Accounting for Free Digital Services and Household Production – An Application to Facebook

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Preliminary version, November 2019

Abstract

Results from choice experiments have revealed that individuals attribute significant value to digitally-enabled services such as those derived from the use of social media. We integrate this consumer value into an accounting framework by treating it as the value of own-account production by households of a particular type of leisure services. Time spent by households, along with social media services and IT hardware capital constitute the relevant inputs. We derive a quality-adjusted unit cost index for such household-produced leisure services whereby the number of network users acts as the main vehicle to capture quality change. These quality adjustment effects turn out to be key when assessing the quantitative importance of own-account leisure services. To illustrate, we consider an Extended Measure of Activity (EMA) that encompasses GDP and own-account household production of digitally-enabled leisure services. A simulation for the U.S. shows that the effects due to Facebook use alone would cause the EMA to grow anywhere between -0.04 percentage points per year less to about +0.2 percentage points per year more than U.S. real GDP between 2004 and 2017, depending on the size of network effects.

*Paper prepared for the 2019 meeting of the Economic Measurement Group at the University of New South Wales, Sydney. Views expressed are those of the author and do not necessarily correspond to views of the OECD or its Members. Thanks go to Peter van de Ven and Pierre-Alain Pionnier for helpful comments.

1 Introduction

In an inspiring paper, Brynjolfsson, Collis, Diewert, Eggers and Fox[7] (BCDEF in what follows) accomplish two important tasks in regard to the measurement of the digital economy. First, they derive explicit index number expressions for the contributions of free products to welfare change. Second, the authors quantify these contributions in the case of several free digital services - notably Facebook - by using incentive compatible choice experiments to determine the value at which consumers are willing to forego the use of Facebook and other digital services. A new metric, 'GDP-B' that includes the so-measured welfare effects turns out to have grown by about 0.5 percentage points per year faster than established GDP growth per year since 2004 in the United States.

This paper puts these results in a framework of production, income and expenditure. A first observation is that free services are not typically free but imply a barter transaction whereby consumers agree to accept advertisements or the use of the data they generate in exchange of the digital service. There is thus some production (and consumption) value equivalent to advertising or data sales revenue that provides a first benchmark for valuing free services and Nakamura and Soloveichik[20] and Ahmad et al.[3] have gone a long way exploring the relevant conceptual and empirical issues. However, BCDEF's[7] discrete choice experiments suggest that the value that consumers attach to a free digital service may well exceed or be at least different from the value of advertising or data revenues. These consumer values are not captured by measures of GDP and income thus ignoring potentially important effects of the digital economy.

One way of recognising otherwise unmeasured consumer value is integrating it into the price index used to derive real measures of consumption: when a new service becomes available but is not yet used, there is a reservation price in the spirit of Hicks[17] that is just high enough to drive demand to zero. At one point the reservation price drops - possibly to zero - and there is positive demand. This one-off price decline from the reservation price to the actual price, if integrated into a price index, raises measured real consumption. This is effectively how BCDEF[7] derive an adjusted measure for real U.S. GDP growth.[1]

Alternatively, or in addition, consumer valuation of a service can be reflected in nominal measures of economic activity and BCDEF's[7] second, *total income*

[1]In this context, Diewert, Fox and Schreyer[14] have shown how reservation prices can be derived from contingent valuations à la BCDE[7] for possible inclusion in a price index.

approach follows this avenue, by adding consumer value to measured nominal GDP without, however, modifying price indexes. Unlike under the price index method, the possible effect on measured GDP remains as long as there is added consumer value. The total income method avoids the rather tricky issue of measuring reservation prices.

However, recognition of this type of consumer value in an accounting framework raises the question to whom the *generation* of such supplementary value should be attributed - the provider of the digital service such as Facebook or Google or the consumer herself who combines capital services or intermediate services from digital providers with household time to produce own-account entertainment or communication services.

This paper will argue that the value associated with free digital services (above and beyond advertising and data sales revenues) is produced by the household itself rather than by the provider of the digital tool. This facilitates consistent treatment in a national accounts framework although we note that current national accounts conventions place the production and consumption of own account services by households outside the production boundary for GDP measurement. [2] But current conventions should not deter from reflecting on concepts and from carrying out experimental computations and reasoning in terms of broader measures of economic activity. Our approach also permits deriving a consistent unit cost index for own account household production.

When it comes to services produced from social media, a particular question arises how to deal with the network effects associated with a changing number of users of social media. Our contribution here is treating the number of users akin to exogenous quality change (or technical change) that reduces the unit costs for the household producing its own services. The introduction of such network effects into the household's unit cost index turns out to be key when assessing the quantitative importance of own-account leisure services. Equipped with nominal values, unit cost and volume indexes, we can simulate the effects of combining household production of leisure services from Facebook with GDP into an Extended Measure of Activity (EMA) or a corresponding satellite account. Depending on the choice of parameter values for the network effects in

[2] The only exception is owner-occupied housing where the System of National Accounts makes an imputation for the value of housing services that an owner-user provides to him/herself.

the household's unit cost index, the EMA aggregate would grow anywhere from 0.04 percentage points per year less than U.S. GDP to about +0.2 percentage points per year more than U.S. GDP between 2004 and 2017. This is significant as an effect from a single social media service.

