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# ICT, growth and happiness

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# Summary

This paper reviews two strands of literature. The first is on *Information and Communication Technology* (ICT) and growth. The increasing role of ICTs came together with stagnating growth rates in many countries. This has been denoted the *Solow paradox*. During the dot-com era from the mid-1990s, many believed that the paradox was solved. Growth rates increased and the internet became pervasive. The great recession has been followed by lower growth in Europe and in the United States and a return of the Solow paradox. Evidence indicates that the share of internet users in a population had a positive effect of growth in the 1990s, but that this effect vanished for developed countries after 2000. The second strand of literature is a heterogeneous research tradition that relates ICT not to income and growth, but to human well-being. That literature indicates positive (as well as some negative) effects of ICT and the internet on people's happiness. Some new evidence indicate that the share of internet users in populations in a panel of countries is positively related to average happiness.

# Introduction*

Information and communication technology (ICT) has always had major importance for human development. In all human history ICT has, in some forms or others, had implications and consequences for economic, social and cultural interaction among humans. Collecting, producing, exchanging, storing, coding, adapting and using information has been important for mankind throughout history. Written and spoken language are *information* and *communications* technologies. Dudley (1999) traces the influence of communication technologies for economic growth over a millennium. Modern ICTs are varieties of old and basic human technology. In this paper, focus is on electronic and mostly digital technology for information and communication.

Modern ICT has gained increasing importance. The ICT industry is large and growing. ICT is being used in all types of economic activities, from simple traditional production to advanced, complicated and integrated production processes, via public and private planning and governance to household production and consumption for individuals. ICT is far-reaching and influences all types of human behavior. While ICT became widespread both in production and consumption from the 1970s on, the internet sparked much more rapid and larger changes. Today, the internet has become omnipresent for most production processes and for most people around the globe. ICT is a general purpose technology (GPT) in the sense that it is used for many purposes, in many applications and that its use involves changes that have potential systemic effects.

There is an enormous literature on ICT and economic growth. This literature traces growth effects from introduction and use of ICT among firms, case studies, effects of ICT in industries and studies at macro level for single or many countries. Some findings in this literature are summarized in section 2 below. The Solow paradox is an important issue in this literature. Even if growth effects from ICT (as measured by increase in GDP) are hard to find, there is no doubt that ICT influence

* I thank Arne Melchior, Jens C. Andvig, Hege Medin and Fulvio Castellacci for comments on a previous version of this paper. This paper was written with financial support from the project Responsible Innovation and Happiness: A New Approach to the Effects of ICTs, founded by the Norwegian Research Council.

people's lives. A main interest in this paper is the relationship between ICT and human well-being or happiness. The use of well-being measures in economics is discussed in section 3. Well-being relates to more than income. Well-being also depends on human sodality, environmental standards, democracy, health and security. In section 4 implications of ICT on happiness are discussed. Section 5 summarizes and concludes. In the next section, some characteristics of ICT are presented and discussed.

The topics discussed in this paper are many and involve important and complicated issues. This paper is not exhaustive neither in summaries of the literature nor in coverage of topics or mechanisms. Rather, the main purpose is to give a short overview of impact of the ICT revolution (or evolution) for human well-being.

# ICT - conceptual issues

There is no doubt that recent years have witnessed dramatic changes in the nature of, the use of and the diffusion of ICT. These changes have happened very fast and they represent *quantitative* and *qualitative* change. Historical comparisons do not overshadow the fact that recent changes in ICT have accelerated and become more pervasive recently. But rapid developments in ICT are not new.

Samuel Morse patented the electric telegraph in 1837 and developed the Morse alphabet. The telegraph was developed fast on both sides of the Atlantic and these telegraph nets were connected with a trans-Atlantic cable in 1866. Obstfeld (1998), writing about international integration of capital markets, notes that (p. 11) “This communication advance in the era was perhaps more significant than anything that has been achieved since”. Almost in the same period, telephones expanded rapidly, from its invention in 1876. Developments were fast and by 1940, 40 percent of all American households had a telephone. In 1915 it took twenty-three minutes to connect telephones between New York and California. In 1951 it took eighteen seconds. In 2013, 91 percent of all American adults had a cell phone.[1]

The radio was developed in the beginning of the twentieth century after inventions inspired by Maxwell’s theories of electromagnetism in the 1860s (see Freeman and Soete, 1997). Developments, led by companies such as Marconi (UK), Telefunken (Germany) and RCA (US), were rapid. Radio became important for communication as well as for mass-consumption of news and entertainment. From radio technology television developed. Based on ambitious R&D projects, RCA launched commercial television in 1939. In 1970 sales of colour TVs in the USA reached five million per annum. European and Japanese producers had followed. The introduction of television involved mass entertainment more than the radio did.

From the 1930s on, R&D was devoted to development of the radar which gained widespread use for military purposes in the Second World War (Freeman and Soete, 1997). The invention of the radar later inspired development of the laser which subsequently gained

[1] Gordon (2016) p. 430.

widespread use in the computer industry (and in particular for CDs) (see Scotchmer, 2004, ch. 5)

The developments of the computer is described in e.g. Ruttan (2001). Its history dates back to long before World War II. IBM was founded in 1924. There was great optimism about potential achivements of the new technology. In 1950, CEO of IBM, Thomas Watson Snr., claimed that the recently developed *Selective Sequence Electronic Calculator* (SSEC) was sufficient to “solve all the important scientific problems in the world involving scientific calculations”. Due to this optimism about potential performance, there was pessimism about the commercial possibilities for computers. Because of the performance, there would not be need for many computers, pessimists feared. It took decades before use of computers become widespread. Life insurance companies bought the first commercially available computer, the UNIVAC 1, from 1954 onwards. But “Progress was slow, because the initial computers did little more than juggle data read from punch cards and printed by punch-card printers” (Gordon, 2016, p. 449).

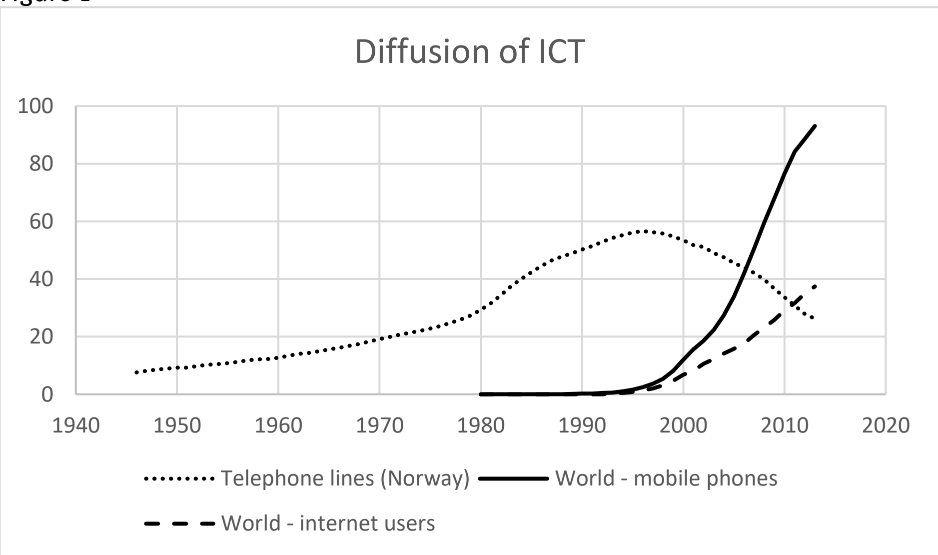
Computers gained widespread use in larger corporations and public agencies before 1980. In addition, from about 1985 PCs became common for individual consumers. PCs became standard for writing, computations, accounting, design work and many other tasks during the 1980s. They were pervasive in business, public governments and households in the 1990s.

The diffusion of computers was closely related to Moore’s law. Computers became more powerful and rapidly cheaper over time. Moores’ law is the observation that computing capacity seems to double every 18$^{th}$ month (Gordon, 2000 and Aizcorbe and Kortum, 2005). Gordon Moore observed in 1965 “that each new memory chip contained roughly twice as many transistors as the previous chip and was released within 18-24 months of its predecessor” (Jorgenson, 2005, p. 748). In 2003, Moore continued being optimistic about future developments in ICT: “No exponential is forever, but we can delay forever” (Moore, 2003). Gordon (2002, p. 51) writes that the cycle in which computers double their performance had shortened to 12 months in 1999, but that it has increased to almost six years after 2006 (Gordon, 2016).

Caselli and Coleman (2001) study diffusion of ICT-equipment for a cross-section of countries. The point of departure is that most countries have a relatively small ICT industry. Therefore the use of ICT equipment is indicated by countries’ imports of such goods. These are easily available data. In data for the period from 1970 to 1990, Caselli and Coleman find that imports of ICT equipment depend on countries' investment shares, the share of manufacturing in GDP, protection of intellectual property rights, level of education and imports of manufactured goods from OECD countries. Interestingly, similar variables also have explanatory power for GDP itself. This points in the direction that ICT is complementary to other growth promoting variables.

Despite many past technological breakthroughs for ICT, many regard the introduction of PCs, the launch of the internet and the digitalization of many production and consumer processes as qualitatively different from previous advances. First, the size of the modern ICT industry is higher than before. Second, the use of ICT is more widespread than before. Third, complementarities, network effects and massive economies of scale have become more important than before. Use of the internet is now common for most people in rich countries and access is becoming available throughout the world. This has come together with smartphones that enable use of the internet everywhere people have access to mobile telephone subscription. The development has been fast and faster than diffusion of previous technologies. Figure 1 graphs diffusion of the number of mobile phone subscribers and users of the internet worldwide, and (for comparison) the number of standard telephone lines in Norway.

Figure 1




Note: Numbers are per 100 inhabitant. Number of internet users is the number who have used internet during the last 12 months. Telephone lines in 1997 in Norway is calculated as the average between 1996 and -98 due to an unexplainable peak. Source: World Development Indicators and Statistics Norway.

The graph illustrates three important aspects about diffusion of internet technologies. The first is the typical S-shaped diffusion. At first diffusion is slow. Thereafter it accelerates and diffusion is fast. When the technology has matured, diffusion is slower and it takes longer for latecomers to apply the technology. The graph shows that the S-shape also was present for diffusion of telephones (in Norway). Hall (2005) analyses diffusion of many technologies. The S-shaped diffusion pattern is typical. Hall discusses heterogeneity among consumers and producers, learning effects and network effects as explanations. Technology is first adopted among those who need it the most. Thereafter consumers and producers who need is successively less start using the technology. If consumers' utility from the technology is normally distributed, the cumulative share of users over time will have the S-shape. Similar effects come from learning. Users of technology learn from each other. If there are few users, learning is limited but increasing. When the technology is widely adopted, there are fewer left to learn. Also network effects give similar diffusion. Network effects denote that utility from being a network member increases with the number of network members. Therefore the utility from adopting a technology increases with the number of other users. Stoneman and Battisti (2010), Geroski (2000) and Stoneman (2002) survey this literature.

The second aspect from the graph above is that diffusion of the internet has been fast (compared to diffusion of telephone lines in Norway, but also compared to many other technologies).[2] In 2015 about 44 percent of the world's population were internet users.[3] In many countries, the share of internet users approach 100 percent. In OECD countries, the number of internet users expanded from 60 percent in 2005 to 80 percent in 2013. In other countries, the share of internet users is on the steepest part of the S-curve. A reasonable prediction is therefore that the share of the world population that uses the internet will continue to increase fast in the years to come. Increasing internet use has benefited from development of mobile infrastructure. Wireless broadband subscriptions in the OECD increased from 250 million to 850 million from 2008 to 2013. In sub-Saharan Africa mobile broadband subscriptions grew from 14 million to 117 million between 2010 and 2013 (OECD, 2014a). In addition comes that broadband connection is becoming less costly. OECD

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[2] Gordon (2016) describes diffusion of television in the United States, which was even faster than diffusion of mobile phones and the internet. In 1950, 9 percent of American households owned a TV set. In 1955, this number had increased to 65 percent.

[3] By 2017, therefore, probably most people in the world are internet users.

(2014a) reports price developments. In most countries, price indexes for broadband decrease. There is great variation in broadband prices between OECD countries, with prices being about three times higher in the United States than in South Korea (which is followed by Hungary, Slovakia, Israel and Denmark).

The last aspect from the graph is that internet substitutes for other technologies. Telephone lines reached a peak at almost 60 per 100 habitant in 1997. Thereafter the number of lines has decreased. The reason is obviously the diffusion of cellular phones.

The fast growth and diffusion of ICT (and the internet in particular) is closely related to technological development in the ICT industry. Moore's law implies that real prices for computers halves every 18 month. There is also quality improvements in other dimensions. Broadband speeds increase and allow full internet services for cellular phone and tablet users.

Research on price developments in ICT is demanding. Computers today are radically different from computers just 5 or 10 years ago. Computers today are even more different from those in the more distant past. Dale Jorgenson is a pioneer in calculating and estimating hedonic price indexes for (among other goods) computers.[4] Hedonic price indexes take into account nominal price changes as well as quality improvements for the goods in question. Jorgenson (2005) presents several results. Some of these are reported in figure 2. That figure shows hedonic price indexes for computers, software, telecommunication and for ICT in aggregate. Also reported is the price index for GDP. The scale in the figure is in logs and so that (log of) prices in 2000 is zero. Values below zero indicate lower prices than in 2000.Values above zero indicates prices higher than in 2000.

The striking fact evidenced by figure 2 is the dramatic decline in prices for computers. The decline has evolved in cycles. In the 1970s, it decelerated first and then accelerated. Price decline was slower during most of the 1980s. After 1995, price declines accelerated again. According to the figure, a computer was 1 635 times more expensive in 1960 than in 2000 (in logs, 7.4). This corresponds to an annual price decline of 18 percent. Software, on the other hand, has had relatively stable prices. But compared to other goods and services (the price index

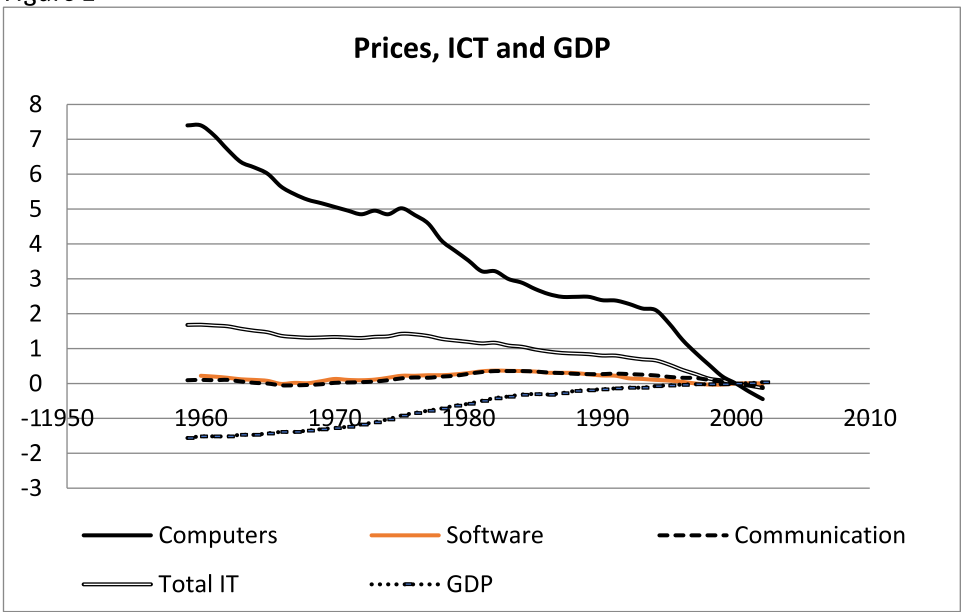
[4] For hedonic price indexes for computers, also see Chow (1967) and Berndt and Griliches (1990).

for GDP), prices of ICT has decreased dramatically in the period described by figure 2.

