

Measurement Challenges in High Tech

Silicon and Statistics

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These slides do not necessarily represent the view of the author's employer.

Outline

- GDP and “standard of living”
- Free content and services
- Non-market transactions
- Quality measurement
 - Software and intangibles
 - Consumer goods
 - Semiconductors
 - Imports
- Global supply chain and multinationals

GDP ≠ welfare

Even though everyone agrees GDP is not intended to be a measure of “welfare”, it is often used as a **proxy** for “standard of living”. (Just search Google...)

- “...a measure for **standard of living**: average real **gross domestic product (GDP)** per capita”
- “...productivity and **living standards**”
- “...GDP per capita as yardstick for **living standards**.”
- “...Measuring **living standards** with GDP per capita”

But: "the welfare of a nation can scarcely be inferred from a measure of national income." [Kuznets \[1934\]](#)

Problems with GDP as welfare measure

GDP = value at **market prices** of all **final** goods and services **produced** in a given **country** in a given time period.

- **Market prices:** does not measure **non-market goods** such as leisure, household production, free goods, most quality improvements, etc.
- **Final:** excludes **intermediate goods** and services, such as marketing spend.
- **Produced:** welfare depends on **consumption**, not production
- **Country:** due to **global supply chains**, the location of production may not be clear

Free content and services

Ad supported and really free content

Advertiser supported content and services

- **Advertising is** counted as a marketing expense = intermediate good
- Therefore **does not show up** directly in GDP
- Impacts radio, TV, newspapers, magazines, and internet
- Switching from pay-per-view to “free” ad support decreases GDP
- See Nakamura, Samuels and Soloveichik [2016] for elaboration.

However, **this doesn't make much difference in aggregate GDP growth** since **total** expenditure on advertising hasn't changed much. Aggregate expenditure on advertising in US has been about 1.3% of nominal GDP for 100 years. ([Bloomberg 2014](#))

Really free content and services: Wikipedia, Blogs, FRED, photo archives, docs, etc. Publishing costs have fallen to near zero. No price = not in GDP, even though highly valuable to consumers.