Section 2 takes a closer look at the question to whom consumer value should be attributed; Section 3 lays out the measurement of unit cost and volume indexes of own-produced services; Section 4 takes the case of Facebook and assesses potential price and volume effects in relation to U.S. GDP based on BCDEF[7] and data from the U.S. NIPA; and Section 5 concludes.

2 Who Produces?

A good or service, whether provided for free or not, needs to be produced somewhere in the economy (or imported). The answer to 'who produces a free digital service?' may seem obvious at first, namely the software provider or the supplier of a social media network (whether located in the domestic economy or abroad). Before discussing digital services further, consider the most prominent and most longstanding case of services that are provided for free to consumers, government services. While provided for free, government services are not costless and need to be financed via current or future taxes. The costs for producing health, education or defense services to citizens are the standard way of valuing freely-provided services. This is by convention and in principle, a different valuation could be envisaged, embracing, for instance, a consumer perspective that allows for cases where citizens value a freely provided service higher or lower than at its unit cost of production[3]. But for many practical reasons such an approach has not been pursued in the national accounts.

Digital services produced by private agents and provided for free to consumers are not altogether different except that financing occurs not via taxes but via sales of advertising services or via sales of data generated by users of the free services. Also, unlike government, market corporations make profits or losses when revenues exceed or fall short of factor costs. A natural choice for valuing free services provided by private operators is thus costs plus or minus residual profits or losses, i.e., the value-added or income generated in the advertising or data sales business. One can then go further and explicitly recognise

[3] For a discussion of valuing government services see Schreyer [23], Diewert [9].

an indirect barter transaction that exists between consumers and the digital service provider by assuming that households sell 'advertising watching services' and use the revenues to pay for accessing Facebook. Such an additional services would increase measures of production and income correspondingly. [4] [5]

But there is evidence that consumers' valuation of free services can be quite different from the value-added originating in the advertising or data sales business. In the case of Facebook, a back-of-the-envelope calculation shows that its advertising revenues of about 50 billion $ in 2017 correspond to about 25 $ per user (2 billion users worldwide), a far cry from the 500 $ of value per Facebook user and year as assessed by BCDEF[7]. How should we deal with such a discrepancy?

Before exploring this point, it is useful to pause and clarify terminology. 'Consumer value' is understood as the marginal willingness to pay for or willingness to forego one unit of a particular product – a shadow price, not to be confused with 'consumer surplus' in the sense of a cumulative measure across all consumers' willingness to pay for the utility derived from all the units consumed. The latter is conceptually different from valuation at market prices in the national accounts and would make any comparison with GDP meaningless, whereas the former permits such comparisons, at least in principle.

Now consider the service provider's production process. Our example here is Facebook with an advertising-only business model but the reasoning can easily be transposed to related cases[6].

Ex-ante, when various business models are considered, the price for Facebook services to consumers constitutes a choice variable. It is not necessary to model

[4]Nakamura and Soloveichik [20])were first to provide relevant estimates that turned out to be of small quantitative impact on U.S. GDP. Other estimates with similar conclusions were provided by Ahmad et al[3]

[5]We note in passing that advertising services, unless exported, and unlike government services, constitute intermediate inputs to other producers of final products in the domestic economy whose value will ultimately reflect the value of advertising services. Ahmad and Schreyer [2] have pointed out that in this sense the value of free products is already captured in final expenditure and GDP. By the same token, the wages, salaries, profits, taxes that are being earned as part of the digital service provider's business are part of national income and GDP.

[6]Li et al. [19] provide an extensive overview of the business models of digital companies. Common to the various configurations is that free or cheap services are provided to consumers with a financing model that operates by selling targeted advertising services or data collected from consumers to third parties.

the decision process here because the intuition is simple: if the *observed ex-post* business model relies on financing through advertising and the observed price to consumers equals zero, we consider this as a profit maximising choice (perhaps a corner solution but profit maximising all the same) and consequently, the observed price and quantity for advertising services are also profit-maximising.

Thus, unlike government, where both a consumer or a producer valuation can be envisaged *in principle*, the private supplier of free services plausibly acts as a market producer and profit maximizer and if consumers were truly willing to pay for benefitting from social media services above and beyond accepting advertisements this begs the question why Facebook would chose an advertising financed-only service in the first place rather than charging a positive price. Indeed, in a world of rational and well-informed consumers and producers, it is difficult to explain how consumer valuation of a service would deviate from producer valuation. [7]

This leaves only three interpretations to the observed difference between the per capita reveneues from advertising services and BCDEF's[7] marginal willingness to forego Facebook: (i) Facebook does not act as a profit maximiser (unlikely), (ii) the BCDEF figures are vastly overstated (implausible) and (iii) the value measured by BCDEF relates to a *different* act of production and consumption, not to the implicit barter transaction between consumers and Facebook. This is indeed the avenue that we shall pursue in what follows.