Gordon (2016) compares real price declines for ICT goods with prices developments for other goods undergoing rapid technological change. He claims that large price declines have been frequent also for other goods. Gordon's estimates of price declines for TV sets in the period from 1952 to 1983 is 4.3 percent annually. Gordon notes that this estimate is "doubtless an understatement" (Gordon, 2016, p. 423). After hedonic price indexes for TV sets were introduced in 1998, estimated price declines per year were 20.4 percent. Raff and Trajtenberg (1995) estimate hedonic price indexes for automobiles in the 1906-40 period. They conclude that hedonic prices fell at an average annual rate of 5 percent. Gordon notes that previous underestimates of price declines also underestimated GDP *growth* more in the past than in the present. Still, Gordon concludes (p. 441):

> *"The improvement in the performance of computers relative to their price has been continuous and exponential since 1960, and the rate of improvement dwarfs any precedent in the history of technology."*

Figure 2




Source: Jorgenson (2005).

Economists have since long agreed that technological change is a main source of economic growth.[5] Important in this respect is Solow

[5] The agreement has weakened somewhat recently. In the wake of the literature about endogenous growth, technological change is the result of economic mechanisms

(1957). Solow decomposed contributions to growth in the American economy in the period from 1909 to 1949 from investments and from increasing employment. Solow's main idea was that with observable changes in production, in use of capital and in employment, one can also estimate the contributions to growth from non-observable variables. These non-observable variables were denoted *Total Factor Productivity* (TFP). Important and controversial assumptions in this *growth accounting* framework is that there is perfect competition (so that labour and capital are paid according to the value of their marginal productivities) and that there is constant returns to scale in production. Solow's main conclusion was that 87.5 percent of observed growth could not be explained by investments or use of labour. This part of growth was therefore attributed to technological progress. Solow's study inspired many subsequent studies. These refined on methods and often decomposed growth into contributions from capital, labour, human capital and technological change. Often, estimates of the contributions from technological change has been more modest, though still large, in more recent studies. An overview is provided in Barro and Sala-I-Martin (1995) ch. 10 and in Jorgenson (2005).[6]

With pervasive adoption and use of ICT in almost all industries (in particular in rich countries), there was great optimism about growth potentials from this type of technology. Many believed that ICT could have far-reaching implications and change the entire economic system and also involve changes in social factors such as working and family life (see e.g. presentation of the book by Helpman (1998)). ICT was compared with previous technological shifts such as the industrial revolution, the steam engine, electricity, motors powered with electricity and the petrochemical industry. Such shifts has been identified as *technological paradigms* (Dosi, 1988) or *General Purpose Technologies* (GPTs). ICT has been characterized as a *General Purpose Technology* (GPT). GPTs have received increasing attention in the literature on economic growth and technological change.

GPTs are characterized as being *general, having widespread use, stimulating further innovations and being complementary.*

GPTs are general in the sense that they have applications in many industries and for many purposes. This is clearly the case for ICT. ICT is

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and in need of explanation itself. As primary explanations for growth have *geography* and *institutions* emerged as candidates (see e.g. Diamond, 1997, Acemoglu *et al*, 2005 or Rodrik *et al*, 2004).

[6] Note that several contributions have relaxed the assumptions of constant returns to scale and perfect competition. See e.g. Feenstra (2004) ch. 10.

used in all industries and for many purposes. OECD (2014a) reports that 94 percent of enterprises in the OECD countries had a broadband connection and that 75 percent had a webpage. Use of ICT include information flows management, accounting, planning, writing, copying and supply chain management. Use of ICT varies between countries and for different purposes. About 50 percent of all firms used e-purchase while 20 percent conducted e-commerce sales in 2013.

ICT has indeed stimulated innovation. Moore's law exemplify that the ICT industry is itself a highly innovative industry. ICT is used for countless purposes and ICT is a major ingredient in all types of research and development (R&D). ICT has stimulated innovation in many industries. OECD (2014a) reports that ICT industries are the most R&D intensive. ICT is used for innovation purposes in most industries. Firm-level data indicate that innovating firms are more ICT intensive than other industries (OECD, 2014a)

ICT is complementary with other types of technology. ICT is used for monitoring, planning, supervision and many other purposes in most industries. Evidence about complementarity abound. One example is that about 25 percent of patented inventions attributed to ICT related technologies are also labelled under other technology classes.[7]

ICT is flexible. ICT can be used for many purposes and be adopted to special needs and requirements in different applications, in different industries and firms and for different persons.

There are many surveys and review articles about ICT as GPT. Examples are Bresnahan (2010), Jovanovic and Rousseau (2005), Bertscheck (2003) and Rousseau (2008). In some of these, ICT is compared with previous GPTs. Many believe that growth effects from ICT will be large. Others warn against effects for income distribution, employment and social life (see e.g. Brynjolfsson and McAfee, 2014, or Keen, 2015). Gordon (2000 and 2016) remains skeptical about growth potentials from ICT.

Cordona *et al.* (2013) relates GPT technologies to spillovers, where social returns from investments exceed private returns. If there are spillovers from ICT producing industries to ICT using industries and from ICT using industries back to ICT producing industries (vertical spillovers), growth may breed itself. Also horizontal spillovers either in

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[7] In patent documents, patents are assigned a technology class (IPC). Patents are sometimes assigned to several IPC-classes.

ICT producing industries or in ICT using industries may be growth promoting.

ICT also has other characteristics. On many instances, ICT has implied *path-dependency*. Path-dependency explains how history matters. One point of departure gives a different result than another point of departure. Often this results from high costs from changing direction. The best-known example is the QWERTY keyboard. It has been claimed that the QWERTY keyboard was introduced in order to reduce the speed with which people wrote on typewriters (David, 1985). A too high speed made the typebars in old fashioned typewriters to "clash and jam together". David writes (p. 333):

> *"From the inventor's trial-and-error rearrangements of the original model's alphabetical key ordering, in an effort to reduce the frequency of type bar clashes, there emerged a four-row, upper case keyboard approaching the modern QWERTY standard."*

The standard was introduced for a completely different reason than what can be relevant today. Still the keyboard is today's standard. David assumes that the reason is costs of changing the established standard. David's argument has later been criticized (see Kay, 2013 for an overview). Still, the case is an illustrating example of path-dependency. Standards are chosen based on very different circumstances from the circumstances under which the standards get widespread use. Therefore, choice of standards can involve errors due to future changes and therefore impose high extra costs in the economy.

Whether path dependency is a major obstacle for change is an open question however. There are many counter examples about rapid technological shifts in use and production of ICT. The telex and the telefax are now outdated by scanning and email correspondence. So is the cassette (and the CD) format for storing and playing music. The video cassette is also out of use.

ICT is network technology. Utility (or productivity effects) from use of ICT increases in the number of users. This is obviously the case for telephone and the internet. If nobody else has a telephone, there is no need for it. Use of the internet is more useful when there are many internet pages. Information and *communication* technology implies human interaction. ICT therefore involves interaction among several human beings (and/or machines).

Since utility increases in the number of users, there are positive externalities from use of ICT. But the marginal user pays a price that equal his marginal utility. Therefore the market solution for ICT may involve too few users. It is easy to think of examples. Facebook-groups for groups where some members are not facebook-users are imperfect. Since utility from networks increases in the number of users, the social marginal utility for an extra user is higher than the marginal utility this marginal user obtain. Schotchmer (2004) and Shy (2001) analyses network effects. They demonstrate that markets for network goods may have multiple equilibria. If everybody expects that use will be widespread, there will be many users. If everybody expects that use will be limited, there will be few users.[8]

Modern network based ICT is different from traditional ICT in the sense that it is often multilateral. Telephone is bilateral while television and radio are unilateral. With modern ICT there are not defined senders or receivers. Rather, all users are (potential) senders and receivers. And, different from telephone, but similar to old fashioned paper mail, ICT does not require that senders and receivers are active at the same time. ICT service production therefore differs from other types of service production (which are often characterized as requiring consumption and production at the same time and at the same location, with haircutting being one example).

ICT depends on infrastructure investments. Infrastructure very often has *public good* characteristics. Once in place, marginal user costs are low or zero (in absence of congestion effects). Infrastructure reduces transaction costs which are important for well-functioning markets. Broadband investments have had priority in recent years.[9] Most OCED countries have reached high coverage of internet broadband. According to OECD (2014a) more than 70 percent of the population in the OECD countries has access to wireless broadband.

Quah (2003) emphasizes that the goods produced by ICT are *digital goods*. Such goods have five characteristics that distinguishes them from other goods. Digital goods are *non-rivial, infinite expandable, discrete, non-spacial and recombinant*. Use of non-rival goods can increase infinitely without reducing consumption possibilities for

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[8] Network effects can be hard to identify. Brynjolfsson and Kemerer analyse the market for spreadsheets in the 1987-1991 period. They find that prices for spreadsheets depend on product characteristics, a time trend *and the accumulated* number of the particular spreadsheet sold. They find positive effects of the latter and interpret it a network effect. They acknowledge however, that also strategic pricing may play a role.

[9] Broadband include connections with data speed of 256 kbit/s or more (OECD, 2014a).

existing users. Infinite expandable means that digital goods can be reproduced infinitely without changing the nature of the original. Copies are identical to the original. Digital goods are discrete in the sense that they cannot be partitioned into parts. Digital goods are non-spacial. They are everywhere and no-where. For production of digital goods, geographical market access is irrelevant. Therefore production can be located independently of market location. Quah argues that this facilitates clustering of production of ICT goods. Since market access has no relevance, production can locate where it is most efficient. Digital goods are recombinant. They can be combined and re-combined in countless versions. Weitzmann (1998) has argued that knowledge and knowhow can grow without limits because of unlimited possibilities for combining existing ideas in a model of economic growth. The number of websites grew from 18 500 globally in 1995 to more than 3 350 000 in 1998. Larry Page and Sergey Brin developed Google as a tool for handling this overload of information. The enormous amount of information also gave name to Google, an unintentional misspelling of *googol*, the mathematical number $1.0x10^{100}$, which denote an extremely large number (see Keen, 2015).

The characteristics of digital goods make them well suited for knowledge sharing and diffusion. Innovating firms in the ICT industries report on collaboration in their innovative activities more often than firms in other industries (OECD, 2014a). However, international collaboration in R&D has not increased much in any technology field (as measured by international co-invention as evidenced in patent documents).

Vannebar Bush (1945) contemplated about future for mankind after World War II. After five years of intense destruction, new efforts for human progress were called for. Scientists could now concentrate on constructive roles for building a better future. A main challenge for scientists is that (p. 3) “There is a growing mountain of research. But there is increased evidence that we are being bogged down today as specialization extends.” But with new storage possibilities, existing knowledge could be made available (p. 8): “The *Encyclopedia Britannica* could be reduced to the volume of a matchbox.” But also data analyses needed to improve (p. 11):

> *“The advanced arithmetical machines in the future will be electrical in nature, and they will perform at 100 times present speeds, or more. Moreover, they will be far more versatile than present commercial machines, so they may readily be adapted for a wide variety of operations.”*

But the future has wider promises, for instance the “memex” (p.18-19):

*“Consider a future device for individual use, which is a sort of file and library. … A memex is a device in which an individual stores all his books, records and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. .. It consists of a desk, … On the top are slanting translucent screens, on which material can be projected for convenient reading. There is a keyboard, and sets of buttons and levers. … Most of the memex contents are purchased on microfilm ready for insertion. Books of all sorts, pictures, current periodicals, newpapers, are thus obtained and dropped into place. Business correspondence takes the same path.”*

And (p. 19-20):

*“It affords an immediate step, …, the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another. This is the essential feature of the memex”.*

Bush concludes (p. 24):

*“The applications of science have built man a well-equipped house, and teaching him to live healthy therein. They have enabled him to throw masses of people against one another with cruel weapons. They may yet allow him truly to encompass the great record and to grow in the wisdom of race experience”.*

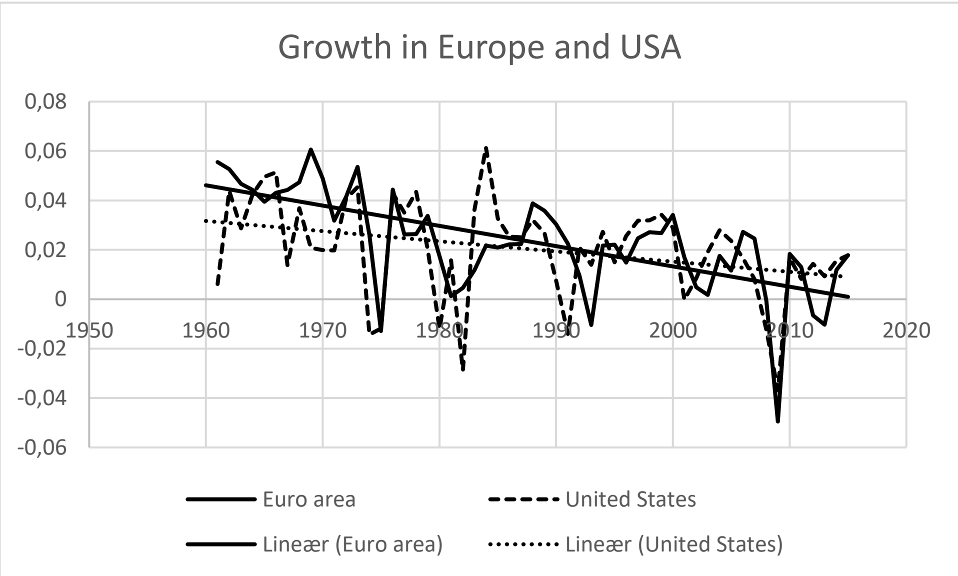
Vannebar Bush’s ideas about the memex influenced generations of computer scientists, who drew inspiration from its vision of the future.

# Growth effects from ICT

## Macro data

Many have shared Vannebar Bush's optimism. The GPT characteristics of ICT could indicate growth-promoting effects. First, the ICT industry itself has grown large. Second, ICT is used in all industries. ICT is complementary to other types of technology and may enhance returns from investments in physical and human capital in many activities. ICT is network based and growth effects could be increasing in the number of users. ICT facilitates reorganization of work life in order to enhance benefits form specialization. Digital goods are characterized by massive scale economies. Observed investments in ICT have been high. Most enterprises now use ICT for many purposes. Introductions of GPTs have previously resulted in high growth rates. Steam engines, the internal combustion engines, the steel industry and mass production are examples of GPTs that stimulated growth after their introduction. Still, growth effects from ICT are debated among economists. One reason is the trends showed in figure 3. That figure graphs annual growth rates in the United States and in Europe (EU member countries) in GDP per capita (in constant 2010 USD) in the period from 1960 to 2015. Along with the data are linear trend lines (from linear regressions).

Figure 3




Source: World Development Report, 2016.

The graph shows clear ups and downs in growth rates. The 1960s had high growth rates. In the 1970s there was a recession in 1974-75 and in the 1980s growth rates went from negative to very high. The great recession in 2008-09 is clearly visible in the graph. Over time, the picture is one of stagnating growth rates, however. This is so for the United States and for Europe, and for Japan as well. The trend lines are falling. European growth rates started higher than those in the United States but trended downwards over the period covered by the graph. In recent years trend growth has been lower in Europe than in the United States. This is the Solow paradox, which is the combination of high investments in ICT and at the same time, low growth rates in productivity (Solow, 1987). He writes in his famous book review that:

> *"What this means is that they, like everyone else, are somewhat embarrassed by the fact that what everyone feels to have been a technological revolution, a drastic change in our productive lives, has been accompanied everywhere, including Japan, by a slowing down of productivity growth, not by a step up. You can see the computer age everywhere but in the productivity statistics."*

Arguing along the same line, Dudley (1999), p. 596 writes:

> *"A paradoxical feature of the productivity-growth slowdown of the 1970s and 1980s is that it coincided with very rapid innovation in information technology"*

Optimism substituted for pessimism in the 1990s. In that period growth rates had increased in the United States and there was much optimism about the dot-com economy. It is seen in Figure 3 that growth rates increased both in the American and in the European economy in the 1990s. The high growth rates in the 1990s were taken as evidence that the Solow paradox was solved. The interpretation was that "Computers are now everywhere in our productivity statistics" (Acemoglu *et al.* 2014). Cardona *et al.* (2013) notes that the higher growth rates in the United States in this period was taken as evidence of the GPT characteristics of ICT: efficiency gains from implementation of more productive ICT equipment was not limited to the ICT industry only, but created productivity growth also in other parts of the economy. For instance, Stiroh and Botsch (2007) find that growth effects spilled over from ICT producing industries to industries that used ICT.

