The Digital Economy, GDP and Consumer Welfare: Theory and Evidence

Erik Brynjolfsson, W. Erwin Diewert, Felix Eggers, Kevin J. Fox and Avinash Gannamaneni

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Background

- **There are two features of the Digital Economy that we focus on here:**
  1. **Free goods**
     - **E.g. Facebook, Wikipedia**
  2. **New goods**
     - **E.g. Smartphones**

- **We introduce a new metric, we call "GDP-B"**
  - **In this paper, we account for the benefits of free goods and new goods**
  - **In the future, we will add other adjustments**

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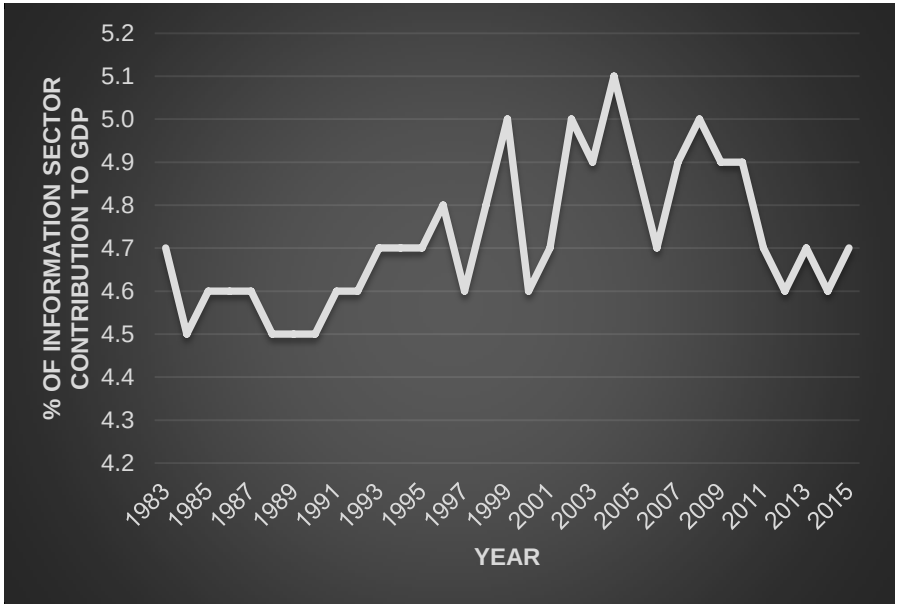
Free Goods: Many Digital Goods and Services

Explosion of free digital goods

Information goods as a share of GDP



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New Goods: Smartphones and Cameras

- **Photos** taken worldwide
  - 2000: 80 billion photos
  - 2015: 1.6 trillion photos
  - Price per photo has gone from **50 cents to 0 cents**.

- Increase doesn't show up in GDP measures since...
  - Price index for photography includes price of (film, developing, cameras) all of which are vanishing
  - Photos are mostly shared, not sold (non-monetary transaction)
  - GDP went *down* when cameras were absorbed into smartphones

Ref: Varian 2017

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Mismeasurement

Diane Coyle (2017):
"The pace of change in the OECD countries is making the existing statistical framework decreasingly appropriate for measuring the economy"

Charlie Bean (2016):
"Statistics have failed to keep pace with the impact of digital technology"

Hal Varian (2015):
"There's a lack of appreciation for what's happening in Silicon Valley, because we don't have a good way to measure it."

Chad Syverson (2017):
"The productivity slowdown has occurred in dozens of countries, and its size is unrelated to measures of the countries' consumption or production intensities of information and communication technologies."

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Preview

Develop a new framework for measuring welfare change

- **Based on the work of Hicks (1941-42), Bennet (1920) and Diewert and Mizobuchi (2009)**
- **This is the foundation for a new measure we call GDP-B**
  - **An extension of traditional GDP**

1. **Derive an explicit term for the welfare change from <u>new goods</u>**
   - **Welfare change is mismeasured if this term is omitted by statistical agencies**
   - **Derive a lower bound for the addition to real GDP growth from a new good**

2. **Further extend the theory allowing <u>free goods</u>**

1. **Directly estimate consumer welfare by running massive online choice experiments**
   - **Apply techniques developed by Brynjolfsson, Eggers and Gannamaneni (2016, 2018)**