The way forward is to allow for a production process by households who use their time, along with capital services (hardware, software) including freely-provided access to Facebook's network to produce, typically, leisure services associated with the use of social media. These services are own-account outputs by households and neither their prices nor quantities need to coincide with the advertising or data sales values that correspond to the production of the digital service provider. The latter are inputs to, the former are outputs of household production. Our main point is that empirical valuations such as by BCDEF[7]

[7] Also, if consumer valuation is intrinsically different from Facebook's measured value-added and should be recognised in Facebook's production accounts, a number of important accounting issues would have to be faced. For instance, 'shadow profits or losses' would have to be imputed to Facebook to account for consumer valuation. Further, any imputation of this kind would have to include user value *world-wide* generated by Facebook and 'shadow exports' would have to be invoked, with corresponding improvements in Instabook's home country's measured trade balance.

can be instrumental in valuating this own-account output of services. Also, the household sector rather than the corporate sector becomes the relevant producer/consumer and a different valuation of these services from the transacted revenues registered by Facebook can be fully accommodated in an accounting framework. We hasten to add that *by convention* the production of own-account leisure services by households is excluded from GDP calculations and we shall return to the question of the production boundary below.

3 How does production take place?

Having brought in households as producer-consumers of their own leisure services rather than mere consumers of such services provided by the corporate sector, it remains to work out the measurement implications of pursuing this avenue. The first implication is that of identifying the right $'p's'$ and $'q's'$ of household production, along with its inputs. This is essentially a problem of time allocation by households, first invoked by Becker[5] and further discussed by Pollak and Wachter[21], Barnett[4] or Golschmidt-Clermont [15]. Diewert et al[13] generalise the analysis by allowing for different types of households and by considering a situation where households make implicit or explicit decisions to spend time either on:

1. Working in the labour market (*type 1 production*).
2. The production of those household goods and services that could also be purchased from the market such as cooking a meal or looking after an invalid parent (*type 2 production*).
3. The production of leisure services that could not be purchased from the market such as watching a movie, playing football or interacting with others by using Instabook's social media software ((*type 3 production*).

The third case includes the type of household production enabled by free digital products. We shall now introduce some notation to explore this case further.

Denote with q_F and p_F the quantity and price of leisure services that a household provides to itself. As this is own-account production neither the quantity nor the price of these services are observable. Indeed, by definition, p_F

has to be a shadow value absent any transaction. To produce leisure services, the household uses a certain quantity of capital services K_F (to use Facebook, a computer and software are required) at price u_F. Some of these capital services may be for free or in exchange of readiness to accept advertisement but as indicated above we refrain from modeling such barter transactions here as they would not alter the basic conclusions to follow.[8] Similarly, other intermediate inputs are ignored here for simplicity but could easily be integrated.

In addition to capital services, the household allocates time to producing own-account services. Let t_F stand for the minutes per day that go into producing leisure services. Further, note a specificity associated with many digitally-enabled services, the existence of network effects: the evolution of the quantity and implicit price (unit cost) of services produced by a household using social media will typically depend on the number of other users of the same service. The household's capacity to produce q_F is thus conditional on Z, the number of network participants:

$$q_F = F(K_F, t_F, Z) \tag{1}$$

$F(K_F, t_F, Z)$ is a continuous, non-negative production function that is non-decreasing in its elements and linear homogenous in K_F and t_F. Z is entirely exogenous. Household utility depends positively on the leisure services produced, along with other own-account production as well as consumption of products that are purchased on the market. Utility may also directly depend on the time spent in working on the labour market and for purposes of own-account production. [9] None of this needs to be spelled out formally here but it is worth recalling that the household's budget constraint is not only made up of monetary income but also includes a binding and non-extensible constraint on time as there are only 24 hours per day that can be allocated to various activities. A central question is how to value the time spent on these activities as it constitutes the single most important cost of input into household production, including of leisure services. How to value the time spent on leisure activities is no matter of course and discussed at length in Diewert et al[13]. Recent standard empirical applications include Ahmad and Ko[1] or Van de Ven et al[25].

[8]This was tested for the case at hand but, given the comparatively small size of advertising revenues per user played hardly any role for the results.

[9]See Schreyer and Diewert[24].

For present purposes, we simplify and consider a situation where the household has already made a utility-maximising decision on the quantity of digitally-enabled services q_F that it wants to consume given its monetary and time constraints. An optimal programme of time allocation for the household must then also entail cost minimising behaviour in regards to producing leisure services. Define a conditional cost function $c(q_F, u_F, w_F, Z)$ as as the minimum cost required to produce the digitally-enabled own-account services given input prices u_F, w_F and a certain number of users Z in the network:

$$c(q_F, u_F, w_F, Z) = min_{K_F, t_F}[u_F K_F + w_F t_F : F(K_F, t_F, Z) \geq q_F] \quad (2)$$

In (2), u_F stands for the user cost of capital services K_F - essentially the user costs of IT equipment in the Facebook case- and w_F stands for the shadow price of the household's time t_F devoted to leisure production. Note that while u_F is a price that is exogenously given, w_F is an endogenous variable that depends on the household's overall constraints, its preference orderings across types of production and consumption and the household's socio-economic status. For the purpose at hand we assume that w_F is the equilibrium imputed price of time spent on leisure services [10] so that (2) depicts the minimum cost for achieving q_F and these are

$$c(q_F, u_F, w_F, Z) = q_F c^F(u_F, w_F, Z) = u_F K_F + w_F t_F \quad (3)$$

In (3) we have made use of the linear homogeneity property of F to identify the unit cost function $c^F(u_F, w_F, Z)$ which constitutes the household's shadow output price for the own-produced leisure service: $p_F \equiv c^F(u_F, w_F, Z)$. p_F depends on input prices and the exogenous variable Z.

