year. Allegedly, the introduction of the Diverted Profit Tax was one of the main reasons prompting Facebook to undergo this internal accounting reorganization.⁷ Figure A in the Appendix provides a visual representation of Facebook UK’s accounting restructuring.

Our empirical strategy is based on analyzing variation in advertising unit prices around this accounting restructuring. In reference to the theoretical model subsequently developed, the accounting restructuring corresponds, for Facebook UK Ltd., to a raise in corporate taxes. In fact, starting from April 2016, the profit generated through ads placed by UK Advertisers is liable for taxation at the local rate of 20% (versus the lower Irish rate of 12.5%).

2.2 Data

The dataset used for the empirical analysis corresponds to a worldwide collection of scraped unit prices for Facebook ads, targeted to country-specific audiences. For the

⁵Irish residents are liable for VAT tax, at Irish rate; EU residents are liable for VAT tax, at their own country specific rate, conditional on appropriate declaration of all transactions to local tax authorities; while non-EU residents are not charged any VAT.

⁶See “Facebook to pay millions of pounds more in UK tax”, available at <http://www.bbc.com/news/business-35724308>.

⁷Interestingly, Google Inc. put in place an identical restructuring for its Australian advertising operations, also at the time of the introduction of the Australian Diverted Profit Tax, which mirrors the new UK legislation. Starting from 2016, all ad-operations from Australian based advertisers will be booked directly in Australia, rather than been diverted to Google Ireland, as customary up until the 2015 fiscal year.

period spanning from July 2015 to May 2016 we collected data on a daily frequency, whereas for the period spanning from May 2016 to February 2017 we collected data on a 10-minutes frequency.

The pricing of online advertising is a complex mechanism. Prices form as the result of an online auction that allocates advertising space on the Facebook “wall” of a chosen audience.⁸ The advertiser who intends to participate in this auction has to use an interface provided by the Facebook Ad Manager (Figure 4), and follow a number of steps. First, she needs to select an audience, which is the *type* of users considered more valuable for the success of her marketing campaign. Audiences are defined by any combination of geographical location, demographical characteristics, personal interests and behaviors. Once the advertiser selects conditions on the audience profiling, the Ad Manager displays the potential reach of the ad campaign, defined by number of potential (active) users that correspond to the selected audience. Second, she needs to select a budget, defined by the total amount she intends to spend in a given interval of time.

The next step is to choose a compensation method. The advertiser who cares about diffusion of her ad generally prefers to pay per impression displayed to the selected audience. For this reason she will favor a compensation based on Cost per Mille (CPM), which is the unit price paid every time the ad is shown a thousand times to users in the selected audience. The advertiser who cares about driving traffic to a specific web-page generally prefers to pay per click-through by individuals in the selected audience, and for this reason will favor a compensation based on Cost per Click (CPC).⁹

Once the advertiser has chosen the preferred audience, budget and compensation method, Facebook will calculate an optimal bid to place in the auction that allocates the impressions. In this last phase of the process, Facebook displays a *suggested bid*, i.e. the minimum price that would allow the advertiser to reach a significant portion

⁸This auction is “global”, in the sense that all advertisers who intend to target a particular audience, take part in the same auction, irrespective of their location, size or industry.

⁹In addition to these more conventional compensation methods, Facebook also allows advertisers to choose hybrid measures such as the Cost per Like and variations of the so-called Cost per Action. ‘Action’ refers to a specific action the user takes w.r.t. the displayed advertisement. Facebook provides a list of options to this regard.

of the selected audience, and a *bid range*, i.e. range of bids that, in the recent past¹⁰, won auctions to allocate impressions on the selected audience (Figure 5).

Note that the auction managed by Facebook is finally based on the “value” of an ad, and not exclusively on the price bid by the advertiser. After the advertiser chooses a price, her bid is weighted by a “relevance score” and an “estimated action rates”, which contribute to the computation of the final bid “value”. The auction is won by the ad with highest total “value”. Naturally, this entire process is controlled by a Facebook automated algorithm, which is not observed by the researcher or the advertiser.

– Insert Figures 3 and 5 here–

Our scraping procedure consists in selecting alternative audiences, each defined exclusively by geographical location (in this case specifically by country of residence), and then collecting information on daily active users and the range of *suggested bid prices*. This is replicated on a daily (and, for the latter part of our sample, ten-minutes) basis, for audiences resident in all countries of the World, and for both CPM and CPC measures. The range of suggested bid prices indicates a minimum, a median and a maximum bid, which we all collect.

A given CPM price scraped with the above described mechanism represents the median (or minimum or maximum) bid that succeeded in auctions for targeting an audience defined by all users resident in a given country, irrespective of advertisers location. This means that we are able to quantify the median willingness to pay for a given audience, rather than the median willingness to pay of a given advertiser. This distinction is fundamental, because, as our theoretical framework will emphasize, corporation taxes are likely to affect the price charged by Facebook to all advertisers located in the country where the tax raise occurs, irrespective of where the targeted audience is located.

¹⁰The actual timespan is not specified by Facebook

2.3 VAR analysis of Facebook Ads' Prices

A preliminary inspection of Facebook ad prices shows that the median CPM for the UK-resident audience increased substantially after the 7th of March 2016, which is when Facebook informed its UK based advertisers of accounting restructuring that would have taken place starting from the 1st of April 2016. Before the accounting restructuring, advertisers would expect to pay around 1.8 USD per thousand impressions displayed to the UK audience, whereas they would expect to pay more than double as much after the 7th of March. The data also show that prices for Irish-resident audience remains around the average price for the audience resident in all other EU countries, and that the price increase is not exclusive to CPM for UK-resident audience (Figure 6, top panel). Looking at differences between country-specific and EU-averaged CPM, we also notice that the increase in CPM is heterogeneous in intensity across different EU countries (Figure 6, bottom panel). Targeting the audience resident in countries like Germany, Denmark, the Netherlands and Sweden became as increasingly costly as targeting the audience resident in the UK. Instead, targeting the audience resident in Spain or France remained approximately as costly as targeting the average EU audience. Finally, targeting the audience resident in countries like Italy or Belgium became more costly, but less so than targeting the average EU audience.

