SUPPLEMENTAL APPENDIX

GDP-B: Accounting for the Value of New and Free Goods

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Valuing Free Digital Goods Using Participants in a Laboratory

We conducted a set of incentive compatible discrete choice experiments in a university laboratory in the Netherlands in order to evaluate additional free digital services.[1] While the online status on Facebook can be monitored remotely to make sure that participants did not use this service, other digital goods do not offer this functionality so that we needed another approach to make the decisions consequential. For services that require a password-protected login, we informed the participants that, if selected, they will have to change the password to a computer-generated code that would be kept in a sealed envelope afterwards. If the seal was still intact and the password remained valid (not reset), we concluded that the participant in fact did not use this service. Additionally, we informed that we would check the usage statistics of the apps on the selected participants' devices. Therefore the laboratory setting was necessary in order to be able to contact participants in person after the study and make their decisions consequential.

We tested the valuation of the services Instagram, Snapchat, Skype, WhatsApp, digital Maps, LinkedIn, Twitter as well as Facebook. We varied the monetary amount that we offered to participants to leave these services for one month randomly within the range of €1 to €500. The respondents had to make decisions regarding each of these services, i.e., each respondent had to make eight decisions. One out of every fifty participants who completed the study got the chance to have their decision fulfilled. The specific service was determined randomly in this case.

[1] These valuations are also reported in Brynjolfsson, Collis and Eggers (2019).

The data collection took place at a large Dutch university in February and October 2017. Overall, 426 participants were available for the analysis, meaning that there were over 400 decisions for each digital service. The resulting estimated demand curves are given in Figure A1. The corresponding median WTA valuations and confidence intervals are given in Table A1.

An unexpected discovery from our experiments was that the participants have remarkably high valuations for WhatsApp. No one was willing to give it up for €1, and the relative insensitivity of demand to price resulted in an estimated monthly median WTA of €535.73, far higher than for the other services. We interviewed participants after the study period to better understand these valuations. They told us that WhatsApp had become a nearly indispensable focal platform for communicating with peers, co-workers and others in their community, leading to enormous disutility from lack of access.[2] Of course, the disutility for an individual would likely be much less if all members of the community could coordinate on switching to an alternative communications platform and the values should be interpreted accordingly. Such network effects are observed with many other goods as well, and do not mean that the valuations should be discounted but it may affect the value of other substitute goods.[3] Hence, the net contribution to welfare should account for changes in both the value on the focal good, and such substitutes.

In general, any good has a certain price/valuation for every state of the world referred to as Arrow-Debreu state prices (for e.g. a bottle of water has a different valuation if you are thirsty in a desert or relaxing in your kitchen). In addition to network effects, digital goods can also have different valuations based on how long you have to give them up for and the availability of substitutes and complements. Specifying the state of the world in choice experiments lets us uncover the set of valuations for a single good across different states.

[2] Some quotes from our interviews: 1. “Whatapp is the only communication tool I use to contact my friends here. Without it, I can do nothing.” 2. “WhatsApp is crucial. I use the app every hour of the day to keep in touch with friends and family but also to discuss group projects or things about my work. I really need to keep access to this app. There is also not a very suitable alternative.”

[3] The fact that most people now use telephones to communicate rather than telegrams does not mean that the price people are prepared to pay for calls should be discounted in any way. That said, the value is partly due to network effects and partly due to intrinsic differences between the two goods.

For example, we could solicit valuations for giving up WhatsApp but letting them use substitutes or completely giving up all instant messaging services.

Facebook was used by almost all participants and had the next highest median WTA monthly valuation of around €100. The valuation for Facebook in this sample was thus significantly higher than that found for the US in the previous section ($42.17 ≈ €34.76). Maps (including Google, Bing, and Apple maps) were also highly valued, with WTA median values of almost €60 per month, followed by Instagram, Snapchat and LinkedIn.

For Skype and Twitter, we found very low median valuations of less than €1. Although 71% of the participants were using Skype, the majority were willing to give it up for one month for just €1, likely because other services offered very similar (video) calling possibilities and was not frequently used. Note that although Skype effectively provides access to a portion of the same network for 71% of sample, the valuation is massively different; €535.73 for WhatsApp and €0.18 for Skype. This suggests that it is not simply a valuation of the network that is being captured.

Twitter is only used by 33% of the sample which explains the low value for the median user, i.e., the utility maximizing strategy for those who do not use Twitter is, of course, to accept any money that was offered, and this encompasses the majority of users in our sample.