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Empirical Implementation

1. **Run incentive compatible discrete choice experiments**
   - **“Incentive compatible” => participants risk losing access to the good**
   - **Recruit a representative sample of the US internet population via online survey panel**
   - **Use data to estimate the consumer valuation of Facebook**

2. **Quantify the adjustment term to real GDP growth (GDP-B) for the contribution of Facebook from 2004 to 2017**

3. **Run additional incentive compatible discrete choice experiments to estimate the consumer valuation of several popular digital goods**
   - **Instagram, Snapchat, Skype, WhatsApp, digital Maps, Linkedin, Twitter, and Facebook**
   - **Conducted in a lab in the Netherlands**

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Welfare Change and the New Goods Problem

Introduction of a new good period 1

Assume (as per Hicks 1940) there is a reservation price (aka virtual price) for the new good that will cause the consumer to consume 0 units in period 0

Let the new good be indexed by the subscript 0 and let the N dimensional vectors of period t prices and quantities for the continuing commodities be denoted by superscripts: p^t and q^t for t = 0, 1

The period 0 quantity for commodity 0 is observed and is equal to 0; i.e., $q_0^0 = 0$

Period 0 reservation price is not directly observed. However, we can estimate it, denoted as $p_0^{0*} > 0$

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Welfare Change and the New Goods Problem

Bennet variation measure of welfare change:

$$V_B = \tfrac{1}{2}(p^0 + p^1)\cdot(q^1 - q^0) + \tfrac{1}{2}(p_0^{0*} + p_0^1)(q_0^1 - 0)$$

$$= p^1\cdot(q^1 - q^0) - \tfrac{1}{2}(p^1 - p^0)\cdot(q^1 - q^0) + p_0^1 q_0^1 - \tfrac{1}{2}(p_0^1 - p_0^{0*})q_0^1$$

Terms:

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Welfare Change and the New Goods Problem

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Terms:

1. $p^1\cdot(q^1 - q^0)$: change in consumption valued at the prices of period 1

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Welfare Change and the New Goods Problem

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Terms:

1. $p^1\cdot(q^1 - q^0)$: change in consumption valued at the prices of period 1

2. $-\tfrac{1}{2}(p^1 - p^0)\cdot(q^1 - q^0)$: sum of the consumer surplus terms associated with the continuing commodities

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Welfare Change and the New Goods Problem

$$V_B = p^1 \cdot (q^1 - q^0) - \tfrac{1}{2}(p^1 - p^0) \cdot (q^1 - q^0) + p_0^1 q_0^1 - \tfrac{1}{2}(p_0^1 - p_0^{0*}) q_0^1$$

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Welfare Change and the New Goods Problem

$$V_B = p^1 \cdot (q^1 - q^0) - \tfrac{1}{2}(p^1 - p^0) \cdot (q^1 - q^0) + p_0^1 q_0^1 - \tfrac{1}{2}(p_0^1 - p_0^{0*}) q_0^1$$

3. $p_0^1 q_0^1$: the usual price times quantity contribution term to the value of real consumption of the new commodity in period 1 which would be recorded as a contribution to period 1 GDP

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Welfare Change and the New Goods Problem

$$V_B = p^1 \cdot (q^1 - q^0) - \tfrac{1}{2}(p^1 - p^0) \cdot (q^1 - q^0) + p_0^1 q_0^1 - \tfrac{1}{2}(p_0^1 - p_0^{0*}) q_0^1$$

3. $p_0^1 q_0^1$: the usual price times quantity contribution term to the value of real consumption of the new commodity in period 1 which would be recorded as a contribution to period 1 GDP

4. The last term, $-\tfrac{1}{2}(p_0^1 - p_0^{0*}) q_0^1 = \tfrac{1}{2}(p_0^{0*} - p_0^1) q_0^1$, is the additional consumer surplus contribution of commodity 0 to overall welfare change (which would not be recorded as a contribution to GDP).

If we assume that $p_0^{0*} = p_0^1$, then the downward bias in the resulting Bennet measure of welfare change will be equal to a Harberger-type triangle, $\tfrac{1}{2}(p_0^{0*} - p_0^1) q_0^1$.