– Insert Figure 6 here–

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. Results are shown in Appendix A.3., and indicate that we can significantly reject the null of no break around the date of announcement of Facebook UK's Accounting Restructuring. 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 announcement, where we use weekly averaged instead of daily data. This takes into account the potential interdependence of country-specific advertising prices as suggested by the co-movement of the CPM across different countries shown in Figure 6, 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 effect of (the lead of) $After_d$, and include one lag (as chosen by the AIC). Thereby we constrain the lag parameter on the equation for $After_d$ to zero, and make a small-sample degrees-of-freedom adjustment. Figures 7 and A2 (in Appendix A.3) illustrate the corresponding impulse response functions (IRF) for the effect of the accounting restructuring on median CPM prices across all OECD countries. As suggested by Figure 7 and 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 the effects are also heterogeneous across different countries. For instance, we find very strong effects for Australia, Japan, and Norway, while the effects are small for many countries which are a) smaller and/or less developed, and b) partly levy lower corporate taxes (see Figure A2). The effect is also not pronounced for larger countries such as Italy and France, and small for Ireland. The following section intends to shed further light on the underlying empirical patterns.

– Insert Figure 7 here–

2.4 Empirical Strategy

The graphical inspection of the CPM data, along with the VAR analysis, suggests that Facebook CPM prices for geographically defined audiences significantly increased after March the 7th of 2016. However, this analysis shows that the effect was not restricted to local UK audience, and in fact spilled over audiences from several other countries with various intensity. To identify the link between the increase of CPM prices and the changes in profit taxes, we need to empirically address the nature of this “contagion”.

Our empirical strategy can be outlined as follows. We conjecture that online ad prices reflect the willingness to target a given audience, averaged across all interested

advertisers. Specifically, bid-winning price p for audience in country i at day d can be expressed as a weighted average

$$p_{id} = \tilde{w}_i^D \tilde{p}_{id}^D + \tilde{w}_i^F \tilde{p}_{id}^F,$$

where $\tilde{p}_{id}^D$ and $\tilde{p}_{id}^F$ indicate the average price that, respectively, domestic and foreign advertisers bid on day d to target audience i . The weight of advertisers from any given country $j \in D, F$, $\tilde{w}_i^j$, is supposed to be time invariant, and to depend on a number of factors. The composition of products purchased and services accessed by the targeted audience on the online market will impact the relevance of the advertisers, and hence her likelihood to win the auction. The extent to which the product or service advertised is generally marketed on the Internet will simultaneously affect its auction placement. Advertisers promoting a very popular product that is heavily marketed online will have high weights, whereas those promoting a product that is either unpopular or moderately marketed will have low weights in defining the average price of advertising to a given audience. Accordingly,

$$\tilde{w}_i^j \sim w_i^j = f(Comm_i^j, Ads_i^j), \quad j = D, F.$$

where $Comm_i^j$ indicates the share of products sold by advertisers from country j on E-commerce consumption of audience i , and Ads_i^j indicates the share of ads displayed by advertisers from country j on all ads displayed to audience i . Because, at this stage, we do not directly observe either $Comm_i^j$ or Ads_i^j , we draw from the macroeconomic literature (Cavallo, 2017) and the literature in international economics (Lendle et al., 2016), which show that prices and trade flows from the web-economy are highly correlated with corresponding figures from the real economy. Consequently, we proxy the weight of UK advertisers into the average price for audience i with market shares of UK imports into the country of audience i . The intuition would be that countries where local audience is mostly targeted by UK advertisers will experience the largest raise in CPM prices, after the Facebook UK accounting restructuring. This will be supported theoretically later on.

For this, we collected additional data. We use manufacturing import trade data

(CIF import volumes) from the WITS database by goods category based on the SITC1 classification to calculate country-specific import shares of UK exports in total exports from the OECD. The SITC1 classified goods categories are matched to BEC-classified categories, where we keep only consumption-relevant classes.¹¹ We then average the data across the years 2005-2011 to smooth out variations which are due to business cycles. Finally, we utilize data on the use of internet and e-commerce for private individuals (*ICT access and use by households and individuals*) and businesses (*ICT access and use by business*). These data stem from the OECD and – as they are unbalanced over time – are averaged across the years 2005-2015. Finally, we collect Facebook quote properties for NASDAQ from Yahoo Finance Historical Data. This provides us with opening, high, low and close daily prices for Facebook Inc. stocks, during the observational period exploited in our online ad prices dataset. For instance, Figure 8 indicates a more or less strong correlation between CPM prices and trade shares with the UK as well as with ICT usage across OECD countries.

– Insert Figure 8 here–

The effect of the change of accounting practices on country-average daily Facebook prices in the OECD is estimated by means of a panel model, where we exploit the variation in country-level exposure to UK (online) imports in order to explain the differential price effect across OECD countries. We postulate the following baseline models:

$$p_{UK,d} = \alpha_0 + \alpha_1 * After_d + Hol_{UK,d} + DW_d + Q_{UK,q} + \epsilon_{UK,d}, \quad (1)$$

$$p_{id} = \beta_0 + \beta_1 * After_d + \beta_2 After_d * Imp_i^{UK} + \beta_3 Imp_i^{UK} + \mathbf{X}_i' \mathbf{f} \\ + Hol_{id} + DW_d + Q_{iq} + \epsilon_{id}, \quad (2)$$

¹¹These are categories 61, 62, 63, 112, 122, 522.

the first estimated for the UK as a single time series, and the second estimated on a pooled panel model of OECD countries. $After_d$ is a dummy equal to 1 for each day on and after the 7th of March 2016, Imp_i^{UK} measures the volume share of imports from the UK, country specific variables related to ICT use are collected in the vector $\mathbf{X}_i$, DW_d , Q_{iq} ($Q_{UK,q}$), Hol_{id} ($Hol_{UK,d}$) are day of the week, country-quarter and holiday dummies, respectively, and ε_{id} ($\varepsilon_{UK,d}$) are iid error terms. Note that the model includes an interaction term between $After_d$ and Imp_i^{UK} . This accounts for the possibility that the slopes differ by country, depending on i 's exposure to the UK. This model includes $After_d$, as well as day of the week, quarterly and holiday dummies. We test the robustness of the results along the following lines. First, we 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 Table 2. We partly reject the null hypothesis of a unit root, and we clearly reject it for the demeaned series. Consequently, we re-estimate Eq. (2) by way of a fixed-effects panel model which, among others, takes account of the unobserved factor Ads_i^j .