These WTA estimates are converted to annual figures by simply multiplying by twelve to get the annual estimates, as per the previous section, and these figures are then used to calculate annual GDP-B growth for the Netherlands. We use the total income method of equation (8), and hence avoid having to estimate a reservation price for each good. The results are reported in Table A2.[4] Since our sample for these laboratory experiments is not representative of the national population of Netherlands, we provide these figures solely to gauge the approximate magnitude of potential underestimation in welfare inferred from conventional GDP growth figures from not accounting for popular free digital services.

[4] The welfare change estimates are available from the authors on request.

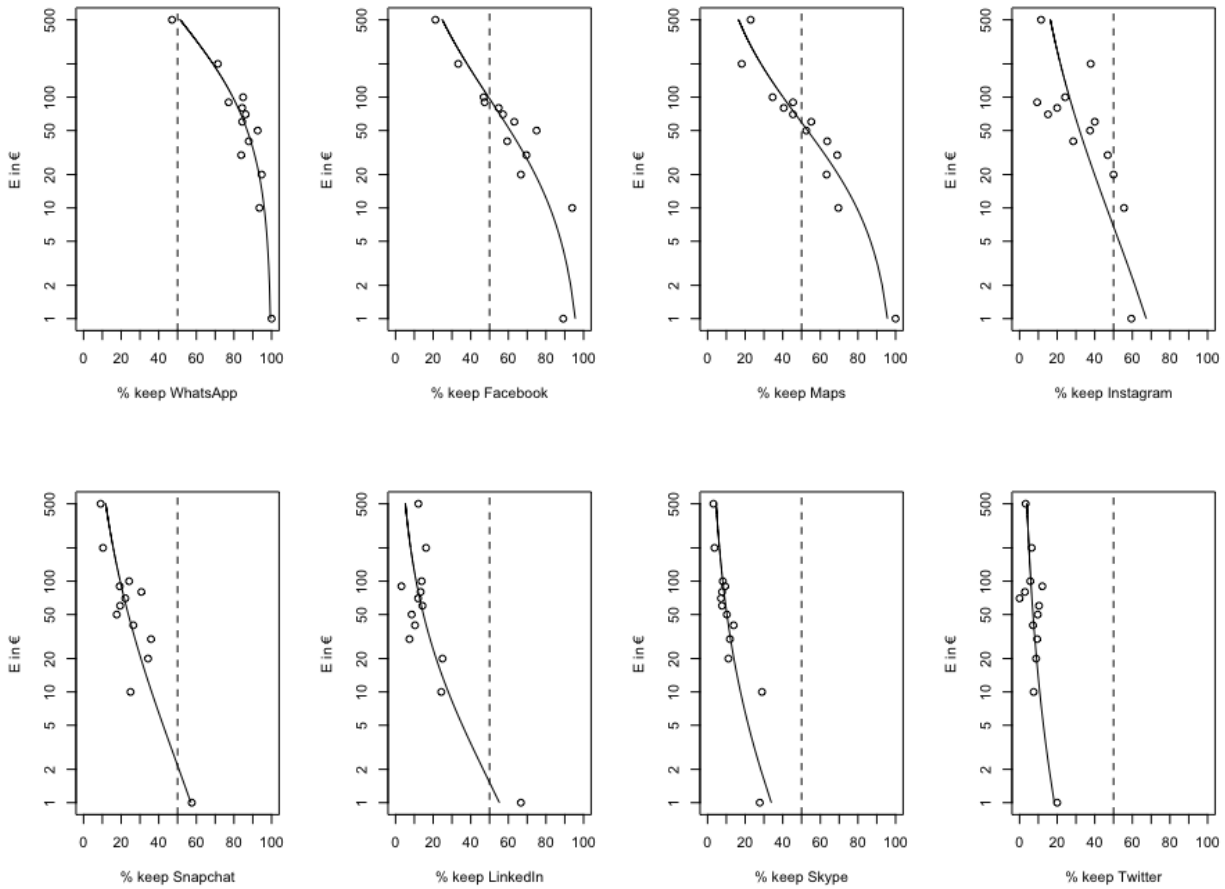

FIGURE A1: WTA DEMAND CURVES FOR POPULAR DIGITAL GOODS MEASURED IN A LABORATORY

TABLE A1— MEDIAN MONTHLY WTA

Service	Launch Date	Median WTA	Lower CI	Upper CI
WhatsApp	January 2009	€535.73	€269.91	€1141.42
Facebook	February 2004	€96.80	€69.54	€136.68
Maps	February 2005	€59.16	€45.17	€78.31
Instagram	October 2010	€6.79	€2.53	€16.22
Snapchat	September 2011	€2.17	€0.41	€8.81
LinkedIn	May 2003	€1.52	€0.30	€5.84
Skype	August 2003	€0.18	€0.01	€2.58
Twitter	March 2006	€0.00	€0.00	€0.49