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Welfare Change and the Free Goods Problem

Consumer holding $Z^{**} > 0$ free goods has utility $u^{**} \equiv f(x^{**}, z^{**})$.

***"Global" willingness to accept (WTA) function* for the disposal of z^{**} as follows:**

$$W_A(u^{**}, p, z^{**}) \equiv c(u^{**}, p, 0_M) - c(u^{**}, p, z^{**})$$

That is, the amount of expenditure needed to achieve the same utility without access to the free good.

Marginal valuation price vector $w \equiv -\nabla_z c(u, p, z)$

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Welfare Change and the Free Goods Problem

Welfare change including the free goods, and adjusting for inflation by using γ = 1 + Growth Rate of CPI:

$$V_B = p^1 \cdot (q^1 - q^0) - \tfrac{1}{2}(p^1 - \gamma p^0) \cdot (q^1 - q^0) + p_0^1 q_0^1 - \tfrac{1}{2}(p_0^1 - \gamma p_0^{0*}) q_0^1$$

$$+ w^1 \cdot (z^1 - z^0) - \tfrac{1}{2}(w^1 - \gamma w^0) \cdot (z^1 - z^0) + w_0^1 z_0^1 - \tfrac{1}{2}(w_0^1 - \gamma w_0^{0*}) z_0^1$$

The last term is for the introduction of a new free good.

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Welfare Change and the Free Goods Problem

Under some assumptions, can make an adjustment to real GDP growth

$\mathscr{P}^F = P^F/\gamma$, with P^F the Fisher index GDP deflator and Q^F a Fisher index of GDP:

$$\text{GDP-B} = Q^F + (\gamma p_0^{0*} - p_0^1)q_0^1/[\gamma p^0 \cdot q^0 (1+ \mathscr{P}^F)]$$

$$+ [2\gamma w^0 \cdot (z^1 - z^0) + (w^1 - \gamma w^0) \cdot (z^1 - z^0) + 2\gamma w_0^1 z_0^1] /[\gamma p^0 \cdot q^0 (1+ \mathscr{P}^F)]$$

$$+ (\gamma w_0^{0*} - w_0^1)z_0^1/[\gamma p^0 \cdot q^0 (1+ \mathscr{P}^F)],$$

where the highlighted term is the contribution from new free goods. This will be our focus in what follows.

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Empirics: Consumer Valuation of Facebook in US

- **Discrete choice experiments on a representative sample of the US internet population.**
- **Set quotas for gender, age, and US regions to match US census data (File and Ryan 2014) and applied post-stratification for education and household income.**
- **Recruited respondents through an online professional panel provider, Research Now, during the year 2016-17.**
- **A total of 2885 participants completed the study including at least 200 participants per price point.**
- **Disqualified participants who did not use Facebook in the previous twelve months.**

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Consumer Valuation of Facebook in US

- **Discrete Choice Experiment**
  - **1) Keep access to Facebook, or**
  - **2) Give up Facebook for one month and get paid $E.**
- **Allocated participants randomly to one of twelve price points:**
  E = (1, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 1000).
- **Informed that their decisions were consequential (incentive compatible)**
  - **We would randomly pick one out of every 200 participants and fulfil that person's selection.**
- **Monitored their online status on Facebook for 30 days to confirm their choices and make payments**