– Insert Table 2 here–

In a next step, we account for the interdependencies of prices in spatial equilibrium by a spatial estimation approach. For this, we collect data about the number of flights between all countries in our sample from <https://openflights.org/data.html#schedule>. For each airport, this database collects all connections from that airport to other airports by country. These data are used to construct an $n \times n$ spatial weighting matrix $\mathbf{W}$ with elements w_{ij} (and zero diagonal elements). The estimated model is:

$$p_{id} = \rho \sum_{j=1}^n w_{ij} p_{jd} + \gamma After_d + Hol_{id} + DW_d + Q_d + \nu_{id}, \quad (3)$$

where $\nu_{id} = \lambda \sum_{j=1}^n w_{ij} v_{jd} + u_{id}$. The equation is estimated by a fixed effects spatial autoregressive model with autoregressive disturbances (SAC). Alternatively, we add the term τp_{id-1} to eq. 3 (allowing for a dynamic structure) and estimate a fixed effects spatial autoregressive (SAR) model, assuming that $\lambda = 0$. Alternatively, we

use a simple distance-based spatial weighting matrix. In any case, the model shows that prices are dependent on prices of closely connected countries through the spatial lag variable. We have tested the presence of autocorrelation in the dimension of the cross-section by Pesaran’s test of cross-sectional independence, rejecting the null of no autocorrelation.¹²

2.4.1 Empirical results

The results are shown in Table 3 and may be summarized as follows. After the announcement, the median CPM price has increased by approximately 1.85 USD in the UK (Column 1). This effect is lower for the full panel of OECD countries, but still quantitatively important. It lies between 1.02 (Columns 3-4) using the pooled OLS model, and 1.2 USD (Column 2) using a fixed effects model. This result is reassuring as it confirms that the effect of the break is not spuriously estimated using the pooled OLS model.¹³ The UK import share has a significant effect on price. In addition, the coefficient on the interaction term reveals that each additional link with the UK in terms of percent import share has increased the price by 5 Cents. This suggests that our model can partly address the underlying co-movement patterns that we find both in the theoretical model and the previous section. To take account of the structural breaks that have occurred after March 7, we trimmed the sample to 1st June 2016 as a first robustness check. The corresponding results are qualitatively and quantitatively similar to the ones shown in Panel A of Table 3.

– Insert Tables 3 and 4 here–

Table 4 summarizes the results from the estimation of eq. (3). Two things are eminent. First, we find that the estimates on both ρ and λ are significant, indicating that the concern of spatial interdependencies is valid. Second, the coefficients on the break are quantitatively and qualitatively similar to the ones shown in Table 3.

¹²Note that we have also tested the spatial Durbin model, which allows for spatial dependence regarding the explanatory variables as $\sum_{k=1}^K \sum_{j=1}^n w_{ij} x_{jdk} \theta_k$ (subsuming all explanatory variables in vector $\mathbf{X}$), but also assuming $\lambda = 0$. The coefficients in parameter vector θ are insignificant.

¹³Note that 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.

Precisely, the coefficient is 0.267 in the fixed effects model based on simple geographic distance (Column 1), and 1.159 in the one with W based on the number of airline connections between any two countries (Column 2). We consider this specification preferable because the number of flights is a better predictor of economic and cultural integration than mere distance. Using a dynamic model in columns 3 and 4 does not substantially change the results, and the coefficient is robust in column 4, amounting to 1.118 (compared to column 2). Overall, the results are similar in Tables 4 and 3, providing overwhelmingly positive effects of the tax announcement on online advertising prices in the magnitude of a USD increase of about 1-1.2.

3 Discussion

In the previous section we show a quantitatively important effect of the Facebook accounting restructuring on online advertising prices, which we interpret as the effect of a tax change on the digital ad market. Estimated across different empirical models, our result proves qualitatively robust. While our evidence provides novel insights into the incidence of taxation in the digital economy, it does not allow us to identify the precise mechanisms behind such an effect. This is mostly due to partial observability of the auctions outcome: on the one hand, we cannot observe distributed ad quantities, and on the other hand we have no access to the assignment technology used by Facebook auctions.¹⁴

While the literature has a small number of theoretical contributions that analyze taxation in markets dominated by two-sided platforms, none of them tackles online advertising or considers cross-country effects. Kind et al. (2008) study the properties of ad-valorem and unit taxes, showing that ad-valorem taxes may result in lower prices and higher quantities of the goods sold by a two-sided platform. Belleflamme and Toulemonde (2016) show that commodity taxes may result in competing two-sided platforms making higher profits. Bourreau et al. (2016) study the implications

¹⁴Regarding ad quantities, we would need to observe the fraction of ads directed to a geographic specific audience which are posted by UK advertisers, in order to understand whether price fluctuations are a response to ad composition. Regarding the auction mechanism, instead, we would need to observe eventual changes in the “score” assigned to ads posted by UK advertisers.

of taxing data and advertisements on a digital platform. Our paper differs from this literature in several respects. First, it analyzes profit taxation, whereas previous papers only look at commodity taxes. Second, it explicitly considers the global dimension of digital platforms. As discussed above, both issues are at the center of the current debate on taxation in the digital economy.

A separate strand of literature, stemming from the seminal paper by Anderson and Coate (2005), studies (traditional) media platforms as two-sided markets. Recently, this literature has emphasized the importance of the link between government policy and media outlets (Prat and Stroemberg, 2013). Some studies have looked at the effects of regulatory policies on advertising. For instance, Kerkhof and Muenster (2015) show that caps on advertising may enhance welfare when advertisers prefer only certain types of content. However, little attention has been devoted to fiscal policy, despite most governments providing support to the media, either via direct subsidies or reduced tax rates (Kind and Moen, 2015). It is therefore a legitimate question whether raising taxes on digital platforms, who are an increasingly central part of the media ecosystem, contrasts with the objectives of traditional media support policies. The results of our study sheds light on this question. Kind and Moen (2015, p. 377) also point out there is a need for empirical evaluations of the effect of direct and indirect taxes and subsidies, to identify the causal effects. To our knowledge, our paper is the first to go in this direction in the context of a major digital platform. In 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. However, our paper focuses on fiscal rather than regulatory policy.