Quality measurement

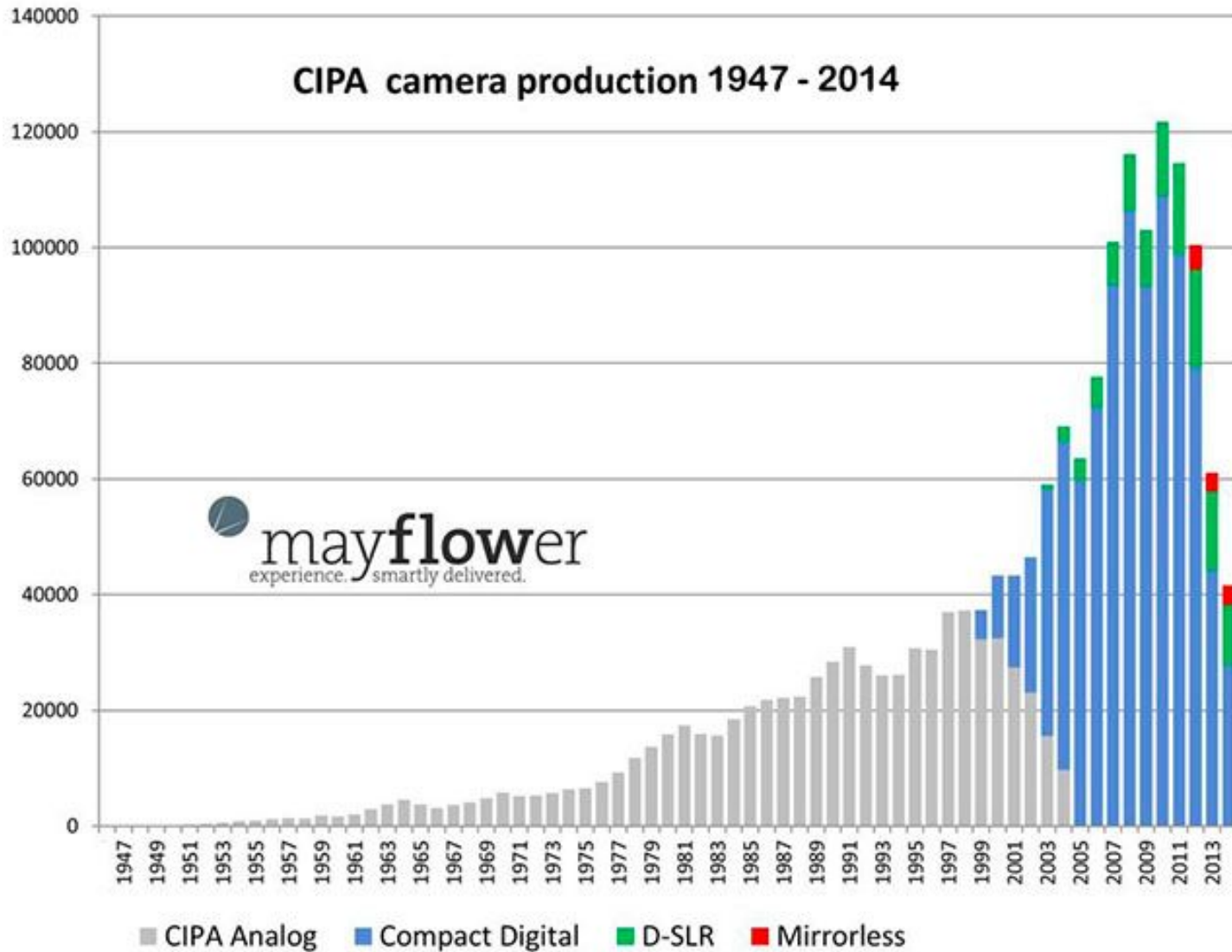
Price reduction: photos

- **Photos** taken worldwide
 - 2000: [80 billion photos](#) [easy to measure]
 - 2015: 1.6 trillion photos [20 times as many]
 - Price per photo has gone from **50 cents to 0 cents**.
- Increase doesn't show up in productivity measures since...
 - Price index for photography includes price of (**film, developing, cameras**) all of which are **vanishing**
 - Photos are mostly **shared, not sold** (non-market transaction)
 - GDP went *down* when cameras were added to smartphones, since people stopped buying cameras.
 - No quality adjustment applied to smartphones

Consumer surplus from free photos

- **Facts:** 80 billion photos produced in 2000 at a cost of \$40 billion; 1.6 trillion photos produced in 2015 at a cost of zero.
- **Surplus bounds**
 - If all of the incremental photos were worth nothing, consumers have saved \$40B
 - If all of the incremental photos were worth 50 cents a piece, consumers have gained \$0.8 trillion.
- Neither of these numbers shows up in GDP, since the price of a marginal photo is now essentially zero.

Camera production



BLS expenditure data for photos

Average spend per household			
Year	Processing	Film	Total
1990	\$25.60	\$19.88	\$45.48
2000	\$31.43	\$21.40	\$52.83
2014	\$4.90	\$0.50	\$5.40

Households reporting expense		
Year	Processing	Film
1990	25%	29%
2000	23%	24%
2014	3%	0.4%

Non-market transactions

Price reduction: GPS systems

- Vehicular monitoring systems for **trucking** in late 90s, early 2000s.
 - Price of GPS system was over \$1000
 - Productivity growth in trucking was twice aggregate productivity growth
- GPS systems for **households**
 - First, price of GPS devices fell to a few hundred dollars and then became free
 - GDP **went down** when GPS systems were absorbed into smartphones
 - (No quality adjustment for smartphones)

Product improvements: smartphones

A **mobile phone is a substitute** for a camera, a GPS, a land line, a game machine, an ebook reader, a computer, a movie player, an audio player, a map, a password generator, a fitness monitor, an alarm clock, a web browser, a calculator, a recording device, video camera, etc.

Building these capabilities into smartphones **reduced GDP** due to reducing sales of special purpose devices and the lack of quality adjustment for smartphones.

When price of a product goes down, real **GDP will typically increase ...** until the price hits zero at which point the product is **taken out of GDP!**

There can be no quality improvement for zero priced goods, imports, or household production.