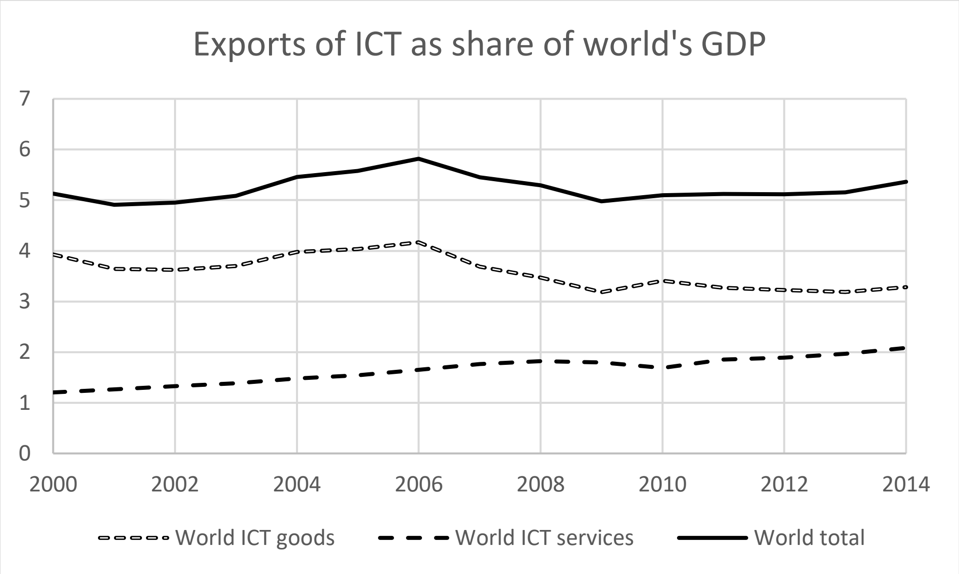
But thereafter, growth rates have decreased again. Whether this is permanent or transitory is a matter of debate. There has been a long debate among economists about the Solow paradox. In recent years, Jorgenson (2005) and Brynjolfsson and McAfee (2014) are examples from the optimist camp while Gordon (2016) and Acemoglu *et al.* (2014) are examples from the pessimist camp. Below is a discussion of recent contributions such as these. Triplett (1999) reviews the earlier debate.

Triplett proposed that computers constitute a too small share of the economy to generate large growth effects. Based on Oliner and Sichel (1994) and Jorgenson and Stiroh (1995), Triplett presents results from growth accounting where contributions to growth from investments in ICT are estimated. Even if there is fast growth in the scale (and quality of) ICT investments, they still contribute little to overall productivity growth. In the 1980-92 period, ICT investments contributed with about 15 per cent of output growth while ICT equipment contributed with only 5 per cent of total output growth in the 1990-96 period. Some estimates indicate higher effects from ICT. But Triplett concludes that (p. 313): "Still, the share of computing equipment is too small for any reasonable return to computer investment to result in a large contribution to economic growth."

This is still relevant. You can see the computer everywhere. One reason is obviously their costs, which have decreased dramatically. ICT industries lead in growth in labour productivity as compared to other industries (OECD, 2014a). But the size of the ICT industry is limited. In figure 4 below, another measure of the importance of ICT is presented. That figure graphs the share of exports of ICT goods and ICT services in the world economy.[10]

[10] ICT service exports include computer and communications services (telecommunications and postal and courier services) and information services (computer data and news-related service transactions). ICT goods exports include computers and peripheral equipment, communication equipment, consumer electronic equipment, electronic components, and other information and technology goods (miscellaneous). The definitions are explained in *World Development Indicators* (2017).

Figure 4




Source: World Development Report, 2016.

The graph shows that trade in ICT represents a small part of the world economy. The graph also shows that such trade has been remarkable stable. Trade in ICT goods decreases somewhat. Trade in ICT service increases slightly. A similar graph for the OECD countries gives a similar picture. Trade in ICT is lower for the OECD countries than for the world economy, but with trade in ICT services representing a larger share. Also growth in trade in ICT services is higher for the OECD countries are compared to total world trade.

In the OECD countries, the ICT industries account for about 6 percent of value added and 3.8 percent of employment (OECD, 2014a). Investments in ICT goods as share of GDP and as share of gross fixed capital formation has decreased in the aftermath of the dot-come era in the end of the 1990s. ICT investments dropped from 3.2 percent of GDP in 2000 to 2.3 percent in 2012.

With increasing use of ICT in all industries, it may be argued that the graph understates the importance of ICT in world trade. Still, the fact that the share of ICT trade in world trade is limited and stable, demonstrates that growth effects from growth *within* the ICT industry might be limited. Since the ICT industry is of limited size, growth effects might be observed in ICT *using* industries, rather than in ICT *producing* industries. The large price declines of ICT (as evidenced in graph 2) also indicates that use of ICT has become cheaper for all users.

Contributions from ICT to growth in non-ICT industries are hard to calculate. Jorgenson (2005), Jorgenson *et al.* (2008) and Jorgenson *et al.* (2014) are important contributions. Jorgenson with co-authors has contributed with several analysis of contributions from ICT on aggregate economic growth. Jorgenson (2005) decomposes contributions to growth from use of labour, investments in non-ICT capital, growth in TFP outside the ICT industries, investments in ICT capital goods and growth in TFP within the ICT industry. The analyses indicate that both investments in ICT and TFP growth in the ICT industries explained a large and increasing share of aggregate growth in the United States in the 1980-2004 period.

European and Japanese economic development has been weaker. This was so during the dot-com period from 1995 to 2001, but also later on. Some have suggested an "Atlantic divide" in the influence of ICT on economic growth. In figure 3 it is clear that European economic growth has been lower than in the United States from the 1990s onwards. While the dot-com era was visible in US productivity statistics there were much weaker signs of ICT lead productivity growth among European countries. van Ark *et al.* (2008) analyse the weak European development. They argue that the European slowdown is attributable to slower diffusion of the knowledge economy in Europe compared as to the United States. While Europe caught up with the United States in the post-war period, this convergence came to an end around 1990.[11] By means of a similar type of growth accounting as used by Jorgenson, van Ark *et al.* estimates contributions to growth from the *knowledge economy*.[12] In the United States total annual growth rates in the market economy was 3.7 percent in the 1995-2004 period. Of this the knowledge economy contributed with 2.6 percentage points. In Europe, on the other hand, total growth rates in output was 2.2 percent of which the knowledge economy contributed with 1.1 percentage points. Even if the contribution from the knowledge economy varied between countries (in Finland it contributed with 3.4 percentage points), European performance was weak. Guerrieri *et al.* (2011) discuss why Europe has lower investments in ICT than the United States. They investigate how ICT investments depend on other variables. They argue that ICT investments depend on countries' industry composition, but also factors such as workers' competence and investments in R&D.

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[11] Note that European and US trend growth rates intersect in the early 1990s in figure 3.

[12] They define the *knowledge economy* as changes in labour composition, ICT capital per hours worked and TFP.

Cette *et al.* (2013) compare the contribution from ICT to growth in labour productivity in the United States, Canada, the Eurozone and the United Kingdom in the 1970-2013 period. They reach four main conclusions. First, ICT capital stock increased over a long time period up until 2000 in all the four areas, but then stabilized after 2000. Second, stabilization happened at different levels, with the United States ranking first and the Eurozone last. Third, the contribution from ICT to labour productivity growth rose in the 1994-2004 period compared to the 1974-1994 period. Fourth, after 2004 the contribution from ICT to labour productivity has fallen considerably. Draca *et al.* (2006) survey the literature. From their reading of the literature, they conclude that both in the United States and in Europe, growth rates were higher in ICT producing industries than in other industries. Only in the United States, however, they find growth stimulus from ICT in ICT using industries.

Studying a longer period, Acemoglu *et al.* (2014) present evidence based on US manufacturing industries. They find little evidence of growth stimulus from ICT. There is labour productivity growth in ICT intensive manufacturing, but the growth in labour productivity is driven by declining output combined with *even more rapid* decline in employment.

Cardona *et al.* (2013) conclude that (p.116) “In particular, during the period from 1995 to 2000 the US showed high investments in IT accompanied by productivity increases”. For Europe, however, they write (p. 117): “Europe, on the other hand, shows lower productivity growth and ICT investments post 1995, while the differential to the US has increased throughout the early 2000s.”

Evangelista *et al.* (2014) investigates the impact of ICT on European economic performance from a somewhat different angle. They make use of a more detailed database covering different indicators for ICT for EU member countries in the period from 2004-2009. From this database they construct measures for ICT *infrastructure* (broadband, bandwidth, number of internet subscribers, internet access for households etc), ICT *usage* (number of people accessing the internet from home, number who accessed daily, ICT skills, etc) and ICT *empowerment* (use of internet-banking, extent of e-purchases, electronic job applications and use of the internet for health and education purposes). They regressed countries’ labour productivity and GDP per capita growth rates on these as well as other variables (like investment shares, population and human capital). They found that only internet usage was significantly positively correlated with labour productivity and that only ICT empowerment was positively correlated with growth.

Yousefi (2011) analyses contributions from ICT investments for growth in a sample of both rich and poor countries. He finds that ICT investments have positive effects for growth in high income and middle income countries, but less so in low income countries. Similar results are found in Papaioannou and Demilis (2007).

Najarzadeh *et al.* (2014) finds that internet use increases labour productivity in a panel data set with 108 countries in the period from 1995 to 2010. Results are significant at the 5 per cent level in fixed effects and GMM model versions, but not in the pooled data.

Choi and Yi (2009) study the impact of share of internet users in the population for economic growth in a panel of countries for the 1990-2000 period. They base their study on data from *World Development Indicators*. From panel data growth regressions for countries covering both developed and developing country (they use an unbalanced panel dataset with a total of 1004 observations) they conclude that the internet significantly and positively increases countries' growth rates. They report results from (successively) pooled OLS, random effects panel models, individual fixed effect model, year fixed effects models and combinations of random effects and year fixed effects model. They also include auxiliary variables (investments share in GDP, government expenditure shares in GDP and inflation rates). The positive effects from use of internet are robust to model specification.

Similar results are reported in table 1. The results are based on data for the period from 1990 to 2015 from *World Development Report*. I have extrapolated some of the data for shares of internet users in the population. Data for many countries start some years after 1990. When this is the case and the share of internet users in the first year was less than 1 percent, I inserted zero for the previous years. In other cases, I included the country observation for shorter time periods (so that I obtained an unbalanced panel data set). When there were incomplete series, I included a constant trend in the share of internet users to fill in the data. This resulted in an unbalanced panel data set for 152 countries in the period from 1990 to 2015 and growth data from 1991 to 2015. In total the dataset contains 3 396 observations. I report results first for the 1991 to 2000 period (similar to Choi and Yi) and thereafter for the 1990 to 2015 period and the 2001 to 2015 period.

The regression is with yearly growth rates in GDP per capita (in purchasing power parities) as dependent variable. I include the same explanatory variables as Choi and Yi, e.g. the share of internet users in the population, investments shares in GDP, government expenditures as share of GDP and yearly increase in consumer prices.[13]

The first column in the table is for a fixed effect panel data model (similar to column c in table 1 in Choi and Yi). The second column is for a random effects model with year dummies included (similar to column e in table 1 in Choi and Yi). The third column reports results from a fixed effects model with year dummies included.

In the two last columns I have included auxiliary variables. In the fourth column I included lagged levels of (log of) GDP per capita to capture convergence and regression towards the mean. In the last column I also included an interaction term for GDP per capita and the share of internet users. It may be that positive effects of the internet requires a high level of income. In that case the estimated coefficient is expected to be positive. In the opposite case, growth effects of the internet is higher in low income countries. Meijers (2014) propose that there are interaction effects between trade and use of the internet. I include trade openness as explanatory variable (but an interaction terms turned out to be insignificant).

The first two columns produce results that are qualitatively similar to Choi and Yi. The share of internet users is significantly and positively correlated with growth in the 1990-2000 period. This is so in the fixed effect model as well as in the random effects model with year dummies included. The sizes of the coefficients are also very similar to those of Choi and Yi. A one percent increase in the share of internet users in the population is associated with an increase in growth rates with 0.053-0.060 percentage points (0.057-0.049 in Choi and Yi). The signs and significance of the other variables are in line with those of Choi and Yi.

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[13] The share of internet users is measured as the share of the population that have used the internet during the last 12 months. Investments shares are gross fixed capital formation as share of GDP. Government expenditures are included. Choi and Li (2009), p. 40 expect this variable to negatively influence on growth since "the government distorts the private decisions". I expect its coefficient to be negative because government expenditures are often more stable than the more varying marked based private sectors (and therefore serve as automatic stabilizers). High rates of inflation is know to retard growth. *A priori*, I don't have any expectations about the coefficient when inflation is low.

Table 1 Regression results for yearly growth rates, 1990-2000

| Variable | Choi and Yi (col. c) | Choi and Yi (col. e) | Fixed effects | Fixed effects | Fixed effects |
|---|---|---|---|---|---|
| Internet | 0.053 (0.022)** | 0.060 (0.214)*** | 0.036 (0.021) | 0.051 (0.025)** | 0.458 (0.664) |
| Investments | 0.141 (0.022)*** | 0.174 (0.012)*** | 0.135 (0.022)*** | 0.155 (0.026)*** | 0.155 (0.026)*** |
| Government | -0.423 (0.056)*** | -0.142 (0.025)*** | -0.383 (0.057)*** | -0.362 (0.054)*** | -0.363 (0.054)*** |
| Inflation | -0.0004 (0.0002)** | -0.0008 (0.0002)*** | -0.0004 (0.0002)*** | -0.0002 (0.0002) | -0.0002 (0.0002) |
| Lagged GDP pc | | | | -0.151 (0.012) | -0.152 (0.012)*** |
| Interact | | | | | -0.039 (0.063) |
| Trade | | | | 0.044 (0.010)*** | 0.044 (0.010)*** |
| Fixed Effects | Yes | No (RE) | Yes | Yes | Yes |
| Year Dummies | No | Yes | Yes | Yes | Yes |
| R2 | 0.13 | 0.23 | 0.16 | 0.00 | 0.00 |
| R2 (within) | 0.08 | 0.09 | 0.11 | 0.00 | 0.00 |
| R2 (between) | 0.27 | 0.53 | 0.29 | 0.21 | 0.22 |
| Countries | 154 | 154 | 154 | 154 | 154 |
| N | 1 386 | 1 386 | 1 386 | 1 386 | 1 386 |

Note: Standard errors in parenthesis. ***, ** and * denotes significance at 1, 5 and 10 percent levels, respectively. RE denotes random effects GLS regression.

The significant effect of the internet, however, does not survive inclusion of both fixed effects and time dummies. In that case the coefficient is positive, but not significant.

Inclusion of lagged (log of) GDP per capita in the regression gives a positive and significant result for internet. Also trade as share of GDP is significantly and positively related to economic growth.

The results in the table therefore lends some support to Choi and Yi's findings. The internet seems to explain growth in the 1990s.

In the last column results from a regression where also an interaction term between income and the share of internet users was included. That regression resulted in insignificant results both for the share of internet users as well as the interaction term. The other variables keep their sign and significance.

Table 2 reports similar results for the entire 1990-2015 period. The table indicates that the effect of the internet for the entire period is the opposite of those reported in table 1. The share of internet users in the population correlates negatively and highly significantly with growth. This is so in all the regressions except for the last column. The last column is for a regression in which also the interaction term is included. This produces a positive and significant (at the 5 percent level) coefficient for the share of internet users and a negatively and significant coefficient for the interaction term. The conclusion is that for the entire period, the effect of internet is positive, but that this effect is lower for richer countries.

In the period covered, the share of internet users increased in all countries. In rich countries, the share approached high levels. In poorer countries, the share increased to lower levels. The results are in accordance with three alternative interpretations. The first is that internet is most productive in poorer countries. The second is that increase in the share of internet users is highest when it increases from lower levels. The latter interpretation is rejected in the data since separate regressions for countries with lower levels of internet users in 2001 did not change the results, neither for the entire period nor for the period after 2001. The third interpretation is that introduction of the internet resulted in level effects for income rather than growth effects.