As is usual in the measurement of non-market production, we have equated the total value of digital-enabled services with the sum of costs. In principle, the nominal value $p_F q_F$ could thus be built up by adding the value of labour input and capital services. However, as explained further in Section 4, determining the price for labour w_F in own-account production is notoriously difficult. We circumvent this issue by making use of BCDEF's[**?**] discrete choice experiments for measuring $p_F q_F$: we interpret the answer to their question 'How much

[10] See Diewert et al[13] for a derivation of the equilibrium value of w_F for various types of households.

compensation would be required to forego the digitally-enabled service?' as an indication of the cost of own account production compared to zero production:[11]

$$
\begin{aligned}
\text{Willingness to forego} =& c(q_F, u_F, w_F, Z) - c(0, u_F, w_F, Z) \\
=& q_F c^F(u_F, w_F, Z) = p_F q_F
\end{aligned} \tag{4}
$$

In (4), the second equality follows from the assumption of constant returns to scale in production. It is now possible to derive a unit cost index for own-account leisure services. The established way of defining a price index is by comparing the unit minimum costs of producing output or utility in two periods, given the set of prices that prevail in these periods (Konüs[18]). But not only input prices u_F and w_F change between periods, so does the number of network users, Z. A rising number of users will de-facto reduce the unit cost, i.e., the price for leisure services that the household generates for itself. Equivalently we could say that a rise in Z increases the quantity of leisure services for each dollar of input costs 'expended' on capital input and leisure time. Expression (5) below then constitutes a quality-adjusted unit cost index of own-produced leisure services between two periods 0 and 1. Quality adjustment reflects the number of users in the network. Put differently, the evolution of the number of users Z acts like exogenous technical change to the household's production of leisure services.

$$
P_F(u_F^1, w_F^1, Z^1, u_F^0, w_F^0, Z^0) = \frac{c^F(u_F^1, w_F^1, Z^1)}{c^F(u_F^0, w_F^0, Z^0)}. \tag{5}
$$

If the unit cost function in the two periods takes a translog form, Diewert [11] has shown that for a cost-minimising producer, (5) can be represented exactly by a Törnqvist index P_F^T:

$$
\begin{aligned}
& lnP_F^T(u_F^1, w_F^1, Z^1, K_F^1, t_F^1, u_F^0, w_F^0, Z^0, K_F^0, t_F^0) \\
& = 0.5\left(\tfrac{u_F^0 K_F^0}{u_F^0 K_F^0 + w_F^0 t_F^0} + \tfrac{u_F^1 K_F^1}{u_F^1 K_F^1 + w_F^1 t_F^1}\right) ln\left(\tfrac{u_F^1}{u_F^0}\right) \\
& +0.5\left(\tfrac{w_F^0 t_F^0}{u_F^0 K_F^0 + w_F^0 t_F^0} + \tfrac{w_F^1 t_F^1}{u_F^1 K_F^1 + w_F^1 t_F^1}\right) ln\left(\tfrac{w_F^1}{w_F^0}\right) \\
& +0.5\left(\tfrac{\partial lnc^F(u_F^0, t_F^0, Z^0)}{\partial lnZ} + \tfrac{\partial lnc^F(u_F^1, t_F^1, Z^1)}{\partial lnZ}\right) ln\left(\tfrac{Z^1}{Z^0}\right)
\end{aligned} \tag{6}
$$

[11] Diewert et al[12] use BCDEF's[7] discrete choice in a model of consumer choice to derive Hicksian reservation prices with a view to integrating new digital goods into consumer price indexes.

(6) indicates that the rate of change in the unit price for own-account leisure services is a share-weighted average of the input prices for capital services and for time spent *plus* a quality adjustment effect that depends on the rate of change of network users $ln(\frac{Z^1}{Z^0})$. Note that the elasticity of leisure price change with regard to Z is non-positive: $-\epsilon \equiv \frac{\partial lnc^F(u_F^1, t_F^{*1}, Z^1)}{\partial lnZ}) \leq 0$ and cannot directly be derived from observed prices and quantities.

(3) indicates how to account for the value of leisure services in *level* terms, and (6) indicates how to account for their *price change*. If we manage to evaluate (3) and (6) we can assess the relative importance of Facebook-enabled leisure services compared to GDP, as well as the level and growth rates of any extended measure of economic activity that would include digitally-enabled household services in addition to GDP.