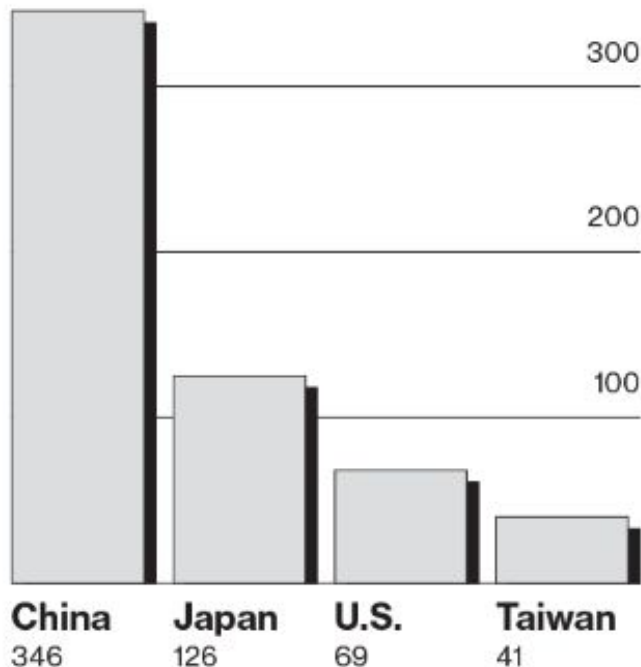
Makes sense for “economic activity”, doesn’t make sense for “standard of living” People *love* their smartphones...see NYTimes survey.

Global supply chain

Where is the iPhone made?

- Cupertino: Design, engineering, software, marketing
- Shenzhen: Foxconn assembly with parts from 28 countries.

Apple has suppliers in 28 countries ...



766 suppliers including...

- **Screen:** made by Corning, facilities in Kentucky, South Korea, Japan and Taiwan, cost: \$20
- **Processor:** designed by Apple, manufactured by Samsung and TSMC (Taiwan)
- **Cellular modem:** designed by Qualcomm, outsourced to Germany, Singapore, New York, Vermont, cost: \$15
- **Etc.**

Konstantin Kakes, "[The All-American iPhone](#)", Technology Review, June 2016.

What is an iPhone made of?

H																		He
Li	Be											B	C	N	O	F		Ne
Na	Mg											Al	Si	P	S	Cl		Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br		Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I		Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At		Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cp		Fl		Lv			

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

“...no tech product from mine to assembly can ever be made in one country,” says David Abraham, author of *The Elements of Power*.

Konstantin Kakes, “[The All-American iPhone](#)”, Technology Review, June 2016.

GDP accounting

- GDP is about what is **produced** in a **given country**.
- But today products are **produced *globally***.
- How can you disentangle this global supply chain?
- Note: **\$400 billion** of smartphones sold in 2015 worldwide



How does GDP measure software?

- Cost of creating software is an investment
- Embedded software is an intermediate product
 - Avoids double counting when product is sold.
- Example from 2013
 - Google's cost of developing Android operating system is an investment
 - Motorola installs Android OS on its smartphone assembled in Texas
 - Phone is sold for \$500 in US
 - Sale of phone counts in GDP, as software is already included as intermediate product [some parts are imported]
- Problem
 - But what if software is made in US and phone is assembled in China?
 - Part of the value of the phone is domestic, part is foreign
 - Important since:
 - All mobile phones are now assembled outside the US
 - Some "parts" (including the software) are made in the US

How does the GDP accounting work? [1993 SNA]

1. Apple sends design+software to China	0
2. Phone is assembled in China	\$150
3. Phone is imported to US	(\$350)
4. Phone is purchased in US	\$350
5. Net change in GDP is zero	0

Apple sending software to China is viewed as an internal transfer within firm. Assembly of phone in China is not counted as US production but creation of software counts as a US investment See Appendix for BEA's description. (We ignore retailing cost in US.)

How does the GDP accounting work? [2008 SNA]

1. Apple sends design+software to China	0
2. Manufacturing services imported from China	(\$150)
3. Phone is purchased in US	\$350
4. Net change in GDP is	\$200

Phone is considered to be domestically produced by “imported manufacturing services”. The \$200 can be thought of as valued added by software+design.

“Factoryless goods producers”

THE WALL STREET JOURNAL.