Table 2. Regression results for yearly growth rates, 1990-2015

| Variable | Choi and Yi (col. c) | Choi and Yi (col. e) | Fixed effects | Fixed effects | Fixed effects |
|---|---|---|---|---|---|
| Internet | -0.015 (0.004)*** | -0.019 (0.473)*** | -0.035 (0.006)*** | -0.038 (0.062)*** | 0.116 (0.062)* |
| Investments | 0.155 (0.011)*** | 0.159 (0.009)*** | 0.115 (0.010)*** | 0.103 (0.012)*** | 0.099 (0.011)*** |
| Government | -0.184 (0.025)*** | -0.078 (0.015)*** | -0.129 (0.025)*** | -0.168 (0.025)*** | -0.171 (0.024)** |
| Inflation | -0.0006 (0.0001)** | -0.0006 (0.0001)*** | -0.0006 (0.0001)*** | -0.0006 (0.0001)*** | -0.0006 (0.00021)*** |
| Lagged GDP pc | | | | -0.049 (0.004)*** | -0.050 (0.004)*** |
| Interact | | | | | -0.014** (0.008) |
| Trade | | | | 0.020 (0.004)*** | 0.021 (0.004)*** |
| Fixed Effects | Yes | No (RE) | Yes | Yes | Yes |
| Year Dummies | No | Yes | Yes | Yes | Yes |
| R2 | 0.11 | 0.20 | 0.16 | 0.00 | 0.03 |
| R2 (within) | 0.08 | 0.15 | 0.18 | 0.00 | 0.01 |
| R2 (between) | 0.25 | 0.38 | 0.27 | 0.21 | 0.20 |
| Countries | 171 | 171 | 171 | 171 | 171 |
| N | 3 781 | 3 781 | 3 781 | 3 780 | 3 780 |

Note: Standard errors in parenthesis. ***, ** and * denotes significance at 1, 5 and 10 percent levels, respectively. RE denotes random effects GLS regression.

The effect of the internet seems to change after 2000. This motivates a separate regression for the post 2000 period. Results from such regressions are reported in table 3. Table 3 indicates that there were negative effects from the internet on economic growth in the post 2000 period. With the same model formulation as in Choi and Yi (2009), effects are strongly and significantly negative. In the post 2000 period, there were negative growth effects after the terror attacks in the United States in 2001 and during the great recession in 2008-09. In the regressions, effects of these events are captured by the year dummies (to the extent that they influenced similarly on all countries). Inclusion of a separate year-country dummy for these years and the United States did not alter the results.

Inclusion of the interaction term between the share of internet users in the population and income makes internet positive and significant (at the 5 percent level). The interaction term is negative and significant. This indicates that in the post 2000 period, the effect of the internet was positive for poor countries, but negative for rich countries.

Table 3. Regression results for yearly growth rates, 2000-2015

| Variable | Choi and Yi (col. c) | Choi and Yi (col. e) | Fixed effects | Fixed effects | Fixed effects |
|---|---|---|---|---|---|
| Internet | -0.050 (0.007)*** | -0.019 (0.005)*** | -0.055 (0.012)*** | -0.043 (0.011)*** | 0.202 (0.080)** |
| Investments | 0.143 (0.016)*** | 0.148 (0.013)*** | 0.138 (0.016)*** | 0.120 (0.016)*** | 0.116 (0.016)*** |
| Government | -0.086 (0.034)** | -0.044 (0.0176)** | -0.020 (0.033) | -0.070 (0.0157)** | -0.074 (0313)** |
| Inflation | -0.0002 (0.0002) | -0.0003 (0.0002) | -0.0002 (0.0002) | 0.0003 (0.0002)* | -0.0003 (0.0002)* |
| Lagged GDP pc | | | | -0.116 (0.008)*** | -0.119 (0.008)*** |
| Interact | | | | | -0.024 (0.008)*** |
| Trade | | | | 0.018 (0.005)*** | 0.020 (0.005)*** |
| Fixed Effects | Yes | No (RE) | Yes | Yes | Yes |
| Year Dummies | No | Yes | Yes | Yes | Yes |
| R2 | 0.07 | 0.17 | 0.15 | 0.01 | 0.01 |
| R2 (within) | 0.06 | 0.16 | 0.16 | 0.00 | 0.00 |
| R2 (between) | 0.16 | 0.24 | 0.15 | 0.26 | 0.26 |
| Countries | 171 | 171 | 171 | 171 | |
| N | 2 395 | 2 395 | 2 395 | 2 394 | |

Note: Standard errors in parenthesis. ***, ** and * denotes significance at 1, 5 and 10 percent levels, respectively. RE denotes random effects GLS regression.

The regression results add to the many findings of small effects of ICT in aggregate data. The results indicate positive effects pre 2000, but negative effects for rich countries after 2000. The results indicate positive effects from the internet on growth in poorer countries, however.

Pradhan *et al.* (2013) investigate the impact of internet users on economic growth in *OECD* countries in the period from 1990 to 2010. They find close relationships, but they also find evidence of bidirectional causality. Economic growth explains increase in the number of internet users and the number of internet users explain economic growth. They conclude that (p. 1514): “these results reinforce the importance of economic growth for the continued development and use of internet in the economy”.

## Disaggregated data

The above studies are macro studies. In macro studies an important challenge is to determine the direction of causality between varibles. In micro studies possibilities to check for direction of causality are often better. Firm level studies often find that large, profitable and productive firms are the ones that most often, earliest and to the largest extent use ICT. Doms *et al.* (1997) finds that the most productive firms were more productive than others, both *before* and *after* their investments in ICT. McGuckin *et al.* (1998) report higher productivity in firms that use advanced technology. The study however, indicates causality running in both directions; more productive firms more often use advanced technology, but productivity growth increases after investments in such technologies. In the survey by Cardona *et al.* (2013) a main conclusion is that micro studies do find growth effects for firms’ productivities while macro studies generally give support to higher growth effects from ICT in the United States than in Europe.

Brynjolfsson and Hitt (2000a) reviews the literature on ICT and productivity as of 2000. They note the discrepancy between studies based on micro data and studies on aggregate productivity developments. Studies based on micro level data often find positive relationships between productivity and investments in ICT. But such studies, both case studies and econometric studies, also reveal reasons why there are only weak relationships between productivity and ICT in studies on aggregate data.

Brynjolfsson and Hitt review several case studies of firms investing in ICT. They note that such investments often require large auxiliary investments in human capital, in business processes and work practices. If such investments do not occur, or if they fail, investments in ICT may give lower, and even negative, returns. ICT investments require a “all or nothing” attitude, according to Brynjolfsson and Hitt. Similarly, computer based supply chains prove more efficient when supplemented with organizational investments.

In service industries, measurement challenges for productivity are often larger than manufacturing (see section 4). Stiroh (1998) finds that many of the most computer intensive industries are service industries. In many of them, non-computer input growth decreased with increased use if ICT. ICT substituted for labour. But output growth increased less than before. Stiroh concludes that total factor productivity grew more slowly as ICT capital increased. Triplett (1999) proposes that the global economy has facilitated outsourcing of many production processes. In developed countries, physical production and also many services are outsourced to low wage countries. Often only headquarters with responsibility for design, marketing, distribution, coordination and R&D are left in high wage countries. Headquarter production is hard to measure and headquarter productivity is harder to measure.

Brynjolfsson and Hitt (2000a) review several studies based on firm level data. Several of these indicate that firms that invest in ICT have higher productivity than other firms, also when other factors are controlled for. Studies based on firm level data also report different results over time. Productivity effects of ICT were low in early studies. They cite Roach (1987) who found that ICT investments increased a lot in the 1977-89 period, but that output per worker did not increase. Studies from the 1990s reported positive effects, however. Brynjolfsson and Hitt (1995 and 1996) find significant and positive effects on firms' productivity levels from investments in ICT in a dataset with more than 300 large firms in the 1988-92 period. That study was based on panel data and included a variety of dummy variables for time, industry and firm. Later studies concentrated on productivity *growth* rather than levels. Brynjolfsson and Hitt (2000b) find that productivity growth effects from ICT investments increase over time. There are lags between productivity effects and these investments.

Brynjolfsson and Hitt (2000a) report studies that use Tobin's q to draw inferences about the impact of ICT investments and market value. Brynjolfsson and Yang (1998) found that while 1 USD investment in traditional physical capital increased firms' market value with about 1 USD, a 1 USD investment in ICT equipment increased firms' market value with 10 USD. They argue that, since the data are from the 1987 to 94 period, this is not a consequence of the "dot.com bubble".

Brynjolfsson and Hitt (2000a) note that firms that invest heavily in ICT are often smaller than other firms. Brynjolfsson *et el.* (1994) found that increase in the level of ICT capital in an industry were associated with a decline in average firm size in that industry. They propose that ICT leads to a reduction in vertical integration. Brynjolfsson and Hitt (2000a) also propose that firms that adopt decentralized work structures have higher returns from investments in ICT than other firms.

From the literature on ICT and growth reviewed above, there seems to be emerging agreement that growth effects from ICT have been limited in aggregate data. The growth revival in the United States in the 1995-2004 period has been attributed to ICT. Oliner and Sichel (2000) write that (p. 4) "we estimate that these developments (ICT investments and growth in the ICT industry) account for about two-thirds of the acceleration in labour productivity (…) in between the first and the second part of the 1990s." Apart from this, growth rates have been stagnating in the computer age. This is so for the United States, for Europe and for Japan. Studies on disaggregate data, on the other hand, find growth effects. Firms that use ICT have higher growth in productivity than other firms and growth rates are often high in ICT producing industries.

## Unbalanced growth and Baumol's disease

Stagnating growth rates at the same time as massive investments in ICT was denoted the Solow paradox. Growth economics provide many potential explanations for stagnating growth, however. From the standard Solow model, growth is predicted to stagnate in the absence of technological progress. Due to decreasing returns from capital, growth effects from savings decrease as capital intensity increases (see e.g. Barro and Sala-I-Martin, 1995). Slower technological progress may also reduce growth. If *research* and *development* faces decreasing returns to scale, for instance because researchers first research the simplest problems and thereafter increasingly complicated problems, technological progress may well stagnate even when endogenous growth mechanisms are present. Gordon (2016) discuss many reasons for stagnating growth. One is demographics and relate to the aging population. Another candidate for explaining stagnating growth rates is Baumol's hypothesis of unbalanced growth. If an economy consists of two industries and there is high productivity growth in one industry and no productivity growth in the other, growth may stagnate over time. High growth rates in the progressive industry may result in decreasing prices for this industry's products. The relative prices for the other industry's products will therefore increase. Depending on demand elasticity, resources used for the stagnating industry may both increase, be constant or fall. In the first case, resources used in the stagnating industry may grow relative to the other industry. In this case, aggregate productivity growth will decrease over time and eventually cease. Baumol (1967) and Baumol *et al.* (1985) applied the above framework to structural change in developed countries' economies. These countries witnessed higher growth in service industries than in manufacturing. Baumol hypothesized that the productivity growth potential in services was lower than in manufacturing. Baumol therefore predicted lower growth rates in productivity over time and increasing social problems, in particular in cities, that have particularly service intensive economies. Baumol *et al.* (1985) added a third industry in a model of unbalanced growth, an “asymptotically stagnant” industry. This industry has one component with high potential for productivity growth and one component with low potential. Such industries may first contribute much to aggregate productivity growth and thereafter less. The reason is that the unbalanced growth mechanism occurs in miniature within the asymptotically stagnant industry itself.

Baumol *et al* hypothesised that the ICT industry belong the asymptotically stagnant industries. They argued that costs of hardware decreased. These price decreases make the ICT industry initially progressive stimulating aggregate growth in its infancy. But software production is more labour intensive. Therefore, the potential for productivity growth is lower in software production. Over time therefore, software becomes a larger cost component in ICT industries. Growth stimuli from ICT therefore decreases over time. Figure 2 lends support to this hypothesis: While price declines for hardware have been very large, prices for software have been almost constant.

Nordhaus (2006) is an attempt to test for the Baumol mechanism in economic growth. Norhaus analyses growth in 67 American industries. In some of these, productivity growth is high. The fast growing industries mainly belong to manufacturing. In other industries productivity growth is low. These are mainly service industries. Nordhaus estimates the growth contributions from each industry to aggregate growth. Due to increasing costs and use of resources, growth contributions from the slow growing industries become larger over time. This depresses aggregate growth.

Triplett and Bosworth (2003a and 2003b) study the impact of ICT on growth in service industries in the 1973 to 2000 period. They argue that ICT contributed to high productivity growth in services after 1995. They conclude that “Baumol’s disease has been cured”. The results of Triplett and Bosworth do not necessarily contradict those of Nordhaus. Also Nordhaus reports, but does not comment on, higher growth in the 1989-2001 period.

## The future

Many has argued that productivity growth effects from ICT has yet to come. As outlined above, ICT has GPT characteristics. There are network effects, there are complementarities and there is need for auxiliary investments, in physical and human capital, and, in particular in infrastructure.

As outlined above, infrastructure in broadband has been high on the policy agenda in many countries and access to broadband has increased in most countries in recent years. Broadband substituted for dial-up internet in the 1990s and the early 2000s and became more available ass time passed. Households adopted broadband thereafter. Therefore growth effects from broadband investments can be found in recent data only.

Ford *et al.* (2011) study broadband investments in the OECD countries. They find that broadband coverage depends on price, GDP per capita, inequality (less inequality correlates positively with broadband coverage), level of education, the share of the population aged 65 or more, population density and the coverage of telephone lines. Ford and co-authors rank countries according to observed broadband coverage versus expected coverage. They conclude that Iceland, Belgium and Canada rank highest and Ireland, Greece and Slovakia lowest.

Koutroumpis (2009) estimate growth effects from broadband penetration for a sample of 22 OCED countries in the period from 2002-2006. Controlling for endogeneity with an instrument variable technique in which broadband demand is separated from broadband supply, Koutroumpis concludes that broadband significantly increased GDP and that there are level effects in the sense that a broadband penetration in excess of 30 percent gives the highest growth effects.

Greenstein and McDevitt (2011) find that effects of broadband for consumers are limited. Their estimates show that returns to broadband investments were not higher than normal returns. The results are based on studies of revenues from sales of broadband. They also present estimates of consumer surplus from broadband. The results indicate that broadband upgrade was equivalent to a price decline between 1.6 percent and 2.2 percent per year for internet access.

Czernich *et al.* (2011) study the relationship between broadband investments and growth in a cross section of countries. They use data from the OECD countries for the period from 1996 to 2007. They both include level effects of broadband investments (does GDP per capita increase as function of broadband investments?) and growth effects (does broadband investments result in higher (permanent) growth rates? An obvious problem is endogeneity. It might well be that richer and fast growing countries invest more in broadband than other countries. Tranos and Mack (2016), for instance, found that sometimes firm level growth explained broadband investments while causality goes in the other direction in other cases. In order to control for this, Czernich and co-authors use existing telephone and cable-TV extensiveness as instruments. Since telephone lines and cable-TV explains broadband investments but not subsequent growth, they claim that their instrument is valid. Their results are astonishing: Introduction of broadband increases GDP per capita with 2.7-3.9 percent. 10 per cent increase in broadband coverage, increases the growth rate of GDP with 0.9-1.5 percentage points. These results contradict for instance Grimes *et al.* (2009) who obtain far more modest results. Based on firm level regional data from New Zealand, they estimate productivity effects from different types of broadband coverage. They find that existence of broadband increases productivity, but that this effect does not depend on broadband speed. They note, however, that the speed of broadband is a “moving target” so that the economic implications of broadband can change over time.

Bojnec and Fertő (2012) investigate the impact of broadband on economic growth in a panel data of OECD countries in the period from 1998-2009. They estimate growth (in GDP per capita) as a function of investments in physical capital, government expenditures and inflation and three alternative measures of broadband availability. The three measures are standard access lines per 100 inhabitants, access channels per 100 inhabitants and total broadband per 100 inhabitants. They find that the first two broadband access measures correlate positively to growth while the last contributes negatively (and partly significantly so). Bjonec and Fertő do not, however, investigate whether the influence of broadband changes over time.