4 Extended Measure of Activity

4.1 Approach

Let $p \equiv [p_1, ...p_N] \leq 0$ and $q \equiv [q_1, ...q_N]$ be the prices and quantities of final goods and services that constitute GDP as measured[12]. The value of GDP at prices of year $t = 0, 1$ is then

$$Y^t = \sum_{i=1}^{N} p_i^t q_i^t \equiv p^t \cot q^t. \tag{7}$$

As we want to assess orders of magnitude relative to U.S. GDP, we note that the U.S. Bureau of Economic Analysis uses a Fisher Ideal price and quantity index in the construction of its national accounts. However, the Törnqvist price index generally constitutes a close approximation to the Fisher price index [13] and for matters of convenience we shall therefore represent the deflator of US GDP by the following expression:

[12] imports can be captured via negative q_i

[13] Diewert[10] showed that the Törnqvist and Fisher index numbers (along with other superlative index numbers) approximate each other to the second order around any point where the price vectors of the comparison periods are equal and where the quantity vectors of the comparison periods are equal.

$$lnP(p^1,p^0,q^1,q^0) = 0.5\sum_{i=1}^{N}\left(\frac{p_i^1q_i^1}{p^1\cdot q^1}+\frac{p_i^0q_i^0}{p^0\cdot q^0}\right)ln(\frac{p_i^1}{p_i^0}) \tag{8}$$

Now suppose that the production-consumption of leisure services were combined with GDP to form an Extended Measure of Activity (EMA). Define the nominal EMA $\tilde{Y}^t$ $(t=0,1)$ including leisure services as:

$$\tilde{Y}^t = p^t\cdot q^t + p_F^tq_F^t. \tag{9}$$

The corresponding Törnqvist price index for EMA is:

$$\begin{aligned}
&ln\tilde{P}(p^1,p^0,p_F^1,p_F^0,q_F^1,q_F^0,q^1,q^0) \qquad (10)\\
&= 0.5\sum_{i=1}^{N}\left(\frac{p_i^1q_i^1}{p^1\cdot q^1+p_F^1q_F^1}+\frac{p_i^0q_i^0}{p^0\cdot q^0+p_F^0q_F^0}\right)ln(\frac{p_i^1}{p_i^0})\\
&+0.5\left(\frac{p_F^1q_F^1}{p^1\cdot q^1+p_F^1q_F^1}+\frac{p_F^0q_F^0}{p^0\cdot q^0+p_F^0q_F^0}\right)ln(\frac{p_F^1}{p_F^0})
\end{aligned}$$

To assess the differences between EMA and GDP, we construct two measures. The first one is:

$$\begin{aligned}
&\text{Percentage difference between } \textit{levels} \text{ of nominal EMA and GDP}\\
&= \frac{\tilde{Y}^t - Y^t}{Y^t}; t=0,1 \qquad (11)
\end{aligned}$$

Expression (11) corresponds to BCDEF's[7] nominal GDP effects under their *total income approach*. However, due to our set-up the interpretation differs somewhat: whereas BCDEF's[7] $(\tilde{Y}^t - Y^t)$ captures the amount that consumers in aggregate would need in compensation for foregoing Facebook, our reading is that this is the value of their leisure production and consumption to which Facebook provides one particular input.

The second comparison relates to the to the difference in measured growth of real EMA and real GDP:

Percentage point difference between *real* EMA and GDP growth rates

$$
\begin{aligned}
&= ln\frac{\tilde{Y}^1}{\tilde{Y}^0} - ln\frac{Y^1}{Y^0} \\
&- \left[ln\tilde{P}(p^1, p^0, p_F^1, p_F^0, q_F^1, q_F^0, q^1, q^0) - lnP(p^1, p^0, q^1, q^0)\right].
\end{aligned} \tag{12}
$$

We can again compare this expression with BCDEF's [7] total income approach. The authors do not explicitly consider the difference between deflators ($ln\tilde{P} - lnP$), and assume that lnP will typically be smaller than $ln\tilde{P}$. BCDEF's[7] total income approach then constitutes a lower boundary for real GDP effects as long as $lnP \geq ln\tilde{P}$. In other words, the price change of the self-produced service has to be less than or equal to the overall rate of inflation. This is plausible in a pure consumer context but less obvious in our set-up of household production where the evolution of wage rates (however measured - see below) constitutes an important part of the deflator for own-account production. Wage rates typically rise quicker than GDP deflators so the conjecture $lnP \geq ln\tilde{P}$ may appear less obvious. This will be further explored as we turn to results.

4.2 Orders of magnitude

Equation (3) states that the nominal value of leisure services for a representative household equals the value of capital services for the activity at hand plus the value of leisure time that the household allocates to the activity. The various components of (3) shall be measured as described below. We use 2017 for period 1 and 2004 for period 0.

Starting with the **quantity of leisure time** t_F^1, we follow BCDEF[7] and estimate that the average user of social media allocates about 40 minutes per day or 240 hours per year to this activity in 2017. [14] We take a guess and set t_F^0 to 20 minutes per day in 2004 (see also Table 1). This appears to be roughly consistent with the time series on the use of the internet for leisure reported by Brynjolfsson and Oh[8]. While in 2017 Facebook counted about 200 million users in the United States, Facebook only operated in university networks during its beginnings in 2003/2004. We set the number of users in 2004 to 100 000 (see

[14] https://www.emarketer.com/Chart/Average-Time-Spent-per-Day-with-Facebook-Instagram-Snapchat-by-US-Adult-Users-of-Each-Platform-2014-2019-minutes/211521

Table 2), noting that this choice is both somewhat arbitrary and important as it has significant impact on the ensuing quality adjustment of the price index for leisure services discussed earlier.