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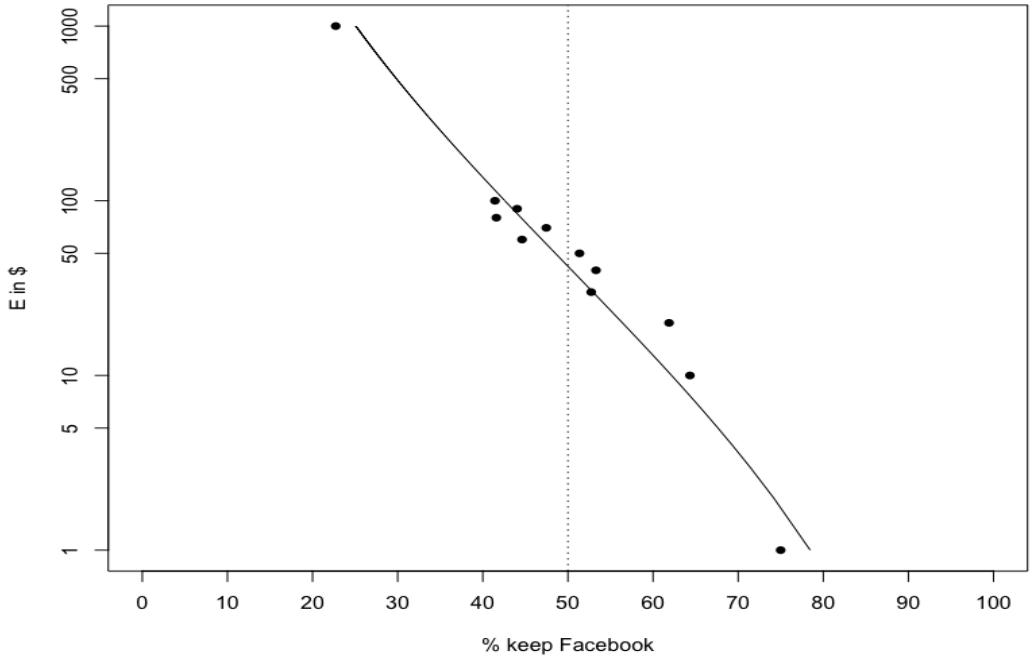
Downward-sloping WTA demand curve for Facebook

The median WTA of Facebook is $42.17/month (95% C.I.: [$32.53; 54.47])



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Welfare Change Estimates for Facebook: Three Different Reservation Prices,

$$\tfrac{1}{2}\,(\gamma w_0^{0*} - w_0^{1}) \times (\text{No. of Facebook users in US in 2017})$$

	$w_0^{0*} = 2w_0^{1}/\gamma$	Estimated 1	Estimated 2
Reservation Price w_0^{0*}, 2003$	$780	$2,152	$8,126
Contribution to Welfare Change, 2017$	$51 billion	$231 billion	$1,013 billion
Per year, 2017$	$4 billion	$16 billion	$72 billion
Per user in 2017	$18.07	$81.65	$358.48
Per user over period	$253	$1,143	$5,018

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GDP-B Contributions, Different Reservation Prices, Facebook

	$w_0^{0*} = 2w_0^1/\gamma$	Estimated 1	Estimated 2	TI
Reservation Price w_0^{0*}, 2003$	**$780**	**$2,152**	**$8,126**	**---**
Percentage Points, 2003-2017	**0.34**	**1.54**	**6.76**	**0.53**
Per year	**0.02**	**0.11**	**0.48**	**0.04**
GDP Growth per year without Facebook	**2.06**	**2.06**	**2.06**	**2.06**
GDP-B Growth per year with Facebook	**2.08**	**2.17**	**2.54**	**2.10**

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Total Income (TI) Method

A simple method that doesn't require estimation of reservation prices.

Consumer has a total income (TI) that that is used to achieve the level of utility at an observed equilibrium, t=0,1:

$TI^t = p^t.x^t + w^t.z^t$ (market income plus imputed income), where $z^0 = 0$

Nominal Total Income Growth = TI^1/TI^0

Deflating this by the GDP deflator gives a quantity index. Of course, the GDP deflator is the wrong deflator as it doesn't take into account new free goods, which would typically mean that the deflator's growth is too high. The resulting quantity index then provides a lower bound estimate on the actual real growth rate.