Majumdar (2010) argue that lower growth in the United States in the post-2000 period, in particular for ICT firms and users of ICT, was caused by lower investments in broadband in the United States as compared to other countries. Broadband has been more expensive and less available in the United States than in other countries and the United States ranked as number 15 among OECD countries in broadband coverage in 2008. Majumdar finds that access to broadband for US firms was positively and significantly correlated with income growth.

Studies on the economic effects of broadband indicate growth effects. As indicated above, however, broadband coverage is approaching 100 per cent in many countries. Further growth effects therefore depend on whether broadband provision gives dynamic or static effects. If pessimists are correct, the main growth effects from ICT were observed in the United States in the dot-com period. Thereafter growth has decreased. Optimists claim that internet based ICT have GPT characteristics that promise higher growth potentials in the future.

David (1990) compares the ICT revolution with development of electricity. Because of, among other factors, network effects, it took time before introduction of electricity increased productivity. David hypothesises that it may be similar for ICT. Bresnahan and Trajtenberg (1995) and Helpman and Trajentenberg (1998) construct growth models where there are substantial lags between investments and subsequent growth effects from introduction of GPT. Occurrence of GPTs open up profitable innovation opportunities for an applicant sector that uses the GPT for their business. The GPT therefore spurs innovation in the applicant sector. Demand from the applicant sector also spurs demand for further innovation in the GPT sector. However, because of horizontal externalities in the applicant sector, they innovate too little. The GPT sector and the applicant sector have linked payoffs. Neither side will have sufficient incentives to innovate. The implication is that introduction of GPTs can be followed by a period with slow growth before productivity effects become larger.

Along the same lines, Dudley (1999) constructs a model of growth and communication technologies where there are growth cycles with three phases. GPTs (in communications technologies) occur exogenously. New GPTs have wide potential for further growth since they open up opportunities for further innovation. New ideas are combined to spur further growth (in a recombinant manner), but with decreasing rates of success. Initially, the growth rate of productivity is low, since when the technology occurs, diffusion remains limited. But innovation is fast and when the technology becomes more widely adopted, productivity growth accelerates. Even if the rate of productivity growth from new vintages of technology is decreasing, this effect is offset by the increase in the proportion of the population that is adopting the new technology. Growth subsequently decelerates as the number of new ideas to be crossed with old one falls. Growth rates becomes low when the technology has become widely diffused.

Brynjolfsson and Hitt (2000a) goes a long way in arguing that auxiliary investments that are needed for ICT investments to be successful are often not counted correctly. For instance, they find that additional invesments in human capital is often needed. This is in line with many studies. Bresnahan, Brynjolfsson and Hitt (2000), for instance, report results from a survey of firms. They found that investments in ICT are associated with increased delegation at the workplace, higher levels of skills and education. They also found that these work practices are correlated with each other.

Akerman *et al.*(2015) study effects of broadband on labor productivity and wages. Based on a public program to support rollout of broadband they obtain exogenous variation in the availability of broadband firms. Their instrument allowed them to estimate effects of broadband on worker productivity. The results indicate that broadband improves wages and productivity for high skilled workers but has the opposite effects for low skilled workers.

The idea that GPTs are introduced long before growth effects can be observed is not new. Triplett (1999) argues that analogies with for instance electricity do not hold. While it took time for electricity to substitute for steam, and water and steam power co-existed with electricity for a period, pre-computer age equipment for doing calculations disappeared long ago. Triplett's 1999 article was written when the internet was new.

18 years later, the internet has expanded rapidly and has become pervasive, widespread and integrated into goods and service production. Smartphones have made the internet available for individuals everywhere. News production, banking and buying and selling are integrated into smartphone activities. The internet of things, where physical goods are online and communicate for the consumer, is becoming common.

E-commerce has become widespread. E-commerce denotes sales or purchases of goods and services conducted over computer networks by methods designed for this purpose (OECD, 2014). In OECD countries, 47 percent of consumers bought products online in 2014, up from 30 percent in 2007. The most common products purchased online are travel services, tickets for events, digital products and books. E-commerce is becoming more popular also for other product types, such as food and grocery products. The extent of e-commerce is likely to increase in the future. With extended e-commerce, many jobs in retailing will disappear. Some of them will be substituted by jobs in warehouses, IT consultants and drivers. Einav *et al.* (2014) analyse the extensiveness and growth in the use of *mobile* e-commerce. They find that mobile e-commerce diffuse in the commonly S-shaped way and that diffusion is fast. They also argue that mobile e-commerce, at least partly, adds to regular e-commerce.

Recent developments in ICT and internet usage includes the growth of the *app*-economy. The app-economy, whereby individuals buy apps for fun and many other purposes, booms. The average smartphone user has 28 apps installed, but uses on average 11 of these (OECD, 2014b).

Integration of functionality and information allows new software applications for mobile operating systems. Machine-to-machine (M2M) account for increasing shares of mobile data traffic. M2M is predicted to expand in the future. For instance, in the automobile industries, M2M communication is now becoming widespread.

Big data analysis has become possible from generation of large amounts of data from use of the internet. OECD (2014a) predicts a yearly growth in data traffic of 20 percent, from 70 exabyte (EB=1 billion gigabites) per month in 2014 to 120 EB in 2017. Big data analysis are used for many purposes, with marketing purposes as a main example (Gordon, 2016). OECD (2014a) predicts that other applications will become more popular, like disaster management and applications in the health sector.

The ICT industry did quite well during the great depression. The major ICT firms (250, monitored by the OECD) did not report decrease in their income or revenues during the crisis (OECD, 2014a).

The ICT industry is vital in the sense that there are many new firms and that new firms have higher survival rates than in other industries. In the 2009-12 period, net business firm growth in the ICT industries was 4.5 percent while the average was 1 percent in other indsutries (OECD, 2014a). Gordon (2016), however, is sceptical about whether this will continue in the same way. He reports that new firm entry in the US economy is on decline. Due to very low interest rates in the aftermath of the great recession, many investments have low internal rate of return. With higher interest rates, many new firms may face challenges.

Gordon (2016) contemplates about likely developments in ICT industries in the future. He lists new medical advances, small robots and 3D printing, Big data and artificial intelligence and driverless cars as the most likely areas of progress in the foreseeable future. For different reasons, he predicts growth effects from each these to be small. Progress in health is stagnating because most possible progress has already been achieved (compare effects of reduced child mortality with cancer treatment of old patients). Robots and 3D printing can increase productivity, but Gordon thinks that (p. 596) “3D printing is not expected to have much effect on mass production and thus on how most U.S. consumer goods are produced". Even if Big data has been available for some time, the lack of any productivity effects from them makes Gordon also pessimistic about their potential. For driverless cars, Gordon sees small potentials, for the reason that even if they can substitute for drivers at the highway, they cannot substitute for all the other man work involved in logistics and transportation.

Jorgenson *et al.* (2008 and 2014) discuss future growth potentials in the aftermath of the great recession. Those studies incorporates projections of TFP growth for ICT producing, ICT using and non-ICT industries bases on historic experiences. A base case is based on average contributions of TFP growth for the three sectors for the 1995-2010 period. For that base case, productivity growth is predicted to increase to about 0.6 percent per annum. This is higher than in the 1990-2010 period. Excluding the great recession from the historical data, makes projected productivity growth reaching almost one percent per annum. Jorgenson *et al.* (2014) conclude however, that (p. 689):

> *"Negative productivity growth during the Great Recession is transitory, but productivity growth is unlikely to return to the high rates of the Investment Boom …"*

Despite Jorgenson's modest optimism several authors are far less optimistic. Gordon (2010) argues that the dot-com era in the US economy was special. ICT has explained a falling share of lower growth in the decade after 2000 as compared to the previous decade. In Gordon (2016) growth projections for the future US growth are presented. These are far less positive than those of Jorgenson. Using TFP growth rates from the *pre*-dot-com period as his base period, Gordon argues that future growth in production per capita will be very limited.

Projections for the future therefore differ among qualified economists. Whether ICT will spur fast growth or whether recent stagnation will continue is a matter of debate. Some are optimists. Brynjolfsson and McAfee (2014) (p. 88) write:

> *"These and countless other innovations will add up over time, and they'll keep coming and keep adding up. Unlike some of our colleagues, we are confident that innovation and productivity will continue to grow at ealthy rate in the future."*

Gordon (2002) compares the promises of the computer with other important innovations during the 20th century, like running indoor water, antibiotics, the internal combustion engine, the private car, air transport and many more and concludes that (p. 50):

*"it is quite plausibel that the greatest benefits of the computer lie a decade or more in the past, not in the future"*

# Happiness

There is no doubt that ICT and the internet has changed people's lives considerably. These changes are profound. They have probably large effects even if macro data do not reveal clear growth effects. How does ICT and the internet influence on peoples well-being?

Economists have a well-established theoretical framework for analyses of welfare and happiness.[14] Individuals are assumed to be equipped with utility functions which measure their utility or welfare. Individuals are assumed to maximize their utility subject to budget constraints. From such maximization, economic behavior is deduced. Typical results are demand functions and labour supply functions. For demand, utility maximization normally implies that demand falls with prices (with the exception of the theoretical artefact *Giffen* goods) and increases with income (with the exception of inferior goods). Standard assumptions about individuals' utility is that they enable the consumers to rank all goods (preferences are complete, negative transitive, reflexive, no-satiation). Individuals are also expected to handle uncertainty (with the introduction of Von-Neumann-Morgenstern expected utility). When individuals are risk averse, they dislike loss of a given amount of income more than they like a similar income gain. Therefore, individuals' utility increase with their income, but less than proportionally.

Based on consumer theory economists have analyzed economic behavior based on what they observe that people do.

It is not straightforward to measure utility, however. For many purposes, it is not even important to measure utility. For deriving demand functions, any increasing function of an utility function will give the same results. All utility functions that give the same ranking of goods are equivalent from this perspective. This *ordinal* approach to utility is widespread.[15] Standard theory for introducing uncertainty in

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[14] For an introduction to consumer theory, see Kreps (1990) or Gravelle and Rees, 1992).

[15] The eminent Norwegian economist Asbjørn Rødseth writes (p. 46, my translations) "Most modern economists make use of such a utility notion (ordinal)" (Rødseth, 1992). Gravelle and Rees writes (p. 182) "The utility function of consumer theory is an *ordinal* function …"

consumer theory restricts the class of utility functions to be unique up to a linear positive transformation (while ordinal utility functions are unique up to a positive monotonic transformation).

For measuring utility one needs a scale. This is cardinal utility. Cardinal utility measures are also used to compare utility (or welfare) between individuals and to aggregate welfare for groups of individuals. Within the ordinal utility framework that does not make sense.

Economic theory favors Pareto improvements. Every change that makes some people better off without harming others should happen. In economic policy making however, politicians need to weigh gains for some against losses for others. There are many criteria for doing so. One is to favor those changes that increases the pie. If the pie increases, the gains will be more than large enough to compensate those who lose. It is a political issue whether there should be compensation. Cardinal welfare measures may help along the way.

In recent years *happiness research* has become popular. Outstanding surveys are Frey and Stutzer (2002), Clark *et al.* (2008) and Stutzer and Frey (2012). Also related is Deaton (2013). A main objective is to measure utility.

Happiness research is based on individuals' subjective well-being. People are asked how happy they are. The results are used as measures of utility or well-being. The research agenda has been controversial. Frey and Stutzer writes (p.403):

> *"Standard economic theory employs an "objectivist" position based on observable choices made by individuals. … Subjective experience (e.g. captured by surveys) is rejected as being "unscientific" because it is not objectively observable"*

Peoples' answers in surveys are known to be unreliable. People misunderstand questions, they don't answer honestly, they do not take questions seriously and the understand scales differently.

For many purposes, however, Frey and Stutzer argue that subjective measures of well-being fruitfully complements standard theory. They can be used for policy evaluation. They can also be important for evaluating the quality of institutions, social capital and social trust. The influence of inequality is another topic that can also be analyzed with well-being measures. Measures of subjective well-being is useful for theoretical economic research on consumers and well-being.

Observed behavior (as used in traditional standard economic theory) is an incomplete indicator for individual well-being. Subjective measures of well-being recognizes that everybody has their own ideas about happiness. Subjective well-being measures therefore respect consumer sovereignty. Frey and Stutzer (2002, p. 405) conclude that “Measures of subjective well-being can thus serve as proxies for utility”.

This point of view is critically discussed in Clark *et al.* (2008). They note that other indviduals’ perception of a person’s well-being matches well with this person’s own reply. This is evidence that own evaluation of happiness reflects signals of happiness to the environment. Reported well-being from individuals correlate with income, marriage, job status, health and other variables that are usually interpreted as positive for well-being. They also discuss studies that have found that subjective well-being at a point of time predicts future behavior in line with economic theory. Individuals choose to discontinue activities associated with low levels of well-being. Experiments also seem to support the hypothesis that well-being reflects utility in the sense that ordinal and cardinal measures generate similar results.

In line with the above, there are by now many data sources for happiness and well-being. Some of these also allow for international comparisons. The *Eurobarometer* Surveys conducted by the European Union is one. The *World Value Survey* (Inglehart *et al.* 2000) asks people: “All things considered, how satisfied are you with your life as whole these days?” Below I make use of data from the *World Happiness Report 2016* (Helliwell *et al.* 2016) which contains data for several years for many countries about individuals’ subjective well-being. Roughly 1 000 individuals per year in more than 150 countries are asked (Helliwell *et al*, 2016, p. 9):

> *“Please imagine a ladder, with steps numbered by from 0 at the bottom to 10 at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say you personally feel you stand at this time?”*

The question is denoted the Cantril ladder question (Cantril, 1965). Respondents are asked to evaluate their life satisfaction on one out 11 steps. This normalizes answers. That normalization does not rule out typical problems from surveys. First, it is not clear that the 11 steps are understood equivalently among individuals. Is 11 obtainable? Is zero obtainable? What is the distance from three to five? Is the distance from three to five the same as the distance from five to seven? Or from seven to nine? Are there systematic differences between how people in different groups approach the scale? One finding, for instance, is that older people's happiness score are higher than younger people's (Frey and Stutzer, 2002) in rich countries. Is this because older people are happier or a does it reflect that age has an influence on how people react to questions about happiness? Further, it might well be that people in different countries deviate systematically in their life evaluations. Similarly, it might be that people do not give honest answers. Whether dishonesty in surveys are systematic or nor, is hard to answer.

Frey and Stutzer (2002) argue that many of the above problems can be overstated. For instance, happy people are rated as happy among those who know them. The scale in the questions is efficiently used. But Di Tella and MacCulloch (2006, p. 29) note that answers can biased just because of the scale. The endpoints of the scale "can make it appear that marginal utility is diminishing as consumption is increasing, when in fact the scores are hitting the top of the scale". Di Tella and MacCulloch underline, however, that many problems that arise from happiness survey are *reduced* when it comes to comparing groups rather than individuals. The possibility of systematic differential reporting biases when groups containing large numbers are compared, could be small. Frey and Stutzer (2002, p. 408) conclude that:

> *"The existing research suggests that, for many purposes, happiness or reported subjective well-being is a satisfactory empirical approximation to individual utility".*

Similarly, Ferrer-i-Carbonell and Ramos (2014) conclude that (p. 1017):

> *"In short, there is now large evidence on the reliability of subjective well-being measures to be confident that we can measure individual's well-being in a meaningful way .."*

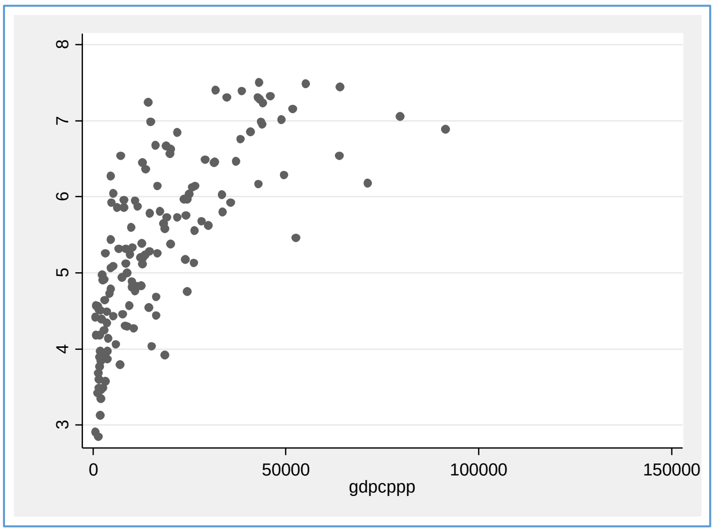
Research on happiness has established a clear and significant relationship between income and happiness. Happiness is positively related to income. This result have been confirmed in several studies (see e.g. Frey and Stutzer (2002) or Clark *et al.* (2008) for surveys or Easterlin (1974 and 1995) or Deaton (2008)). The finding that income is positively related to happiness is confirmed in micro studies as well as macro studies and in cross-country studies. Evidence also points in the direction of a causal relationship (so that income make people happier rather than happy people earning higher incomes). In micro studies, lottery winners reported higher well-being in the following year (Gardner and Oswald, 2001).