Valuation of leisure time (*type 3* household production in the classification above) with a unit rate w_F is more complicated. Studies such as Ahmad and Koh (2011)[1] or Van de Ven et al (2018)[25] have used both replacement and opportunity cost approaches to value time spent in *type 2* household production (see above). Brynjolfsson and Oh[8] and Goolsebee and Klenow[16] have also used time valuation to gauge the value of digital services. However, Schreyer and Diewert [24] and Diewert et al[13] have shown that the choice for valuing different types of household production depends on the socio-economic characteristics of the household - for example whether or not it is constrained in its supply of labour on the market. Even in the simplest case of an unconstrained person who both works on the labour market and uses market services for household work such as cleaning, the authors show that the correct valuation of leisure time is the minimum of the household's wage rate on the labour market and the wage rate of a person who provides household services. We have no possibility to establish the socio-economic situation of the representative Facebook user.

However, the median valuation for the use of Facebook that was established through discrete choice experiments by Brynjolfsson et al.[6] and BCDEF[7] gives rise to an additional degree of freedom in empirical implementation. As indicated in the previous section, our interpretation of the WTA measure is the *total value of leisure services per person*, or $p_F q_F$ in the notation at hand. This is a value measure, the product of the quantity of unobserved leisure services per person and their price. Given the total value of the leisure service, the quantity of time input and a value for the capital services used (see below), we can derive the shadow wage rate for the time spent on leisure services from (4) as $w_F = \frac{p_F q_F - u_F K_F}{t_F}$.

Table 1 starts from the value of 506 dollars per year in 2017, reflecting the WTA to forego Facebook during a year, as established by BCDEF [7]. We then deduct the user costs of ICT capital services for Facebook use per year - a rather modest sum of 6.6 dollars - to derive a value of leisure time of 499 dollars per year in 2017 or an hourly shadow wage of $w_F = 2.05$ dollars. To obtain a value for 2004, we apply the rate of change of average hourly earnings in the

US between 2004 and 2017 (ca. 30 percent) [15] and obtain a shadow wage rate of 1.58 dollars per hour. The imputed wage rates are clearly lower than any market wage rate, implying that the 506 dollars of leisure value in 2017 and the 194 dollars in 2004 constitute a lower bound.

Table 1: Value of Leisure Services Corresponding to Facebook Use

Variable		**Unit**	**Acronym**	**Year**	
				2004	2017
Time spent on Facebook	1	Minutes per day		20	40
	2	Hours/year	t_F	122	243
WTA (BCDEF[7])	3	$/year		–	506
User costs					
—all ICT capital services	4	$/hour		0.01	0.03
—Facebook ICT capital services	5=4*2	$/year	$u_F K_F$	1.46	6.58
Implied wage rate	6	$/hour	w_F	1.58	2.05
Value of leisure time per person	7=6*2	$/year	$w_F t_F$	192	499
Value of leisure services per person	8=7+5	$/year	$p_F q_F$	194	506

Source: Authors' calculations, see text.

User costs of ICT capital for Facebook use were derived using the net stock of consumer ICT durables at current prices as published by the BEA to which we applied a constant real rate of return of 4 percent and a depreciation rate of 20 percent per year. The resulting country-wide value is then divided by the working age population and expressed as an hourly rate of about 3 cents. Multiplied by 243 hours of Facebook use per year yields a user cost of 6.58 dollars. [16] A similar calculation is put in place for 2004. The price change for ICT capital services corresponds to the implicit deflator of the net stock of consumer ICT durables as published by the BEA. By 2017, it had fallen to 36 percent of its 2004 level (2nd line in Table 2). We are now in a position to construct a Törnqvist unit cost index for the household production of leisure services, as a weighted geometric average of the log price change of the wage rate for leisure services and the log price change of ICT capital servicess for leisure services. Weights are the average shares in 2004 and 2017 of the value

[15] see https://www.bls.gov/news.release/empsit.t19.htm

[16] This is a lower bound that underestimates the actual user costs as computers depreciate even when not in use. However, figures are so small that even tripling the ICT capital costs would not materially affect conclusions.

of leisure time and the value of ICT capital services in the total value of leisure services. Table 2 shows that in the simplest case without any quality adjustment ($-\epsilon \equiv \frac{\partial lnc^F(u_F^1,t_F^1,Z^1)}{\partial lnZ}) = 0$), i.e., ignoring the size of the user network, the unit cost index rises by about 25 percent between 2004 and 2017.

Table 2: Unit Cost Index for Leisure Services

Variable		**Unit**	**Acronym**	**Year**	
				2004	2017
Change of wage rate for leisure services		Index	w_F^1/w_F^0	1.00	1.30
Price change of ICT capital services		Index	u_K^1/u_K^0	1.00	0.3604
U.S. Facebook users		Million persons	Z	0.10	200
Törnqvist unit cost index of leisure services		Index	p_F^1/p_F^0		
—no quality adjustment	$\epsilon = 0$			1.000	1.2493364
—quality adjustment	$\epsilon = 0.5$			1.000	0.0279360
—quality adjustment	$\epsilon = 1.0$			1.000	0.0006247
—quality adjustment	$\epsilon = 1.5$			1.000	0.0000140

Source: Authors' calculations, see text.