In the remainder of this paper, we build a model of taxation of a two-sided digital platform operating in a global market, that allows us to rationalize the empirical patterns documented in the previous analysis. Initially, we contribute to the literature by studying the platform’s response to changes in profit taxation in a single country and its effect on the global market. Extending the model to a multilateral

framework allows us to go beyond the empirical results. Assuming that governments maximize tax revenue or welfare theoretically results in inefficiently low tax rates. This extension is interesting because, given the growing importance of MDPs in modern economies, taxation may have far-reaching implications, beyond changes in government revenue. Furthermore, it is not obvious that governments choose inefficiently low tax rates: for instance, taxation in one country increases the quantity of ads sold to firms abroad, which in principle may reduce the utility that local consumers get from using the platform.

4 Theoretical model

We consider two countries, indexed by $i = 1, 2$, and a digital platform that provides free content to consumers in one of these countries (we assume this country is $i = 1$ without loss of generality). The platform also serves advertisers that intend to reach these consumers. Advertisers are divided according to the jurisdiction i they belong to. We denote by n_i the quantity of advertisers in i .¹⁵

The platform sells impressions to advertisers through its respective local subsidiaries. We assume no taxes are due on revenue in $i = 2$ (the "low-tax" jurisdiction), whereas revenue collected in $i = 1$ (the "high-tax" jurisdiction) is subject to a profit tax $t > 0$. This setup is the simplest one capturing differences in effective profit tax rates among countries. It may also capture a situation where statutory tax rates are identical, but tax rules in country 2 allow the platform to shift the revenue generated therein to a tax heaven. For example, consider that Facebook books the advertising revenue generated from most EU countries in Ireland (as if its Irish subsidiary made all such sales), where the profit tax regime is highly favorable.

We denote by $z(q)$ the quantity of consumers that connect to the platform, where q is the quantity of ad impressions that the platform exposes any consumer to. We have $q = n_1 q_1 + n_2 q_2$, where q_i is the quantity of advertisement per consumer sold to a firm of type i . We assume that $z'(q) < 0$. This assumption captures in a simple

¹⁵Below, we extend the model to consider the case where the platform is available to consumers in both countries.

way the fact that consumers have a limited time and attention span. Therefore, being exposed to a higher quantity of ads implies that a consumer has to reduce the time and attention allocated to content (say, news). Provided that consumers derive more utility from viewing the platform's content than ads, therefore, more ads reduce a consumer's surplus from using the platform.

Let $p_i(q_i)$ be the willingness to pay for impressions on a consumer by an advertiser from jurisdiction i . We assume that $p'_i(q_i) < 0$, as the marginal value of an impression on a given consumer is decreasing.¹⁶ In equilibrium, advertisers buy impressions until $p_i = p_i(q_i)$ holds, where p_i is the price per impression that the platform charges to an advertiser in i .

We assume the platform sustains no variable costs, which is realistic for providers of digital content. Thus, the platform's profit is

$$\pi = z(q) [(1-t)n_1q_1p_1 + n_2q_2p_2]. \quad (4)$$

Our objective is to analyze the implications of the profit tax t for the quantity and price of ads on the platform. The first step is to solve the platform's problem, maximizing (4) with respect to q_1 and q_2 . The FOCs of this problem are

$$\frac{\partial \pi}{\partial q_1} = z(1-t)n_1 \left(p_1 + \frac{\partial p_1}{\partial q_1} q_1 \right) + z'(q) [n_1q_1p_1(1-t) + n_2q_2p_2] = 0. \quad (5)$$

$$\frac{\partial \pi}{\partial q_2} = zn_2 \left(p_2 + \frac{\partial p_2}{\partial q_2} q_2 \right) + z'(q) [n_1q_1p_1(1-t) + n_2q_2p_2] = 0, \quad (6)$$

Next, we analyze the effect of t on the quantity and price of ads. Using (6) and (5), it is fairly easy to show (see the appendix) that

$$\frac{\partial q_1}{\partial t} < 0, \frac{\partial q_2}{\partial t} > 0, \quad (7)$$

¹⁶Decreasing returns can be generated by several forces. For example, the more an ad is shown to a consumer, the higher the probability that the consumer is already aware of its content. Thus, marginal ads are less likely to inform the consumer. See, e.g., Ambrus, Calvano and Reisinger (2016).

which implies directly that

$$\frac{\partial p_1}{\partial t} > 0, \frac{\partial p_2}{\partial t} < 0. \quad (8)$$

Therefore, the quantity of impressions per consumer sold to advertisers from jurisdiction 1 (resp. 2) decreases (increases) with the tax rate applied in the high tax jurisdiction. Consequently, the price of impressions to advertisers from jurisdiction 1 (resp. 2) increases (decreases). Note that this result originates from the two-sided nature of the platform. Specifically, as the reader can easily see from (5) and (6), if there is no effect of advertising on viewer behavior (i.e. $z' = 0$), profit taxation has no effect on prices and quantities. We summarize in the following proposition

Proposition 1 *An increase in the profit tax in one jurisdiction generates higher prices for advertisers located in that jurisdiction, and lower prices for advertisers in the other jurisdiction.*

Some discussion of the results is in order. First of all, we assumed the platform charges different prices to advertisers in different jurisdictions (third-degree price discrimination), even though they target the same audience. Alternatively, we could assume a unique price. This assumption would not change the main results, but it would make the analysis more involved. Furthermore, price discrimination is justified by the fact that our main focus is on large advertisers (from which platforms like Facebook generate most of the revenue). Our conversations with marketing experts suggest that platforms often strike special deals with large advertisers, specifying such conditions as quantity discounts. Thus, the final price paid for impressions by different advertisers is not necessarily the same, even if they target the same audience. In addition, platforms like Facebook assign scores to advertisers targeting a given audience, based on the relevance of their message. This score affects the probability of winning the auction for reaching a certain audience. A lower score implies that a higher bid is necessary, all else equal, to win. Because relevance depends also on the advertiser's location, the effective prices per impression may change according to where the advertiser is located.