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<http://blogs.wsj.com/economics/2014/07/23/the-furor-over-factoryless-manufacturers/>

REAL TIME ECONOMICS

The Furor Over “Factoryless” Manufacturers

1. In 2014, OMB proposed US agencies adopt the FGP classification in [2008 SNA](#)
2. Received 22,000 comments objecting to change from labor unions and others
3. [OMB tabled the proposal](#) in 2014

How does the GDP accounting work? [suggested]

1. Apple exports design+software from US	\$200
2. Phone is assembled in China	\$150
3. Phone is imported to US	(\$350)
4. Phone is purchased in US	\$350
5. Net change in GDP	\$200

If you must use SNA 1993, then count software/design as an export using the imputed value from wholesale price - manufacturing cost. iPhone sold in France is a \$150 export from China and a \$200 export from US so a \$350 import to France.

“Designed in California, assembled in China.”

Android phones: 80% of mobile phones sold

- Android's operating system is **open source**
 - US GDP counts Android development as **investment**
 - US GDP counts installed **Android OS at zero**
 - US GDP counts **Android hardware at ~ zero** since it is (mostly) designed and assembled abroad
- So quality adjustment for Android smartphones won't show up in GDP anyway!
 - Software is key component for quality improvement
- **Total mobile phones sold worldwide = \$400 billion**
 - **Smartphone software** is (perhaps) **\$200 billion of US exports to ROW** in terms of "value"
 - Equals 1% of US GDP or about half of trade deficit

Factoryless production is not just high tech

Average household spend)

- Semiconductors
- Vehicles (\$4,000)
- Consumer electronics (\$1,600)
- Furniture (\$746)
- Toys (\$740)
- Clothes: (\$1,700)

Design of toys/furniture/clothes/etc is an investment
The payoff to that investment is the value added to
the cost of producing the hardware.

Further examples: autos and clothes

Ford 11,000 suppliers, 60 countries

- **Mustang**
 - windshield: Japan's Asahi Glass (Japan)
 - dashboard and center console: Faurecia (France)
 - seats: Recaro (Germany)
- **Focus**
 - bumper: Magna (Canada)
 - seatbelts: Autoliv (Sweden)
 - climate controls: Johnson Electric (China)

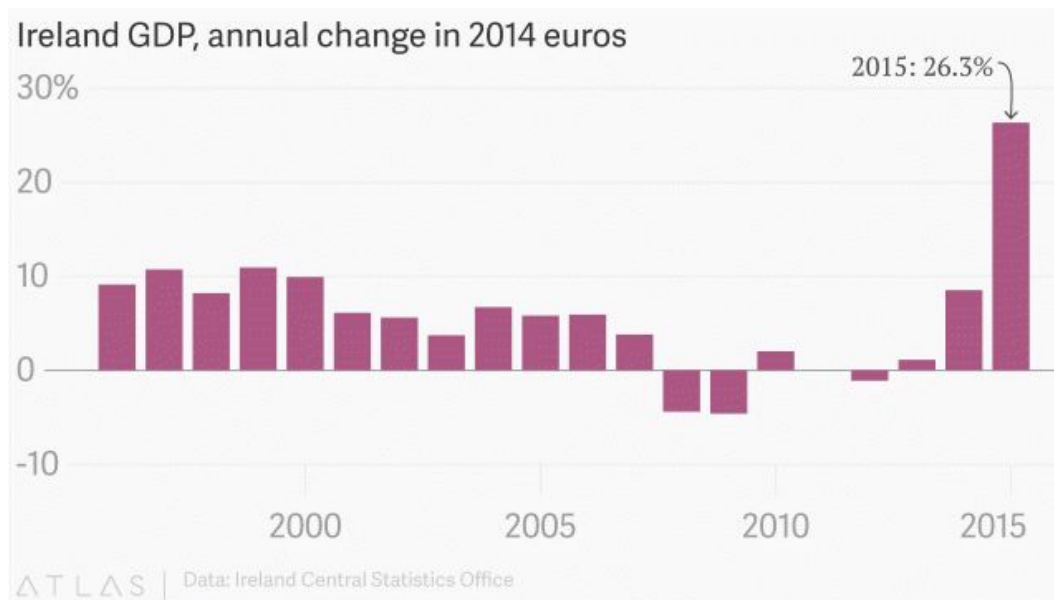
Clothes

- Cost is 20% of retail price, primarily made abroad

Country where IP is held may be relevant

IP may be created in one country but held elsewhere. The **Irish economy grew by 26%** in 2015 due to huge rise in [investment and net exports](#), caused in part by inversions. Pharma previously exported from US may now be considered as an export from Ireland.