When the effects of a growing network are accounted for, the quality-adjusted unit cost index changes significantly. For instance, in the case of a unitary elasticity $\epsilon = 1$, the quality adjusted unit cost of leisure production drops to 0.0062 in 2017, at an annual rate of about -57 percent. With an elasticity of 1.5, this drops further to an annual rate of -86 percent[17]

With the value of Facebook leisure services and of their unit costs (and therefore quantities) in hand, we can now proceed to a comparison between EMA and existing GDP figures for the United States. Table 3 starts out by computing the total value of Facebook leisure services by multiplying the average value per user into the number of Facebook users, yielding about 101 billion dollars in 2017, corresponding to 0.517 percent of U.S. GDP as measured. With the small number of Facebook users in 2004, household production value of leisure services is essentially zero in 2004.

[17]Note that we have put the number of Facebook users in 2017 at 200 million, i.e., the number of U.S. users. The worldwide number of Facebook users in 2017 was around 2 billion users (https://techcrunch.com/2017/06/27/facebook-2-billion-users/?guccounter=1). Allowing for the network effects of worldwide users would further bring down the price index of leisure services but we have no empirical handle on assessing these effects.

Table 3: Extended Measure of Activity

Variable		Unit	Acronym	Year	
				2004	2017
Value of leisure services all Facebook users		Million $/year	$p_F q_F Z$	19	101200
GDP		Million $/year		12213700	19485400
Extended measure of activity					
(GDP plus Facebook-enabled leisure services)		Million $/year		12213719	19586600
Facebook enabled leisure services relative to GDP		Percent		0.000	0.517
Deflator GDP		Index	P^1/P^0	1.000	1.273
		% change per year	$ln(P^1/P^0)$		1.86
Deflator Extended Measure of Activity		Index	$\tilde{P}^1/\tilde{P}^0$		
—no quality adjustment	$\epsilon = 0$			1.000	1.273
—quality adjustment	$\epsilon = 0.5$			1.000	1.261
—quality adjustment	$\epsilon = 1.0$			1.000	1.248
—quality adjustment	$\epsilon = 1.5$			1.000	1.236
Real GDP		Index	$(Y^1/Y^0)/(P^1/P^0))$	1.000	1.265
		% change per year	$ln(Y^1/Y^0) - ln(P^1/P^0)$		1.81
Real Extended Measure of Activity		Index	$(\tilde{Y}^1/\tilde{Y}^0)/(\tilde{P}^1/\tilde{P}^0)$		
—no quality adjustment	$\epsilon = 0$			1.000	1.260
—quality adjustment	$\epsilon = 0.5$			1.000	1.272
—quality adjustment	$\epsilon = 1.0$			1.000	1.285
—quality adjustment	$\epsilon = 1.5$			1.000	1.297
Real Extended Measure of Activity		% change per year	$ln(\tilde{Y}^1/\tilde{Y}^0) - ln(\tilde{P}^1/\tilde{P}^0)$		
—no quality adjustment	$\epsilon = 0$				1.77
—quality adjustment	$\epsilon = 0.5$				1.85
—quality adjustment	$\epsilon = 1.0$				1.93
—quality adjustment	$\epsilon = 1.5$				2.00
Difference: Real Extended Measure of			$ln(\tilde{Y}^1/\tilde{Y}^0)-$		
Activty minus Real GDP		% point per year	$ln(Y^1/Y^0)$		
—no quality adjustment	$\epsilon = 0$		$-[ln(\tilde{P}^1/\tilde{P}^0) - ln(P^1/P^0)]$		-0.04
—quality adjustment	$\epsilon = 0.5$				0.04
—quality adjustment	$\epsilon = 1.0$				0.12
—quality adjustment	$\epsilon = 1.5$				0.19

Source: Authors' calculations, see text.

Next is computing the difference between the growth of real GDP and the growth of real EMA. We first observe that in the case where no account is taken of the number of Facebook users in the construction of the household deflator ($\epsilon = 0$), EMA growth is lower than GDP as measured, by 0.04 percentage point per year on average. Allowing for effects of a rising Z reverses this direction - for instance with an elasticity of $\epsilon = 1$), EMA grows by 0.12 percentage point per year more than GDP between 2004 and 2017. An elasticity of 1.5 would bring that figure up to nearly 0.2 percentage point. By way of comparison, BCDEF's[7] reservation price approach produces a measurement effect between

0.08 percentage point per year and 0.37 percentage point per year, depending on the estimated reservation price . Their total income approach yields an addition to GDP growth of 0.04 percentage points per year. So the ballpark is not altogether different in spite of a different framework.

A final comparison relates to labour productivity growth (Table 4). With U.S. GDP having grown by about 1.8 percent per year in 2004-17 and corresponding official hours worked by about 0.6 percent per year, standard labour productivity growth was about 1.2 percent per year. EMA growth was estimated between about 1.8 percent and 2.0 percent per year. Adding hours spent on Facebook to the official hours worked yields a growth rate of labour input that is consistent with EMA of around 1.9 percent per year – a great deal more than the official, mainly market-based change in hours worked. The consequence is that labour productivity if based on EMA would at best have risen by 0.09 percent per year (assuming a strong network effect) and at worst have fallen by -0.14 percent per year (assuming no network effect).