In sum, platforms such as Facebook have more than one way to discriminate among advertisers targeting the same audience. Hence, assuming geographical price

discrimination is reasonable. Nevertheless, in the empirical application we do not observe prices specific to the location of the advertiser.¹⁷ Rather, we observe a range of prices that Facebook suggests to *all* advertisers targeting a given country. These prices are claimed to be the lowest ones that provide a good chance of a successful bid, based on the results of recent previous auctions. Thus, the price we observe should be considered a composite measure of the prices paid for that audience by advertisers of different countries. Our conjecture is that the larger is the share of advertisers from a country, the larger its importance in determining the outcome of previous auctions, and the larger the weight it should have on the composite price we observe. Hence, the larger the share of advertisers from country 1 (resp. 2), the larger (smaller) the increase in the composite price following an increase in the profit tax.¹⁸

4.1 Interactions between governments

Several governments have recently considered adopting new instruments to tax the profits of digital platforms (see the examples in the Introduction). Shall we expect them to coordinate on pareto-efficient policies? And, if not, should international organizations, such as the OECD, foster the adoption of higher, or lower, tax rates? To answer these questions, we now consider the interaction between multiple governments. We proceed under two alternative assumptions. First, we consider the case where governments are revenue-maximizers. Second, we assume governments maximize the welfare of the respective countries, taking the surplus of consumers, advertisers and platform into account.

The setup of the model is the same as in the previous section, except that we allow each government to set a tax t_i on the platform's revenue collected from advertisers

¹⁷Facebook does not release detailed information on how it computes the scores determining the relevance of advertisers. Furthermore, as mentioned, for the main advertisers the final prices are also determined by private contractual arrangements that we do not observe.

¹⁸The prices p_1 and p_2 are also functions of n_1 and n_2 . Unfortunately, deriving the effect of these quantities on the change in p_1 and p_2 with respect to t in the model above is cumbersome. However, in a more specific version of the model (with linear demands), it is possible to show that the effect of the tax on the price intended for advertisers from jurisdiction i increases in magnitude with n_i . These results are available from the authors.

located in its jurisdiction. Furthermore, the platform is available to consumers in both countries. Let z_i be the quantity of consumers connecting in country i . Further, let q_{ij} be the quantity of ads that a firm in i sends to a consumer connecting to the platform in country j . Thus, a consumer in country j is exposed to $\sum_{i=1,2} n_i q_{ij}$ total ads.

We assume that in each country there is a mass of size one of consumers with heterogeneous preferences for the platform. Let v be the value that a consumer attributes to the platform and assume it is distributed according to a CdF $F(v)$ with support $[0, V]$. This distribution is assumed to be identical in the two countries for simplicity. We normalize to one the marginal disutility that a consumer suffers from each ad. Hence, letting $v(z_i)$ denote the surplus of the individual in country i who is indifferent as to connecting to the platform, we have

$$v(z_i) = \sum_{j=1,2} n_j q_{ji}. \quad (9)$$

It follows that the aggregate surplus of consumers in country i is

$$CS_i = \int_0^{v(z_i)} v dF(v) - z_i \sum_{j=1,2} n_j q_{ji}. \quad (10)$$

Furthermore, advertisers in country i obtain a total net surplus of

$$AS_i = n_i \sum_{j=1,2} z_j \left(\int_0^{q_{ij}} s(q) dq - p_{ij} q_{ij} \right). \quad (11)$$

This is given by the difference between the advertisers' gross surplus, $s(q)$, from reaching consumers in both countries and the price of impressions paid to platform.

Each government collects the following revenue from taxing the platform in its own jurisdiction:

$$R_i = t_i \sum_{j=1,2} z_j n_i p_{ij} q_{ij}. \quad (12)$$

We assume there are no other sources of revenue for each government and that the revenue is redistributed to the respective populations in lump-sum fashion.

4.1.1 Revenue maximizing governments

Consider now the problem of each government choosing the tax rate on locally-generated platform profits. As anticipated, we begin by assuming that each government cares only for its tax revenue, given by (12). Assuming the tax rates t_i are chosen simultaneously and non-cooperatively, the equilibrium is characterized by the following system of FOCs:

$$\begin{aligned} \frac{\partial R_i}{\partial t_i} = & n_i \sum_{j=1,2} z_j p_{ij} q_{ij} + t_i n_i \sum_{j=1,2} z'_j (n_1 \frac{\partial q_{1j}}{\partial t_i} + n_2 \frac{\partial q_{2j}}{\partial t_i}) q_{ij} p_{ij} + \\ & t_i n_i \sum_{j=1,2} z_j (p_{ij} + q_{ij} \frac{\partial p_{ij}}{\partial q_{ij}}) \frac{\partial q_{ij}}{\partial t_i} = 0, i = 1, 2. \end{aligned} \quad (13)$$

The first term on the right hand side of this expression is the mechanical increase in tax revenue following a tax increase. The second and third terms capture behavioral responses. Specifically, the former captures the effect on revenues due to the response to ads of the marginal consumers. This effect is positive because the net effect of the increase in t_i is to raise the total quantity of ads to which a consumer is exposed to. This effect is captured by the term $n_1 \frac{\partial q_{1i}}{\partial t_i} + n_2 \frac{\partial q_{2i}}{\partial t_i}$. The sign of this term is a priori ambiguous, because taxing the revenue generated in country i reduces the volume of ads sold to advertisers in that country, but increases that of ads sold to advertisers in the other country. However, we find that the net effect is to reduce the total quantity of ads. This outcome is intuitive because the tax induces the platform to substitute some ads from the country where the tax goes up with less profitable ones from the other country (which would have been dominated otherwise).

The last term in (12) captures the change in platform revenue from inframarginal consumers. Using the FOCs of the platform's profit maximization problem, (6) and (5), it can be shown that this term is negative (recall that $\frac{\partial q_{ij}}{\partial t_i} < 0$).

Let us now compare the above result to the case where tax rates are chosen in a cooperative way, i.e. with the objective of maximizing the joint tax revenue, $R = \sum_{i=1,2} R_i$. This scenario can represent a situation where the two governments

stipulate an agreement on coordinated tax policy, possibly fostered by an international institution (e.g. the OECD). Our objective is to determine whether the coordinated solution involves higher or lower equilibrium tax rates than the decentralized one. This can be established by comparing 13 to the following FOC:

$$\begin{aligned} \frac{\partial R}{\partial t_i} &= \frac{\partial R_i}{\partial t_i} + t_{i'} n_{i'} \sum_{j=1,2} z'_j \left(n_1 \frac{\partial q_{1j}}{\partial t_i} + n_2 \frac{\partial q_{2j}}{\partial t_i} \right) p_{i'j} q_{i'j} + \\ & t_{i'} n_{i'} \sum_{j=1,2} z_j \left(p_{i'j} + q_{i'j} \frac{\partial p_{i'j}}{\partial q_{i'j}} \right) \frac{\partial q_{i'j}}{\partial t_i} = 0, i = 1, 2; i' \neq i. \end{aligned} \quad (14)$$

The last two terms in the above expression capture spillover effects. The first of these terms captures the spillover effect on revenue from marginal users: raising the tax rate in country i reduces the volume of ads and thus increases the quantity of users. This increases the revenue collected by the other government. Furthermore, a higher tax in country i increases the supply of ads to firms in the other country at the margin, which also expands tax revenue. Overall, therefore, the spillover effects are positive. This observation leads to the following conclusion

Proposition 2 *When each country's objective is to maximize tax revenue, the equilibrium is such that tax rates are below the joint-revenue-maximizing level.*

Hence, when governments are purely interested in extracting tax revenue from the platform, they compete away part of this revenue, setting tax rates below the revenue-maximizing level. This outcome is consistent with previous literature analyzing tax competition in an international context (Keen and Konrad, 2013).