But happiness does not increase linearly with income. The relationship is logarithmic. This is in line with diminishing marginal utility from income. Also this finding is robust in the sense that it is found in micro studies as well as macro studies and cross-country studies.

To discuss results already established in the literature I have made use of data from the World Happiness report. The data set constructed is an unbalanced panel for happiness scores (Cantril ladder) for up to 128 countries. The data also contains auxiliary variables (such as standard deviations in answers) as well as some other data (such as trust, Gini-index and governance quality indicators).

The typical result for the relationship between happiness and income is shown in Figure 5. That figure graphs average happiness scores (from the *World Happiness Report*) in 2014 for a sample of 144 countries and GDP per capita in constant purchasing power parity dollars. Data for GDP per capita is from *World Development Indicators*.

Figure 5

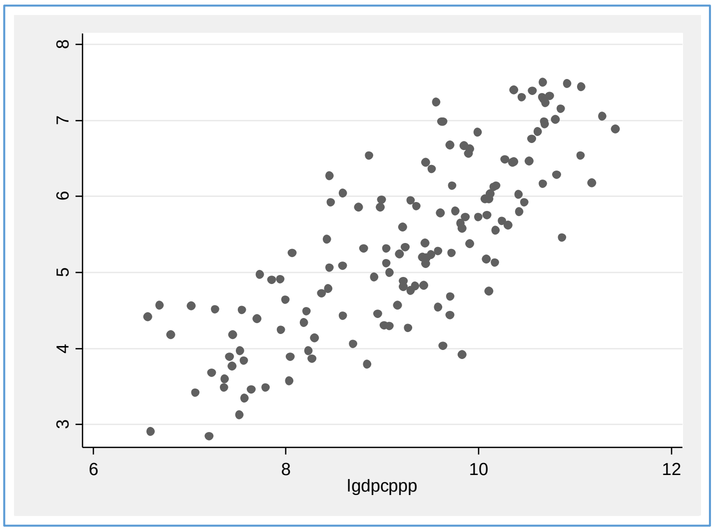



Source: World Happiness Report (2016) and World Development Indicators (2017).

Using log of GDP per capita instead of the absolute number produces figure 6. That figure suggests an almost linear relationship between happiness and (log of) income per capita. The implication is that a given percentage increase in income corresponds to the same absolute increase in happiness. The scatter plot does not form a straight line. But that is not to be expected. Apart from income, many other variables influence on happiness (such as e.g. health, democracy, climate etc). Still, the graph gives a clear impression that income is a main determinant for human happiness.

Note that the seemingly logarithmic relationship between happiness and income corresponds well with risk aversion and therefore decreasing marginal utility from income. An increase in income from a low level gives larger increase in happiness than a similar increase in income from a high level.

Figure 6




Source: World Happiness Report (2016) and World Development Indicators (2017).

Deaton (2008, p. 58) presents further evidence: The linear relationship between happiness and log of GDP per capita offers a reasonable fit for all countries, whether high-income or low-income. The result is striking. Many countries differ in income distribution. In a country with large income differences, many are poor while a few are rich. In very uneven countries, therefore, one might expect some happy people and many unhappy people, and therefore less happiness on average. Still, the linear relationship seems to bear validity. A cross-country regression of happiness, log of GDP per capita and estimates of Gini-coefficients give a *positive* albeit hardly significant result for the Gini-coefficient. The sample size also reduces to 61 with inclusion of estimates of Gini-coefficients.

Deaton regresses cross country average happiness on other variables, such as health indicators. He includes life expectancy, infant and child mortality. Neither of these turn out to be significant in regressions. Deaton adds HIV prevalence which is also insignificant. Age, on the other hand, turns out to matter. Younger people are on average more happy than elderly, except for the richest countries in which old people are more happy than younger ones. This finding does not necessarily contradict those reported by Frey and Stutzer (2002) since their study are based on data from developed countries.

A major finding from happiness research is that happiness scores *within* countries tend to stay quite constant despite growth in income over time. Easterlin (1974, updated in 1995) found that despite growing income over time in some countries (in particular Japan), happiness stayed relatively constant. Easterlin (1995) reports such findings for Japan, the USA and several European countries. Later, many other studies have given similar results (for an overview, see Clark *et al.* 2008). Easterlin (1995) still finds a positive cross-country relationship between happiness and income. For a sample of developed countries, he finds an almost linear relationship. Deaton (2008) finds, for a cross section of countries, that even if there is a positive relationship between happiness and log of GDP per capita, there is a negative relationship between happiness and growth.[16]

Two complementary explanations for the lack of a positive happiness-growth relationship have been proposed. First, what matters for people is not income as such, but their relative income vis-à-vis others. Therefore, if income increases for everybody, average happiness does not necessarily increase. Clark *et al.* (2008) discuss implications for persons' utility functions from such explanations. They presume a utility function for individuals that depend on income (in a standard manner), but also in individuals' income relative to others (others refer to reference groups, and may be other people in the same country, or people with closer relationships to the individual). With this assumption, there are strong relationships between happiness and income for individuals at *a point of time*, but much weaker relationships for average relationships between happiness and income *over time*. Inclusion of income in other countries as reference incomes, gives a positive relationship between happiness and income in cross-sections of countries. With relative income as argument in utility functions, average happiness will tend to decrease with more unequal income distribution. Income growth for individuals have negative externalities for others.

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[16] Deaton (2008) regresses happiness on log of income in the same year as well as average yearly growth rates in for two alternative time periods.

Second, as people get richer, they get used to higher standards of living. Therefore, their aspirations increase in line with income and the relationships between income and happiness over time gets weaker than one would expect. In this case, short run and long run effects of growth in income on happiness differ. In the short run, happiness increases with income, in the long run, effects are lower.

Tsui (2014) investigates happiness in Taiwan. He includes income, average income and *expected* income in regressions on happiness together with other control variables. Expected income is estimated as the expected income given individual characteristics. The results indicate higher happiness with income and lower happiness with average income as well as expected income. Tsui interpret his result as support for both explanations (comparison with reference persons and aspirations) discussed above.

Some has claimed that there are strong relationships between happiness and income for low-income persons (and also in cross sections of countries), but that this relationship weakens as incomes grow. As figures 5 and 6 shows, in cross section of countries, average happiness seems to grow logarithmic with income. One reason for lower effects on happiness from income in aggregate data may be that for low income countries, marginal utility from own (standard) consumption is high, while with higher incomes, the marginal utility from relative consumption (vis-à-vis others) increases. Therefore, increase in average incomes may have larger effects in poor countries than in richer countries (where happiness depend more on being richer than reference persons).

An impression of developments in happiness across country is given from Figure 7. That figure shows average happiness scores in 2007 (horizontal axis) and 2015 (vertical axis).[17] The straight line shows what happiness would be if it was constant. In countries above the straight line, average happiness scores increase over time. In countries below, average happiness decreased over time.

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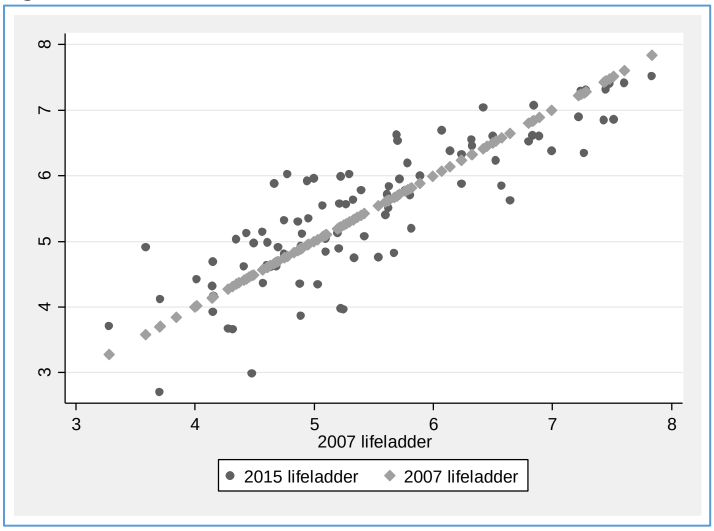
[17] Data coverage increases much from 2006 (89 countries) to 2007 (102 countries).

Figure 7




Source: World Happiness Report 2016

Three conclusions are easily read from the figure. First, happiness is indeed quite constant. Countries that scored high on happiness in 2007 tended to do so also in 2015. Second, it is not clear that the world is becoming more happy. There are more countries above the straight line, than below. But the average growth in happiness scores was 0.009 with a standard deviation of 0.57. Average happiness scores, therefore, was almost constant. Third, there is some convergence in happiness. From the graph it seems that countries that ranked low in the graph in 2007 had higher growth in their average happiness scores than countries that ranked high. This is confirmed in a simple cross country regression with change in happiness scores as dependent variable and level in happiness in 2007 as independent variable. The regression gives a negative (-0.14) and significant (p-value 0.011) coefficient. A fixed effect panel data regression of growth in happiness versus initial happiness scores gives a negative and significant coefficient.

As noted above, a main finding from happiness research is that, despite growing income, happiness stays constant over time. Still, happiness correlates positively with income. Expected results from a regression of happiness on income and growth in income would therefore be positive coefficients for income and insignificant coefficients for growth. Deaton (2008) found a negative and significant coefficient for growth.[18] In table 4 regression results from an unbalanced panel regression for the period from 2005 to 2015 are

[18] Note that a regression of happiness level on current income and previous income growth is indistinguishable from a regression on current and past income levels.

presented. The first column is for a random effects model, the second for a fixed effects model.

Table 4. Panel regression results for happiness

| Variable | Random effects | Fixed effects | Cross country |
|---|---|---|---|
| Income, current | 0.74***<br>(0.039) | 0.80***<br>(0.116) | 0.77***<br>(0.049) |
| Growth in income (from previous year) | 0.55**<br>(0.269) | 0.57**<br>(0.271) | |
| Growth in income (2005-2015) | | | 0.77<br>(2.922) |
| $R^2$within | 0.05 | 0.05 | |
| $R^2$between | 0.67 | 0.67 | |
| $R^2$ | 0.61 | 0.61 | 0.67 |
| N | 1216<br>159 countries | 1216<br>159 countries | 128 |

Note: Standard errors in parenthesis. *, * and *** represents significance at 10, 5 and 1 percentage levels, respectively.

The regression results indicate that both levels and growth rates in income influence average happiness scores positively and significantly. These results contradicts those of Deaton (negative coefficients in growth). Deaton, however, reports results from regressions of happiness scores on income and growth rates lagged three years and average growth rates for over a decade in the past. Deaton's regressions are on a cross-section of countries. In the above regressions, it is clear that between variation is far better explained between countries than within countries (compare the $R^2$s). The third column in the table are results from a similar regression to that of Deaton. That is for happiness in 2015 regressed on income in 2015 as well as average annual growth rates in the period from 2005 to 2015. The results still contradict Deaton's. The regression gives a non-negative but insignificant coefficient for growth rates. Splitting the sample in two at the median income does not change the results. The coefficients for growth rates are still insignificant. The coefficient for income is higher for the high income countries than for the low income countries. This is the Easterlin paradox: Well-being is explained by income in the cross section, but growth in income does not leads to growth in happiness.

# Happiness and ICT

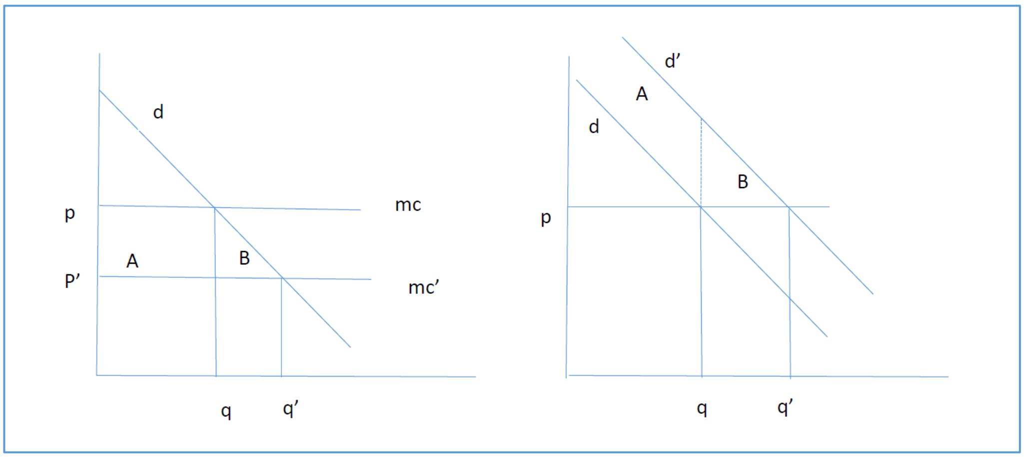
The review of the literature on ICT and productivity above demonstrated contrasting views, although there seems to be increasing agreement that ICT contributed to high growth during the dot-com era, in particular in the United States. Thereafter, growth rates in the United States and in Europe have stagnated again, in particular during the great recession. Micro studies on the other hand, have given higher estimates of effects of ICT on productivity and on growth.

Many have proposed that one reason for low reported productivity effects from ICT is measurement issues (see references above as Triplett (1999) or Brynjolfsson (1996)). Quality improvements in ICT have been enourmous, as evidenced by Jorgenson (2005) and many more. And use of ICT have become widespread, in production processes and for the consumer in particular.

Some have argued that official national accounts underestimate the effects from ICT on welfare. One reason why macro studies do not give larger productivity effects from ICT may be that price deflators' fail to account fully for quality changes for consumer products. If quality increase while prices are constant and price deflators do not reflect the quality increase, quality improvements will be nonexistent in national accounts statistics. If quality improvements are constant over time, the above concern will be equally important over time. Brynjolfsson and Hitt (2000a), however, argue that measurement problems are particularly important problem for ICT goods. For instance, in banking, official productivity statistics for the United States indicate a productivity increase of about 70 percent in the period from 1977 to 2000. According to Brynjolfsson and Hitt, this number massively underestimate productivity growth in this industry. For instance, in this period, the ATM was introduced everywhere. This had major benefits for consumers.

The essence of the argument is illustrated in figure 8 (left side).

Figure 8




That figure shows a market with a demand curve and a constant marginal cost curve. In a perfectly competitive market price is at p (which equals presumed constant marginal costs, mc) and the good is purchased in a quantity equal to q. The first graph illustrates effects of a price decrease. Technological change reduces marginal costs. The new price is p' and the new quantity is q'. The change in consumer surplus is represented by the areas A and B in the left graph. The change consists of increased surplus for existing buyers and the surplus for new buyers. If the price change is due to quality improvements that are not properly measured (so that nominal price for a better good is constant), only the quantity effect is measured. Brynjolfsson (1996) argue that this is often the case. As argued by Bresnahan (1986) the same reasoning applies also when upstream producers reduce costs for downstream producers and costs reductions spill over to consumers. When increase in consumer surplus is hard to measure, or when productivity increase in downstream sectors, such as e.g. services, government , health care etc, lack good measures, or real output is hardly measured, calculation of the impact of new technology will often underestimate real effects. As seen from the graph, welfare effects from reduced prices will tend to be underestimated, in particular if real price decrease are underestimated.

The graph to the right illustrate possible effects from quality improvement with constant prices. In this case, consumers expand their demand towards the good in question. The welfare impact of the improved quality is given by the areas A and B. Also in this case, when physical quantities are accounted for, but not consumer surplus, national accounts will grossly underestimate welfare effects.