Table 4: Labour Productivity

Variable		**Unit**	**Year**	
			2004	2017
Real GDP		%/year		1.81
Hours worked		%/year		0.64
Labour productivity based on GDP and official hours worked		%/year		1.17
Real Extended Measure of Activity				
—no quality adjustment	$\epsilon = 0$	%/year		1.77
—quality adjustment	$\epsilon = 0.5$	%/year		1.85
—quality adjustment	$\epsilon = 1.0$	%/year		1.93
—quality adjustment	$\epsilon = 1.5$	%/year		2.00
Hours worked				
—as measured		Million	249065	270679
—in Facebook-enabled leisure production		Million	12	48667
Total		Million	249077	319345
		%/year		1.91
Labour productivity based on EMA				
—no quality adjustment	$\epsilon = 0$	%/year		-0.14
—quality adjustment	$\epsilon = 0.5$	%/year		-0.06
—quality adjustment	$\epsilon = 1.0$	%/year		0.01
—quality adjustment	$\epsilon = 1.5$	%/year		0.09

Source: Authors' calculations, see text.

5 Discussion and conclusions

Treating the household as a producer and consumer of own-account services based on freely provided digital services along with capital and time, brings several advantages over treating the household as a consumer only of such services produced elsewhere in the economy:

- A situation can be accommodated where user valuation of leisure services deviates from market revenues by the corporations that provide free data services - the former are the value of own-account production by households, the latter are the results of whatever business model a profit-oriented corporation chooses.
- Unit costs or shadow prices and quantities of own-account production and consumption are conceptually clearly identified. In particular, the unit cost for own-account leisure services depends on the user costs of household capital, on the value of time spent on producing-consuming leisure services and on the size of the network. These network effects can be interpreted as a quality adjustment to the household's unit cost index of producing its services. We have found no good empirical handle to assess the size of these network effects as their cost elasticity is unknown. We took refuge to simulating 3 different scenarios, each reflecting a different cost elasticity. When time series of observations on WTA become available it will be possible to estimate the relevant cost elasticity.
- As the quantity of leisure services is not directly observable, we estimate it by deflating the nominal value of household leisure services (revealed via discrete choice experiments) with the relevant unit cost index. As the latter declines with a rising number of network users, the measured quantity of services will increase accordingly. Network effects then play a role akin to technical change.

A fundamental question is whether such *type 3* household production should be included in GDP rather than forming part of a satellite measure à la EMA . A good portion of caution is needed here, for at least three reasons.

- First is that it is not obvious why *type 3* household production (leisure) should be brought inside the production boundary rather than or before *type 2* household production (cooking a meal) that corresponds more closely to a notion of production. Margret Reid's[22] *Third Party Criterion* [18] has long constituted a reference for separating production activities from other activities and Facebook-type leisure activities would not qualify as production. A broadening of the production boundary to include *type 3* activities would naturally entail to also include *type 2* activities. Given the size of the latter (anywhere between 25 percent and 45 percent of GDP in OECD countries – see Van de Ven et al[25] such a move would fundamentally alter the nature of GDP, its measured level and growth rates. Clearly, such a decision would warrant extensive discussions and consultation with users before going near implementation. While an inclusion of only *type 3* own-account leisure service production in GDP would be less consequential, proceeding in this way appears to be ad hoc.

- Second is robustness of estimates of *type 3* (and *type 2*) activities. While discrete choice experiments such as those used above are a defensible way of valuing leisure services, their break-down into price and volume components is subject to significant uncertainty. Clearly the biggest gap exists in regards to the quality adjustment of prices (or volumes) - witness the discussion on the size of the elasticity of the unit costs of leisure services with regard to the size of the user network. Longer time series or cross-section observations of WTA with corresponding information about the number of users could help here but some time will pass before reliable estimates are available.

- Third is communication on the inclusion of leisure services into the production boundary and the consequences for acceptance and credibility of national accounts variables. Consider for instance real household consumption and consumption price indices. An inclusion of leisure services would raise the level of measured household consumption and income in nominal and likely in real terms if measured consumer inflation declines. Already today, with the current production boundary, there is a widespread perception that inflation is understated and, correspondingly, real income and consumption, overstated. A related point is how time spent on producing leisure services should be counted: most people would

[18] Reid[22] states her criterion as follows: "[i]f an activity is of such character that it might be delegated to a paid worker, then(that activity shall be deemed productive" (p.11).

object to treating it as a form of self-employment as this would define away all unemployment, defeating common sense. So it has to be something different with a notion yet to be defined. Overall, then an inclusion of leisure services into our standard production framework would run the risk of weakening trust in statistics - it is hard to convey that people are actually better off than they think because they produce consumption services for themselves. Incomprehension would probably be exacerbated if relevant statistics such as consumption price indices were used to escalate social transfers or pensions or as a benchmark in wage negotiations.

Research into measurement of household activity is important and needs encouragement. This concerns both *type 3* and *type 2* activities as these will gain in importance modern societies as a consequence of digitalisation and demographic developments. From there to bringing these activities inside GDP is still a long way however and deserves a good deal of reflection among national accountants and, more importantly, with society's stakeholders. A useful way forward at this junction is the systematic and periodic development of measures of household production and consumption outside the current SNA boundaries but inside a framework of satellite accounts so that accounting concepts are adhered to, results can be compared with established national accounts aggregates and experimental aggregates à la EMA can be constructed.

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