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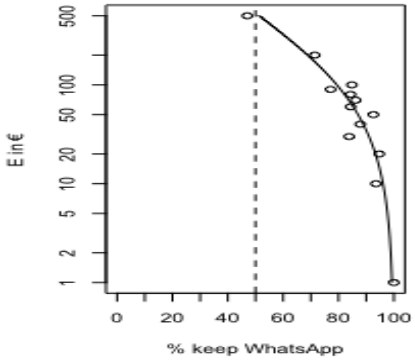
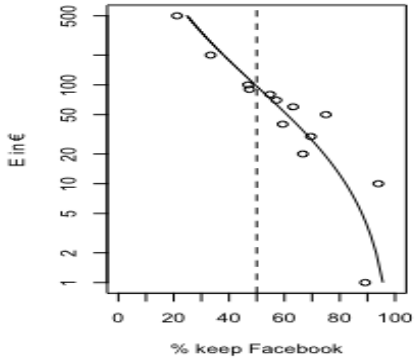
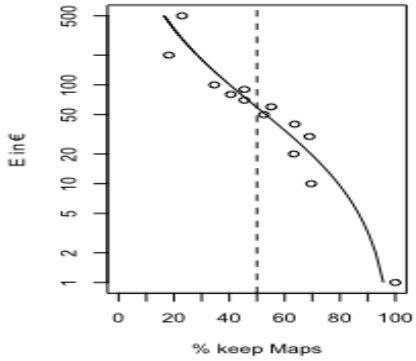
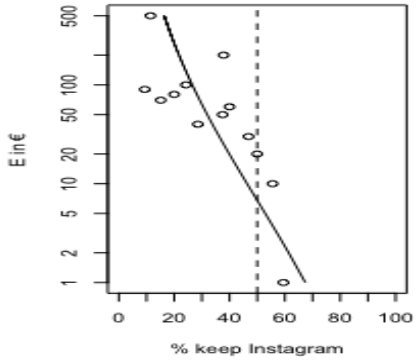
Monthly WTA Demand Curves for Popular Digital Goods

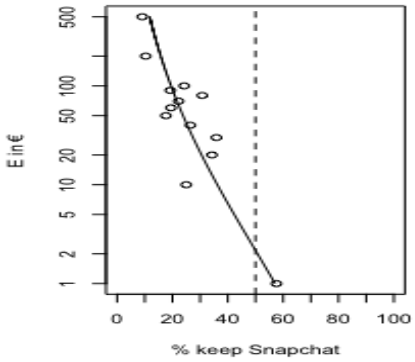
Netherlands lab experiment; x-axis: percentage keep, y-axis: payment required

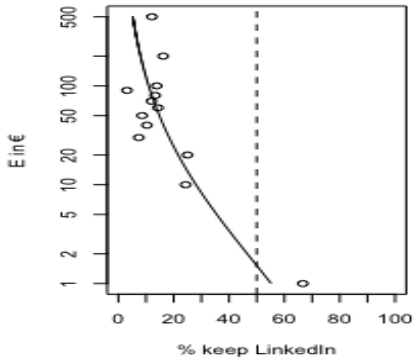


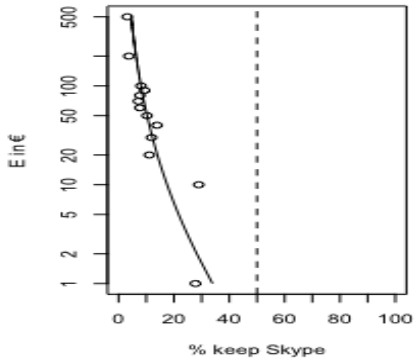


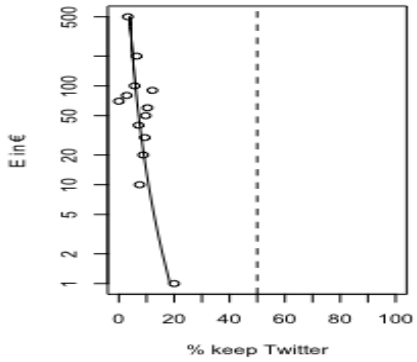












Median WTA for Popular Free Digital Goods

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

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Contributions to GDP-B growth in the Netherlands, percentage points (Total Income Method)

Users Service	TI per year 10 million	TI per year 2 million
WhatsApp	3.74	0.75
Facebook	0.43	0.09
Maps	0.29	0.06
Instagram	0.06	0.01
Snapchat	0.02	0.00
LinkedIn	0.01	0.00
Skype	0.00	0.00
Twitter	0.00	0.00

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Importance of Adjusting for Quality Change

BDM lottery (Becker, DeGroot, and Marschak 1964) in order to estimate the consumers' valuation of their smartphone camera: Netherlands lab

Asked participants to state the minimum amount of money they would request in order to give up their smartphone camera (both main camera and front camera) for 1 month.

Participants informed that one out of 50 participants would be selected for the lottery and that we would block their smartphone cameras with a special sealing tape, if their bid was successful.

If, after the one month period, the seal was still intact participants were rewarded with the money and the seal could be removed.