Hitt and Brynjolfsson (1996) estimates three different measures of impacts from ICT. The first is productivity, the second is profitability and the third is consumer surplus. The study is based on a panel of 370 United States firms in the period from 1988-92. They find that ICT capital has positive and significant effects on firms' productivity. This is in line with other studies. They find no significant effect (but considerable variation) of ICT investments on firms' profitability. Hitt and Brynjolfsson argue that this indicates well-functioning markets and that lack of systematic effects on profits is well in line with profit maximization behavior (the envelope theorem predicts zero effects). They find large effects from ICT on consumer surplus. Their estimation strategy is based on Bresnahan (1986), and consists in estimating the increase in the area under the demand curve but above the price line after price reductions on ICT-goods. The method assumes that demand curves are constant over time. If demand increases over time, the method underestimates effects on consumer surplus from ICT. The method is used on firms buying ICT goods as intermediates. It is demonstrated in Bresnahan (1986) that in competitive markets, producers who purchase an intermediate good act as proxies for the ultimate consumers. In imperfectly competitive markets, there are additional gains from ICT. In a similar study Brynjolfson (1996) estimates that the contribution from ICT to consumer surplus represents approximately 0.3 percent of GDP in 1987 and that ICT investments generate about three times their cost in value for consumers. An industry decomposition of the method indicates that ICT increased consumer surplus the most in banking and finance. Notably, in the period under analysis, this industry had low measured productivity growth.

Similar concerns are relevant also for the treatment of new goods. Sales of new goods are measured in GDP as their sales value. This does not capture the consumer surplus of these goods.

Many new goods are introduced in the price indexes after a lag only. Often price declines are most rapid in the beginning of the life cycle of a product category. Official statistics will therefore be without price declines in the start of life cycle. As for inaccurate price indexes, the treatment of new goods could well be a constant problem and not particularly relevant for ICT goods. This is the argument by Gordon (2000). He argues that ICT does not stand out as a special case when it comes to the impact of innovations. Rather, Gordon argues, electricity, indoor running water, health systems, new medications, private cars and public transport are examples of inventions that increased standards of living to a larger extent than what computers do.

Greenstein and McDevitt (2011) discuss effects on consumer surplus from broadband upgrading. They find limited effects. They consider whether the data give exact information. They write (p. 630):

Consider YouTube, which is just over five years old, and the fourth most popular site on the Internet in the US. This site obviously benefits from widespread use of broadband. Have YouTube's economic gains been high? There is no way to tell because YouTube has never contributed a positive sum to measured GDP. According to financial analysis, Google has lost several hundred million dollars a year since it bought the site.

With underestimates of quality improvement and real price declines in the ICT industries and of productivity effects from ICT in other industries, ICT may have important effects on people's life even if the effects are not visible in economic statistics.

How does the internet influence on people's happiness? People around the globe use the internet daily, in work life and in their personal life. They use the internet for direct and indirect benefits. The internet is used for entertainment, for searching and processing information and for storing information. The internet is used of for transaction purposes. Internet is used for financial services.

Studies have revealed effects of ICT on well-being.

Social media, from traditional emailing to social networking, have characteristics of relational goods (where utility increases when consumed together with friends or family members). Consumption of such goods can increase happiness (Gui and Stanca, 2010). Others have proposed that the internet is a means of sustaining and building social capital (Franzen, 2003, and Pénard and Poussing, 2010).[19]

Kraut *et al.* (2001) find that internet use increases social interaction only in some strata of the population (people rich in social capital). For others, use of the internet may increase isolation. Evidence indicates that this effect is present for TV viewers (Bruni and Stanca, 2008). Frey *et al.* (2007) estimate the relationship between TV viewership and life

[19] The term *Social capital* is used with different definitions in social sciences. It can be used at group level as "informal values or norms shared among members of a group that permits them to co-operate with one another" (Fukuyama, 1999). The term is also used as individual characteristics as "the number of trusting relationships and social ties in which she is involved and where she has access" (Laumann and Sandefur, 1998). See the discussion in Pénard and Poussing, 2010.

satisfaction in a cross-section of European countries. They find that heavy TV viewer report significantly lower life satisfaction. Lee *et al.* (2011) present evidence that only face-to-face communication has a positive effect on perceived quality of life. Li and Chung (2006) argue that the internet may create addictive behavior and be detrimental to mental health. Following up Kraut *et al.* (1998) Kraut *et al.* (2001) study the impact of use of the internet on psychological well being. Kraut *et al.* (1998) found that heavy internet users became less socially involved and more lonely than light users. Kraut *et al.* (2001) find that these effects dissipate in a longitudinal study based on the original data. This study also made use of a larger data set with a control group. Also for the larger data set it was found that internet use had positive effects for communication, social involvement and well-being.

Elgin (2013) finds that use of internet reduces the size of the shadow economy in a panel data with 152 countries in the period from 1999 to 2007, but more so in developing countries than in developed countries.

Bhuller *et al.* (2013) investigates the impact of the internet on sex crime. Using exogenous variation in broadband access in Norway, they estimate the effect of access to broadband internet on reports, charges and convictions of rape and other sex crimes. They suggest that the possible causality goes through broadband's effects on consumption of pornography. They relate their findings to a broader literature on the effect of media. For instance, Besley and Burgess (2002) and Gentzow (2006) provide evidence that media exposure affects political outcomes. On the other hand, Bello (2015) finds that the internet (with development of online dating services) has significantly increased marriage rates among youth (aged 21-30) in the United States.

Junco (2013) study inequalities in Facebook use. Facebook is now established as a common platform for social networking. 92 percent of US college students used Facebook with 58 percent using it several times a day. Still, there are differences along gender, racial and socio-economic lines. Junco finds that women used Facebook more often than men. African Americans and students from lower socio-economic strata were less likely to use Facebook. Similar inequalities are present for ownership of cell phones, use of text messages and for knowledge about the internet. Similarly, college students whose parents had a college degree themselves were more likely to use Facebook than students whose parents that did not have a college degree.

Jin (2013) studies relationship between loneliness and Facebook use. The data was collected among Facebook users and consisted of about 550 observations. Jin finds that loneliness was associated with fewer Facebook friends and less overlap between Facebook friends and real-life friends. Lonely people had lower satisfaction from Facebook use than people who were not lonely.

Lee *et al.* (2011) present results from a Chinese data set collected in four big cities (Wuhan, Beijing, Hong Kong and Taipei). The results indicate that internet use for personal communication does not predict people' quality of life, while face-to-face contact does. They even find, from regressions, that communicating with people on the internet has a negative impact on people's quality of life while face-to-face communication increases quality of life. This study, however, is a cross-section study and it does not control for other characteristics of internet users (such as income, education, gender, etc).

Franzen (2003) reports results from a survey conducted twice on a sample of about 843 participants from Switzerland in 1998 and then in 2001. Franzen use a difference in difference method to test the impact of internet use on participation in social activities and networks. Franzen does not find any significant effect of internet use. Franzen finds, however, that internet use substitutes for TV watching.

Pénard and Possuing (2010) use a survey data from Luxembourg collected in 2002 with about 1500 individuals. They find that internet users more often are involved in organizations (civic and leisure) and declare higher levels of trust than do non-internet users. Internet users also have higher social abilities. Internet users have higher education and income than others. Use of the internet is complementary with ICT equipments such as smart phone, GPS and DVD players, but substitutes for TV watching. Initial levels of social capital has limited impact on internet use, but investments in social capital is positively correlated with internet use. Pénard and Poussing propose that since internet users build social capital internet use may increase inequalities in social capital. They also propose that, since social capital is positively associated with economic growth, the internet may increase an economy's growth potential. With internet access becoming a social norm, the necessity for it also increases. Internet may increase happiness through increasing opportunity costs: without internet access, people become increasingly socially excluded. With such an effect, the impact of the internet on happiness in time series may be small, but in cross-section data the impact may be large.

Sun Lee and Chen (2017) find that digital competency can contribute to networking skills in a study using a data set consisting of about 600 college students in southwest United States. The findings suggest that engagement in digital cultural production is more important for networking skills than being technologically competent.

Penard *et al. (2013)* use a dataset from Luxembourg from 2008 based on the *European Social Survey*. They find evidence that Internet users have higher life satisfaction than non-users. They do not find, however, that happiness depends on the extent of use of the internet among the users. They control for other socio-demographic variables, social capital, religious beliefs and income. They find evidence that the positive impact of internet use on well-being is higher for young people and people who are not satisfied with their income. They argue that some benefits of the internet are mediated through welfare effects. The internet helps people in consumer markets (online shopping), entertainment and to getter paid jobs. There are endogeneity issues in the data that are hard to handle without panel data.

BCS – The Chartered Institute for IT (2010) is a consultant report. The report discusses the impact of ICT, and the internet in particular, on well-being. The report is based on international data as well as more detailed data from the UK. The analysis suggests that ICT has a direct positive impact on life satisfaction when controlling for income and other factor known to be important in determining well-being. The report suggests that ICT *reduces* inequality in the sense that gains are higher for people with lower incomes and fewer educational qualifications. For UK data, however, the report indicates the highest gains for middle income groups. The report indicates that those who were recently connected to the internet experience the highest improvements in well-being. This is in line with the Easterlin paradox and may well be because people get used to using the internet (as they get used to higher incomes) or that happiness from using the internet depends on whether other people in one's reference group also use the internet.

The report reject the assertion that ICT is linked to social isolation. Rather, the report suggests that ICT enhance social contact with friends and family. People's job satisfaction depended in their use of ICT. But changes in job satisfaction did not correlate systematically with use of ICT over income groups. People in the lowest income groups felt larger increase in their job satisfaction as they started using ICT as compared to other income groups.

The international data indicates that several developing countries benefit greatly from ICT. Based on micro data from 39 countries with more than 30 000 individual observations, they find significant effects of access to the internet on individuals life satisfaction. With micro data, they are able to control for the influence of other variables, such as gender, age, education, employment status, country effects and income. Adjusting for GDP and other variables, developing countries such as Zambia and Malawi outperforms many other countries in their use of ICT. Happiness depends on people's sense of freedom and being in control of one's life. ICT enhances these instruments for happiness. But even when controlling for this indirect effect, ICT has an independent positive effect on people's well-being. The report concludes that there is a significant positive correlation between IT access and use and reported life satisfaction.

Valberg (2017) studies the impact of ICT on gender equality in labour markets. The approach is a panel data regression of relative labour market participation among females and males in dataset containing many countries. Valberg concludes that (p. IV) that: "The most interesting contribution from this thesis is that ICTs impact in developing countries is almost non-existing and suggests that ICTs for female empowerment and employment might not, at least not alone, be a sufficient strategy for development."

Also refereed academic studies indicate positive effects from ICT in peoples' happiness.

Graham and Nikolova (2013) use data from the *Gallup World Poll,* which contains data from yearly interviews with representative samples of persons from about 140 countries. The data contain life evaluation scores (on a 11 point scale) as well as indicators for hedonic well-being (as whether the respondent smiled yesterday, experienced stress yesterday and experienced anger yesterday). The data also contains many individual characteristics (such as e.g. age, gender, married, education and household income). In addition, the data contains information about access to ICT. The data contains information whether the household had landline telephone, cell phone, internet and TV. In total the data contains about 300 000 observations for the period from 2009 to 2011. The results indicate positive and significant effects on happiness from access to each of the four IC-technologies. Separate regressions for developed and developing countries indicate that access to TV and mobile phones was not important (insignificant) for people in developed countries but important in developing countries. In developed countries, people without TV and mobile phones have presumably chosen not to have these goods without serious budgetary restrictions. In all countries, however, access to the internet was important for well-being. To test for income sensitivity, Graham and Nikolova interacted income with internet and mobile phone access. The results indicate that both mobile phones and access to the internet increases well-being, but less so when income increases. They conclude that (p. 138): “technology access is positive for well-being around the world in general, but with diminishing marginal returns for those respondents who already have a great deal of access to these technologies”.

Kavetsos and Koutroumpis (2011) use a pooled cross-sectional data set of European countries and study the impact of ICT on subjective well-being. Their study is based on the *Eurobarometer* 2005-08. They find that access to ICT goods, such as mobile telephones, PCs or internet access correlates positively with higher levels of well-being. Similarly, living in a country with high proportions of mobile subscribers or internet users also improves subjective well-being scores. They argue that the latter finding indicate network effects from ICT. The utility derived from the internet and mobile subscription increases with the number of other users.

Kavetsos and Koutroumpis note the cross-section correlation between income and happiness. This allows them to find the monetary equivalent of welfare effects from internet. They report estimates of welfare effects from a 10 percentage point increase in penetration of ICT. They find that such an increase is equivalent with a 2.89 rise in real GDP per capita for broadband coverage and 2.36 from mobile network adoption. The results vary between European countries, with the lowest effects in the poorest countries. But in all countries, monetized happiness effects from broadband far exceed the expenditure on broadband connection.

As described above, there is a clear correlation between measures of happiness and income levels in cross country data. It is a general finding that also measures of health, income distribution and social security matters for life satisfaction, in addition to income levels (see e.g. Helliwell *et al.*, 2016).

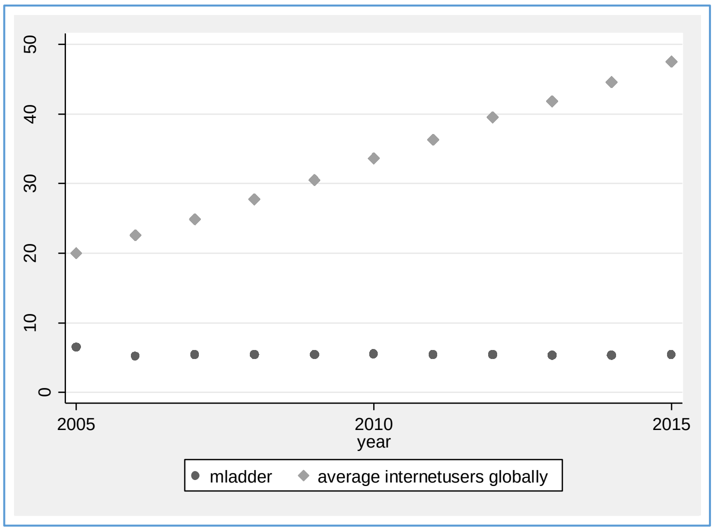
The literature on ICT and happiness indicate that ICT has potential for increasing life satisfaction. Evidence is mostly based on micro data or data limited to single countries. An exception is, as described above BCS – The Chartered Institute for IT (2010).

Here I make use of data from *World Happiness Report*. I use country averages for happiness scores from that report to construct an unbalanced panel. I combine average happiness scores with auxiliary data from that database as well as data on GDP per capita (PPP adjusted), unemployment (ILO estimates) and the percent of the population that use internet from *World Development Indicators*. This gives an ubalanced data set for the period from 2005 to 2014 for 135 countries.

The idea is that use of the internet may influence on average happiness scores. The effects can be direct: People who use the internet gain utility from their own use. The effects can also be indirect: People's utility increase from increased average internet use for instance because of network effects. Indirect gains may also come through other channels. For instance, information flows increase with widespread use of the internet and some types of production may become more efficient (one example is banking services). There is also a third interpretation for potential effects of the internet on happiness. This is that the share of people using internet correlates with other variables, such as ownership of a computer, a tablet or a smartphone.

In the period covered here, use of the internet increased over time. Figure 9 demonstrates that the (unweighted) average among countries increased almost linearly while mean scores of happiness slightly decreased. The average of internet users in the sample of countries increased from about 20 percent to almost 50 percent. Average happiness scores declined from 6.44 to 5.42 (on the scale ranging from 0 to 10).