4.1.2 Welfare maximizing governments

We previously established that governments fail to coordinate on a pareto-efficient level of taxation when their objective is to maximize revenue. Let us now consider the case where governments maximize the welfare of their own country. We assume each government cares for the surplus of its respective consumers and advertisers, as

well as for the tax revenue. Finally, the government cares for the profit the platform generates in its own jurisdiction. We have

$$W_i = \pi_i + CS_i + AS_i + R_i. \quad (15)$$

This formula boils down to

$$W_i = n_i \sum_{j=1,2} z_j \int_0^{q_{ij}} s(q) dq + \int_0^{z_i} v dF(v) - z_i \sum_{j=1,2} n_j q_{ji} \quad (16)$$

In words, welfare for each government is given by the gross advertising surplus and the net surplus of consumers located in its jurisdiction. This follows from the fact that transfers between advertisers and the platform cancel out in the welfare computation.

Each government maximizes (16) with respect to t_i . Assuming that second order conditions hold and using (9), the equilibrium tax vector is the solution to the system of FOCs $\frac{\partial W_i}{\partial t_i} = 0$. At this level of generality, the expressions are quite hard to interpret (we report them in the appendix). To facilitate this, we focus here on the special case where the two countries are symmetric. Hence, the number of advertisers n_i is identical and so is the number of consumers that connect to the platform. When the equilibrium is symmetric, the FOCs simplify to

$$\begin{aligned} \frac{\partial W_i}{\partial t_i} &= n_i \sum_{k=1,2} z'_k \left(n_1 \frac{\partial q_{1k}}{\partial t_i} + n_2 \frac{\partial q_{2k}}{\partial t_i} \right) \int_0^{q_{ik}} s(q) dq \\ &+ n_i \sum_{k=1,2} z_k s(q_{ik}) \frac{\partial q_{ik}}{\partial t_i} - z_i \left(n_1 \frac{\partial q_{1i}}{\partial t_i} + n_2 \frac{\partial q_{2i}}{\partial t_i} \right) = 0, i = 1, 2. \end{aligned} \quad (17)$$

Inspection of (17) highlights three main effects of the tax increase on welfare in country i . First, there is a direct negative effect on the advertising industry, because the platform carries fewer ads per consumer. Hence, the industry suffers a loss equal to the gross advertiser surplus from the marginal impression. Second, there is an indirect effect on advertiser surplus. This effect stems from the fact that a change in the quantity of ads affects the quantity of consumers connecting to the platform

and thus exposed to the ads placed by firms in i .¹⁹ The sign of this effect is positive because, as discussed previously, the total quantity of ads per consumers decreases with a tax increase. Hence, the indirect effect on the advertising industry is positive.

Finally, there is a positive effect on consumers in country i , who benefit from a reduction in the platform's ad intensity. Overall, therefore, the net welfare effect of the tax in i can be either positive or negative, depending on which of the above components prevails. We investigate this point further in the welfare analysis.

To establish whether the two countries coordinate on a socially optimal equilibrium, let us now consider the choice of tax rates by a supra-national government that maximizes the welfare of both countries. The problem of this government is

$$\max_{t_1, t_2} W = \sum_{i=1,2} (\pi_i + CS_i + AS_i + R_i). \quad (18)$$

The key difference with respect to the previous setup is that the government internalizes the effects of policy on both jurisdictions. Applying the envelope theorem, we can write the FOCs of problem (18) as

$$\begin{aligned} \frac{\partial W}{\partial t_i} = & \sum_{j=1,2} n_j \sum_{k=1,2} z'_k \left(n_1 \frac{\partial q_1 k}{\partial t_i} + n_2 \frac{\partial q_2 k}{\partial t_i} \right) \int_0^{q_{jk}} s(q) dq \\ & + \sum_{j=1,2} n_j \sum_{k=1,2} z_k s(q_{jk}) \frac{\partial q_{jk}}{\partial t_i} - \sum_j z_j \left(n_1 \frac{\partial q_1 j}{\partial t_i} + n_2 \frac{\partial q_2 j}{\partial t_i} \right). \end{aligned} \quad (19)$$

Comparing these expressions to (17) reveals that taxes on the platform's revenue in one country have three spillover effects on the other one. First, an increase in t_i induces the platform to increase the provision of ads from advertisers of country j , whose surplus increases. Second, as the total quantity of ads served to a consumer decreases (see the discussion above), the number of consumers connecting to the platform increases. Each government internalizes the ensuing effect on the surplus of its own advertisers, but ignores the effect on advertisers in the other country.

¹⁹This indirect effect is only partially internalized by the platform when choosing its own strategy, because the latter only accounts for the equilibrium price of ads, which equals the value of the marginal ad. Hence, it ignores the effect on the inframarginal ones.

Finally, consumer surplus increases in both countries, but again each government takes only the surplus of its own consumers into account.

Summing up, all three spillovers are positive, because they raise consumer welfare and advertising surplus in the other country. However, one cannot expect country governments to internalize these effects. Therefore, we can conclude that tax rates are inefficiently low in equilibrium (see the Appendix for the proof).

Proposition 3 *When governments maximize the welfare of their own jurisdiction, the symmetric equilibrium is such that the each country sets its tax rate below the socially optimal level.*

Note that, because the platform is two-sided, it is not obvious that welfare-maximizing governments coordinate on inefficiently low tax rates. On the one hand, taxation induces the platform to reallocate advertising to the other country. This effect reduces government revenue and penalizes local advertisers, while it has the opposite impact in the other country. But the reallocation may in principle also hurt the other country’s consumers: their utility from browsing the platform’s content decreases when the latter becomes more advertising-intensive. However, we find that this effect is more than compensated by the decrease in advertising from firms located in the tax-raising country. Hence, consumers in the other country benefit as well.