Irish GDP



Semiconductors

Semiconductors

Rapid decline in semiconductor quality-adjusted prices in 90s, much slower since then. Virtually all of **productivity improvement in manufacturing** in the 1990s was due to **quality adjustment for semiconductors**. What about now?

“This slowdown in the rate of decline is puzzling in light of evidence that the performance of microprocessor units (MPUs) has continued to improve at a rapid pace.” Byrne, Oliner, Sichel [2015].

They examine 1) change in **pricing practices**, 2) **multicore CPUs**, 43% change v 8% change. I would add 3) **power consumption** due to demands from mobile devices and data centers and 4) **GPUs** and special purpose chips for machine learning.

Real value added avg annual growth rate 1997-2007

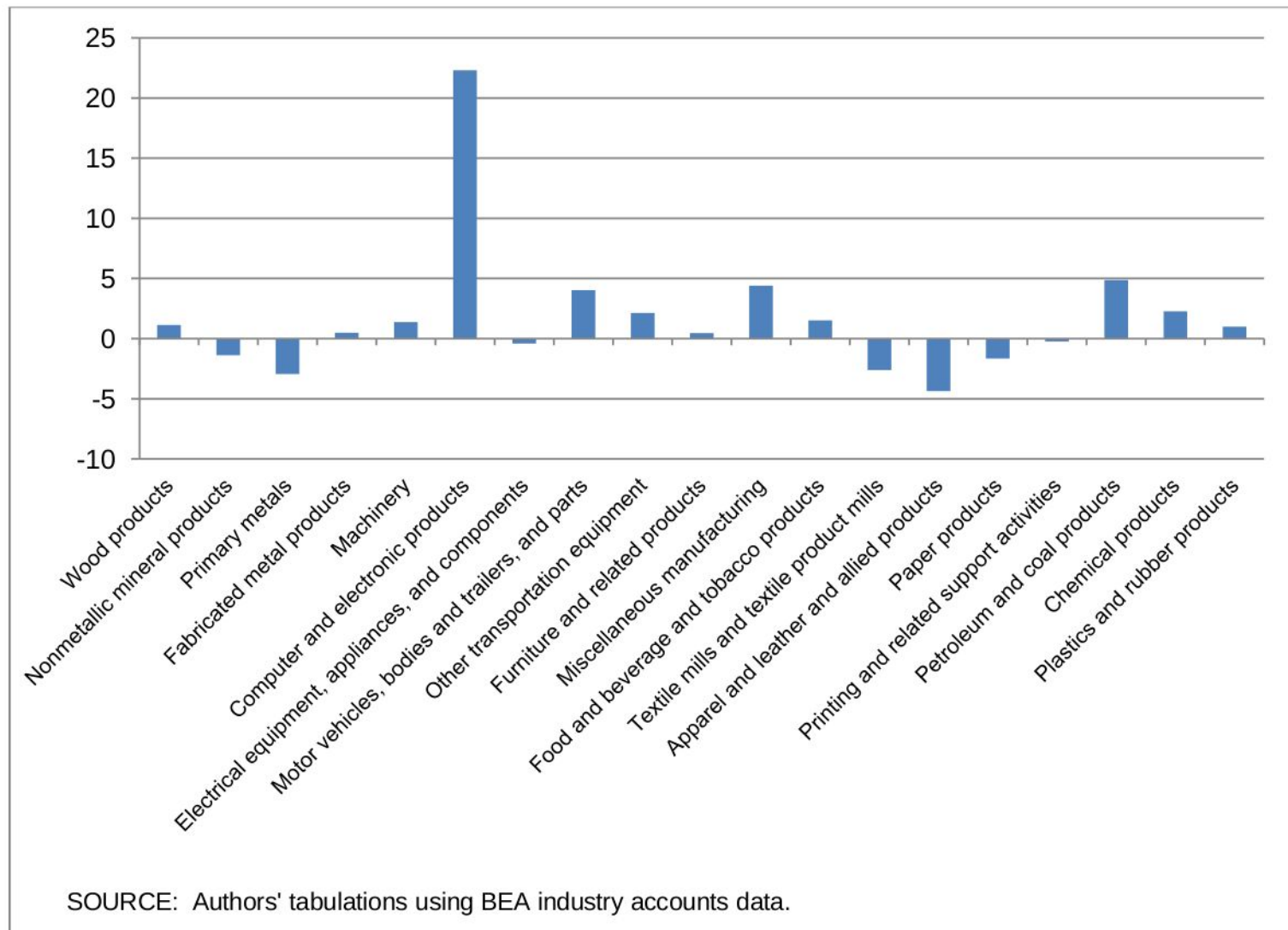
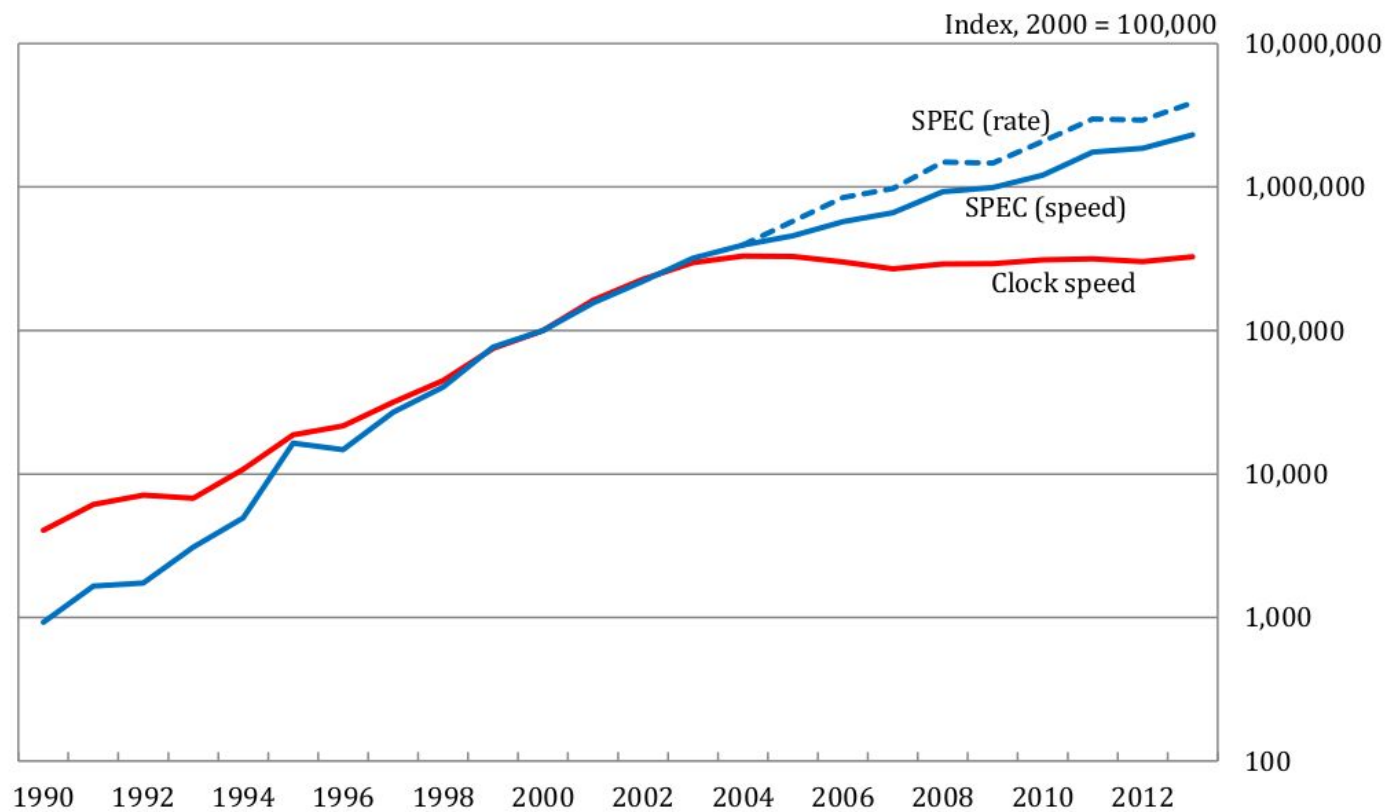


Figure 2 Average Annual Growth Rate, 1997–2007.

Quality change?

Figure 1: Desktop MPU Performance Measures



Source. Authors' calculations using data provided by Unni Pillai and performance information from Intel price lists and SPEC corporation.