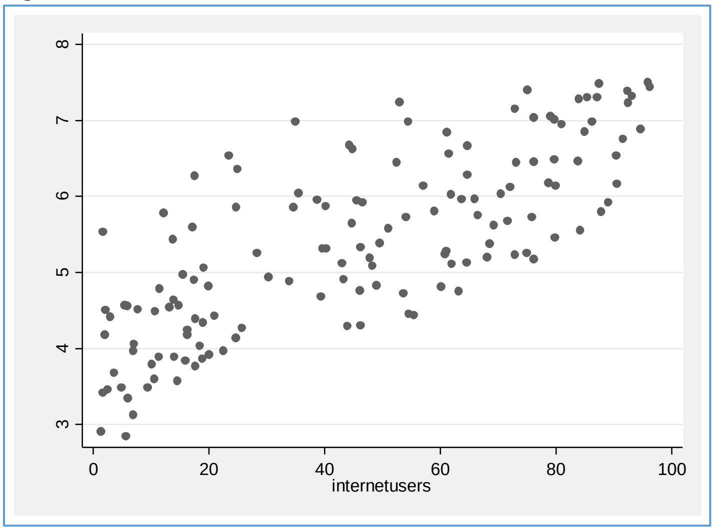
Figure 9




Source: See text.

In the cross section, there is a clear relationship between average life satisfaction and the proportion of internet users in the population. Figure 10 plots the relationship for 2014. The figure indicates a positive relationship. On the average people are more happy in countries where many are internet users.

Figure 10



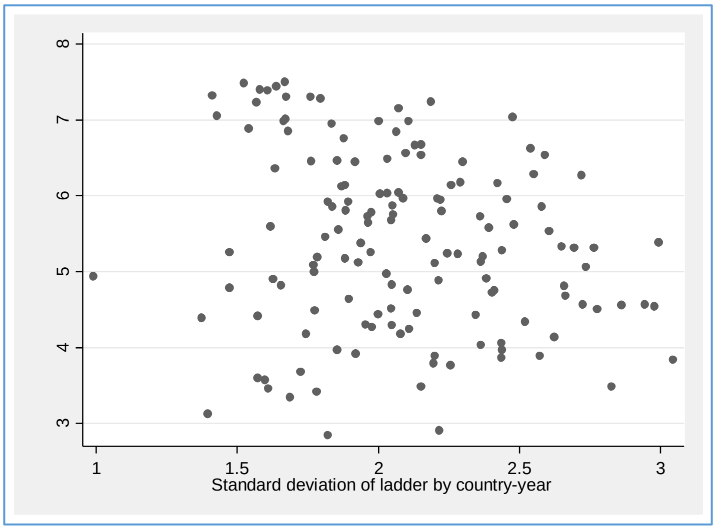

Source: See text.

The five countries that ranked lowest on average happiness scores in 2014 were Togo, Burundi, Afghanistan, Benin and Guinea. The five countries that ranked highest were Denmark, Switzerland, Norway, Israel and Finland. The five countries that have the largest negative changes in happiness scores in the period from 2005 to 2014 were Yemen, Ukraine, Ghana, Greece and Malawi. The five countries were average happiness scores increased the most were Sierra Leone, Moldova, Latvia, Nicaragua and Ecuador.

Variation in answers about happiness correlates with average levels in happiness. The countries that have the highest average scores on happiness are also the countries with the lowest standard deviations in people's answers about happiness. Figure 11 is a scatterplot of average happiness scores and standard deviation in 2014.[20]

[20] A plot of *relative* standard deviation shows an even closer relationship.

Figure 11




Source: See text.

The figure indicates a negative correlation between average happiness and variation in people's average answer (the correlation coefficient is -0.19). It indicates that it is hard to obtain high average happiness without allowing many to become happy. The outlier in the graph, with low average but little inequality in happiness is the isolated country Bhutan (known for having pioneered *gross national happiness* as a policy target).

Determinants for happiness in international data have been discussed in *World Happiness Report*. The 2016 issue presents typical results. Table 2.1 in that report reports regression results from regressions of happiness on log of GDP per capita and a set of other variables. The first is *social support* which indicates whether people feel they have someone to support them in times of trouble. The second is *healthy life expectancy at birth*. This variable is a constructed variable from the *World Health Organization* that captures both life expectancy at birth but also other health indicators. *Freedom to make life choices* are people's response to whether they feel free to do what they want with their life. *Generosity* indicates whether people donate to charity. Finally, *Perceptions of corruption* reflects whether people have the impression that the country they live in is corrupt (within the government or in business). They find that these variables significantly influence on people's perceived happiness, all positively, except from perceived corruption (that influenced negatively). I have supplemented this data set with variables downloaded from the *World Development Indicators*.

Table 5 report two regression results. The regressions are for country averages in happiness on country averages in peoples answers about *social support, health, freedom to make life shoices, generosity* and *perceived corruption*. The first set is similar to the first column in table 2.1 in Helliwell *et al.* (2016), included for comparison. The second set is when I also include the share of internet users in the population in the regressions. The regression is a pooled OLS that includes time dummies.

I also include unemployment rates (ILO estimates, taken from *World Development Report*). The reason for including unemployment rates is that unemployment is known to reduce people's happiness in micro level studies (see e.g. Frey and Stutzer, 2002). Unemployment reduces happiness by far more than the estimated effect of the resulting income shortfall. The period covered by the data include the Great Recession that resulted in increased unemployment in many countries. Inclusion of internet users and unemployment rates reduces the sample from 1108 to 890 observations and from 153 countries to 135 countries.

Table 5 Regression results for happiness

| Variable | Helliwell et al. 2016 | With internet |
|---|---|---|
| Ln(GDP per capita) | 0.337 (0.091)*** | 0.287 (0.041)*** |
| Sosial support | 2.336 (0.205)*** | 1.952 (0.226)*** |
| Health | 0.030 (0.004)*** | 0.027 (0.004)*** |
| Freedom | 0.983 (0.154)*** | 0.804 (0.173)*** |
| Generosity | 0.867 (0.120)*** | 0.921 (0.134)*** |
| Perceptions of corruption | -0.593 (0.112)*** | -0.596 (0.124)*** |
| Internetusers | | 0.006 (0.002)*** |
| Unemployment | | -0.013 (0.004)*** |
| Year fixed effect | Yes | Yes |
| Number of countries | 153 | 135 |
| N | 1108 | 890 |
| Adj.$R^2$ | 0.74 | 0.77 |

Note: standard errors in parenthesis. *** denote significant at 1 percent level.

The regressions confirm the findings by Helliwell *et al.* (2016) about determinants of average happiness in countries.

Also unemployment influences on happiness, significantly and with the expected sign. From the regression results, one cannot however, know whether this reflects whether unemployed are more unhappy than others or whether times of unemployment also reduces employed people's happiness, for instance, due to job uncertainty, income uncertainty or effects via altruism.

The regression results indicate significant and positive effects of the internet on happiness. The coefficients of Helliwell *et al.*'s regressors keep their sign and significance when internet and unemployment is included in the regression.

The included variable is the share of internet users in the population. A 1 percentage point increase in the share of internet users increases happiness with 0.006 on the 0-10 scale for happiness. A ten percentage increase therefore implies a 0.06 increase in the scale. A rough calculation therefore implies that going from zero to full internet coverage implies a 0.6 increase on the happiness scale. According to the estimates, this corresponds to a 2 percent increase in GDP per capita.

The positive effect on the internet is for the share of internet users in the population. This effect has two alternative interpretations. The first is that as more people start using the internet, these people get more happy. The other effect is the network effect. As more people start using the internet, existing internet users get more happy. There is no way to distinguish between these two from the data. The may well co-exist. They may also co-exist in varying degrees. In countries were use of the internet is widespread, the least motivated users are mobilized last. It may be that the network effects dominates when the internet is widespread while individual effects from personal use the internet is higher when use of the internet is limited.

As noted above, the estimated impact of the share of internet users in the population may also reflect potential correlation with other variables, such as access to ICT goods. In line with Caselli and Coleman (2001), I also experimented with inclusion of the share of ICT goods in imports to capture investments in ICT goods. Neither this variable nor the share of imports of ICT goods in GDP gave significant results. Exports of ICT goods did not significantly influence on countries happiness.[21]

Separate regressions for countries in which the share of internet users were below and above the median in 2005 (9.6 percent) indicates larger and more significant effects of internet users in the latter group than in the first.

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[21] Results were not significant. But the signs of the coefficient indicated that ICT imports increase happiness and that ICT export (as share of total exports) decrease happiness.

Table 6

| | Random effects | | Fixed effects | |
|---|---|---|---|---|
| Variable | Helliwell et al. 2016 | With internet | Helliwell et al.2016 | With internet |
| Ln(GDP per cap.) | 0.494 (0.054)*** | 0.385 (0.064)*** | 1.047 (0.166)*** | 0.787 (0.219)*** |
| Sosial support | 1.530 (0.221)*** | 1.392 (0.239)*** | 1.260 (0.242)*** | 1.114 (0.267)*** |
| Health | 0.011 (0.007) | 0.012 (0.008) | -0.030 (0.142)** | -0.021 (0.0167) |
| Freedom | 0.963 (0.160)*** | 0.793 (0.179)*** | 0.842 (0.175)*** | 0.687 (0.197)*** |
| Generosity | 0.562 (0.141)*** | 0.478 (0.157)*** | 0.409 (0.159)*** | 0.315 (0.181)* |
| Perc. of corr. | -0.656 (0.159)*** | -0.675 (0.169)*** | -0.664 (0.195)*** | -0.727 (0.218)*** |
| Internetusers | | 0.006 (0.002)*** | | 0.005 (0.002)** |
| Unemployment | | -0.019 (0.005)*** | | -0.021 (0.008)*** |
| Year fixed effect | Yes | Yes | Yes | Yes |
| Number of countries | 153 | 135 | 153 | 135 |
| N | 1108 | 890 | 1108 | 890 |
| $R^2$ | 0.74 | 0.76 | 0.67 | 0.75 |
| $R^2$ (within) | 0.16 | 0.17 | 0.18 | 0.19 |
| $R^2$ (between) | 0.79 | 0.80 | 0.71 | 0.71 |

Note: standard errors in parenthesis. *** and ** denote significant at 1 and 5 percent level, respectively.

Table 6 reports two other set of regressions. These are for panel data regressions for the 2005-2014 period The first set is for a random effects regression model while the second is for fixed effect regressions.

The table demonstrates that the positive effect of internet on happiness survives the most stringent test with inclusion of fixed effects in a panel data regression (significant at 5 percent level).

Table 7 introduces distribution in happiness as a new explanatory variable. Figure 11 above demonstrated a negative relationship between average happiness and inequality in happiness.[22] The

[22] I also experimented with using the Gini-coefficient. Use of the Gini-coeffcients produced qualitatively similar results, but reduced sample size and significance of several variables (internet users included). In fixed effects regressions, internet

causality may run in both directions. Inequality may influence on average happiness if people dislike it (see Wilkinson and Pickett, 2009 or Ferrer-i-Carbonell and Ramos, 2014).

But if average happiness increases, inequality may decrease since unhappy people become more happy. Since the Cantril ladder has an upper limit, this effect may be inherently present in the nature of the data. Results in table 7 should therefore be taken with a (larger) grain of salt than the other regression results.

Table 7

| | Random effects | | Fixed effects | |
|---|---|---|---|---|
| Variable | Helliwell et al. 2016 | With internet | Helliwell et al.2016 | With internet |
| Ln(GDP per cap.) | 0.495 (0.054)*** | 0.390 (0.064)*** | 1.093 (0.166)*** | 0.878 (0.220)*** |
| Sosial support | 1.466 (0.223)*** | 1.363 (0.240)*** | 1.156 (0.244)*** | 1.009 (0.268)*** |
| Health | 0.013 (0.007)* | 0.014 (0.008)* | -0.022 (0.145)** | -0.013 (0.017) |
| Freedom | 0.979 (0.160)*** | 0.812 (0.179)*** | 0.863 (0.174)*** | 0.712 (0.196)*** |
| Generosity | 0.5624 (0.141)*** | 0.487 (0.157)*** | 0.435 (0.159)*** | 0.340 (0.180)* |
| Perc. of corr. | -0.656 (0.159)*** | -0.632 (0.170)*** | -0.610 (0.195)*** | -0.669 (0.218)*** |
| Internetusers | | 0.006 (0.002)*** | | 0.004 (0.002)** |
| Unemployment | | -0.018 (0.005)*** | | -0.018 (0.008)** |
| Inequality | -0.117 (0.052)** | -0.097 (0.061) | -0.157 (0.056)*** | -0.201 (0.067)*** |
| Year fixed effect | Yes | Yes | Yes | Yes |
| Number of countries | 153 | 135 | 153 | 135 |
| N | 1108 | 890 | 1108 | 890 |
| $R^2$ | 0.73 | 0.76 | 0.67 | 0.75 |
| $R^2$ (within) | 0.17 | 0.18 | 0.18 | 0.20 |
| $R^2$ (between) | 0.78 | 0.80 | 0.71 | 0.71 |

Note: standard errors in parenthesis. *** and ** denote significant at 1 and 5 percent level, respectively. Inequality is measured as country wise standard deviation in happiness.

users was no longer significant. In pooled cross country regressions, internet users significantly and positively correlates with average happiness scores.

Inclusion of inequality is relevant. Several studies have indicated that individuals in more unequal societies report on average a lower score for happiness (Ferrer-i-Carbonell and Ramos, 2014). The literature is not conclusive, however. Preferences for equality is higher in Western countries and higher in Europe than in the United States. In Europe, dislike for inequality also depends on the respondents' political preferences (on the left and right axis). Also perceived income mobility in society is believed to influence on people's preferences for inequality. Poor may dislike inequality if mobility is low and rich may dislike inequality if mobility is high.

The table confirms the positive effect of the internet for happiness. The coefficient is positive and significant both in the random effects model and in the fixed effects model. The coefficients are also quite stable (in the range from 0.004-0.006) independently of model version.[23]

Macro data with average happiness scores in panels of countries therefore seem to support the findings in microstudies that access to the internet does increase people's happiness.

[23] Using coefficient of variation (relative standard deviation) as a measure of inequality, leaves several estimated coefficients unsignficant, including internet users.

# Summary and conclusion

ICT has gained widespread use during the last generation. ICT facilitates and increases efficiency in collecting, producing, storing, coding, adapting, exchanging and using information. ICT is now used in most production processes and also by consumers for many purposes. ICT is a general purpose technology. It is complementary with other technologies. ICT-industries has experienced very fast productivity growth and prices on ICT goods has decreased. The internet has further increased use of ICT. Network effects abound in the internet. Information is immediately accessible. Opportunities for combining information is unlimited. On the internet everybody is potentially both a sender and a receiver of information.

Many have been optimistic about potential growth stimuli from ICT and the internet. But widespread use of ICT came together with slowdown of growth. Long run trends in growth rates are decreasing in the OECD countries. It was argued that growth would accelerate when the new technology became widespread. Economic historians drew parallels to the introduction of electricity when growth increased first after massive use was established.

In the 1995-2005 period growth rates increased. Many has attributed the higher growth rates to ICT and the internet. But after the great recession, growth rates have remained low.

Optimists about effects of ICT must now defend a more difficult case. If there are high growth potential from ICT and the internet, low growth must be explained by other reasons, such as Baumol's disease, macroeconomic policy, growth deceleration in other industries, demography etc. Whether ICT has the potential for accelerating growth, despite strong headwinds, is a matter of controversy.

Evidence presented in this paper indicates that in the post dot-com era, growth stagnated. The internet does not seem to have been able to accelerate it. For developed countries, growth effects from the share of internet users in the population have been negative. For developing countries, on the other hand, evidence suggest that there are positive effects of the internet on economic growth.

ICT is everywhere. It has transformed human life. Has it made us more happy? Happiness scores are believed to reflect individuals' utility. Research on happiness indicates that people are more happy if they are rich. This is in line with economic theory. But people do not get happier when their incomes increase. The Easterlin paradox has demonstrasted that average happiness is constant despite increasing incomes. People get used to welfare and they compare their individual situation with their reference groups.

Income buys happiness. But other variables matter too. Research indicates that happiness depends on health, freedom, having people you trust, unemployment and other factors. Does ICT matter as well?

Some findings were reviewed above. Micro studies seem to indicate positive effects on happiness from access to ICT goods and from use of the internet. These effects are partly contradictory to findings about TV watching. Available data from the *World Happpines Report* indicates that average happiness scores in a panel of countries increase significantly from increasing shares of internet users in the population. These effects may reflect direct and indirect effects from more use of the internet or that the share of internet users correlate with other variables.

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