5 Conclusion

This paper analyzes the incidence of taxation of digital platforms on the online advertising market. Precisely, we study the effect of a change in Facebook UK’s accounting practices that followed the introduction of the UK Diverted Profit Tax, on the company’s online advertising prices across countries. Our key finding is that advertising prices increase substantially not only in the UK, but also across countries. We find generally starker effects for countries that exhibit larger market shares of UK-based advertisers. Our findings can be rationalized by a theoretical model of a two-sided platform operating in the global advertising market. In the model,

advertising affects user demand, and higher taxes in one country make the price of impressions to local advertisers go up and reduce it to foreign ones. Therefore, average ad prices tend to increase in that country, but also where the country's advertisers have a substantial market share. Furthermore, the burden of profit taxation in one country falls partly on local advertisers, whereas foreign advertisers actually benefit.

Beyond this, we extend the model to a multilateral setting. We find that both revenue-maximizing and welfare-maximizing governments coordinate on taxes below the jointly revenue-maximizing level. The former is rather intuitive: when one government reduces its own tax rate, it does not take into account the resulting decrease in the volume of advertising sold by the platform in the other country, and the ensuing loss in tax revenue for the other government. The latter is less intuitive. For instance, taxation in one country increases the quantity of ads sold to firms in the other one, which in principle may reduce the utility that country's consumers get from browsing the platform. We conclude that international cooperation on tax rules may improve welfare.

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Figures and Tables

Figure 1: Net Digital Ad Revenue Worldwide, by Company (USD Bil.)

Source: EMarketer.com, 2017

Figure 2: Digital Ad Revenue Shares, Facebook (USD Bil.)

Source: Facebook Income Statements 2012-2016

Figure 3: Market structure

Figure 4: Facebook Ad Manager - Screenshot

Figure 5: Facebook Ad Suggested Bid - Screenshot

Figure 6: CPM PRICES ACROSS EU COUNTRIES

Figure 7: Impulse response functions for the effect of tax announcement on median CPM prices for selected OECD countries

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 8: CPM Prices, import shares from the UK, GPD and ICT usage (EU)

Table 1: Digital Companies' Tax Settlements and Ongoing Investigations

Company	Institution	Year	Content
Amazon	EU	2014	Luxembourg sweetheart deal
Apple	EU	2014	Transfer Pricing Investigation
Apple	Italy	2015	Tax Settlement of 318milEUR
Facebook	Germany	2016	Abuse of dominant position
Google	EU	2015	Abuse of dominant position
Google	Italy	2017	Tax Settlement for 306milEUR
Google	UK	2016	Tax Settlement for 130milGBP
Google	France	2016	Tax Avoidance Investigation

Table 2: TEST FOR UNIT ROOT OF MEDIAN CPM

	(1)	(2)	(3)
Statistic	DF	IPS	IPS
Z(t)	-1.801	-2.4115	-10.2376
p-value	0.3798	0.0079	0.0000

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 3: Effect of Facebook Accounting restructuring on Online Ad Prices

Dep.var.: Median CPM in USD	(1) UK	(2) FE	(3) POLS	(4) POLS
Panel A: Full time period				
$After_d$	1.848*** (0.192)	1.203*** (0.148)	1.027*** (0.042)	1.022*** (0.045)
Imp_i^{UK}				0.024*** (0.001)
$After_d \times Imp_i^{UK}$				0.005*** (0.001)
Constant	1.699*** (0.101)	0.979*** (0.179)	-0.444*** (0.066)	-0.054 (0.072)
Obs.	471	19,349	11,789	10,373
Adj. R ²	0.864	0.563	0.697	0.695
Panel B: Sample trimmed before June 2016				
$After_d$	1.822*** (0.196)	1.186*** (0.147)	1.001*** (0.037)	0.977*** (0.041)
Imp_i^{UK}				0.019*** (0.001)
$After_d \times Imp_i^{UK}$				0.008*** (0.003)
Constant	1.652*** (0.156)	0.889*** (0.071)	-0.103 (0.072)	0.224*** (0.077)
Obs.	273	11,231	6,839	6,017
Adj. R ²	0.890	0.468	0.570	0.565

SE are clustered at the Country level, and reported in parenthesis. The models in Panel B use the trimmed sample, restricted to all observations before 1st of June 2016. The model (1) only uses the time series of ad prices targeted to UK audiences, whereas the models (2)-(4) extend the analysis to a panel of ads targeted to all OECD audiences (excluding the UK). Model (2) is estimated using a fixed effects panel model, whereas models (3) and (4) are estimated using pooled OLS. In addition, models (3) and (4) include country specific indicators of internet penetration (not reported). All model specifications include day-of-the-week dummies, country-quarter dummies, and holiday dummies (not reported). Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: A spatial model for the effect of Facebook accounting restructuring on online ad prices

Dep.var.: Median CPM in USD	(1) Fixed effects	(2) SAC	(3) Dynamic (FE)	(4) SAR
$After_d$	0.267*** (0.077)	1.159*** (0.195)	0.454*** (0.043)	1.118*** (0.051)
p_{id-1}			1.122*** (0.070)	0.476*** (0.048)
ρ	2.183*** (0.086)	0.557* (0.313)	0.700*** (0.066)	0.170*** (0.046)
λ	-2.499*** (0.692)	0.695*** (0.172)		
Obs.	24,272	20,128	24,231	20,094

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses and clustered at the country level. All models use a panel of ads targeted to all OECD audiences (including the UK). Models (1) and (3) are based on a spatial lag based on distance, whereas models (2) and (4) use a spatial lag based on the number of flights. Models (1) and (2) are estimated using a fixed effects SAC model, (3) and (4) use a dynamic fixed effects SAR. All model specifications include day-of-the-week dummies, country-quarter dummies, and holiday dummies (not reported).