Summary

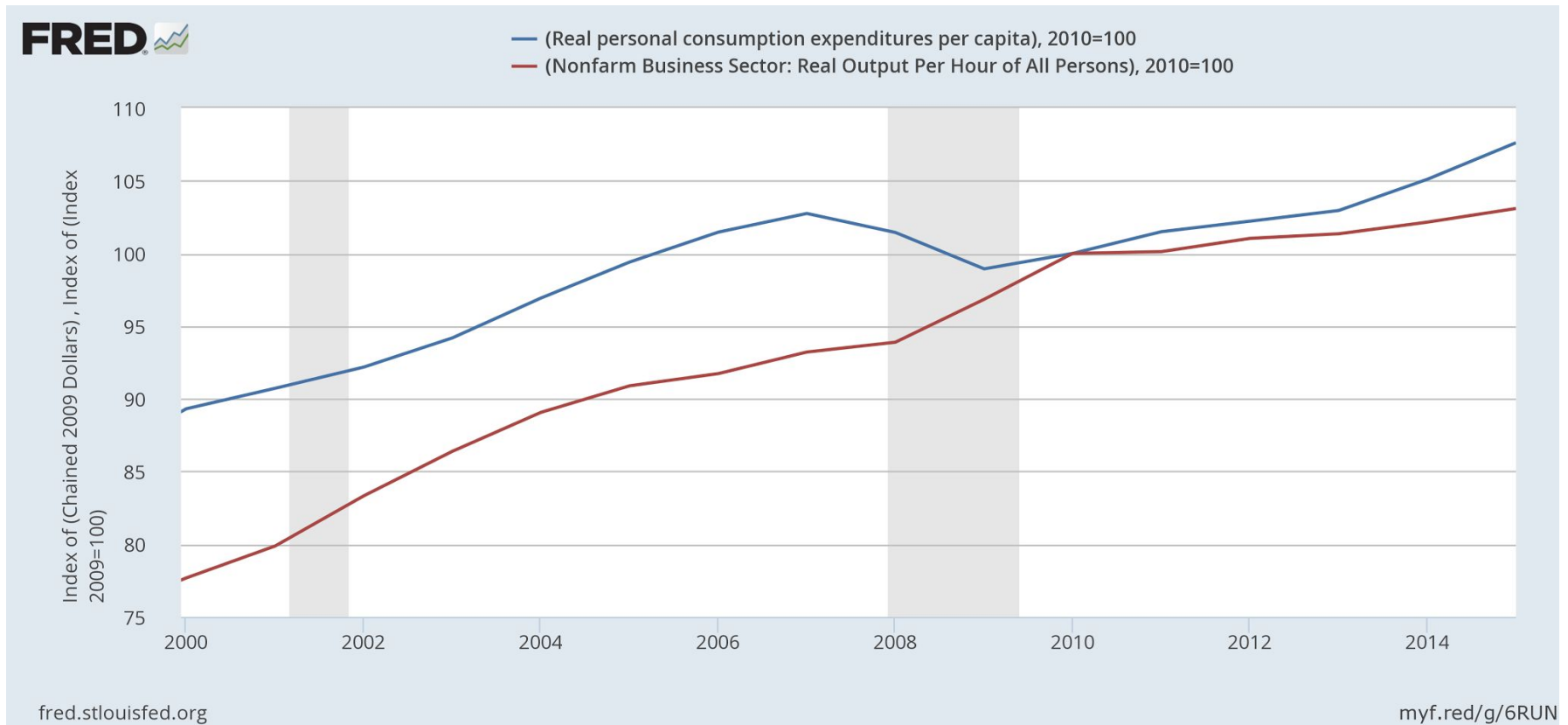
Conclusions and questions

1. GDP has problems with “**free**”
2. Big question: **is the measurement problem worse than it used to be?**
 - a. **Perhaps:** due to rise of global value chain, cloud computing, smartphones, unmeasured quality changes (all post 1980)
 - b. Quality adjustments for **semiconductors** needs updating
 - c. “ICT technological change potentially contributes as much as **1.4 percentage points per year to labor productivity growth**” Byrne-Corrado [2016].
3. Is there a better measure of “standard of living”? Perhaps. Consider domestic consumption using imputed prices for free goods.