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Incentive compatibility

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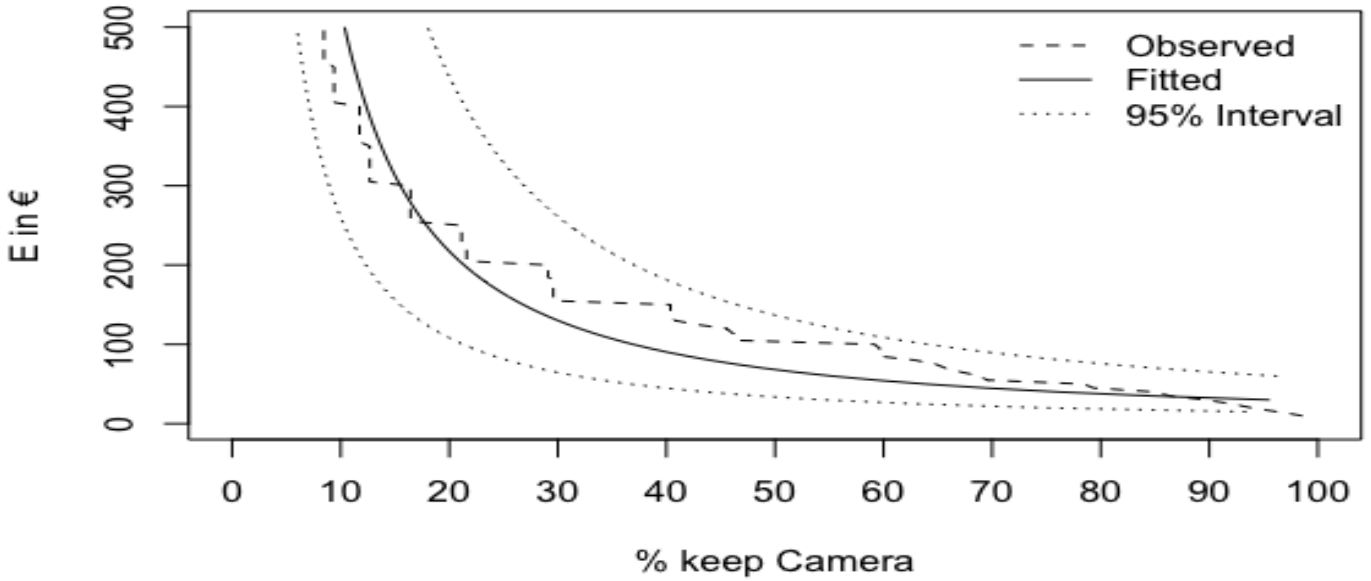
Demand Function for the Smartphone Camera



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Importance of Adjusting for Quality Change

- **The median WTA for giving up the smartphone camera for one month is €68.13**
  - 95% CI = [€33.53; €136.78]
- **It costs between €20-€35 to manufacture smartphone cameras present in the latest flagship models**
  - A modular smartphone sold in the Netherlands charges €70 for adding front and back cameras
- **Strong evidence that consumers obtain a significant amount of surplus from using their smartphone cameras**
  - This surplus is an order of magnitude larger than what they actually pay
- **Therefore, even for paid goods such as smartphones, it is crucial to adjust for quality improvements before estimating GDP statistics**

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Conclusions

- **Derived new theory for the measuring welfare from new and free goods**
  - Defined a new metric: GDP-B.
  - GDP-B provides an approximate additive adjustment to traditional GDP growth for new and free goods.
  - GDP-B is a lower bound on the adjustment
  - Additional terms can be added to GDP-B as other types of welfare implications are considered

- **Empirically implemented theory using both massive online experiments and lab experiments.**
  - Find that consumers can have very high valuations of “free” digital goods, with significant variation over different products
  - Estimated effects of quality change in a physical good: digital cameras in smart phones
    - Valuations dramatically exceed the market price
    - This emphasizes the importance of quality adjustment for goods with rapid quality change

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Closing Thoughts

- **This line of research is still in its infancy**
- **This paper demonstrates the feasibility of implementing simple adjustments to official data to better understand the impact of digital goods and services on the economy**
- **We call this GDP-B**

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Thank You

MIT Measuring the Economy Project

http://MeasuringTheEconomy.org

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