TABLE A2 — ESTIMATES OF GROSS CONTRIBUTIONS OF POPULAR DIGITAL GOODS TO REAL GDP-B GROWTH IN THE NETHERLANDS, PERCENTAGE POINTS, TOTAL INCOME METHOD

Users / Service	Average per year 10 million	Average per year 2 million
WhatsApp	1.37	0.27
Facebook	0.18	0.04
Maps	0.11	0.02
Instagram	0.02	0.00
Snapchat	0.02	0.00
LinkedIn	0.01	0.00
Skype	0.00	0.00
Twitter	0.00	0.00

Notes: Two alternative user populations are considered, 10 million and 2 million. The population in July 2017 was approximately 17 million, with around 2 million in the 15-24 age group (https://www.indexmundi.com/netherlands/demographics_profile.html), which is the age group of our laboratory sample. In January 2016, WhatsApp had 9.8 million (https://nltimes.nl/2016/01/25/dutch-people-leaving-twitter-en-masse-use-whatsapp-facebook). Quarterly data are used.[5] For products launched in the first half of the year, the period 0 values are taken to be those from quarter 4 of the preceding year. For products launched in the second half of the year, period 0 values are taken to be those of quarter 4 of the launch year. Per year estimates are calculated using arithmetic means of the percentage point difference in growth over the period that the respective goods were available.

[5] Real GDP: https://fred.stlouisfed.org/series/CLVMNACNSAB1GQNL;
Nominal GDP: https://fred.stlouisfed.org/series/CPMNACNSAB1GQNL
The GDP Implicit Price Deflator is calculated as the ratio of the nominal GDP series divided by the real GDP series. This is because the official deflator series is annual (an average over the four quarters of each year), and we need to ensure that price times quantity equals value.

From Table A2 we can see that WhatsApp, Facebook and digital maps contribute significantly towards GDP-B_T growth and hence conventional GDP estimates miss a great deal of value by not accounting for these goods. According to our estimates, if WhatsApp is used by only two million people in the Netherlands (the approximate population in the 15-24 years old age group in 2017 and the age group of our laboratory sample), its gross contribution to GDP growth over 2003 to 2017 would be 0.82 percentage points per year. This is large, especially when considering that (i) this is just one digital good, and (ii) that the actual using population of WhatsApp is likely to be much larger than 2 million. The actual Dutch number of users has been reported to be closer to 10 million, for both WhatsApp and Facebook.[6]

Hence, in Table A2 we also report results for a user population of 10 million and find that, if accounted for, the annual average gross contribution of WhatsApp to GDP-B growth would have been a substantial 4.10 percentage points according to the total income method. It is important to note that if WhatsApp largely replaces conventional telephone calls and texting, then the traditional GDP captures the *fall* in disappearing value of these telephone services but misses the *gains* from WhatsApp. In contrast, the adjustment term to GDP-B growth due to WhatsApp could be very high because it captures these benefits from the introduction of WhatsApp relative to the counterfactual of lower valued telephone services.[7] This problem of GDP not reflecting benefits from free goods could become increasingly severe as more and more free digital goods are used as substitutes for traditional paid goods, such as Wikipedia replacing encyclopedias and various smartphone apps replacing a variety of traditional goods. In fact, reported declines in GDP (e.g. from

[6] According to an NL Times story on January 25 2016, "Whatsapp is the largest social network in the Netherlands with 9.8 million users. Facebook came in second place with 9.6 million...." https://nltimes.nl/2016/01/25/dutch-people-leaving-twitter-en-masse-use-whatsapp-facebook. Given definitional uncertainty about what constitutes a "user", and the potential for rapid change in user numbers, we consider potential bounds of 2 million to 10 million users out of a population of 17 million.

[7] In other words, in an alternative world without WhatsApp, the counterfactual GDP-B would drop by somewhat less than our estimate because users would probably have relatively higher valuations for telephone services.

reduced paid-for telephone services) may reflect actual increases in welfare (e.g. from free goods like WhatsApp).

FIGURE A2: SEALED SMARTPHONE CAMERA (INTACT AND BROKEN)