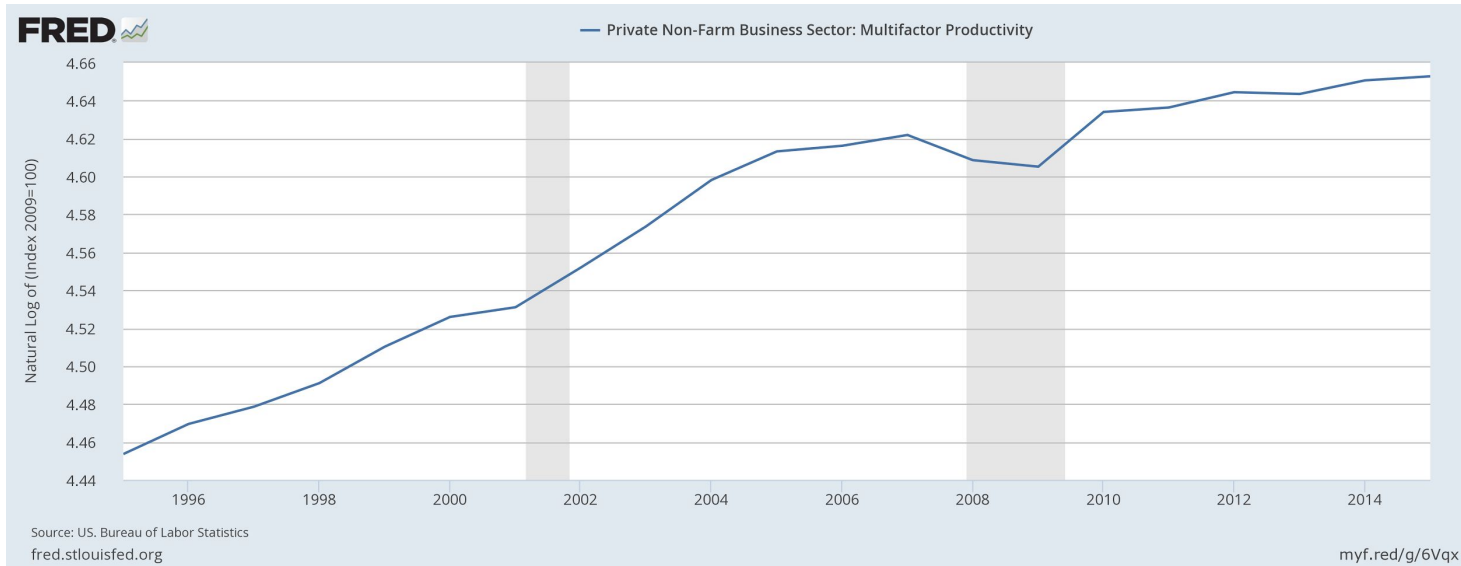
APPENDIX

Standard of living: per capita consumption?

- Imputed values for non market services
- More quality adjustment
- Even without these, per capita cons grew more than twice fast as productivity in last 5 years



Chinese imports and MFP (logs)



How the BEA treats smartphones

“How Government Statistics Adjust for Potential Biases from Quality Change and New Goods in an Age of Digital Technologies: A View from the Trenches”, Erica L. Groshen, Brian C. Moyer, Ana M. Aizcorbe, Ralph Bradley, and David M. Friedman, [Journal of Economic Perspectives](#), page 203:

“...consider a smartphone that is designed in the United States, produced in an Asian country, and then purchased and imported by the US firm for final sale. The Bureau of Economic Analysis counts the wholesale value of the phone, which may include the value of the US firm’s intellectual property, as an import and in final sales. Ideally, BEA would also capture the export of the intellectual property to the foreign producer on its surveys of international trade in services. However, under certain contract manufacturing arrangements, there may be no separate transaction for exports of design/software to the Asian manufacturer, thus understating exports in the national accounts.”

How to start up a startup...

- Fund your project on Kickstarter
- Hire employees using LinkedIn
- Cloud cloud computing and network from Google, Amazon, MS
- Use open source software like Linux, Python, Tensorflow, etc
- Manage your software using GitHub
- Become a micro-multinational and hire programmers from abroad
- Set up a Kaggle competition for machine learning
- Communicate with Skype, Hangouts, Google Docs, gmail
- Use Nolo for legal documents (form company, patents, NDAs)
- Use QuickBooks for accounting and TurboTax
- Market your product using AdWords
- User support provided by ZenDesk for user support

IT's ALL OUTSOURCED!!

THE END