A Appendix

A.1 Proof of (7)

We have

$$\frac{\partial q_H}{\partial t} = -\frac{\frac{\partial^2 \pi}{\partial q_L \partial t} \frac{\partial^2 \pi}{\partial q_H^2} - \frac{\partial^2 \pi}{\partial q_H \partial t} \frac{\partial^2 \pi}{\partial q_H \partial q_L}}{\frac{\partial^2 \pi}{\partial q_L^2} \frac{\partial^2 \pi}{\partial q_H \partial q_L} - \frac{\partial^2 \pi}{\partial q_H \partial q_L} \frac{\partial^2 \pi}{\partial q_H^2}}, \quad \frac{\partial q_L}{\partial t} = -\frac{\frac{\partial^2 \pi}{\partial q_H \partial t} \frac{\partial^2 \pi}{\partial q_L^2} - \frac{\partial^2 \pi}{\partial q_L \partial t} \frac{\partial^2 \pi}{\partial q_H \partial q_L}}{\frac{\partial^2 \pi}{\partial q_L^2} \frac{\partial^2 \pi}{\partial q_H \partial q_L} - \frac{\partial^2 \pi}{\partial q_H \partial q_L} \frac{\partial^2 \pi}{\partial q_H^2}}. \quad (A.1)$$

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

$$\frac{\partial^2 \pi}{\partial q_H \partial q_L} = z'(q) \left[n_L \left(p_L + \frac{\partial p_L}{\partial q_L} q_L \right) + (1-t) n_H \left(p_H + \frac{\partial p_H}{\partial q_H} q_H \right) \right] < 0,$$

$$\frac{\partial^2 \pi}{\partial q_L \partial t} = -z'(q)q_H p_H n_H > 0, \quad \frac{\partial^2 \pi}{\partial q_H \partial t} = -n_H \left[z'(q)q_H p_H + z \left(\frac{\partial p_H}{\partial q_H} q_H + p_H \right) \right] < 0.$$

The last inequality follows from inspection of (6). For this expression to be satisfied, given that $z'(q)q_L p_L n_L < 0$ and $(1-t) > 0$, it has to be the case that $z'(q)q_H p_H + z \left(\frac{\partial p_H}{\partial q_H} q_H + p_H \right) > 0$ holds. Hence, we get

$$\frac{\partial q_L}{\partial t} > 0 \iff \frac{\partial^2 \pi}{\partial q_L \partial t} \frac{\partial^2 \pi}{\partial q_H^2} < \frac{\partial^2 \pi}{\partial q_H \partial t} \frac{\partial^2 \pi}{\partial q_H \partial q_L}.$$

Given the above expressions, this inequality is satisfied, because $\frac{\partial^2 \pi}{\partial q_H \partial t} < 0$. Furthermore, we have

$$\frac{\partial q_H}{\partial t} < 0 \iff \frac{\partial^2 \pi}{\partial q_H \partial t} \frac{\partial^2 \pi}{\partial q_L^2} > \frac{\partial^2 \pi}{\partial q_L \partial t} \frac{\partial^2 \pi}{\partial q_H \partial q_L}.$$

Again, the inequality is satisfied because $\frac{\partial^2 \pi}{\partial q_H \partial t} < 0$.

A.2 Proof of Proposition 2

Let us evaluate the FOD of the joint-revenue-maximization problem in (14) in the set of tax rates satisfying the equilibrium conditions in (13). The term $\frac{\partial R_i}{\partial t_i}$ drops out. As discussed in the text, the remaining terms are positive. Because the objective function is concave by assumption, it must be the case that the couple of tax rates satisfying (14) must be larger than the ones satisfying (13).

A.3 Proof of Proposition 3

We report here the FOC of the governments' problem in the general case:

$$\begin{aligned}
\frac{\partial W_i}{\partial t_i} &= \sum_{j=1,2} n_j \sum_{k=1,2} z'_k \left(n_1 \frac{\partial q_{1k}}{\partial t_i} + n_2 \frac{\partial q_{2k}}{\partial t_i} \right) \int_0^{q_{jk}} s(q) dq \\
&+ \sum_{j=1,2} n_j \sum_{k=1,2} z_k s(q_{jk}) \frac{\partial q_{jk}}{\partial t_i} - \sum_{j=1,2} z_j \left(n_1 \frac{\partial q_{1j}}{\partial t_i} + n_2 \frac{\partial q_{2j}}{\partial t_i} \right) + \\
&z_i n_{i'} \left(p_{i'i} \frac{\partial q_{i'i}}{\partial t_i} + q_{i'i} \frac{\partial p_{i'i}}{\partial t_i} \right) - z_{i'} \left(n_i \left(p_{ii'} \frac{\partial q_{ii'}}{\partial t_i} + q_{ii'} \frac{\partial p_{ii'}}{\partial t_i} \right) + \right. \\
&\quad \left. z'_i n_{i'} p_{i'i} q_{i'i} \left(n_1 \frac{\partial q_{1i}}{\partial t_i} + n_2 \frac{\partial q_{2i}}{\partial t_i} \right) + \right. \\
&\quad \left. - z'_{i'} n_i p_{ii'} q_{ii'} \left(n_1 \frac{\partial q_{1i'}}{\partial t_i} + n_2 \frac{\partial q_{2i'}}{\partial t_i} \right) \right) = 0, i = 1, 2; i' \neq i.
\end{aligned} \tag{A.2}$$

Turning to the symmetric case, let us evaluate the FOD of problem (19) in the set of tax rates satisfying the equilibrium conditions in (17). The FOD thus simplifies to

$$\begin{aligned}
\frac{\partial W}{\partial t_i} &= n_{i'} \sum_{k=1,2} z'_k \left(n_1 \frac{\partial q_{1k}}{\partial t_i} + n_2 \frac{\partial q_{2k}}{\partial t_i} \right) \int_0^{q_{i'k}} s(q) dq + \\
&n_{i'} \sum_{k=1,2} z_k s(q_{i'k}) \frac{\partial q_{i'k}}{\partial t_i} - z_{i'} \left(n_1 \frac{\partial q_{1i'}}{\partial t_i} + n_2 \frac{\partial q_{2i'}}{\partial t_i} \right). i = 1, 2; i' \neq i
\end{aligned} \tag{A.3}$$

As discussed in the text, the terms in this expression are positive. Because the objective function is concave by assumption, it must be the case that the couple of tax rates satisfying (19) must be larger than the ones satisfying (17).

A.4 Facebook UK Accounting Restructuring

Figure A1: Facebook UK Accounting Restructuring

A.5 Structural Break Test

Table A1: 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.

Figure A2: Impulse response functions for the effect of tax announcement on median CPM prices across OECD countries

Figure A3: (Continued)

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 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.